Christopher Culbreath

Working Personnel Action File

Cal Poly Physics Department · January 2022

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Dr. Christopher Culbreath

Lecturer, Physics Department
California Polytechnic State University
San Luis Obispo, California
cculbrea@calpoly.edu

Educational Preparation

- *Ph.D. Chemical Physics* (2015)
  Liquid Crystal Institute. Kent State University. Kent, Ohio.
  Subject: Artificial Microscopic Structures in Nematic Liquid Crystals Created by Patterned Photoalignment and Controlled Confinement: Instrumentation, Fabrication and Characterization.
  Advisor: Hiroshi Yokoyama.
- *B.S. Physics* (2008)
  California Polytechnic State University. San Luis Obispo, California.

Employment

- *Lecturer* (August 2016–present)
  California Polytechnic State University Physics Department
  San Luis Obispo, California.
- *Automation and Materials Engineer* (April 2020–Aug 2021)
  NRD, LLC
  San Luis Obispo, California.
- *R&D Consultant* (May 2019–Jan 2020)
  Nuance Designs
  San Luis Obispo, California
- *Automation and Materials Consultant* (Summer 2017, 2018)
  TiNi Alloy Company
  Emeryville, California.
- *Lecturer* (January 2015–June 2016)
  Chico State University Department of Physics
  Chico, California.
- *Graduate Researcher* (2008-2015)
  Liquid Crystal Institute
  Kent, Ohio.
- *Partner, Photographer* (2009-2014)
  Iconic Photography *iconic-photo.com*
  Kent, Ohio.
- *Senior Service Technician* (2005-2007)
  MacSuperstore
  San Luis Obispo, California.

Teaching Related Activities

Cal Poly Courses

- PHYS-132 Virtual General Physics II (Virtual Instruction) · S20, F20, W21, S21
- PHYS-132 Studio General Physics II (Studio Format) · F19, F21, W22
- PHYS-132 General Physics II · F16, W17, S17, W18, S18, F18, W19, S19
- PHYS-132 Lab General Physics II Laboratory · F16, W17, S17, W18, S18, F18, S19
- PHYS-133 General Physics II · F17, W18, F18
- PHYS-133 Lab General Physics II Laboratory · S17, F17, W18, S18, F18, F19, F21
- PHYS-122 College Physics II Laboratory · S19
- PHYS-122 Lab College Physics II Laboratory · W19
- PHYS-123 Lab College Physics III Laboratory · W20

Chico State Courses

- PHYS-204A Physics for Students of Science and Engineering: Mechanics · Spring 2015, Fall 2015, Spring 2016
- PHYS-204A Lab Physics for Students of Science and Engineering: Mechanics Laboratory · Spring 2015, Fall 2015, Spring 2016
- PHYS-202A Lab General Physics Laboratory (Mechanics) · Fall 2015
- PHYS-202B General Physics (Algebra-based) · Spring 2016
- PHYS-202B Lab General Physics Laboratory (E/M and Optics) · Spring 2016

Note: Fall/Spring in this section refers to either of Chico State's two 17-week *semesters* that comprise an academic year.

Curriculum Contributions

- *Physics 132 Studio Collaboration Visualization Library* — Developed and refined a growing library of custom-written animations and visualizations for demonstrating the key time-dependent concepts in Physics 132. Currently the library contains over 120 graphics and animations created with a distinctive visual style and designed specifically to augment our PHYS 132 curriculum.
- *Uncertainty in Measurement* — Interactive and competitive laboratory exercise written to introduce the concepts of measurement uncertainty, error propagation and the statistics of repeated measurements to introductory laboratory students, piloted at Cal Poly, Winter 2017. (page 177)

Advising

- Eric Gomez (Chico State). Measurement of surface anchoring strength of nematic liquid crystals on photo-aligned substrates. One semester preparation and six-week summer research trip to the Liquid Crystal Institute, Kent, Ohio. Summer 2016.
- Ryan Lau (Cal Poly Physics). Frost Research Program, Summer 2017. We investigated the development and testing of a novel thermal actuator made from a single-crystal Cu-Al-Ni shape memory material. I advised Ryan on research and directly instructed him in the machine shop, where he developed the skills to produce experimental components on his own, from scratch.
- Lauren Smith (Cal Poly Physics). Frost Research Program, Summer 2017. We probed the origin and character of a previously uninvestigated spontaneous EMF observed in single-crystal Cu-Al-Ni during the martensitic transition. Lauren's work mainly focused on the development and design of an apparatus for systematically inducing the martensitic transition with varying strain regimes.

Scholarship

Publications (Other Institutions)

- C. Culbreath, N. Glazar and H. Yokoyama. "Automated maskless micro-multidomain photoalignment" *Rev. Sci. Instrum.* **82**, 126107 (2011).
- N.Glazar, C. Culbreath, Y. Li, H. Yokoyama: "Switchable liquid crystal phase shift mask for super-resolution photolithography based on Pancharatnam-Berry phase" *Appl. Phys. Express.* **8** 116501 (2015)
- J. Angelo, C. Culbreath, and H. Yokoyama. "Breaking Planar Liquid Crystal Anchoring to Form Controllable Twist Disclination Loops." Molecular Crystals and Liquid Crystals **646**, 1 (2017)

Presentations

External Presentations (Other Institutions)

- N. Glazar, C. Culbreath and H. Yokoyama. "Switchable phase mask for super-resolution photolithography" Chirality at the Nanoscale Conference, Poster Presentation. June 4 - June 5, 2015. Kent, Ohio
- C. Culbreath, N. Glazar and H. Yokoyama."Controlled Generation of Disclination Lines: A Quantitative Study of Defect Energetics". International Liquid Crystal Conference. Poster Presentation. June 29 - July 4, 2014. Dublin, Ireland
- N. Glazar, C. Culbreath and H. Yokoyama."Real Time Imaging Polarimeter using Pancharatnam Retarder". International Liquid Crystal Conference. Refereed Talk. N. Glazar, presenter. June 29 - July 4, 2014. Dublin, Ireland

- C.Cheng, C. Culbreath, N. Glazar, P. Palffy-Muhoray and H. Yokoyama."Observation of Angular Momentum in Liquid Crystals Using a Torsion Pendulum". International Liquid Crystal Conference. Poster Presentation. June 29 - July 4, 2014. Dublin, Ireland
- C. Culbreath, N. Glazar and H. Yokoyama: "Maskless Automated Photoalignment". Symposium on Flexible Liquid Crystal Devices. Poster Presentation. Sep 2012. Kent, Ohio
- C. Culbreath, N. Glazar and H. Yokoyama: "Maskless Automated Photoalignment". Liquid Crystal Day. Poster Presentation. Nov 8, 2012. Kent, Ohio.
- Christopher Culbreath."Nanoparticles in Electrospun Liquid Crystal Celluloses". Christopher Culbreath, presenter. Invited Talk. NSF-OTKA Symposium for Complex Fluids. July 8 and 10, 2009. Eger, Hungary.
- C. Culbreath and P. Palffy-Muhoray. "Falling Magnets and Electromagnetic Braking". APS March Meeting. Pittsburgh, Pennsylvania. Christopher Culbreath, presenter. Refereed talk. March 2009.

Service and University Citizenship

Departmental Service

- Studio Physics 132 Collaboration Fall 2019, Spring 2020, Fall 2021, Winter 2022
- Lower Division Curriculum Committee Fall 2016, Winter 2017
- Demonstration Committee (ad-hoc) Fall 2016, Winter 2017
- Assessment Committee Fall 2017, Winter 2018
- Facilities Committee AY 18–20
- 12x Textbook Committee Spring 2019

Student Service

- Society of Physics Students. Faculty participant. Fall 2016, Winter 2017.

Community Service

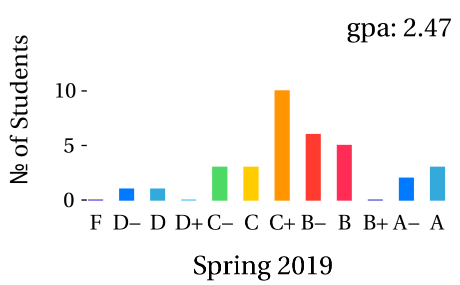
- Supplemental Physics Instruction *(informal weekly tutoring)*, AP Physics Students, San Luis Obispo High School. September 2017–present.
- San Luis Obispo High School Band *Level III Volunteer.* Aug 2018 – present.

Christopher Culbreath

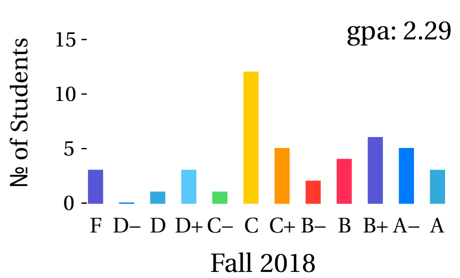
Grading Patterns

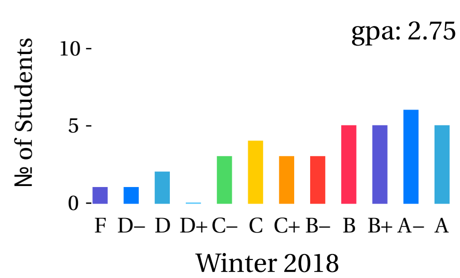
Assigned Grades: By Course and Term

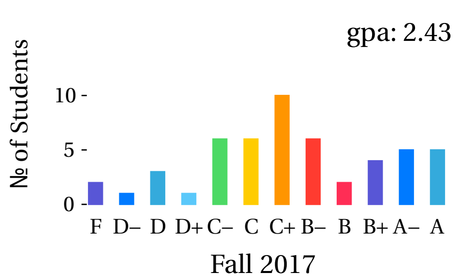
PHYS 122



PHYS 133







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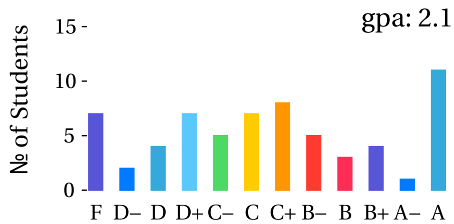
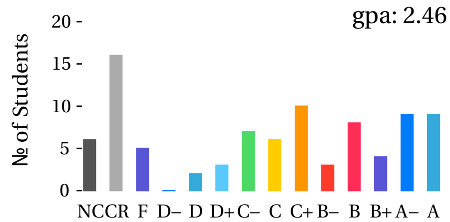
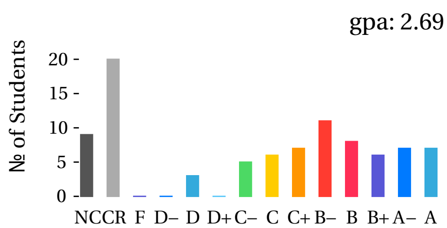


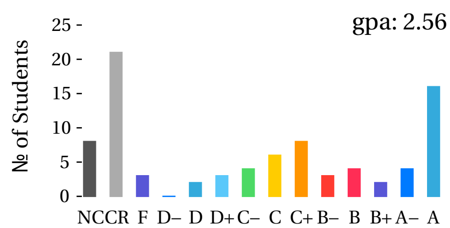
Fall 2021



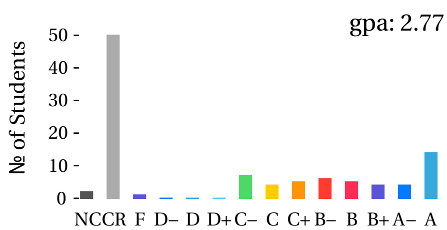
Spring 2021



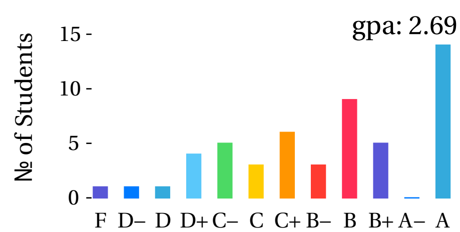
Winter 2021



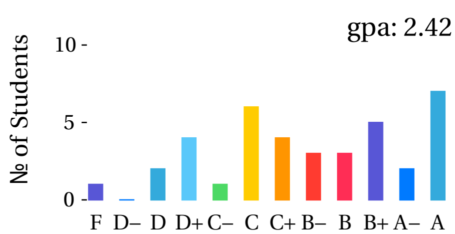
Fall 2020



Spring 2020



Winter 2020



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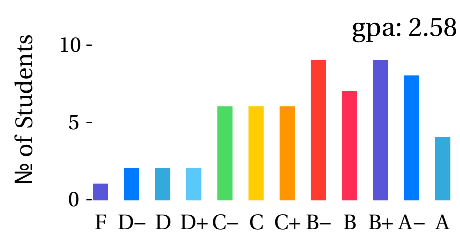
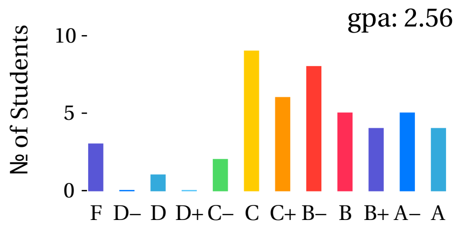
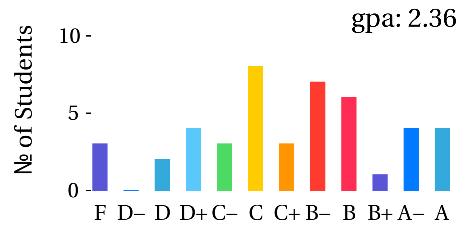


Spring 2019

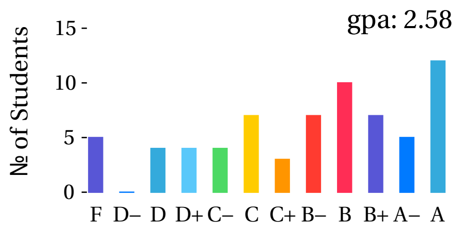
PHYS 132 Continued



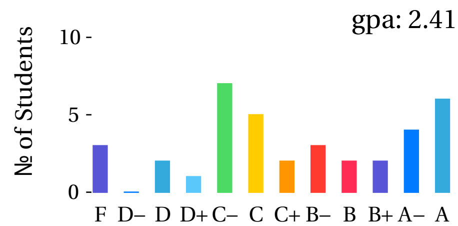
Winter 2019



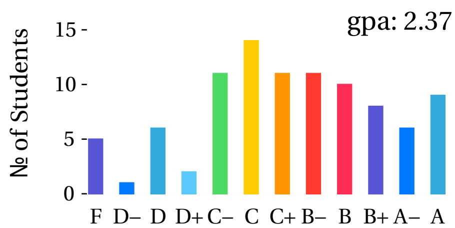
Fall 2018



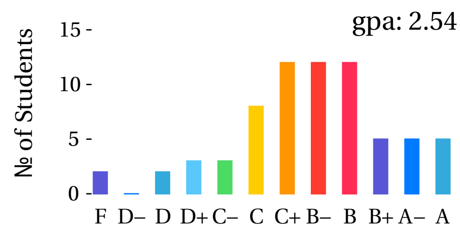
Spring 2018



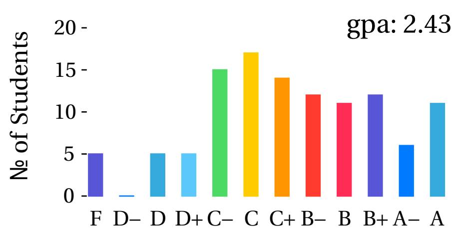
Winter 2018



Spring 2017

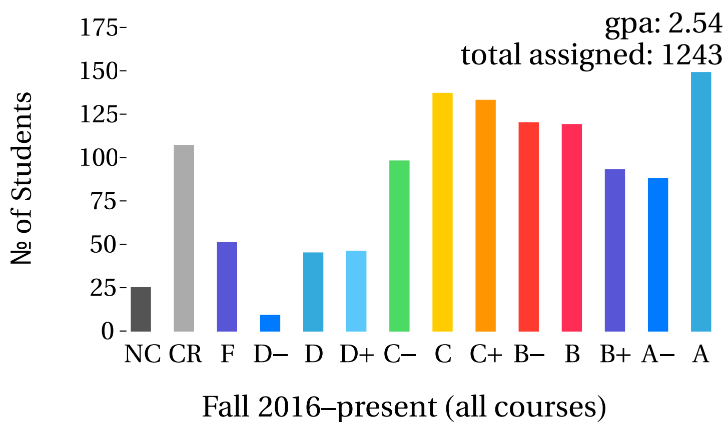


Winter 2017



Fall 2016

Assigned Grades: Career totals



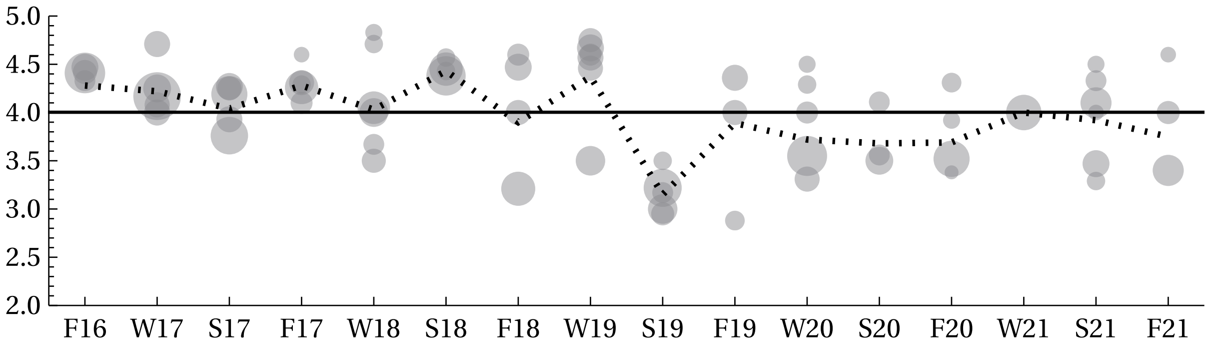
Grading Pattern Summary Table

Term	Course	№ enrolled	CR	A	B	C	D	F/WU	NC	W/I	GPA
Fall 2021	PHYS 132	32	0.0%	18.8%	12.5%	31.3%	18.8%	18.8%	0.0%	0.0%	1.94
Fall 2021	PHYS 132	34	0.0%	17.6%	23.5%	29.4%	20.6%	2.9%	0.0%	5.9%	2.21
Spring 2021	PHYS 132	46	21.7%	17.4%	15.2%	28.3%	6.5%	0.0%	6.5%	4.3%	2.48
Spring 2021	PHYS 132	44	13.6%	22.7%	18.2%	22.7%	4.5%	11.4%	6.8%	0.0%	2.46
Winter 2021	PHYS 132	47	21.3%	17.0%	29.8%	21.3%	2.1%	0.0%	6.4%	2.1%	2.79
Winter 2021	PHYS 132	44	22.7%	13.6%	25.0%	18.2%	4.5%	2.3%	13.6%	0.0%	2.68
Fall 2020	PHYS 132	87	24.1%	23.0%	10.3%	20.7%	5.7%	3.4%	9.2%	3.4%	2.55
Spring 2020	PHYS 132	34	44.1%	23.5%	14.7%	11.8%	0.0%	0.0%	0.0%	5.9%	2.89
Spring 2020	PHYS 132	36	55.6%	5.6%	11.1%	16.7%	0.0%	2.8%	5.6%	2.8%	2.29
Spring 2020	PHYS 132	35	42.9%	22.9%	17.1%	17.1%	0.0%	0.0%	0.0%	0.0%	3.10
Winter 2020	PHYS 132	53	0.0%	26.4%	32.1%	26.4%	11.3%	1.9%	0.0%	1.9%	2.66
Fall 2019	PHYS 132	26	0.0%	19.2%	34.6%	26.9%	11.5%	3.8%	0.0%	3.8%	2.46
Fall 2019	PHYS 132	15	0.0%	26.7%	13.3%	26.7%	20.0%	6.7%	0.0%	6.7%	2.20
Spring 2019	PHYS 122	35	0.0%	14.3%	31.4%	45.7%	5.7%	2.9%	0.0%	0.0%	2.49
Spring 2019	PHYS 132	63	0.0%	19.0%	39.7%	28.6%	9.5%	1.6%	0.0%	1.6%	2.62
Winter 2019	PHYS 132	47	0.0%	19.1%	36.2%	36.2%	2.1%	6.4%	0.0%	0.0%	2.60
Fall 2018	PHYS 133	48	0.0%	16.7%	25.0%	37.5%	8.3%	6.2%	0.0%	6.2%	2.25
Fall 2018	PHYS 132	45	0.0%	17.8%	31.1%	31.1%	13.3%	6.7%	0.0%	0.0%	2.40
Spring 2018	PHYS 132	68	0.0%	25.0%	35.3%	20.6%	11.8%	7.4%	0.0%	0.0%	2.59
Winter 2018	PHYS 133	38	0.0%	28.9%	34.2%	26.3%	7.9%	2.6%	0.0%	0.0%	2.79
Winter 2018	PHYS 132	37	0.0%	27.0%	18.9%	37.8%	8.1%	8.1%	0.0%	0.0%	2.49
Fall 2017	PHYS 133	51	0.0%	19.6%	23.5%	43.1%	9.8%	3.9%	0.0%	0.0%	2.45
Spring 2017	PHYS 132	47	0.0%	17.0%	34.0%	34.0%	8.5%	4.3%	0.0%	2.1%	2.47
Spring 2017	PHYS 132	48	0.0%	14.6%	27.1%	41.7%	10.4%	6.2%	0.0%	0.0%	2.33
Winter 2017	PHYS 132	70	0.0%	14.3%	41.4%	32.9%	7.1%	2.9%	0.0%	1.4%	2.54
Fall 2016	PHYS 132	66	0.0%	16.7%	30.3%	37.9%	12.1%	3.0%	0.0%	0.0%	2.45
Fall 2016	PHYS 132	47	0.0%	12.8%	31.9%	44.7%	4.3%	6.4%	0.0%	0.0%	2.40
	Overall	**1243**	**8.6%**	**19.1%**	**26.7%**	**29.6%**	**8.0%**	**4.3%**	**2.0%**	**1.6%**	**2.49**

Christopher Culbreath

Student Evaluations

Evaluation Summary



Overall, this instructor was educationally effective (5-point basis). Each point indicates the mean score for an individual course section— the area of the point is proportional to the number of respondents. The overall weighted average ($\overline{x} = 4.0$) is shown by the horizontal solid line, and the dotted-line follows the historical weighted average, calculated at each term.

Evaluation History

Year	Quarter	Prefix	Course	Type	№ of responses	№ of eligible evaluations	Response rate	Average Score
2021	Fall	PHYS	133	Lab	5	11	45.5%	4.60
2021	Fall	PHYS	132	Studio	11	32	34.4%	4.00
2021	Fall	PHYS	132	Studio	20	34	58.8%	3.40
2021	Spring	PHYS	132	Virtual	6	22	27.3%	4.50
2021	Spring	PHYS	132	Virtual	7	22	31.8%	3.29
2021	Spring	PHYS	132	Virtual	15	44	34.1%	3.47
2021	Spring	PHYS	132	Virtual	5	22	22.7%	4.00
2021	Spring	PHYS	132	Virtual	9	24	37.5%	4.33
2021	Spring	PHYS	132	Virtual	20	46	43.5%	4.10
2021	Winter	PHYS	132	Virtual	16	47	34.%	4.00
2021	Winter	PHYS	132	Virtual	10	44	22.7%	4.00
2020	Fall	PHYS	132	Virtual	8	24	33.3%	4.31
2020	Fall	PHYS	132	Virtual	6	30	20.%	3.92
2020	Fall	PHYS	132	Virtual	4	33	12.1%	3.38
2020	Fall	PHYS	132	Virtual	27	87	31.%	3.52
2020	Spring	PHYS	132	Virtual	9	34	26.5%	3.56
2020	Spring	PHYS	132	Virtual	16	36	44.4%	3.50

Year	Quarter	Prefix	Course	Type	№ of responses	№ of eligible evaluations	Response rate	Average Score
2020	Spring	PHYS	132	Virtual	9	35	25.7%	4.11
2020	Winter	PHYS	132	Lab	7	17	41.2%	4.29
2020	Winter	PHYS	132	Lab	13	21	61.9%	3.31
2020	Winter	PHYS	132	Lecture	33	53	62.3%	3.55
2020	Winter	PHYS	123	Lab	10	19	52.6%	4.00
2020	Winter	PHYS	132	Lab	6	15	40.%	4.50
2019	Fall	PHYS	133	Lab	13	24	54.2%	4.00
2019	Fall	PHYS	132	Studio	14	26	53.8%	4.36
2019	Fall	PHYS	132	Studio	8	15	53.3%	2.88
2019	Spring	PHYS	132	Lab	7	21	33.3%	3.50
2019	Spring	PHYS	132	Lab	9	19	47.4%	3.17
2019	Spring	PHYS	132	Lab	11	23	47.8%	2.95
2019	Spring	PHYS	132	Lecture	30	63	47.6%	3.22
2019	Spring	PHYS	122	Lecture	18	35	51.4%	3.00
2019	Winter	PHYS	132	Lecture	18	47	38.3%	3.50
2019	Winter	PHYS	122	Lab	14	19	73.7%	4.57
2019	Winter	PHYS	122	Lab	15	23	65.2%	4.67
2019	Winter	PHYS	122	Lab	12	23	52.2%	4.75
2019	Winter	PHYS	122	Lab	13	23	56.5%	4.46
2019	Winter	PHYS	122	Lab	10	14	71.4%	4.60
2018	Fall	PHYS	133	Lab	7	24	29.2%	4.00
2018	Fall	PHYS	132	Lab	6	23	26.1%	4.00
2018	Fall	PHYS	133	Lecture	24	48	50.%	3.21
2018	Fall	PHYS	132	Lab	10	22	45.5%	4.60
2018	Fall	PHYS	132	Lecture	15	45	33.3%	4.47
2018	Spring	PHYS	133	Lab	1	21	4.8%	4.45
2018	Spring	PHYS	132	Lab	7	23	30.4%	4.43
2018	Spring	PHYS	132	Lab	11	23	47.8%	4.45
2018	Spring	PHYS	132	Lab	11	22	50.%	4.45
2018	Spring	PHYS	132	Lecture	32	68	47.1%	4.38
2018	Spring	PHYS	132	Lab	7	22	31.8%	4.57
2018	Winter	PHYS	133	Lab	6	8	75.%	4.83
2018	Winter	PHYS	133	Lab	11	23	47.8%	4.00
2018	Winter	PHYS	133	Lab	7	15	46.7%	4.71
2018	Winter	PHYS	133	Lecture	22	38	57.9%	4.05
2018	Winter	PHYS	132	Lab	6	18	33.3%	4.00
2018	Winter	PHYS	132	Lab	9	19	47.4%	3.67
2018	Winter	PHYS	132	Lecture	12	37	32.4%	3.50
2017	Fall	PHYS	133	Lab	5	12	41.7%	4.60
2017	Fall	PHYS	133	Lab	10	17	58.8%	4.10
2017	Fall	PHYS	133	Lab	13	24	54.2%	4.31
2017	Fall	PHYS	133	Lecture	23	51	45.1%	4.26
2017	Fall	PHYS	133	Lab	7	22	31.8%	4.29
2017	Spring	PHYS	132	Lecture	27	48	56.3%	4.19

Year	Quarter	Prefix	Course	Type	№ of responses	№ of eligible evaluations	Response rate	Average Score
2017	Spring	PHYS	132	Lab	12	23	52.2%	4.25
2017	Spring	PHYS	132	Lecture	29	47	61.7%	3.76
2017	Spring	PHYS	132	Lab	14	23	60.9%	3.93
2017	Spring	PHYS	133	Lab	15	23	65.2%	4.27
2017	Winter	PHYS	132	Lab	14	21	66.7%	4.71
2017	Winter	PHYS	132	Lab	14	22	63.6%	4.00
2017	Winter	PHYS	132	Lab	16	24	66.7%	4.25
2017	Winter	PHYS	132	Lab	13	24	54.2%	4.08
2017	Winter	PHYS	132	Lecture	47	70	67.1%	4.17
2016	Fall	PHYS	132	Lab	9	22	40.9%	4.33
2016	Fall	PHYS	132	Lab	15	22	68.2%	4.47
2016	Fall	PHYS	132	Lecture	34	66	51.5%	4.41
2016	Fall	PHYS	132	Lab	12	22	54.5%	4.42
Cumulative Results†					Σ: 997	Σ: 2178	$\overline{x}$: 45.8%	$\overline{x}$: 4.00

†The total number of eligible evaluators differs signifcantly from the total number of grades assigned (2178 vs. 1243, see page 10) because students enrolled in tradtionally structured lab/lecture courses haven an opportunity to evaluate both their lab and lecture instructors regardless of chain continuity. By comparison, studio courses are afforded a single instructor evaluation for the combined lab-lecture offering. This introduces a weighting bias towards traditionally structured courses when calculating a summary evaluation score.

Christopher Culbreath

Statement of Teaching Philosophy and Approach

Forward

It has been nearly two years since the whole world departed on a journey of no one's choosing.

The swiftness with which the coronavirus pandemic entered our consciousness was rivaled only by the extent of the ensuing disruption and the staggering scope its reach. Even today, the shadow of coronavirus is remains—each new greek-lettered variant poses a new trial to which we must adapt, lest we endure its tribulation. In a testament to our nature, we have sacrificed social pleasure in the name of public heath. But even the most well-intentioned and disciplined among us cannot sustain an indifference to unyielding uncertainty. Everyone of us has been meaningfully changed in someway by this virus. It's a worldwide trauma. We shouldn't hesitate to say it. We mustn't let the dark fact that everyone, especially our children, now has some baggage to work though overwhelm or delay the critical work of healing. The ubiquity of the burden does not diminish the significance of the individual costs. It'll take more than a single academic quarter or even a year to work out was this means for each of us. Clearly, we are all ready for the pandemic to be over, but this remains a journey of no one's choosing. Until we reach our destination, we must be compassionate and patient with one another. And perhaps more importantly, we must remember to extend that same attitude of patience and compassion to ourselves.

The Bright Side

Fortunately, there is a brighter side to all of this. The story of coronavirus more than just a story of trauma. Regardless of the the extent of our suffering, and no-matter the healing required from each us, there are parts of this pandemic that have changed each of us *for the better*. As I reflect on how my teaching philosophy and approach have evolved through the lockdown all that has followed, I've concluded that the core principles of my teaching approach form a sturdy foundation upon which a quality course can be built, regardless of the content delivery method. When comparing my online classes to a traditionally structured course the large contours of my approach are unchanged. But upon inspection, there exist subtle, but meaningful ways that my teaching has been improved by our online experience. Broadly speaking, my classes and policies are now more flexible, immediate, accessible and accommodating of individual student needs than they they were pre-pandemic. In the paragraphs that follow, I describe the core principles of my teaching philosophy and approach as well as highlight some of the positive ways that the experiences of remote instruction have left a lasting positive change on my work.

Mind the basics

The core competencies of the job are knowing the material, assigning and grading coursework and providing meaningful assessment. While simple in nature, these skills require hard work and dedication to do right. Meeting and succeeding students expectations in these areas requires putting in the time and preparation to deliver nuanced lessons that educate and inspire. I also believe that specific instructional techniques should be guided by evidence-based Physics Education Research (PER). Beyond these fundamental building blocks, the content and topics of a given course are largely static and prescribed—the catalog description mandates a list of topics that requires a brisk pace and leaves little time for exploration. Compare any number of undergraduate physics textbooks and you'll find a uniformity in pedagogy and presentation that reflects a broad continuity in the state the art. Anf there is little variation, by practice and policy, in the distribution of grades assigned from class to class and quarter to quarter. Students, like all of us, are also creatures of habit and they are resistant to instructional methods that vary significantly from the traditional set of tools to which they are accustomed. Yet we all know from our own experience as a student, that there is a wide variation experience from one course to another. It follows, that what makes one course, or one quarter or one section shine over another comes down to the nuanced choices, policies and attitude of the instructor. Along with an emphasis on fostering this positive class culture while integrating evidence-based best practices that have been identified through Physics Education Research. I have relied on a set of core guiding principles when designing and updated my courses. These principles, and how they affect my approach to teaching are enumerated below:

Culture is critical

As mentioned above, most of the elements of a course are constant from class to class and quarter to quarter. It comes down to nuance whether students embrace the class, support the instructor and willingly engage with the material and each other. It's these intangible cultural factors that ultimately dictate whether a course is remembered as enjoyable, collaborative and educational or if the course merely endured with minumum effort as a requirement of graduation or a paycheck.

While I've given passing credit in the past to the importance class culture, I have only recently become aware of the vital role that the culture of a class plays in determining whether a class is enjoyable and educationally successful. With the benefits of youth, enthusiasm, force of personality and fair measure of luck, my early classes benefited from an inherently positive environment. It was through the process of reflecting on critical student evaluations that I've since identified attitude and culture as the primary indicators of course success. In every instance of student dissatisfaction, I found that I had shared their dissatisfaction with the class and felt it throughout the quarter. While the instructor is responsible for setting the tone and attitude applied to the course, the nature of the class culture is a product of both nature and nurture. Any number of external factors that can set a course on a downward path—a class scheduled at an inconvenient time, incompatible small group dynamics, the personal struggles of the instructor or the toxicity of even a single student. All too easily, a seed of discontent devolves into a selfreinforcing downward spiral. Whatever the source, it is critical that the forces of negative class culture be addressed with promptly, directly and with positivity.

While addressing bad attitudes as they appear can limit the spread of negative class culture, the best remedies are preventive. Since we're only given one opportunity to make a first impression, I give special care to getting the course off on the right foot. While I've always tried for a strong start, I've taken a more purposeful approach to shaping this critical time in the student-instructor relationship. I now make a conscious effort to set aside the inherent fatigue that often accompanies the routine of final-exams, assigning grades, and prepping for a new quarter. I find it to be a worthwhile investment to expend extra effort into making the first week of a course shine.

As both a student and an instructor, there are few things in life that I enjoy more than a great physics class. While there remains some unidentifiable magic that distinguishes the exceptional from the good from the bad, a realtime awareness of class culture and taking an active role in shaping that culture are the most important tools for promoting student engagement and satisfaction.[1]

Teach a class that I would enjoy taking

This principle is a broad mandate and really it's at the core of every decision I make as a teacher. It is often emphasized that as an academically successful bunch, those of us with PhDs in physics may not understand what the challenges and needs of a freshmen student are. While I agree that my experience differs from my the average experience of my students, I contend that one's imagination of what a freshmen student needs or would enjoy in a course has even less accuracy and should be given less authority in designing elements of a course. My standard—would I enjoy this in a class— is as clear a test as I can find in determining the viability of innovation and change in my class. It's a pulse to keep my finger on as I navigate ahead. While this might slow the pace at which I integrate PER elements to my classes, it does ensure that each is well considered and carefully implemented. From instant response questions to in-class group work, I have added PER-vetted teaching elements, but each was added with care and in a way that would have earned the buy-in and acceptance of Christopher-the-student. I don't want to contend that my opinion is somehow infallible or the ultimate arbiter of what makes a good class, it's that there's no evidence to suggest that my imagination of students, as somehow foreign and so different from me that they enjoy what I despise, has any validity at all. The person in one's imagination can be anyone, but ultimately is no one. I think that many instructors get off base thinking this way. Once you let your imagination be the standard to judge against, you can twist your course into something both unrecognizable and unenjoyable. I don't find this principle to be in conflict with innovation. I have found it compatible with my commitment to implementing PER- vetted pedagogies. It has, however, required that I give enough thought and care to my implementation that I can move forward ownership of my approach, never imposing work that

[1] I want to make an important clarification about my goals of student "satisfaction" or "enjoyment." There are plenty of academically challenging courses that are well received by students. All of my most memorable classes as a student, were also some of the most difficult I had ever taken. Although some students surely profess to enjoy classes that are easy, and there's a case to be made that a class-wide low-scoring exam might accelerate bad attitudes, I'm not tempted to make the class easier as a tool for improving the class culture. Besides my own philosophical opposition to that sort of pandering, I don't think that it would work. Not onlu would I would derive less satisfaction from a teaching a watered-down course, students are eminently attuned to their time being wasted—and making the class easier would waste the time many enrolled. Neither is a recipe for a successful class.

I wouldn't like under the assumption that students are somehow fundamentally different that me.

Cast a wide net

I try to incorporate all students when teaching, regardless of skill level. This core philosophy addresses another common criticism of PER methodologies, namely that techniques of active learning like worksheet tutorials are aimed only at the weakest students in the class. The challenge, as I've seen it, is to incorporate these elements in balance with more advanced topics. When teaching studio physics, for example, I emphasize from the beginning the value of peer instruction. Peer instruction is a great example of a "wide net" teaching practice, because more advanced students solidify their understanding while weaker students gain basic understanding that they were lacking. I also include multi-part, appropriately weighted, problems on my exams that allow weaker students to demonstrate their core competencies while allowing top students to demonstrate their ability to synthesize different aspects of the content to approach a new problem or application that they hadn't seen before. The ideal exam question has something for everyone, and ends with an element that leads to an "a-ha moment" in which a problem seemed initially unsolvable until students discovered a way to look at it a bit differently.
In all, I believe that my results reflect success in casting a wide net. While some students offer comments that my exams are too hard, or too foreign, there's tends to be a pretty balanced distribution of performance on each exam that reflects department guidelines.

Never underestimate the value of having fun

Given the full schedule and ambitious scope of the content in all of our introductory classes, this guiding principle is the hardest to keep up with. But, I do try and craft a lecture that's engaging, funny at times and includes the bestdemonstrations. Based on my understanding of PER literature, the educational value of demonstrations is marginal. What I don't believe is captured in those studies is whether students had fun with them. A good example of a demonstration that I think captures the right elements of fun, but may not teach the answer to an exam question is breaking a glass with sound or viewing standing waves with a strobe light in Physics 132. Both of these demonstrations bring a smile to students' faces, and inspire questions well after they're done. They also bring camaraderie and to the class and build instructor-student rapport. I am often credited with being enthusiastic in student reviews, because I am. I think my excitement for physics, and that excitement that I hope to share with students, is encapsulated in this guiding principle of valuing fun in the educational experience.

Be flexible

One thing that has struck me now that I've been at this job for a while is how very unconventional my own student experience was. When I was an undergraduate student at Cal Poly, I had two kids and full-time job, and I encountered mixed levels of understanding and flexibility from my instructors. This awareness has lead me to establish some flexible policies in my class. I accept late work (for 2/3 credit) until the last day of the course. I'm willing to offer make up exams when missed with a good excuse. I typically drop the lowest midterm score over the quarter. I don't track attendance or assign points to in-class work (except in lab). In general, when a student comes to me with a struggle or difficulty in the class, I try to work with them to find a way forward. I try to present an attitude that I won't be sweating the small stuff. That said, from my perspective as a former Cal Poly student and as an instructor, high standards of assessment are largely what maintain Cal Poly's reputation of excellence. I certainly hold a high standards for assessment, and the grade distributions in my class reflect this. But apart from assessment—the key measurement of whether or not the course material has been learned (or not)—I try to offer whatever flexibility I can to students. This benefits everyone, but I think it provides particular benefit to underrepresented students. My default is to be accommodating, because I know the challenge of adulthood are real, and they don't need any extra rules or the stringent policies of a self-important physics class to add to those inevitable challenges that life sends our way.

The pandemic motivated an even greater attitude of flexibility in my classes: I try to say yes-by-default to student requests around due dates or alternate exam times. I've widely expanded my late-work policy, and will accept late homework, without penalty, if it's submitted before the set has been graded and return to students. By keeping homework submission online, even for in-person classes, the chore of tracking paperwork is eliminated and so late work can be incorporated into the main set without having to manage loose, late-submitted papers. Perhaps I've been lucky, but I haven't had students clamoring to take advantage of my lenient policies or a glut of late assignments My library of zoom recordings is a resource of four complete class offerings, and I use this content to provide supplemental lecture for those who miss lecture (this has been particularly valuable during the omricon surge). Another pandemic-inspired change that I don't expect that I will ever retreat from is that I now give my phone number to students in the course syllabus. Student communication through text messaging presents a number of advantages over traditional email communication. For one, it elevates their correspondence out of my inbox which has been relentlessly active. In general, I respond to texts with greater regularity than any other form of communication, which affords student questions and concerns a priority commensurate with their value. In addition, I find that the informal, short-form nature of texting promotes more regular conversational communication, so I get the little questions that wouldn't overcome the barrier of formality that students perceive around email. Since texting is part of everyone's regular routine and has some expectation of immediacy (as opposed to the processed in batches nature of email) that allows for an extended conversation with a dynamic back and forth. This immediacy also makes it appropriate to suggest an adhoc zoom meeting in the text-based medium is inadequate for the question at hand. Working with students one-on-one is one of my favorite aspects of the job, and I've found that my switch to text message has reduced barriers and improved the quality of discourse with my students.

Let students choose

I believe that students will embrace what they've created. In this light, I always have some elements of my course that are left to student online vote. Often these decisions I bring to a vote because I couldn't make a determination of the best choice on the above guiding principles alone. Examples of student-directed course structure include: Assessment scheme— weekly exams, versus two midterms and a final, versus three midterms and a final, drop one. Homework grading— lottery grading versus credit/no-credit by problem. Homework due date— Monday or Friday. Sometimes the result of a student vote surprise me, and other times they're completely predictable. In recent quarters, I've used an online scheduling tool that I've written for my website to solicit student input on the best times for me to hold my office hours[2]. In every case, students appreciate having agency over the structure of the course, they appreciate my flexibility in honoring their vote, and there's widespread acceptance over the outcome. I believe that if I had introduced weekly assessments in lieu of midterm exams by fiat, I would have had endless complaints about the rigor of the new system. Since students themselves voted this experiment into existence, I heard no complaints about the exams at all in person, or in my student evaluations. Every course I teach has some element of student-determined structure, and I think the most successful courses have several significant elements that were shaped by student vote.

In recent quarters, I have added an even greater level of individual student control over their course experience. In the past, I've assigned some fraction of the overall course grade to homework assignments. While I believe that the majority of the grade earned in the course should reflect a student's abilities to demonstrate an understanding course competencies on an exam, I've have traditionally seen homework points as a carrot to keep students in sync with the pace and content of the course. Baked into that policy is the presumption that every student wants to feast on carrots. Not every student has the time and hunger for a carrot feast. With this in mind, I've written a feature for Physics Cloud Gradebook that allows a student to choose, as an individual preference, what percentage of their overall grade calculation is to be determined by their homework scores. In my most recent implementation of this system, any value between zero and 15% of student's overal grade could be assigned to homework. Any portion of the 15% not applied to homework is instead added to the weight afforded to exam scores. I'll use my Fall 2021 weight percentages as an example: A student choosing the maximum 15% homework weight, would have the minimum weight of 55% weight assigned to exams, 15% determined by final exam performance and 15% going to lab and in-class group work. In contrast, a student electing for homework to be omitted from their grade calculation entirely would see their grade calculated with 70% of the score determined by exam performance along with the 15% applied the final and 15% coming from labs. By policy, students are given roughly the first two weeks of term to make adjustments to their preference. I always wait a few days after the first homework assignment and first exam have been graded and returned to lock changes. This gives students a few data points to inform their choice.

My biggest motivation for allowing this unique level of customization comes from my own experience as a non-traditional Cal Poly student. My oldest daughter[3]. was born the year before I transferred to Cal Poly, and my son was born during my junior year[4] During most of my undergraduate years, I also had a full-time job, working as a technician at the local Apple reseller. Given these constraints on my time, I rarely completed all the homework as assigned in my classes. Instead I honed an academic routine that relied on a combination of focused in-class participation, a knack for test taking, and a wack-a-mole (often overdue) approach to homework. For much of my time in college this technique worked well, I learned the material and

[2]This quarter, Sunday afternoon was the most requested time, so I'm holding a Sunday office hour— so far it's been great

[3]I've got found memories of my less-than-two year old daughter Jane, holding my hand and quite literally toddling along side me through the spider building as I made my way to Ron Zammit's office hour with PHYS 206 homework questions. She turned 17(!) last week

[4]Conveniently (and remarkably) he was born during Spring break, and while I took a reduced course load that-Spring, I didn't end up missing class for his actual birth

had strong test scores[5]. However, I found that in many cases, instructors assigned what they considered to be a "generous" weight of the overall grade to rote homework assignments. To those with the time, these "easy" points acted as a buffer and that padded their grades and insulated their scores against variable test perfomance. In my case, these assignments left a big hole in my total score which in some instances could not be overcome even with the best of exam scores. My experience showed me that what amounts to generosity in grading and which points count as easy points is largely in the eye of the beholder. By allowing to students to initially choose the weight of their homework grade, they can adopt a learning strategy and allocate their time in a way that fits their skills and the unknown constraints that may limit their bandwidth out of the classroom.

* * *

In updating my Teaching Statement, I'm left with a familiar feeling of surprised satisfaction. The process of digging into these topics, and putting words to my ideas that surround my teaching has left me with a greater sense of purpose, focus and inspiration than I knew was lying just below the surface. This reflection has certainly inspired a more meaningful and comprehensive rewrite (and expansion) of this essay than I would have ever anticipated. While I must confess to a subtle pang of indignation when the task of this annual rewrite first appears on the horizon. The process soon reveals the wisdom of the requirement. Not only is this exercise a valuable reflection of a year gone by, but it's an a reminder of my goals, achievements and motivations and as I set my course for the year the year ahead. More than anything, this analysis reminds me of one of my favorite aspects of this career. I love that this is a job that is just as much about learning as it is about teaching.

* * *

[5] This unconventional approach worked until suddenly it didn't. I remember distinctly the moment in Karl Saunders' PHYS-305–my first upper-division physics course– that I realized this course was different than any class I had taken before. We received our first exam scores and it was immediately clear to me that success would require nothing but my full, dedicated attention. It was both humbling and exciting. It's in that class that I learned for the first time, how to study, and I worked my butt off to make up for that terrible performance on the first exam

Christopher Culbreath

Professional Plan

Outline of Proposed Achievements

Teaching

- Obtain a three-year lecturer appointment
- Teach introductory physics courses
  - PHYS-132 Studio
  - PHYS-141
  - PHYS-133 Studio
  - Traditionally structured PHYS-132 and PHYS-133 as required to satisfy course demand
  - PHYS-121, PHYS-122 and PHYS-123 as required to satisfy course demand
- Participate in faculty collaborations associated with studio courses (PHYS-132/PHYS-133)
- Develop skills and curriculum to maximize the benefits of Learning Assistants in PHYS-132 Studio and PHYS-133 Studio
- Refine and develop integrated lab exercises in PHYS-132 Studio
- Develop standards-based assessment for PHYS-132 Studio
- Develop new online tools to tailored to PHYS-132 curriculum
- Develop LMS-based curriculum an assessment tools that adapt to individual student performance
- Explore PHYS-141 parallel pedagogy in collaboration with other faculty

Scholarship

- Supervise and advise students in developing and fabricating instrumentation that support the research activities of a fellow faculty member

Service and University Scholarship

- Serve as a course-coordinator for PHYS-132

Explanation of Proposed Achievements

Teaching

Career Goals

As a lecturer I appreciate the my role in supporting the primary function of the Cal Poly Physics Department—providing high quality physics instruction to students from every academic discipline. When I accepted a lecturer position at Cal Poly, I assumed the job would end up being a stepping to a future tenure-track gig. But working as a lecturer has caused me to reevaluate this assumption. I've always known that in whatever career I ultimately arrived, that research would be secondary to the work that I enjoy most, teaching in the classroom. At many universities, the role of adjunct faculty us diminished by a stigma of illegitimacy or expendability. With the Cal Poly physics department, I've found an environment where the work of lecturers is not stigmatized, but instead role as lecturers is unambiguously valued and respected by colleagues. True to my experience as a Cal Poly alumnus, Cal Poly remains an environment where the supremacy of research output over top-quality teaching is not a universally held truth. Having experienced first-hand the benefits of Cal Poly's focus on quality instruction, and in-line with my current interests, I deeply appreciate the teaching-first focus of my job. As such, I come to see a long-term lecturer appointment as fundamentally better suited to my skills, interest and enjoyment than a tenure-track position and the limitations posed by a significant research expectation.

Introductory Courses

The bulk of what we do in the physics department is teach introductory physics to non-majors. I believe that this is important work. Physics classes are an important element to a complete polytechnic education. Fortunately, even having taught some introductory courses nearly 20 times, I still find the material exciting. I've found that I derive a greater level of fulfillment teaching these classes as my understanding of the material gains further depth, richness and nuance with each new term.

Consequently, the largest component of my professional plan is a full-time contribution to fulfilling the department's obligation to introductory courses.

Studio Improvements

I have enjoyed the flexibility, adaptability and effectiveness of teaching introductory courses in the studio format. Based on my own inexperience with the studio format, my presentation in this format presents an opportunity to be refined and improved. Specifically, I would like to refine and develop the laboratory exercises to better leverage the benefits and constraints of the studio format. One of the most challenging aspects of the of lab exercises in the studio is time management. From group to group there is a wide variation in the amount of time that it takes students to complete lab exercises. In a traditional structure, students who finish early can leave lab early. When the labs exercise is just a portion of a larger studio lesson, varying execution times present a challenge to occupy those students who finish before others. My goal is refine the lab exercises to be more modular with optional components and open-ended elements that can be mixed with finite-scoped measurements to provide a buffer against large variations in the time that students take to complete any one portion.

I also intend to transition my mode of assessment in PHYS-132 Studio from a traditional points based system to a standards-based assessment. I would like to implement mode of assessment inspired by a Physics Education researcher/former colleague at Chico State. Dr. David Brookes assessed students in introductory mechanics (121/141 equivalent) against a list of learning objectives for the course. In my time working with Dr. Brookes this system was still in development. For each objective (I believe that there were 14 overall) he developed a panel of (single question) tests and a panel of (single question) advanced tests. Each week, a class meeting or portion of class meeting is dedicated to taking these objective tests. In order to obtain a passing grade in the course, a student must pass an exam for every objective. Each objective test has a minimum of three variants, to allow students three attempts at a passing score for that objective. The forth attempt requires an oral exam/discussion with the instructor. Students who pass all of the objectives earn a C in the course. If even one objective is unmet, a failing grade is awarded. A and B grades are awarded based on the proportion of advanced objective tests passed. Test days are student-paced, with students requesting a test for one of their unmet objectives and taking as many (or few) tests in a single period that appropriately suits their progress. Tests can also be taken during office hours. In some instances a single test could cover more than one objective.

I find an assessment scheme of this sort incredibly appealing. The whole formulation is fundamentally more meaningful than an analog grade based system. What does a 67% really mean in terms of learning? Measuring success against objectives, as well as setting a clear minimum standard is far less arbitrary and systematically fair than traditional point-based partial credit. However, even a cursory evaluation of this approach reveals the tremendous amount of work that is required for its implementation. Boiling down any one of our introductory courses into a dozen testable objectives is a decidedly non-trivial task in its own right. Writing three easy and three advanced questions for each of these objectives, as well as managing the time required to take and grafe these test also present sizable challenges. Even developing a gradebook that efficiently tracks student progress is not straightforward. Nevertheless, I am convinced that is in principle a better way to assess student learning. I would like to experiment with this approach to assessment in my classes, and see it as a meritorious component of my profession plan.

Learning Assistants

I have had several opportunities to employ learning assistants in PHYS-132 Studio. While the benefits of LAs are immediately evident in the course, there are some aspects of working with LAs that could be improved relative to the level of success that I've had with prior experiences. Synchronizing LA prep, LA availability and course presentation is a significant scheduling challenge. I have yet to find the ideal schedule that keeps LA-time from intermittently overlapping with lecture-time. During the quarters where I've offered frequent chapter tests, the opportunity for schedule conflicts in even more acute. I also seek to be a better mentor to LAs and provide in class exercises where their contribution has maximum impact. I intend to improve by making the resolution of these challenges a specific, targeted goal of a future offering of PHYS-132. Further, the studio collaboration meetings present an opportunity, yet underutilized, to be guided by more experienced faculty in structuring my classes to optimize the contributions of Learning Assistants.

Adaptive Assessments

In recent quarters, I have implemented a final assessment scheme that is adaptive to each student's prior performance. The bulk of assessment is spread across seven chapter tests given weekly most weeks. The final exam is then given in three parts: i) An eighth chapter test covering the last week of lecture content and ii) a two-part cumulative exam covering materials from each individual student's two scoring chapter tests. Students who are satisfied with the scores from their low scoring tests may apply their original exam scores to the final and skip those portions of the test. If a student improved their score on the the cumulative final exams relative to their score on the orignal chapter tests is applied to both the final exam and the new score raises the original chapter test score. The management and application of the grading for this somewhat complex scheme is handled entirely through my Physics Cloud gradebook software. By loggin in to the website, students can see their realtime grade calculation and opt out of either cumulative portion of the final exam. Developing Physics Cloud has enabled me to experiment with this sort of student-tailored customized approach. I would like to develop this idea further and incorporate additional elements to my class that respond and adjust to student performance. In particular, developing homework sets that emphasized those areas of the course content that a student has demonstrated a need for extra practice is an application that I think would benefit my students. One of my guiding principles in designing my courses is to "cast a wide net," by adjusting and responding to the needs of individual students in terms of the content, practice problems as well as offering a tailored second chance to students on a assessments, I can cast the widest possible net, while maintaining a high, consistent standard in terms of the learning objectives and goal of the course.

Parallel Pedagogy

I have been invited by Dr. Schwartz to participate in trial and development of his novel Parallel Pedagogy PHYS-121/141 curriculum. I'm interested to participate not only because I'm intrigued by his approach and recognize its the potential benefits to student learning, but because I also yearn to have a more collaborative relationship with my colleagues that gives my work with a sense of shared purpose and mutual support. I see a potential partnership with Dr. Schwartz as promising in this regard.

Scholarship

Instrumentation Collaboration

I have long expressed an interest in the practical side of developing and fabricating custom instrumentation in the service of experimental research. While I don't currently seek to pursue my own research effort, I see working in collaboration with another faculty member as a good fit to my work as a lecture. Many experiments, especially in undergraduate research programs, are constrained by the cost, development time or skill required to develop and fabricate custom instruments. While our department technicians are second to none, their broad portfolio of responsibilities prevents them from committing significant sustained resources in any one research effort. I propose that I collaborate with a faculty member with an existing research project that requires the development of customized instrumentation. I would head up that aspect of the project and supervise a student or two in the fabrication of the instrument, An ideal project would span a couple of academic quarters and be of significant scope to satisfy the senior project requirements of one or two students.

Service and University Citizenship

I have enjoyed my experience serving on various department committees and value the opportunity to contribute to the direction and decision making within the department. I intend to continue to serve on various committees each year an the need and opportunity for collaboration arrises. I also intend to volunteer to be the course coordinator for Physics 132, a course that I have significant experience teaching.

Christopher Culbreath

Case for Three-Year Lecturer Appointment

Dear Committee Members:

I have worked as a lecturer in the Physics Department at Cal Poly since Septemner of 2016. During that time, I have sought to inspire and educate students, while upholding the high academic standards and spirit of “learn by doing,” that set Cal Poly apart. As a Cal Poly graduate, I know first-hand the value of a Cal Poly education, and I know just how high the bar has been set by my accomplished and talented colleagues. My own teaching is distinguished by a enthusiastic and passionate presentation. I seek to share with my students my love for physics and the spark of joy that comes with snapping together its many interconnected pieces. The essays and materials assembled here for your inspection reflect the high standard of quality and attention to detail that I bring to all of my work.

Beyond the core elements of teaching, I have also developed a suite of online tools to support my classes and provide one-of-a-kind tutorials, instructional videos and animations, assessment, administration and scheduling tools and most prominently, feedback to students about their course progress. A unique aspect of my courses is the extent to which the structure and policies of a particular class are determined both individually and collectively by student preference. Throughout my years at Cal Poly, I have not grown complacent but instead I have envolved my teaching by incorporating evidence-based practices that maximize student engagement and success.

I have sought to be a easy-going and helpful member of the department, and I have shown agreeability and flexibility with scheduling as assigned teaching load and a willingness to help cover unforeseen teaching needs as they arise. I have demonstrated adaptability to various teaching modalities, and have taught classes in traditional, studio, and virtual formats. And, in response to the COVID-19 pandemic I was aided by my technical background in building multi-camera, motion tracking, virtual classroom in pursuit of an ideal implementation of virtually delivered.

My achievements during the current review period are enumerated on the following page.

Courses Taught

- PHYS-132 Virtual General Physics II (Virtual Instruction) · S20, F20, W21, S21
- PHYS-132 Studio General Physics II (Studio Format) · F19, F21, W22
- PHYS-132 General Physics II · F16, W17, S17, W18, S18, F18, W19, S19
- PHYS-132 Lab General Physics II Laboratory · F16, W17, S17, W18, S18, F18, S19
- PHYS-133 General Physics II · F17, W18, F18
- PHYS-133 Lab General Physics II Laboratory · S17, F17, W18, S18, F18, F19, F21
- PHYS-122 College Physics II Laboratory · S19
- PHYS-122 Lab College Physics II Laboratory · W19
- PHYS-123 Lab College Physics III Laboratory · W20

Student Advising

- Ryan Lau (Cal Poly Physics). Frost Research Program, Summer 2017. We investigated the development and testing of a novel thermal actuator made from a single-crystal Cu-Al-Ni shape memory material. I advised Ryan on research and directly instructed him in the machine shop, where he developed the skills to produce experimental components on his own, from scratch.
- Lauren Smith (Cal Poly Physics). Frost Research Program, Summer 2017. We probed the origin and character of a previously uninvestigated spontaneous EMF observed in single-crystal Cu-Al-Ni during the martensitic transition. Lauren's work mainly focused on the development and design of an apparatus for systematically inducing the martensitic transition with varying strain regimes.

Departmental Service

- Studio Physics 132 Collaboration Fall 2019, Spring 2020, Fall 2021, Winter 2022
- Lower Division Curriculum Committee Fall 2016, Winter 2017
- Demonstration Committee (ad-hoc) Fall 2016, Winter 2017
- Assessment Committee Fall 2017, Winter 2018
- Facilities Committee AY 18–20
- 12x Textbook Committee Spring 2019

Student Service

- Society of Physics Students. Faculty participant. Fall 2016, Winter 2017.

Christopher Culbreath

Materials by Course

Physics Courses

Physics 132 Studio (F19, S20‡ , W21‡, F21, W22)

Physics 132 (F16, W17, S17, W18, S18, F18, W19, F20‡, S21‡)

Physics 133 (F17, W18, S18, F18)

‡Virtual Instruction

*The content of the comprehensive portion of each student's final exam is determined by their lowest two chapter exam scores.

Physics 132 Studio

Fall 2021

Instructor: Dr. Christopher Culbreath (he/him/his)
Office Hours: MWF and Sunday 12:40-1:30 via Zoom

Lecture: MWF 8:10-10:00 | 2:10-4:00 **Email:** cculbrea@calpoly.edu

Web: physicscloud.net/132 **Mobile:** (805) 234-0847 **Zoom Meeting ID:** drculbreath

Course Objectives: Physics 132 is the second course in the series of calculus-based introductory physics classes. Unlike the other courses in the introductory physics series, Physics 132 covers three broad topics: Waves, Optics and Thermodynamics. A full outline of the course objectives is posted on the course website.

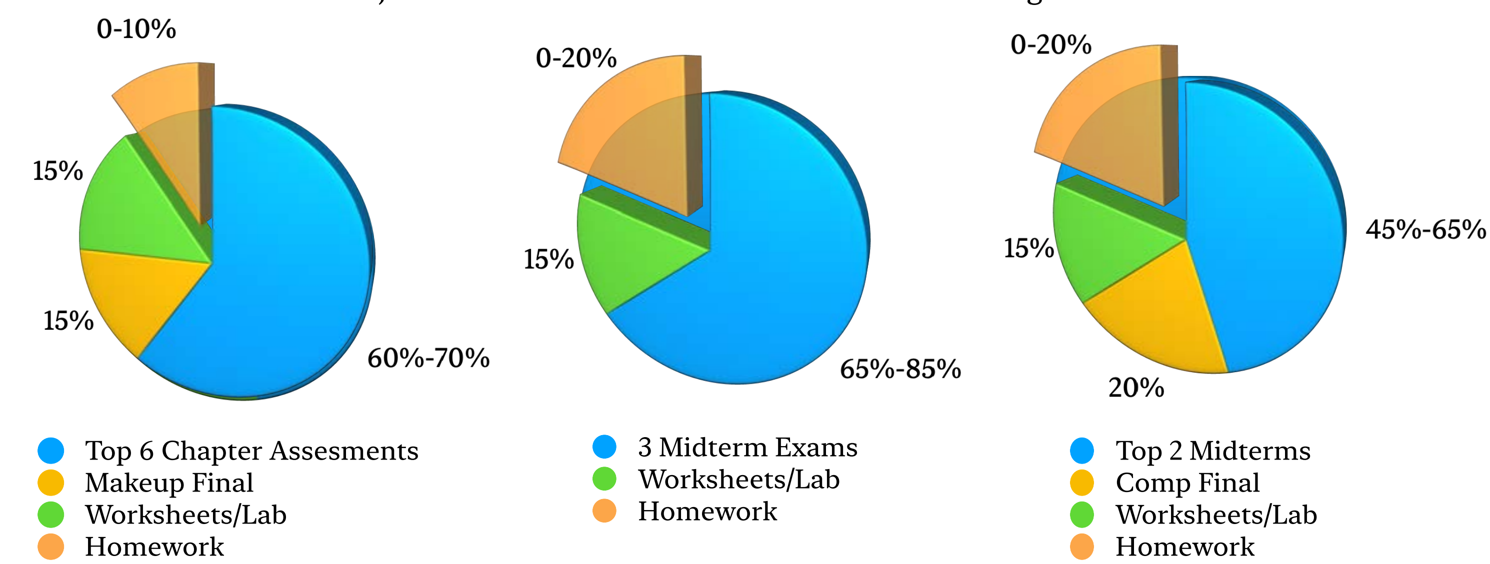
Textbook: *Physics for Scientists and Engineers: A Strategic Approach with Modern Physics*, by Randall D. Knight, 4th Edition. The textbook is well-written and accessible, and my lecture notes generally align with the textbook presentation. Handouts will be distributed digitally on the course website.

Course Website: The course website is https://physicscloud.net/132/ ***The website is a source of essential information for this course.*** Assignments, solutions, the syllabus, course objectives, course schedule, lab handouts and exam solutions will all be posted to the site. A login is not required to access the main course site (grades and other sensitive content require login access). Please check the course website regularly. **I do not use the campus Canvas or Poly Learn systems.**

Prerequisites: Prior completion of PHYS 141 (or equivalent) is a required prerequisite.

Grading: Course grades will be tabulated according to a weighted average. The specific weighting of assignment types will be determined by the outcome of the assessment scheme class vote (see details below). In every scheme, homework is weighted at 0–20% of the overall course grade, according to individual student preference. When a student chooses a homework weighting less than 20%, the grading weight assigned to their midterm exam scores is increased commensurately. The default weight assigned to homework (without student intervention) is 10% or 15%. The page for adjusting your individual homework grading weight will be first be available on Physics Cloud after the first homework assignment has been graded. The last opportunity to adjust your homework grading weight will be just after grades for the first exam have been posted (the specific cutoff date will be announced in class and by email at least 48 hours in advance).
The three grading schemes to be considered are summarized graphically below, and are described in greater detail on the voting website.

Grading Curve: At the end of the term, every student's weighted point total will be ranked with letter grades assigned using a normal (Gaussian) distribution with the median score assigned a C+ and the width of the distribution adjusted such that the number of students earning an *A* or *A-* is no fewer than



at an answer or equation without this justification are not acceptable for full credit. **Calculators are not allowed on any exams in this course.** Submitted solutions should always show *all* steps of the calculation and be worked *symbolically* until the last step, which should be a calculator-ready expression for the desired quantity. Unless otherwise specified a complete calculator-ready expression is sufficient for full credit. *Calculator-ready* means that the expression has all numeric substitutions applied such that it can be entered into a calculator, *as written*, without referencing additional equations or definitions[1] Avoid using exam time to perform tedious arithmetic. **Any time a number is used, anywhere on an exam, appropriate units are required.** This applies to numbers used in intermediate steps as well as numbers used in a final answer. Numbers require appropriate units: every number, every step, every time. This only applies to dimensional quantities written as a numeric values; symbolic quantities should not be written with explicit units.

Submitting Assignments: Assignments will either be collected on paper or by online submission as determined by class vote. If the class elects to submit assignments virtually, all assignments shall be submitted digitally by email to `turnitin@physicscloud.net`. *Turn it in* is an automated mailbox system and assignments must be submitted according to the following rules in order to be routed and saved properly:

1. All work shall be encapsulated in **a single PDF attachment scanned using a document scanner or scanner app.**
   - **Emails containing multiple attachments or image files (png, jpg, bmp) will be automatically rejected by the system.**
   - **Unprocessed photographs** of submitted work (regardless of file format) **will not be accepted for full credit. You must use a scanner or scanner app** to prepare your **documents (the app should straighten the page, remove background etc). Keep in mind that your submission should reasonably represent a print-ready scanned document.**
   - You should establish a procedure for producing multi-page PDF scans, using a desktop scanner or a scanner app on your mobile device. Ensure that the document is well-lit and that the final scan is readily legible.
   - If you use an iOS device, I can recommend **Scanner Pro** ($3.99), although **the multi-page scanning capability of Apple's Notes app**, is a little-known-yet-capable option worth trying (it's free).
   - Microsoft Office Lens is included with the university's Office 365 subscription as is a good choice for both **iOS** and **Android**
2. **By default, a**ll submitted attachments must be **sent from your Cal Poly email address.** This is how the system identifies which student to tag when the attachment is processed.
   - Emails submitted from unknown addresses will be rejected by the system
   - If you would like to use an email address other than your Cal Poly email for submitting assignments, you can add your personal email address to your Physics Cloud account (when logged in to Physics Cloud choose the gear in the upper-right (⚙) to add an additional trusted email addresses)
3. The **subject line of the email should match the assignment's short name *exactly*.**
   - An assignment's short name is posted with its listing on the course website.
   - Generally, the short names follow a memorable scheme. For example, the first homework assignment will have the short name HW1 and the first midterm will be short named MT1.
   - Emails submitted with an unknown short name in the subject line will be rejected automatically.
   - On the backend, submitted short names are stripped of white space and converted to all lowercase letters. Consequently variations in the capitalization and use of extra spaces will not, on their own, prevent your assignment from being accepted acceptance.

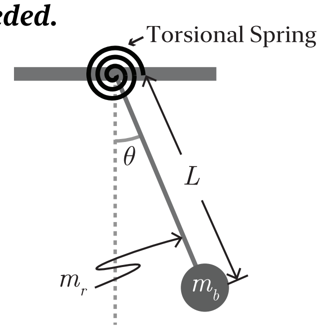
[1] My calculator has a π-button, so including π is okay (encouraged!) in calculator-ready responses.

Physics 132 Exam 1 • Fall 2021

Name: ____________________

No calculators. No notes. Use only the provided paper and equation sheet. 40 minutes · 50 points

Show your work and all steps. Provide written explanations as needed that clearly show how you arrived at your answer. ***You may attach additional work/explanation on a separate sheet if needed.***



1. Shown to the right, a ball of mass m_b swings on the end of a rigid rod of mass m_r which has a torsional spring attached at its pivot. The torsional spring exerts a torque proportional to the angle θ, given by $\tau = -\xi\theta$ where ξ is the torsional spring constant. Incorporating the influence of gravity, the net torque about the pivot is given by

$$\sum \tau = I\alpha$$

$$-\xi\theta - m_b g L \sin\theta - m_r g \frac{L}{2}\sin\theta = \left(\frac{1}{3}m_r L^2 + m_b L^2\right)\alpha$$

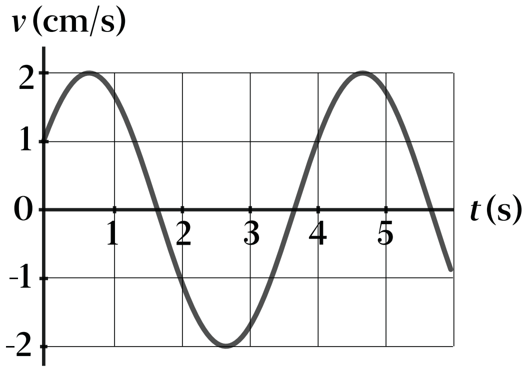
a) Determine the equation of motion (differential equation) for this system in terms of L, m_b, m_r, g, ξ, θ, and any time-derivatives of θ

b) Based on your equation of motion from part a, will the torques on this system produce simple harmonic motion in all conditions? Explain why or why not. If not, identify and apply a simplifying constraint and revise your equation of motion so that it approximates a simple harmonic motion. Explain your reasoning and show all steps.

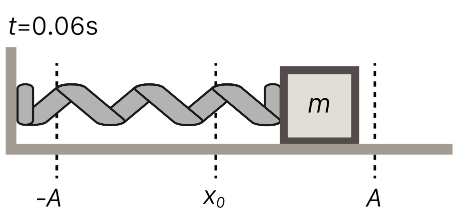
c) From your equation of motion (including any revisions) determine an expression for the period of oscillation for this system.

2. The damping constant of a certain pendulum undergoing damped harmonic motion is 0.1 kg/s. The pendulum is initially pulled to an angle of 10° and released from rest. After 30s, the pendulum's motion is decayed such that its maximum angular displacement is 3.7°. What is the pendulum's mass?
(Note: The quick approach to this problem requires neither a calculator nor a significant amount of time. If you're stuck, you should skip it and come back if you've got time at the end)

Continued on back



3. The plot to the left shows the velocity of a frictionless, horizontal 2kg mass on a spring as a function of time.
   a) Using the information given on the plot, determine a function for the oscillator's position as a function of time *x(t)*. *(For a given time* t, *your expression for* x(t) *should not depend on any unknown parameters.)*



4. The figure to the left depicts the position of ideal mass-spring system on a frictionless surface at $t = 0.06$ s. The period of the motion is 0.16 s. At $t = 0$ block was released from rest. The block has a mass of 2.0 kg and oscillates with an amplitude of 20cm. *For all parts below, explain your reasoning (using words, not just math) when distinguishing among valid algebraic solutions or when drawing conclusions inferred, but not explicitly given, in the text of the problem.*

a) What is the total phase ϕ at the time shown in the figure?

b) What is the initial phase constant ϕ_0 for this mass-spring system?

c) What the block's speed, direction and position at the time shown in the figure?

Physics 132 Exam 2 • Spring 2020

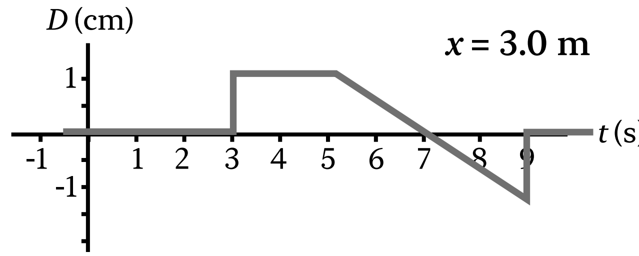
Name: ______________________

No calculators. No notes. Use only the provided paper and equation sheet. 40 minutes · 50 points

Section 1: Traveling Wave Graphs

1a. Starting at $t = 0$, a wave source located at $x = 0$ uses a particular motion to create the pulse depicted in the plot to the right. **The pulse travels to the right at 1 m/s** along a string stretched by 90 N of tension.

Include axes labels, units and scale on all plots



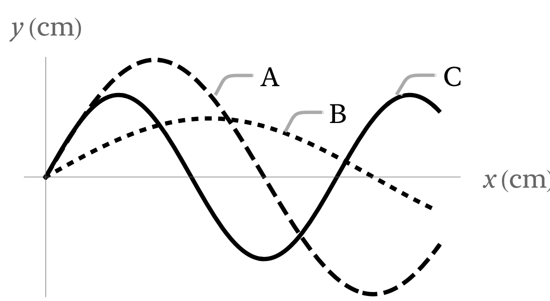
Draw a history graph for the position $x = 0$ m	Draw a snapshot graph at $t = 6$ s.

1b. **We then repeat the experiment with the string tension reduced to 10 N** (any changes to the string's length are negligible). Starting again at $t = 0$, the same source executes the same motion from the same position as it did in part a, and generates a second pulse on the re-tensioned string.

Draw a history graph for the position $x = 0$ m	Draw a snapshot graph at $t = 6$ s.

Section 2: Ranking and Multiple Choice

2. The figure to the right shows three waves that are *separately* sent along a string that is stretched under a certain tension along the x axis. **Rank the waves according to their**



(i) wavelengths

			OR	
1 Greatest	2	3 Least		All the same

(ii) speed

			OR	
1 Greatest	2	3 Least		All the same

(iii) angular frequency

			OR	
1 Greatest	2	3 Least		All the same

Continued on back

3a. When a beam of light, originally traveling in air, enters a piece of glass having an index of refraction of 3/2, its wavelength

❒ increases by a factor of 3/2 ❒ is reduced to 2/3 its original value. ❒ is unaffected.

b. Consider the waves on a vibrating guitar string and the sound waves the guitar produces in the surrounding air. The string waves and the sound waves must have the same

❒ amplitude ❒ wavelength ❒ frequency ❒ phase ❒ intensity

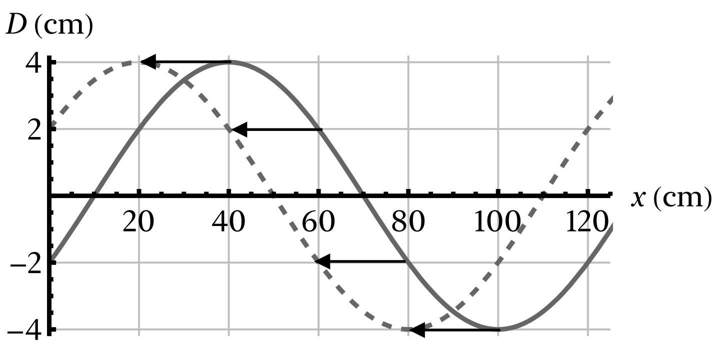
c. You are generating traveling waves on a stretched string by wiggling one end. If you suddenly begin to wiggle more rapidly, you will cause the waves to move down the string

❒ faster than before. ❒ slower than before. ❒ at the same speed as before.

d. A wave pulse traveling to the right along a thin cord reaches a discontinuity where the rope becomes thicker and heavier. What is the orientation of the reflected and transmitted pulses?

❒ Both pulses are right side up
❒ The reflected pulse returns right side up while the transmitted pulse is inverted.
❒ The reflected pulse returns inverted while the transmitted pulse is right side up.
❒ Both pulses are inverted.

Section 3: Calculation



4. The adjacent plot shows the displacement of a traveling wave on a long string at two moments in time. The solid grey line depicts the wave's displacement of the string at $t = 0.050$ s, and the dashed plot shows the same wave at $t = 0.100$ s. Using this information,
   a) determine an expression $D(x, t)$ for calculating the displacement as a function of the location on the string x and time t.
   b) At the time $t = 0.075$ s, what is the is the *transverse speed* and *direction of motion* of the bit of string located at $x = 60$ cm?

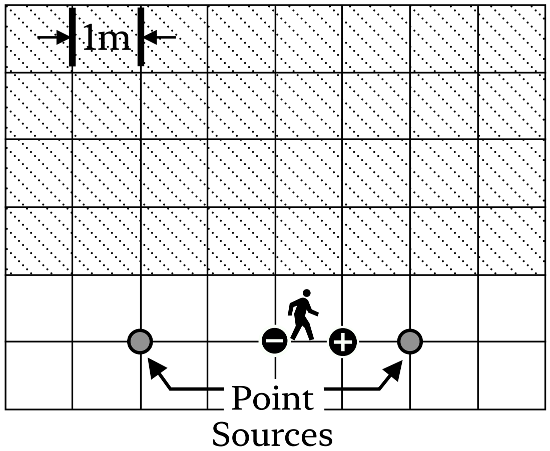
   Tip: think critically, engage your imagination and consider the ***string's motion*** *before diving into a thorny black-box-calculation*

Physics 132 Exam 3 • Fall 2021

Name: ____________________

No calculators. No notes. Use only the provided paper and equation sheet. 45 minutes · 50 points

1. The figure to the shows a top-down view of two point-source speakers that are generating waves with the same amplitude at an unknown frequency. Take the speed of sound to be 340 m/s. An observer stands at the location marked ⊖ where she observes a point of minimum intensity (complete destructive interference). As the observer walks to the right the intensity steadily increases, reaching a maximum at the location marked ⊕



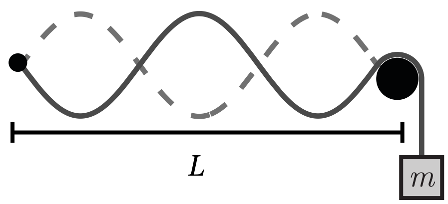
   a) Using both the information stated above and the locations marked in the figure, determine the initial phase difference between the two sources and their frequency of oscillation. Record your answers in the boxes provided.
   b) Mark a location ***in the shaded region*** of the figure where you expect a listener to observe a point of maximum intensity (maximum constructive interference). Label this point Ⓒ.
   c) Mark a second location in the shaded region where you expect a listener to observe a point of minimum intensity (total destructive interference). Label this point Ⓓ.

Calculated Source Parameters

Frequency	Initial phase difference

In the space below, show your work and explain your reasoning for each part (a-c); attach an extra sheet if needed.

2. A wave source oscillating at 100Hz is used to drive a string with fixed end points, and produces the standing wave pattern shown to the right. In this setup, the driving frequency is fixed at 100Hz and the string's vibrating length is fixed at L, so that the only way to generate different standing wave patterns is to vary the mass hanging from the pulley. ***For each part below (a-c) show your work or explain your reasoning; attach an extra sheet if needed.***



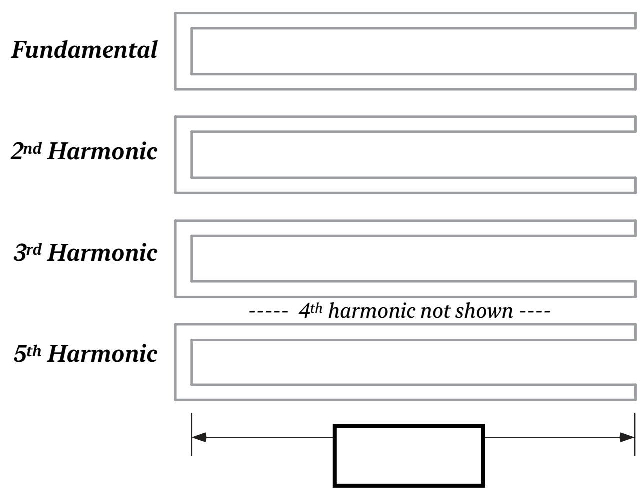
a) If the hanging mass is replaced with one having four times the mass of the original ($m \rightarrow 4m$), does another standing wave pattern emerge? If so, draw the new pattern that emerges in the space below. If no standing wave is observed with the $4m$ hanging mass, explain why not.

Continued on back

b) How much mass should hang from the pulley (expressed as a multiple of the original mass *m)* for the 5th harmonic resonance to be observed on the string?

c) You're told that the maximum mass that the string can support is 10*m* without breaking. What limitation, if any, will this mass restriction impose on your ability to observe standing wave patterns on the string? If a maximum 10*m* hanging mass won't impose a limitation, explain why not.

3. A pipe of unknown length is closed at one end and open at the other. Sound is created in the pipe at four different frequencies, and measured using a the same experimental setup for each.



Frequency	Wavelength	Wave Speed
		360 m/s
900 Hz		

a) Determine the length of the pipe, complete the table of frequencies, wavelengths, and wave speeds for the four modes, and sketch the displacement standing wave pattern in each pipe.

b) If a second identical pipe is fitted agains the first pipe as shown below, determine the frequency, wavelength and wave speed of the lowest frequency resonance for the combined tube and draw the corresponding displacement standing wave pattern in the pipe.

Frequency	Wavelength	Wave Speed

c) In part a, before the pipes were joined, a driving frequency of 900Hz produced the 5th Harmonic resonance. After joining the two pipes, which harmonic, if any, is formed in the combined pipe when driven with a 900Hz tone? Explain your answer and reasoning.

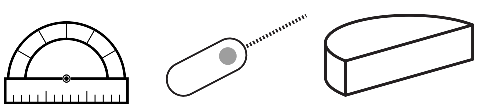
Physics 132 Exam 4 • Fall 2021

Name: ____________________________

No calculators. No notes. Use only the provided paper and equation sheet. 50 minutes · 50 points

1. In the figure below, a beam of *white light* is incident on a crystal with an index of refraction for red light given by $n_{red} = 1.4142$. Draw directly on the figure provided two rays that traverse the crystal, **one for the red light and another for the blue/purple light.** Both rays are initially combined in the incident white beam. For each ray, include the ray's entire path through the crystal including the ray's exit from the crystal. Each ray should terminate with an arrowhead that indicates the direction of propagation in the air, after exiting the crystal. ***Exact angles are not important, just draw the relative direction of the ray at each interface so that it's qualitatively correct and clearly indicated.*** *Note: arcsin(1/1.4142) = 45˚*

2. You are trapped on a desert island with three tools: a laser pointer, a protractor and a semi-circular transparent slab of plastic (and a calculator). Inexplicably, you decide to measure the index of refraction of the plastic. Explain the experiment you use to measure the index of refraction. Include a sketch that illustrates the path of the laser-beam, and explain the significance of the laser placement and which angles are to be measured with the protractor



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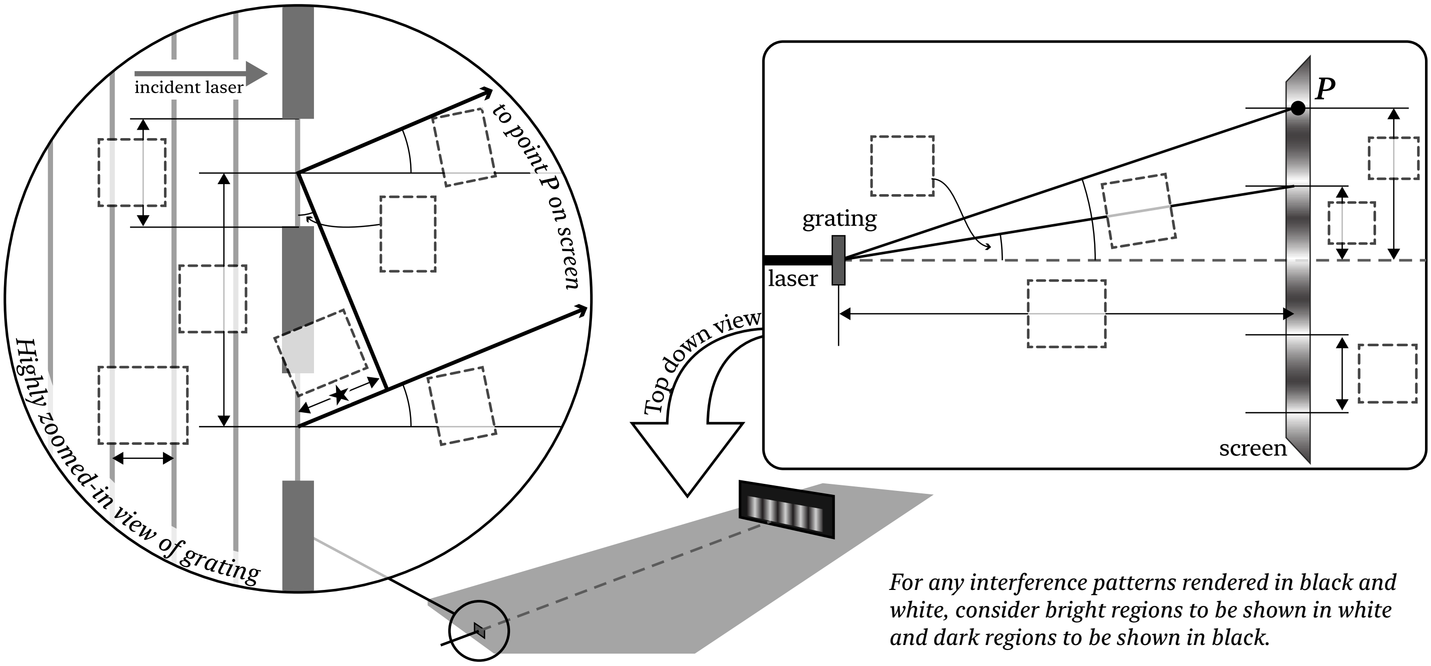
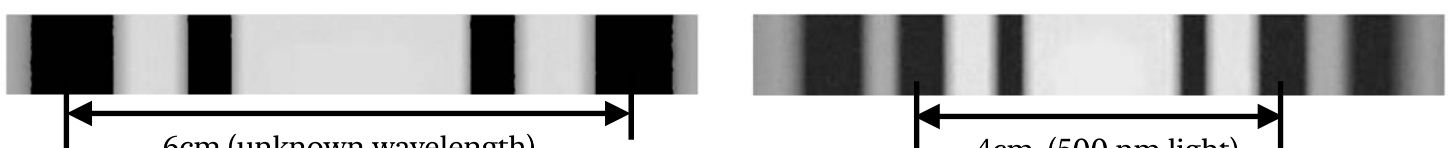
3. For each boxed quantity below, record the symbol (as used in our textbook and introduced in class) that represents the indicated length or angle.



For any interference patterns rendered in black and white, consider bright regions to be shown in white and dark regions to be shown in black.

3b. If this grating is illuminated with 700 nm light, the distance from the grating to the screen is 3.0 m and the spacing between the slits in 50 μm, determine a numeric value for the distance labeled with a ★



4. Light of an unknown wavelength is passed through an unknown grating 2.0 m from a screen. The same grating is then used with 500 nm light, as shown above.
   a) Based on the interference pattern shown, how many openings are in the grating?
      ❐ One **❐ Two** **❐ More than two**
   b) Determine the wavelength of light used to produce the pattern on the left.

Physics 132 Exam 4M • Fall 2021

Name: ______________________

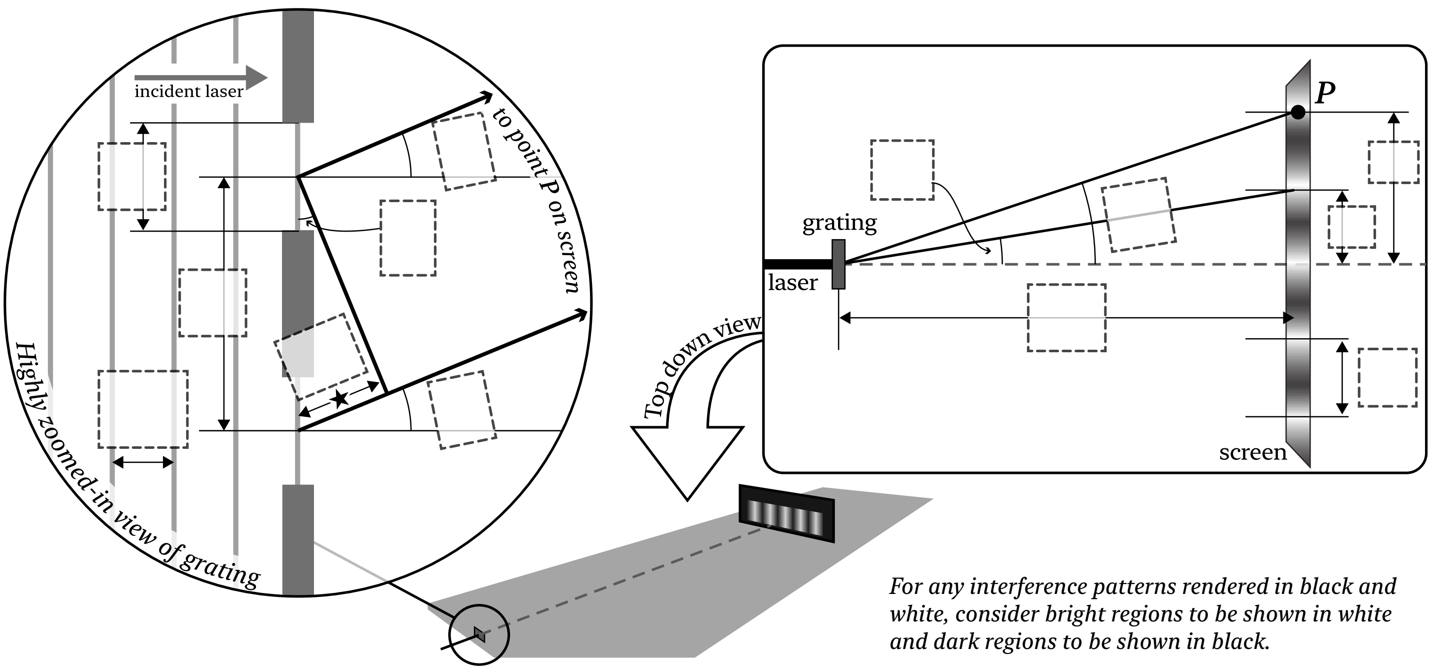
No calculators. No notes. Use only the provided paper and equation sheet. 50 minutes · 50 points

1. In the lab, monochromatic light is passed through a grating onto a screen and produces the interference pattern shown to the right. For each change listed in the table below, state whether the spacing between the bright spots *increases*, *decreases*, or *remains the same*. All of the other control parameters remain constant for each specified change)

		Spacing between the bright spots observed on the screen		
	Change to system	*Increases*	*Decreases*	*Stays the Same*
a	the slit separation is increased			
b	the color of the light is switched from red to blue			
c	the whole apparatus is submerged in water			
d	the screen is moved closer to the grating			
e	the width of each slit is halved			
f	the two slit grating is replaced with a 100-slit grating with the same slit spacing			

g. Based on the interference pattern shown, what can you say about the number of slits in the grating?
❒ The grating has single slit ❒ The grating has more than one slit
❒ The pattern shown could be produced by either type of grating

2. For each boxed quantity below, record the symbol (as used in our textbook and introduced in class) that represents the indicated length or angle.



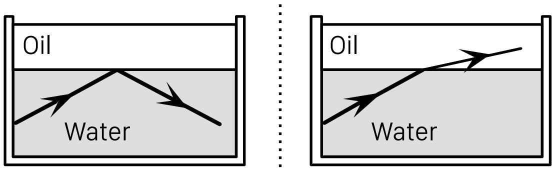
For any interference patterns rendered in black and white, consider bright regions to be shown in white and dark regions to be shown in black.

2b. If this grating is illuminated with 700 nm light, the distance from the grating to the screen is 3.0 m and the spacing between the slits in 50 μm, determine a numeric value for the distance labeled with a ★

Continued on back ☞

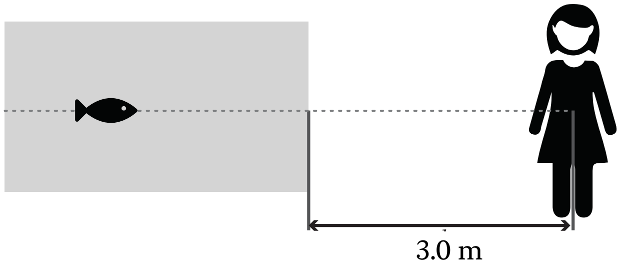
3. Show to the right, an aquarium is partially filled with water, and a layer of oil is floating on top of the water. The two cases are identical except for the type of oil used. Based on the behavior illustrated, the index of refraction of the oil is

   ❒ greater in Case A. ❒ greater in Case B.
   ❒ the same for both cases



Case A *Case B*

4. A fish is inside an aquarium observes a person standing distance $d = 3$ m from the tank's surface, as shown in the figure to the right.



a) From the fish's perspective, what distance from the tank's surface does the person appear to be standing?
   i) Determine an expression for the image distance in terms of d, n_{air}, and n_{water}.
   ii) Include a sketch to justify your answer.
   iii) For a full credit response, also apply $n_a = 1$ and $n_w = 4/3$ along with the small-angle approximation to determine a numeric answer.

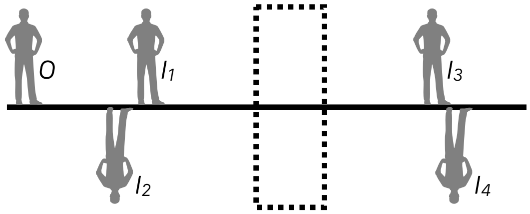
b) If you assume that the analysis applied and answer you obtained in part (a) applied only to a scenario in which all the illuminating light were blue, how would the fish's perceived distance to the person change if the illuminating light were changed to red instead? Discuss the anticipated change and your reasoning quantitatively as no numeric result is required. However, ***an explanatory sketch is required*** for full-credit.

Physics 132 Exam 5 • Fall 2021

Name: ______________________________

No calculators. No notes. Use only the provided paper, equation sheet and a straight edge. 50 minutes. 50 points.
Points will be deducted for messy ray diagrams. Additional ray tracing grids and rulers are available.

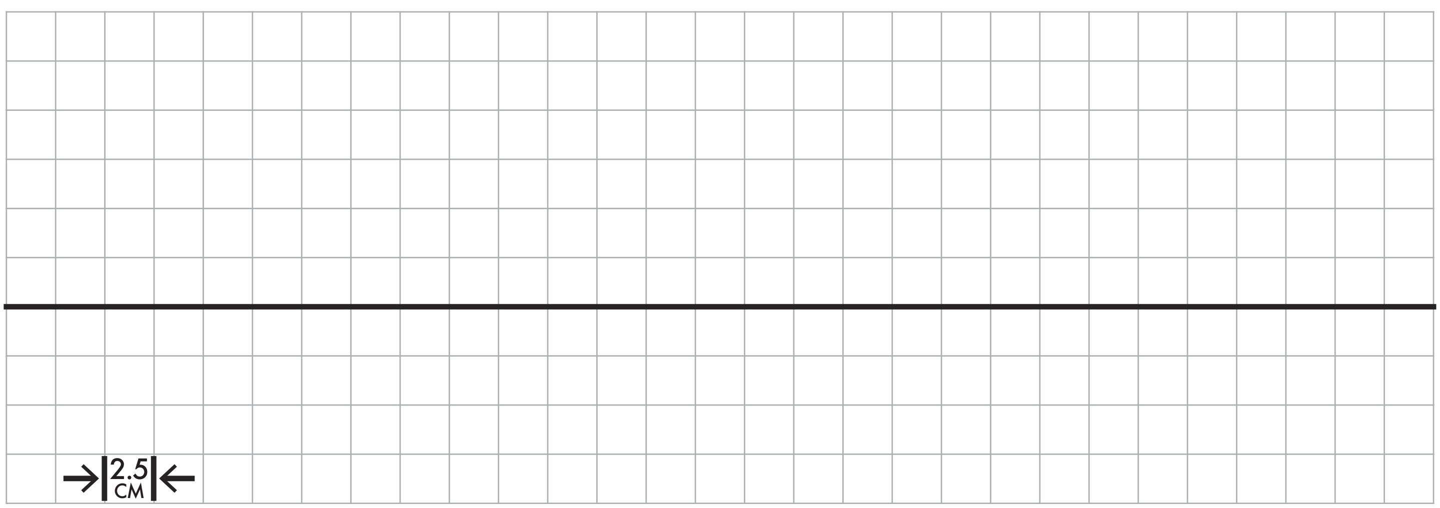
1. In the figure to the right, stick figure O stands in front of an optical element (either a thin lens or spherical mirror) that is positioned in the boxed region; the optic axis is shown. The four stick figures I_1 to I_4 suggest the *general location* and *orientation* (but not necessarily the size) of potential images. For each of the optical elements listed, indicate which of the stick figure(s) (if any) represent the position and orientation of a physically possible image. In every scenario the object remains fixed at O.



	Scenario	**Possible image location/ orientations** *Check all that apply* I_1	I_2	I_3	I_4	*None apply*
1	Converging lens in boxed region					
2	Diverging lens in boxed region					
3	Converging mirror in boxed					
4	Diverging mirror in boxed region					

2. Ralph is excited to try out his new cosmetic mirror whose box prominently advertises to make his face "3 times life size when placed 10cm from the mirror!" Eager to observe his newly grown mustache, Ralph rushes home and places his face 10cm from the mirror
   a) Determine s, s' and f for this system.

   b) Use a straightedge and the grid below to ray-trace the system. Include at least three primary rays.



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c) If Ralph's eyeglasses have a prescription of -3⅓ diopters. Can he clearly see his image in the mirror without his glasses on?

3. In the lab, a well-illuminated object is positioned 12 cm in front of an unknown lens. A 2nd lens is positioned 36 cm behind the unknown lens. The 2nd lens produces a well-focused image onto a screen that is located 36 cm behind the (2nd) lens plane. The relative positions of the object, lenses and screen are illustrated on the grid below. A colleague mentions that the height of the image on the screen is 3 cm, but does not indicate if the image is upright or inverted. The absolute value of the 2nd lens' focal length is 24cm, but the specific type of lens (converging/diverging) and the corresponding sign for f must be inferred from the given information.

   a) Is the 2nd **lens** converging or diverging? Explain your reasoning.

   ❒ Converging ❒ Diverging

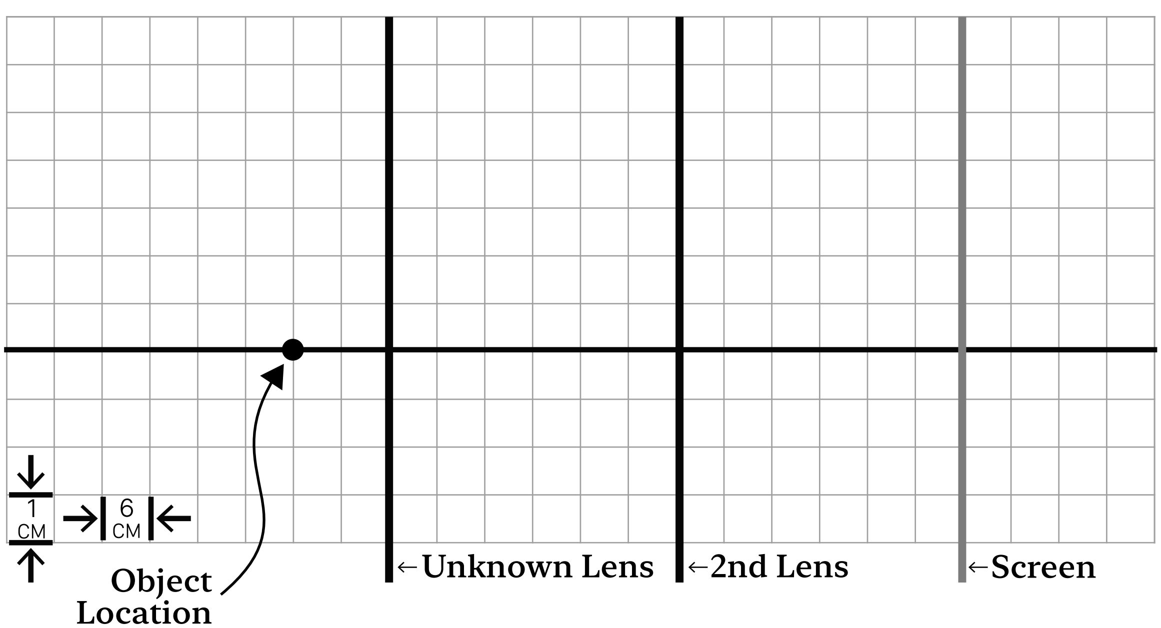
   b) Using the thin lens equations, determine the focal length of the unknown lens and the total magnification of the system. Is the unknown lens converging or diverging?

   f_{unknown} =

   m_{total} =

   ❒ Converging ❒ Diverging

   c) **Use a straightedge** and this grid to ray-trace the described system. Ray diagrams should be produced to scale, consistent with the vertical and horizontal scale printed on the grid. For full credit, ***include at least three primary rays for each lens.***



Physics 132 Exam 5M • Fall 2021 Name: ______________________

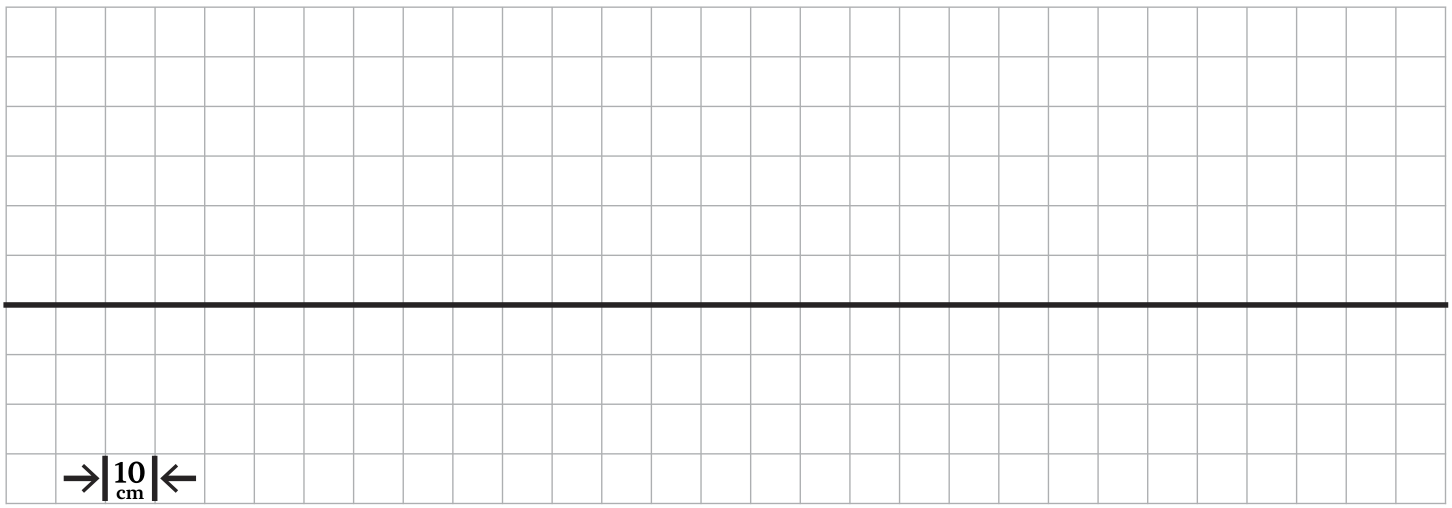
No calculators. No notes. Use only the provided paper, equation sheet and a straight edge. 50 minutes. 50 points.

Points will be deducted for messy ray diagrams. Additional ray tracing grids and rulers are available.

3. A grasshopper hops to a point on the central axis of a spherical mirror. The absolute magnitude of the mirror's focal length is 40.0 cm, and the lateral magnification of the image produced by the mirror is 0.2.

a) Determine *s*, *s′* and *f* for this system. b) Is the mirror convex or concave?

c) Using the grid below, use raytracing and illustrate the location of the grasshopper, the mirror, the image, and three primary rays. Represent the grasshopper as a vertical arrow 5 boxes tall.



2. Ralph is excited to try out his new magnifying glass whose box prominently advertises to make objects "5 times life size when placed 4cm from the lens!" Eager to observe his collection of bottle caps Ralph rushes home and holds the magnifying glass 4 cm above the bottle cap he wants to observe.

a) Determine *s*, *s′* and *f* for this system

b) Use a ruler and the grid below to ray-trace the system. Include at least three primary rays. Make the object 1 square tall. This question (part c) continues on the next page.

Question 2 continues immediately below (Q2 given/calculated values still apply)

c) Ralph looks through the magnifying glass, positioning is eye 20cm from the lens. Ralph's reading glasses (which he isn't wearing) have a prescription of +⅔ diopters, and allow him to read at a distance of 25cm. Will Ralph be able to see the bottle cap (through the magnifying glass) without his glasses? Show your work and explain your reasoning.

3. In the lab, a well-illuminated object is positioned 12 cm in front of an unknown lens. A 2nd lens is positioned 36 cm behind the unknown lens. The 2nd lens produces a well-focused image onto a screen that is located 36 cm behind the (2nd) lens plane. The relative positions of the object, lenses and screen are illustrated on the grid below. A colleague mentions that the height of the image on the screen is 3 cm, but does not indicate if the image is upright or inverted. The absolute value of the 2nd lens' focal length is 24cm, but the specific type of lens (converging/diverging) and the corresponding sign for *f* must be inferred from the given information.

a) Is the 2nd **lens** converging or diverging? Explain your reasoning.

❒ Converging ❒ Diverging

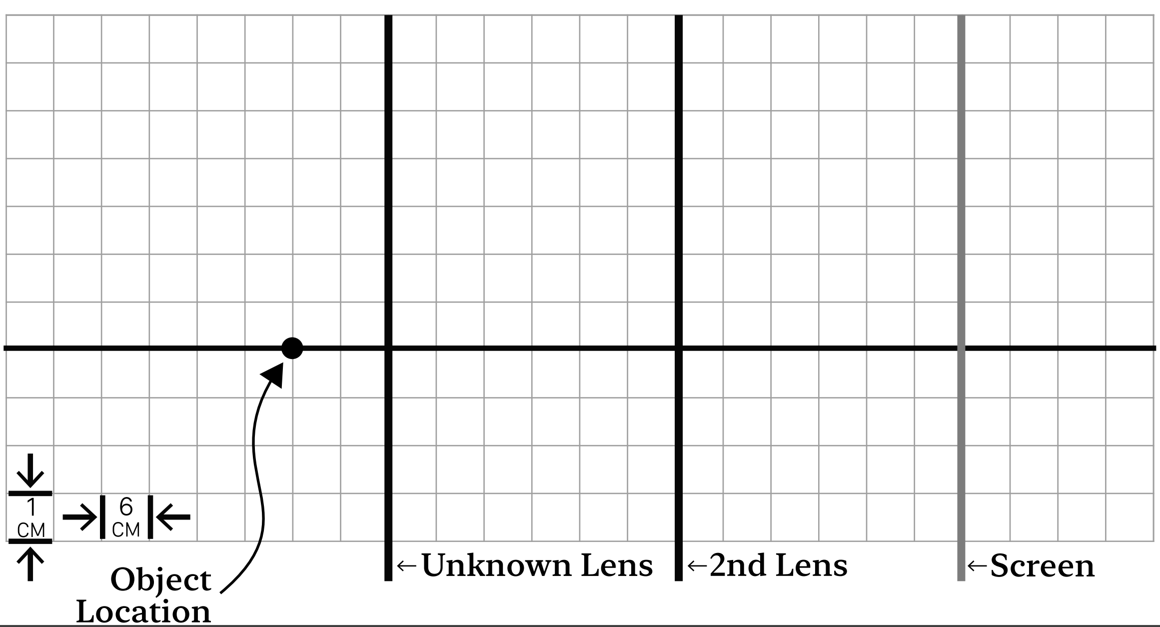
b) Using the thin lens equations, determine the focal length of the unknown lens and the total magnification of the system. Is the unknown lens converging or diverging?

$f_{\text{unknown}} =$

$m_{\text{total}} =$

❒ Converging ❒ Diverging

c) **Use a straightedge** and this grid to ray-trace the described system. Ray diagrams should be produced to scale, consistent with the vertical and horizontal scale printed on the grid. For full credit, ***include at least three primary rays for each lens.***

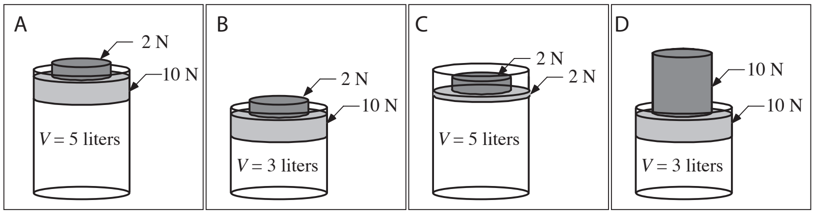


Physics 132 Exam 6 • Fall 2021

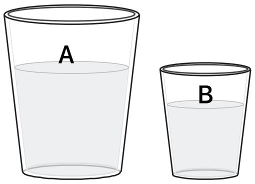
Name: ______________________

No calculators. No notes. Use only the provided paper, equation sheet and a pencil. 50 minutes. 50 points.

1. Cylinders with equal cross-sectional areas contain different volumes of an ideal gas sealed in by pistons. There is a weight sitting on top of each piston. The gas is the same in all four cases and is at the same temperature. The pistons are free to move without friction. **Rank the mass of the gas in the cylinders.**

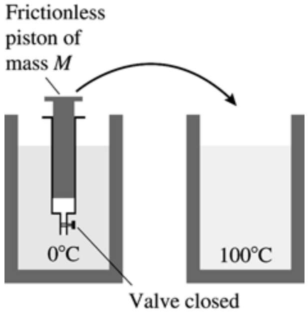


				OR	
1 Greatest	2	3	4 Least		All the same



2. Two different glasses contain different samples of water. Glass A contains 750 grams of water, and Glass B contains 500 grams of water. The water in Glass A has twice the thermal energy as the water in Glass B. Is the temperature of Glass A greater than, less than, or the same as the temperature of Glass B? Explain your reasoning.

3. A vertical syringe with a frictionless piston of mass *M* is initially at thermal equilibrium in ice water and then transferred to boiling water, and allowed to come to thermal equilibrium.



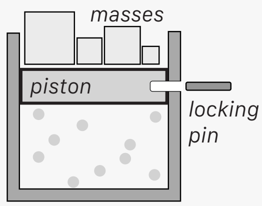
a) Does the volume of the gas increase, decrease or stay the same? Explain.

b) Does the pressure of the gas increase, decrease or stay the same? Explain.

Continued on back

4. $\frac{2}{8.315}$ mol of an ideal is contained in the apparatus shown to the right. The pressure of the gas is initially $P_0 = 120$ kPa, and the initial temperature is 27°C. The ambient atmospheric pressure is 100kPa. From the initial state (P_0, V_0, T_0) the gas undergoes the following three-step process;

With this cylinder you can:



i) Lock or unlock the piston in place with a pin
ii) Add or remove masses from the piston
iii) Place the entire cylinder in a hot or cold liquid (Consider the cylinder to be well-insulated when not in contact with either liquid).

i. With the pin unlocked, masses are *slowly* added to the piston until the volume is reduced to ½ its original value $(V_1 = V_0/2)$. Ice is applied throughout the process so that the thermal energy of the gas remains constant.

ii. Next the gas undergoes an isochoric process. The gas pressure after the isochoric process is $1.5 \times$ greater than the gas pressure before the isochoric process $P_2 = \frac{3}{2}P_1$`

iii. The gas is then undergoes an isobaric process that returns it to its original volume $(V_3 = V_0)$

a) What is the final temperature of the gas?`

b) Draw a single PV diagram that depicts each of the three processes. Your axes should be labeled and scaled such that the points before and after each process depict the given or calculated values of the pressure and volume at each point.

c) Explain how you would use the provided cylinder to perform process (iii)

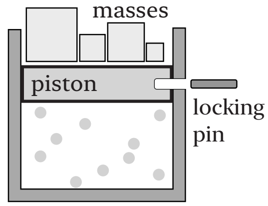
d) If total of the applied masses on top of the cylinder in the initial state is m_0, how much mass (expressed as a multiple of m_0) is atop the cylinder after process (i) is complete?

Physics 132 Exam 7 • Fall 2021

Name:____________________

No calculators. No notes. Use only the provided paper and equation sheet. 50 minutes

Section 1 • Multiple Choice



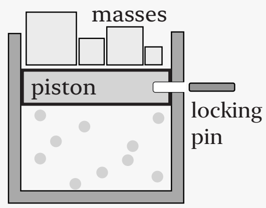
1. In completing the table below, consider a cylinder of an ideal gas, **initially at room temperature**, contained by a frictionless piston as shown to the right. During every scenario in the table, **a flame applied to the cylinder,** but the masses applied to the piston or the state of the locking pin can be changed.

The processes below are performed with a flame applied to the cylinder	**Q**			***W*** (work *on* gas)			**ΔE$_{th}$**			**Volume**			**Temperature**			**Impossible with flame applied**
	positive $Q>0$	*negative* $Q<0$	*zero* $Q=0$	*positive* $W>0$	*negative* $W<0$	*zero* $W=0$	*positive* $\Delta E_{th}>0$	*negative* $\Delta E_{th}<0$	*zero* $\Delta E_{th}=0$	*increase* $V_f>V_i$	*decrease* $V_f<V_i$	*constant* $V_f=V_i$	*increase* $T_f>T_i$	*decrease* $T_f<T_i$	*constant* $T_f=T_i$	*If impossible, check only the box below and none to its left*
isochoric																
adiabatic																
isobaric																
isothermal																

Either **i) check five boxes in each row (one for each** $Q, W, \Delta E_{th}, V$ **and** T**)** ***or*** **ii) mark "Impossible with flame"**

Section 2 • Short Answer

With this cylinder you can:



i) Fix or release the piston with a locking pin

ii) Add or remove masses from atop the piston

iii) Place the entire cylinder in a hot or cold liquid (Consider the cylinder to be well-insulated when not in contact with either liquid).

2. a) Using the setup to the right, can the temperature of an ideal gas be increased without heat?
   If so, explain how. If not, explain why not.

   a) Using the setup to the right, describe a process in which heating a substance does not change its temperature.

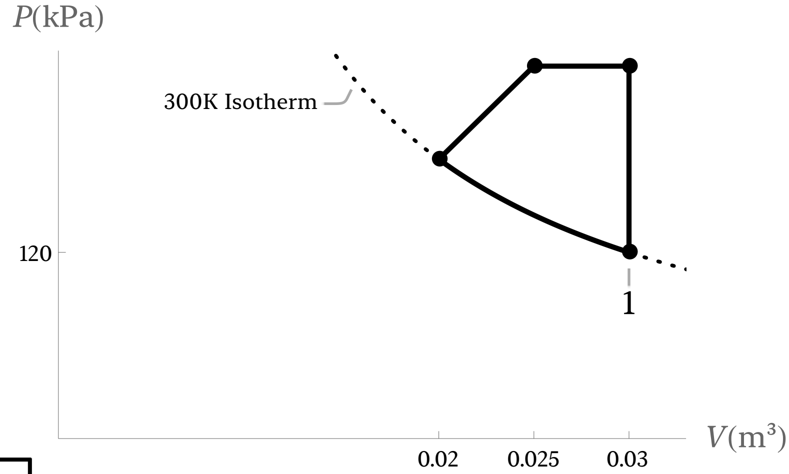
   b) In a sentence or two explain what is meant by the thermodynamic term *heat.*

3. You have cold hands on a winter day and take two different (successful) approaches to comfort:
   a. You rapidly rub your palms together, and
   b. You breathe into to your cupped hands

Which processes, if any, involve heat? Which processes, if any, involve a change in the thermal energy of your hands? Explain your reasoning.

Continued on back

4. A four part thermodynamic cycle operates on an ideal gas and as diagrammed below to the right. The cycle requires a net work input of 700 J (explicitly, $W_{\text{net}} = 700\,\text{J}$ and $W_{s\,\text{net}} = -700\,\text{J}$). There are three temperatures 300 K, 500K and 600K. As the temperature of the gas increases, 9 kJ of heat are required.



a) Starting at point 1, add directional arrowheads that indicate the sequence of the cycle described.

b) Complete the P, V, T and First Law charts provided.

	P	V	T
1			
2			
3			
4			

c) **Complete the table to include values *P*, *V* and *T* at all four states.**

d) **Complete the a table to include Q, W (or W_S) and ΔE_{th} for each process in the cycle.**

PHYSICS 132 MIDTERM 3
EQUATION SHEET

SIMPLE HARMONIC MOTION

$x(t) = A\cos(\omega t + \phi_0)$ $\omega = 2\pi f$ $T = 1/f$ $E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2 = \frac{1}{2}m(v_{\text{max}})^2$

$v(t) = -\omega A\sin(\omega t + \phi_0) = -v_{\text{max}}\sin(\omega t + \phi_0)$ $x(t) = Ae^{\frac{-bt}{2m}}\cos(\omega t + \phi_0)$ $\tau = m/b$

$\omega_{\text{spring}} = \sqrt{k/m}$ $\omega_{\text{pendulum}} = \sqrt{g/L}$ $\omega_{\text{phys-p}} = \sqrt{Mgl/I}$ $\omega_{\text{damp}} = \sqrt{\omega_0^2 - b^2/(4m^2)}$

TRAVELING WAVES

$v = \frac{\lambda}{T} = \lambda f$ $k = \frac{2\pi}{\lambda}$ $D(x,t) = A\sin(kx - \omega t + \phi_0)$ $\Delta\phi_{\text{const.}} = 2\pi\frac{\Delta r}{\lambda} + \Delta\phi_0 = m \cdot 2\pi$

$v_{\text{string}} = \sqrt{T_s/\mu}$ $n = c/v$ $f_{\text{beat}} = f_2 - f_1$ $\Delta\phi_{\text{destr.}} = 2\pi\frac{\Delta r}{\lambda} + \Delta\phi_0 = \left(m + \frac{1}{2}\right)2\pi$

$D(x,t) = A(x)\cos\omega t = 2a\sin kx\cos\omega t$ $I = \frac{P}{A}$ $I_1/I_2 = r_2^2/r_1^2$ $\beta = (10\text{dB})\log_{10}\left(\frac{I}{I_0}\right)$

$\lambda_m = \frac{2L}{m}$ $D_{\text{net}} = \sum_i D_i$ $\lambda' = \lambda_0\sqrt{\frac{1 \pm v_s/c}{1 \mp v_s/c}}$ $f_\pm = \frac{f_0}{1 \mp v_s/v}$ $f_\pm = (1 \pm v_o/v)f_0$

OPTICS

$d\sin\theta_m = \left(m + \frac{1}{2}\right)\lambda$

$n = c/v$ $\lambda = \lambda_0/n$ $\theta_i = \theta_r$ $n_1\sin\theta_1 = n_2\sin\theta_2$ $\sin\theta_{\text{crit}} = n_2/n_1$ $d\sin\theta_m = m\lambda$

$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$ $m = \frac{h'}{h} = -\frac{s'}{s}$ $\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R}$ $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ $a\sin\theta_p = p\lambda$

FLUIDS AND THERMODYNAMICS

$\Delta E_{\text{th}} = W + Q$ $pV = nRT = Nk_BT$ $T_K = T_C + 273$

$p = F/A$ $p = p_0 + \rho gh$ $F_B = m_f g = \rho_f V_f g$ $W = -\int_{V_i}^{V_f} p\,dV$ $\Delta E_{\text{th}} = nC_V\Delta T$

$W_{\text{isobaric}} = -p\Delta V$ $Q_V = nC_V\Delta T$ $Q_P = nC_P\Delta T$ $C_p = C_V + R$ $Q = Mc\Delta T = nC\Delta T$

$W_{\text{isothermal}} = -nRT\ln(V_f/V_i)$ $W_{s\text{ (gas on environment)}} = -W$ $E_{\text{per DOF}} = \frac{1}{2}Nk_BT = \frac{1}{2}nRT$ $Q = \pm ML$

$W_{\text{adiabatic}} = \Delta E_{\text{th}} = -\left(\frac{p_fV_f - p_iV_i}{1-\gamma}\right)$ $pV^\gamma = \text{const.}$ $\gamma = C_P/C_V$ $\eta = W_{\text{out}}/Q_H$ $\eta_{\text{Carnot}} = 1 - T_C/T_H$

KINEMATICS

$s = \frac{1}{2}a_s\Delta t^2 + v_{0s}\Delta t + s_0$

$v_s = v_{0s} + a_s\Delta t$ $v_s = \frac{ds}{dt}$

$v_s^2 = v_{0s}^2 + 2a_s\Delta s$ $a_s = \frac{dv_s}{dt}$

DYNAMICS

$\Sigma\vec{F} = m\vec{a}$ $\vec{F}_{\text{A on B}} = -\vec{F}_{\text{B on A}}$

$f_s \le \mu_s n$ $f_k = \mu_k n$

$\vec{F}_{\text{spring}} = -k\vec{x}$

CIRCULAR MOTION

$s = \theta r$ $\omega = \frac{d\theta}{dt}$ $\alpha = \frac{d\omega}{dt}$

$v_t = \omega r$ $a_t = \alpha r$

$a_r = a_{\text{centrip}} = \frac{v^2}{r} = r\omega^2$

CONSERVATION LAWS

$W_{\text{ext}} = \Delta K + \Delta U + \Delta E_{\text{th}}$ $K_{\text{trans}} = \frac{1}{2}mv^2$ $K_{\text{rot}} = \frac{1}{2}I\omega^2$ $\vec{p} = m\vec{v}$ $\vec{p}_i = \vec{p}_f$ $\vec{J} = \Delta\vec{p}$

$\Delta E_{\text{th}} = f_kd$ $U_g(y) = mgy$ $U_{\text{spring}} = \frac{1}{2}kx^2$ $W = \int_{x_1}^{x_2} F_x(x)dx$ $\vec{J} = \int_{t_1}^{t_2}\vec{F}(t)dt = F_{\text{avg}}\Delta t$

ROTATION OF A RIGID BODY

$\tau = rF\sin\phi = rF_\perp = r_\perp F$ $\vec{\tau}_{\text{net}} = I\vec{\alpha}$ $\vec{\ell} = \vec{r} \times \vec{p} = m(\vec{r} \times \vec{v})$ $\ell = I\omega$ $\vec{\ell}_i = \vec{\ell}_f$

$I_{\text{point}} = \sum_i^N m_ir_i^2$ $I_{\text{sphere}} = \frac{2}{5}MR^2$ $I_{\text{baton}} = \frac{1}{12}ML^2$ $I_{\text{log or disk}} = \frac{1}{2}MR^2$ $I_\parallel = I_{\text{com}} + Md^2$

$k_B = 1.38064 \times 10^{-23}$ J/K $R = 8.314598$ J/mol K $N_A = 6.02214 \times 10^{23}$ particles/mol

$c_{\text{ice}} = 2090$ J/kg K $c_{\text{water}} = 4190$ J/kg K $c_{\text{steam}} = 1996$ J/kg K $L_{f,\text{ water}} = 334$ kJ/kg $L_{v,\text{ water}} = 2265$ kJ/kg

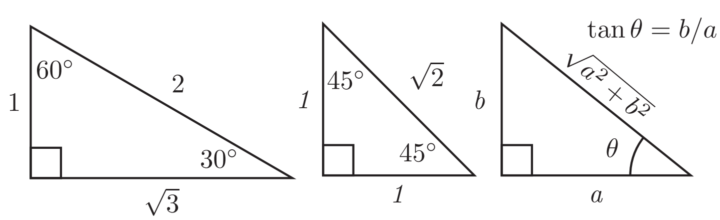
$C_{v,\text{mono}} = 12.5$ J/mol K $C_{v,\text{dia}} = 20.8$ J/mol K

$1\text{ atm} = 101,300$ Pa $\gamma_{\text{mono}} = 1.67$ $\gamma_{\text{dia}} = 1.4$

$n_{\text{air}} = 1.003$ $n_{\text{water}} = 1.33$ $n_{\text{glass}} = 1.5$

$v_{\text{sound}} = 343\,\frac{\text{m}}{\text{s}}$ $g = 9.8066\,\frac{\text{m}}{\text{s}^2}$ $I_0 = 10^{-12}\,\frac{\text{W}}{\text{m}^2}$

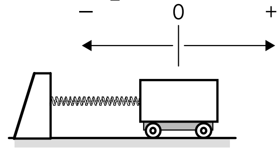
$c = 2.99782 \times 10^8\,\frac{\text{m}}{\text{s}}$ $\tan\theta \approx \sin\theta \approx \theta$ (small θ)



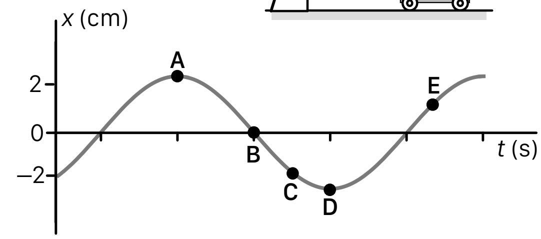
Physics 132 Exam 1F • Fall 2021

Name: ______________________

No calculators. No notes. Use only the provided paper and equation sheet. 50 minutes · 50 points



1. A cart attached to a spring is displaced from equilibrium and then released. A graph of displacement as a function of time for the cart is shown. There is no friction. Points are labeled A–E in the graph. The arrows and signs above the cart indicate the positive and negative directions for the displacement of the cart.



Point	Acceleration	Velocity	Displacement	Net Force
A				
B				
C				
D				
E				

For each labeled point above, identify if the vector quantity listed in the table is in the positive (+) direction, negative (–) direction, or is zero (0) for no direction.

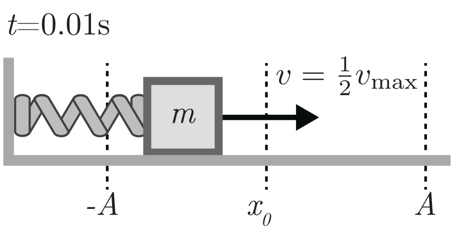
2. In the table to the left are sets of values for the spring constant k, damping constant b, and mass m for a particle in damped harmonic motion. Which of the sets takes the ***shortest time*** for its mechanical energy to decrease to one-fourth of its initial value?

❒ **A** ❒ **B** ❒ **C** ❒ **D** ❒ **E**

	k	b	m
A	k_0	b_0	m_0
B	$3k_0$	$2b_0$	m_0
C	$k_0/2$	$6b_0$	$2m_0$
D	$4k_0$	b_0	$2m_0$
E	k_0	b_0	$10m_0$

Section 2 • Calculation

Show your work and all steps. Provide written explanations as needed that clearly show how you arrived at your answer. ***You may attach a separate sheet if necessary.***

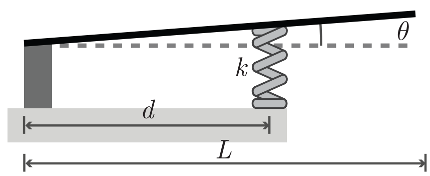


3. The figure to the left shows an ideal mass and spring system on a frictionless surface at t=0.01s, where its speed is ½ of v_{max} moving to the right. The mass oscillates with a period T of 0.12s. a) Determine the initial phase constant ϕ_0 for this scenario, and explain your reasoning.

Continued on back ☞

b) What is the instantaneous phase ϕ at the moment captured in the figure ($t = 0.01$ s)?

4. A spring loaded diving board is shown in the figure to the right. The torque about the pivot is given by



$$\begin{aligned}\Sigma\tau &= -d^2 k \sin\theta = I\alpha \\ &= -d^2 k \sin\theta = \frac{1}{3} m L^2 \alpha\end{aligned}$$

a) What is the equation of motion (differential equation) for this system in terms of d, k, m, L, θ (and their derivatives)?

b) Will the diving board move in simple harmonic motion under all initial conditions? Explain why or why not. If the motion is simple harmonic under certain initial conditions, explain under what conditions, if any, the motion is expected to be simple harmonic. If (under any condition) the diving board moves with simple harmonic motion, determine an expression for the angular frequency ω in the solution that satisfies the equation of motion.

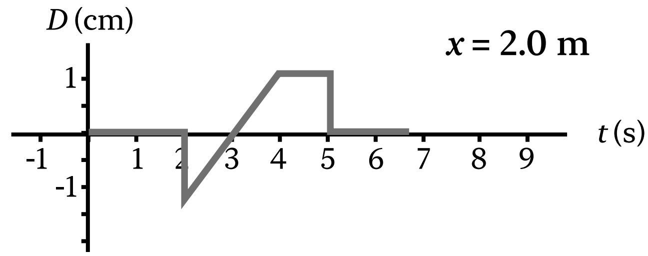
Physics 132 Exam 2F • Fall 2021

Name: ______________________

No calculators. No notes. Use only the provided paper and equation sheet. 50 minutes · 50 points

Section 1: Traveling Wave Graphs

1a. Starting at $t = 0$, a wave source located at $x = 0$ uses a particular motion to create the pulse depicted in the plot to the right. **The pulse travels to the right at 1 m/s** along a string stretched by 40 N of tension.



Include axes labels, units and scale on all plots

Draw a history graph for the position $x = 0$ m	Draw a snapshot graph at $t = 5$ s.

Section 2: Calculations

Show your work and all steps. Provide written explanations as needed that clearly show how you arrived at your answer. ***You may attach a separate sheet if necessary.***

2. The sound intensity level of a lawn mower at a distance of 1.0 m is 104 dB. You wake up one morning to find that four of your neighbors are all mowing their lawns using identical mowers. When they are each 20 m away from you, what is the value sound intensity level you expect to observe?

Continued on back ☞

3. In a timed experiment a simple harmonic oscillator produces a traveling wave on a string. The weight and length of the string have been chosen so the effect of any reflections is negligible. The traveling wave's displacement is given by $D(x,t) = (2\text{ cm})\sin\left((4\pi\,\text{m}^{-1})x + (\frac{2\pi}{1.6}\,\text{s}^{-1})t + \frac{3\pi}{2}\right)$

a) Based on the displacement equation identify the wave parameters and complete the table below (include appropriate units)

Wavelength	**Frequency**	**Wave speed**	**Direction of propagation**	**Displacement at** $x=0, t=0$	**Transverse velocity at** $x=0, t=0$
			❒ +x direction ❒ -x direction		

b) Based on the displacement equation provided draw the requested graphical representations of the wave in the boxes below. Graphs should include an appropriate scale and units for both axes.

Draw a history graph for the position $x = 0$ m	Draw a snapshot graph at $t = 0.8$ s.

c) You make a change the setup and repeat the experiment. The new displacement is given by $D(x,t) = (2\text{ cm})\sin\left((2\pi\,\text{m}^{-1})x + (\frac{2\pi}{1.6}\,\text{s}^{-1})t + \frac{3\pi}{2}\right)$. If you were the experimenter, how would you physically change the original setup to produce this new displacement function?

d) Based on the new displacement equation provided in part c, draw the history graph for $x = 0$ in the box below. Your graph should include an appropriate scale and units for both axes.

Draw a history graph for the position $x = 0$ m for the new experiment

Physics 132 Exam 3F • Fall 2021

Name: ____________________________

No calculators. No notes. Use only the provided paper and equation sheet. 45 minutes · 50 points

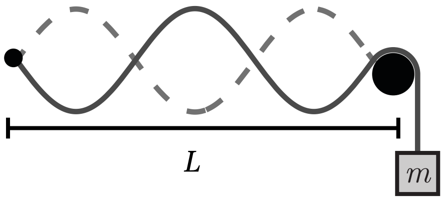
1. The lowest-pitch tone to resonate in a pipe of length L that is closed at one end and open at the other end is 200 Hz. Which one of the following frequencies will NOT resonate in the same pipe?

   ❒ 400Hz ❒ 600Hz ❒ 1000 Hz ❒ 1400 Hz ❒ 1800 Hz

2. In a resonating pipe that is open at one end and closed at the other end, there
   - ❒ are displacement nodes at each end.
   - ❒ are displacement antinodes at each end.
   - ❒ is a displacement node at the open end and a displacement antinode at the closed end.
   - ❒ is a displacement node at the closed end and a displacement antinode at the open end.

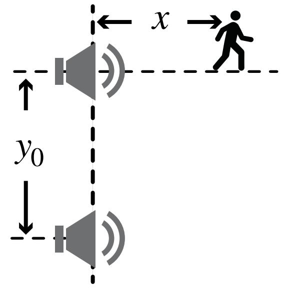
3. When a wave in the ocean hits a sea wall (as shown to the right), it often dramatically crashes over the top of the wall, even though the amplitude of the incoming wave was much smaller than the height of the wall. **Using your knowledge of waves, explain how this is possible.**

4. A wave source oscillating at 100Hz is used to drive a string with fixed end points, and produces the standing wave pattern shown to the right. In this setup, the driving frequency is fixed at 100Hz and the string's vibrating length is fixed at L, so that the only way to generate different standing wave patterns is to vary the mass hanging from the pulley. If the hanging mass is replaced with one having nine times the mass of the original ($m \to 9m$), does another standing wave pattern emerge? If so, draw the new pattern that emerges in the space below. If no standing wave is observed with the $9m$ hanging mass, explain why not.



Continued on back

5. As shown to the right, two speakers are separated by a distance y_0 and emit a monotone sound of frequency f in an environment where the speed of sound is v. The speakers driven with signals that are 180° out-of-phase from one another. An observer encounters multiple points of maximum intensity as they walk straight out from one of the speakers as shown. Determine an expression for the distances x_m in terms of v, y_0, f (or λ) and m (where m is an integer that distinguishes one maximum from the others) that someone must walk straight out from one of the speakers to be at each of the positions of maximum constructive interference.



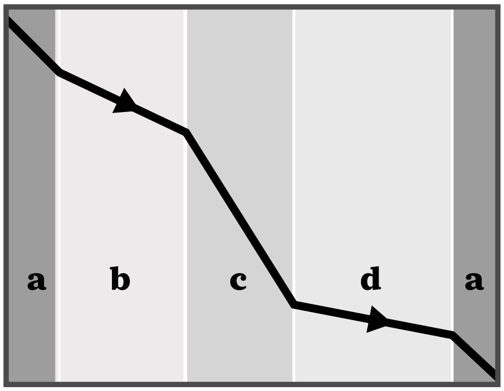
6. If the distance between the speakers y_0 is equal to $9/2\lambda$, determine (in terms of v, f and λ, as appropriate) what the difference in the path length traveled from each source to the observer at the location of the first (closest) observed maximum. In other words, what is the path length difference, evaluated for a particular value m, such that x_m is the distance to the first maximum? Explain your reasoning.

Physics 132 Exam 4F • Fall 2021

Name: ____________________________

No calculators. No notes. Use only the provided paper and equation sheet. 50 minutes · 50 points

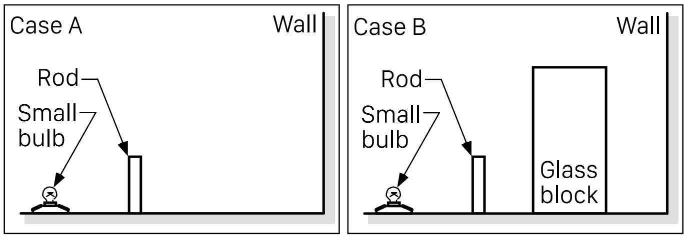
1. As shown to the right, light travels from material *a*, through three layers of other materials with surfaces parallel to one another, and then back into another layer of material *a*. The refractions (but not the associated reflections) at each surface are shown.



Rank the materials according to index of refraction.

				or	
1 Greatest	2	3	4		All the same

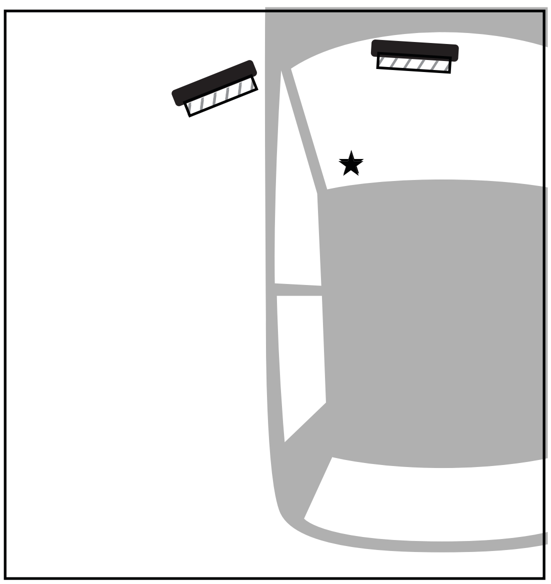
2. An interference pattern is reproduced above at actual size (scale 1:1)
   a) Based on the interference pattern, how many openings are in the grating?
      ❐ **One** ❐ **Two** ❐ **More than two**
   b) The pattern is produced on a screen positioned 5.0 m from the grating using light from a 600 nm laser. **Using a ruler**, make the necessary measurements and determine the **slit spacing** (if applicable) or **slit width** (for a single slit pattern only) of the grating. Indicate the measured distance(s) and record the value of each measurement directly on the image above. In calculating the required grating parameters, use only the equations provided on the equation sheet as a starting point, and show all steps (including any approximations).



3. Shown to the left, a small light bulb illuminates a wall. A shadow is created on the wall of a rod placed between the wall and the bulb. The two cases are identical except that in Case B there is a glass block between the rod and the wall. Is the height of the shadow of the rod on the wall greater in Case A or Case B (or the same in both cases)? **Using a sketch that illustrates the path of at least one ray, explain your reasoning.** (There's more space for your work on the next page)

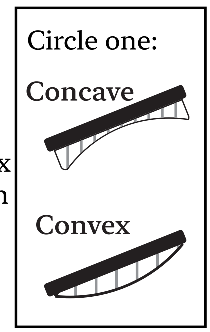
Continued on back

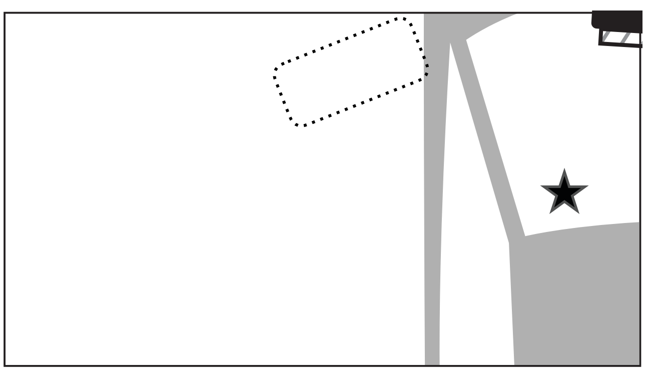
Question 3 additional work space



4a) Cars are equipped with mirrors to provide a view of the scene behind and to the side of the automobile. Shown in the figure immediately at left is a top-down schematic that approximates a typical arrangement of the driver, driver's side mirror and rearview mirror. The location of the driver is marked with a ★. Using the figure and at least four constructed rays, determine the location and extent of the driver's ***blind spot*** — the region along the left/left-rear of the car that cannot be observed by the driver's position using the mirrors. **Clearly label the blind spot region on the figure.**

4a) If we replace the flat driver's side mirror with one of the two mirrors shown in the box at right, we can reduce the extent of the driver's blindspot. Using constructed rays and the space below, determine which mirror— spherical concave or spherical convex —will best improve visibility. Justify your choice with an explanation and sketch.





b) After determining the best mirror shape among the choices to the right, draw it (with reasonable accuracy) in the dotted box in the figure above. Then, illustrate at least two rays on the diagram that reflect off the new mirror. **Provide a written explanation** as to how you know that the curved mirror reduces the extent of the blind spot region. Your written explanation and accompanying illustrations should make specific comparisons to the flat mirror scenario above.

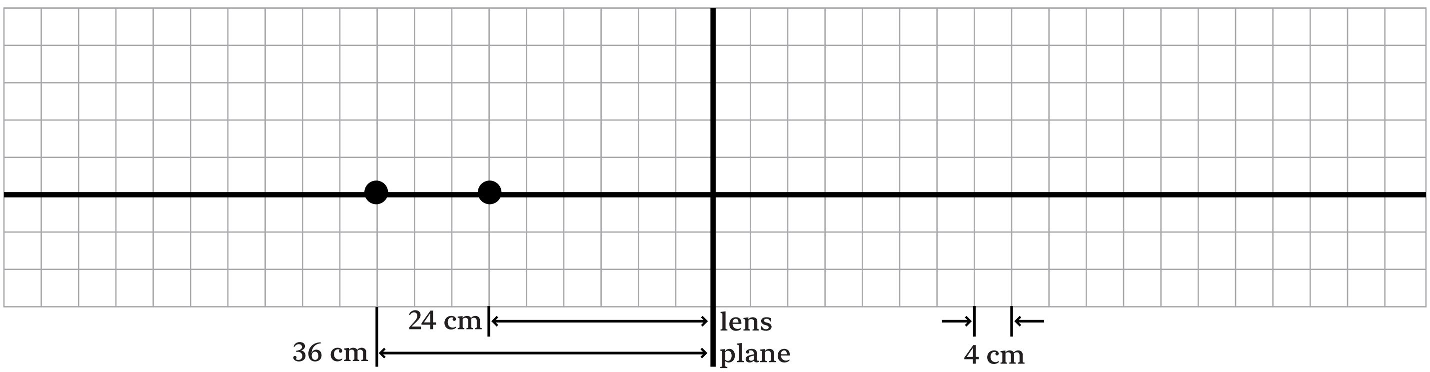
Physics 132 Exam 5F • Fall 2021

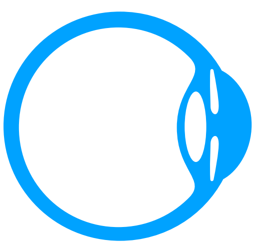
Name: ____________________

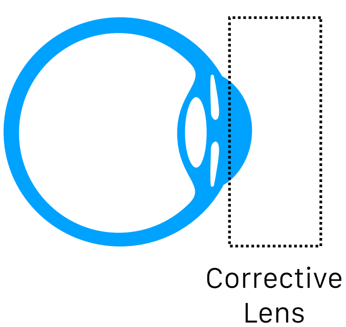
No calculators. No notes. Use only the provided paper and equation sheet. 50 minutes · 50 points

1. Zoey is farsighted, and the nearest distance that she can focus her eyes is 36cm. Use the thin lens equation to determine what focal length lens she needs to comfortably read a book 24 cm away. Is the lens converging or diverging?

Draw the representative ray diagram below (make the object two squares tall)







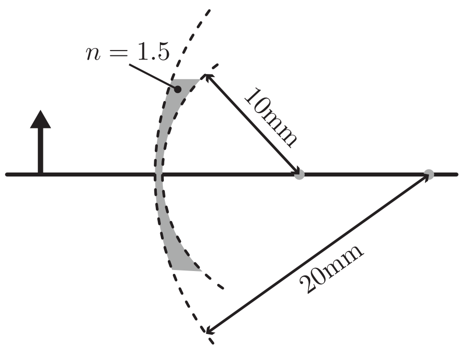
2. Ralph has myopia (he's *nearsighted*) and wears glasses to correct his vision.

a) Draw at least two rays that demonstrate how incoming rays travel through Ralph's uncorrected eye. The incoming rays should be incident on the cornea at an angle consistent with an object distance that Ralph struggles to see without correction. Explanation why the image isn't sharp

b) Draw at least two rays that demonstrate how incoming rays travel through Ralph's with the addition of on an appropriate corrective lens, and explain what about the rays makes he image sharp.

Continued on back

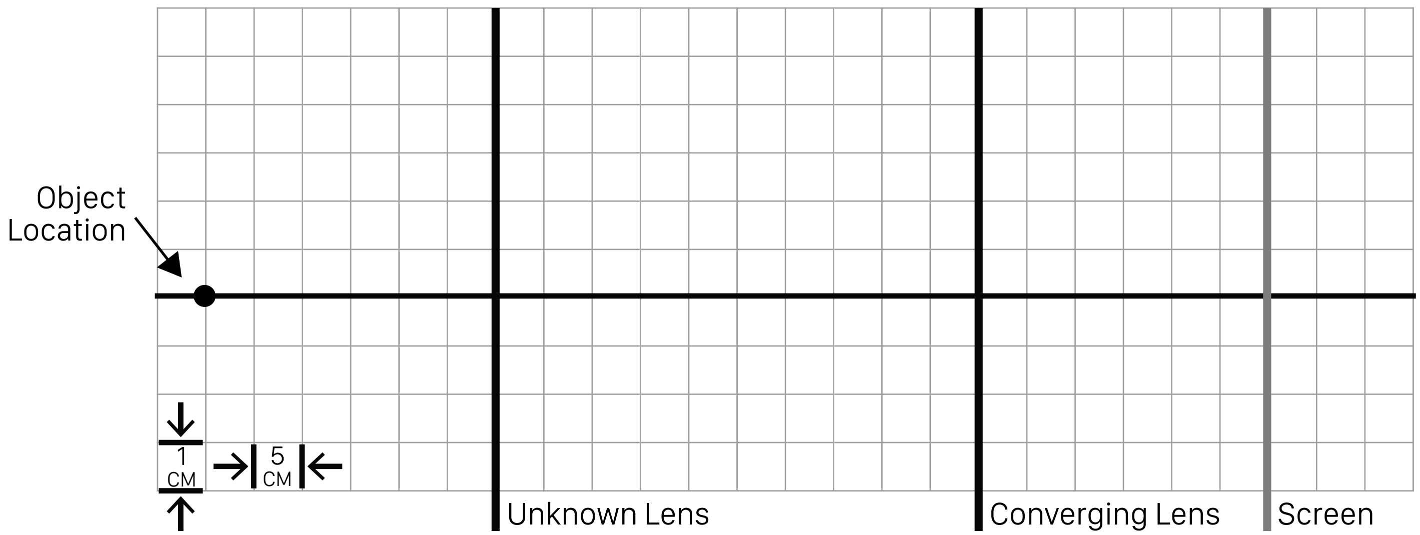
3. A spherical thin lens is constructed from glass (n=1.5) as shown in the figure to the right. The extent of the lens is determined by the shaded region in the diagram. What is the focal length of the lens?



4. As shown on the grid below, a self-luminous object is positioned 30 cm in front of an unknown lens. A converging lens with a focal length of 20cm is placed 50 cm behind the unknown lens. An inverted 1-cm-tall image is formed on a screen 30 cm behind the converging lens.
   a) Calculate the focal length of the unknown lens and the total magnification of the system.

   b) Is the unknown lens converging or diverging?, Is the image inverted or upright, real or virtual?

   c) Use a ruler and the grid below to ray-trace the system. Include at least three primary rays for each lens.



Physics 132 Exam 6F • Fall 2019

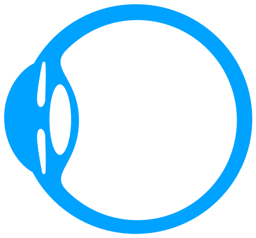
Name: ____________________

No calculators. No notes. Use only the provided paper and equation sheet. 35 minutes · 50 points

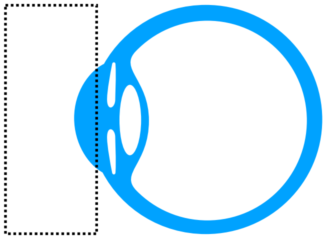
Section 1 • Short Answer

1. Ralph has myopia (he's *nearsighted*) and wears glasses to correct his vision.

a) Draw at least two rays that demonstrate how incoming rays travel through Ralph's uncorrected eye. The incoming rays should be incident on the cornea at an angle consistent with an object distance that Ralph struggles to see without correction. Explanation why the image isn't sharp



b) Draw at least two rays that demonstrate how incoming rays travel through Ralph's with the addition of on an appropriate corrective lens, and explain what about the rays makes he image sharp.



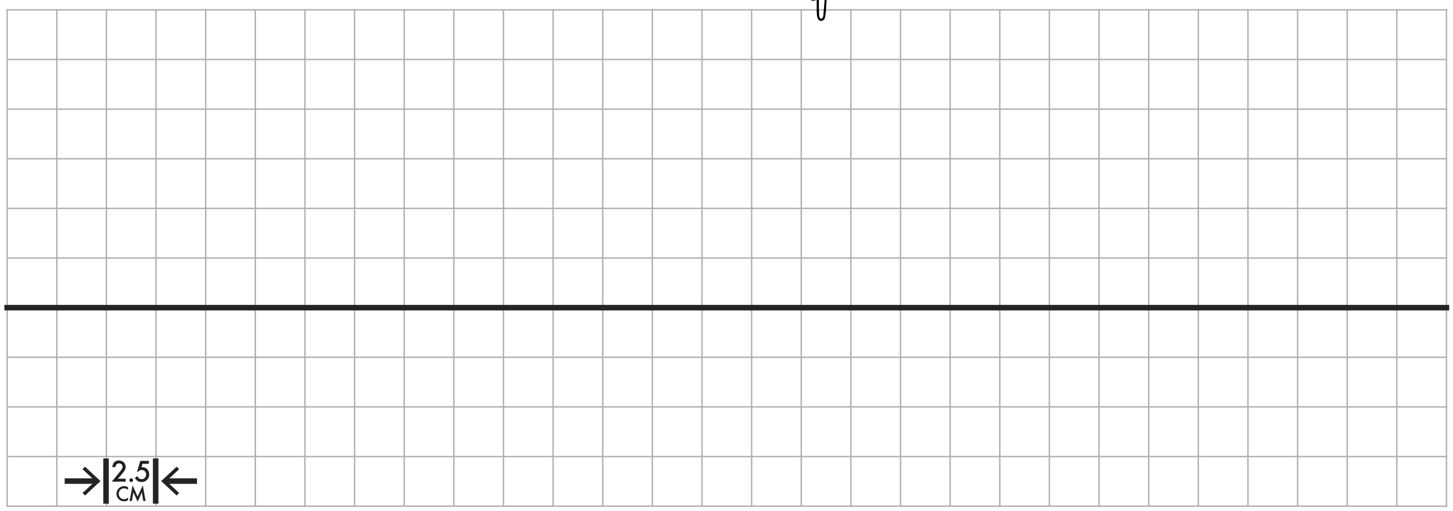
Section 3 • Ray tracing and Calculation

2. Ralph is excited to try out his new cosmetic mirror whose box prominently advertises to make his face "3 times life size when placed 10cm from the mirror!" Eager to observe his newly grown mustache, Ralph rushes home and places his face 10cm from the mirror
   a) Determine s, s', and f for this system.

   b) Use a ruler and the grid on the back of this page to ray-trace the system. Include at least three primary rays
   c) If Ralph's eyeglasses have a prescription of -3⅓ diopters. Can he clearly see his image in the mirror without his glasses on?

Continued on back

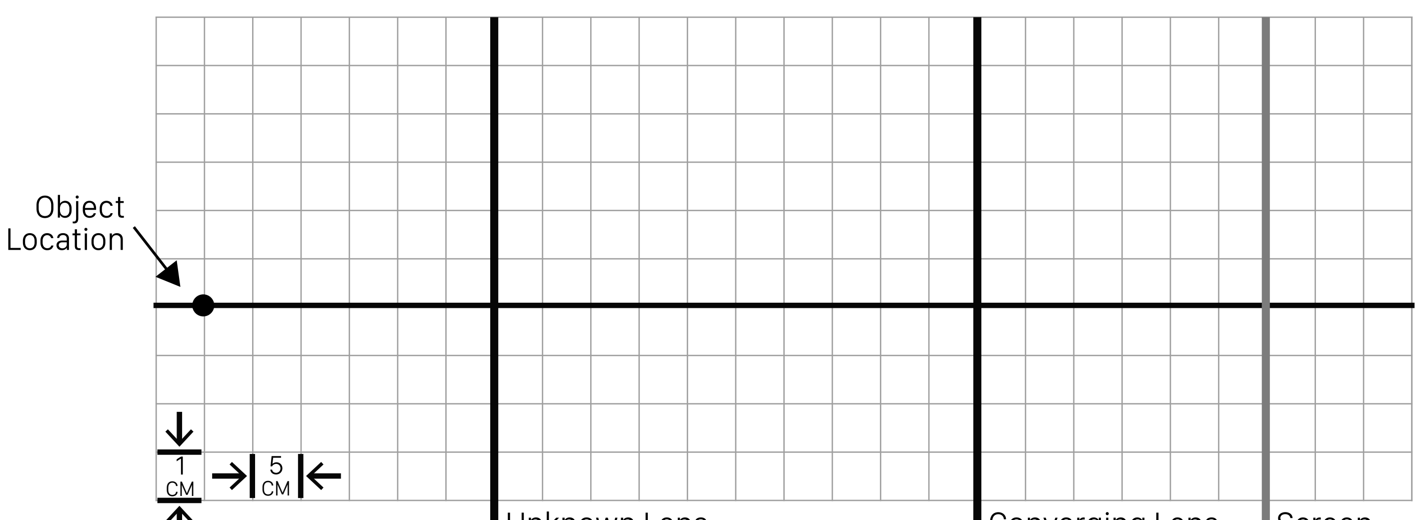
This grid goes with **№ 2** from the front of the exam ☟



3. As shown on the grid below, a light source is positioned 30 cm in front of an unknown lens. A converging lens with a focal length of 20cm is placed 50 cm behind the unknown lens. An inverted 1-cm-tall image is formed on a screen 30 cm behind the converging lens.
   a) Calculate the focal length of the unknown lens and the total magnification of the system.

   b) Is the unknown lens converging or diverging?, Is the image inverted or upright, real or virtual?

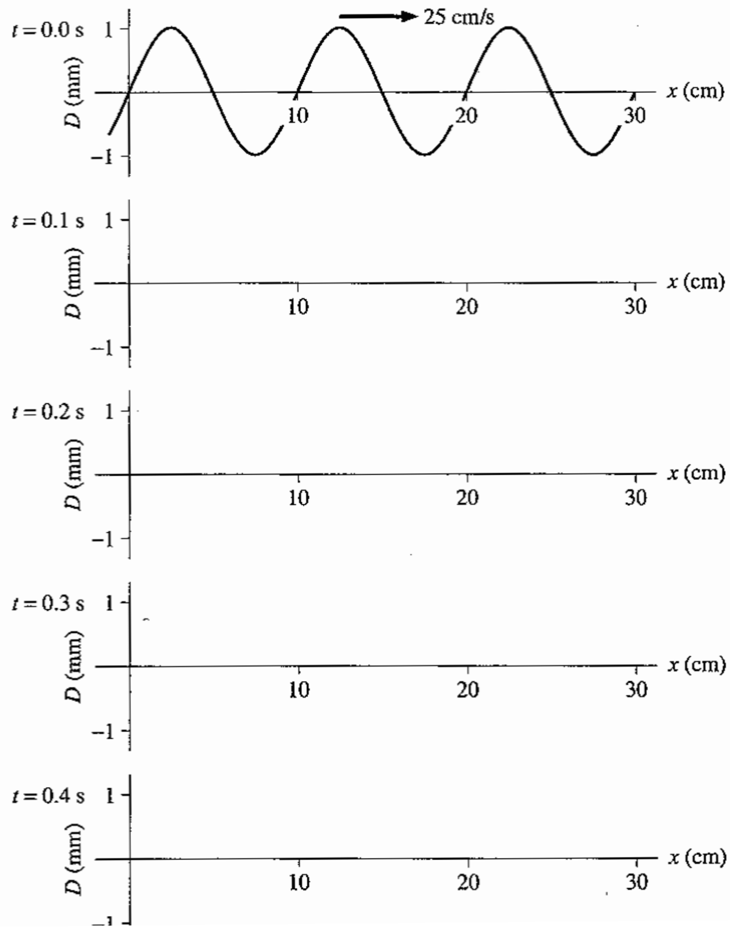
   c) Use a ruler and the grid below to ray-trace the system. Include at least three primary rays for each lens.



Name: ______________________________

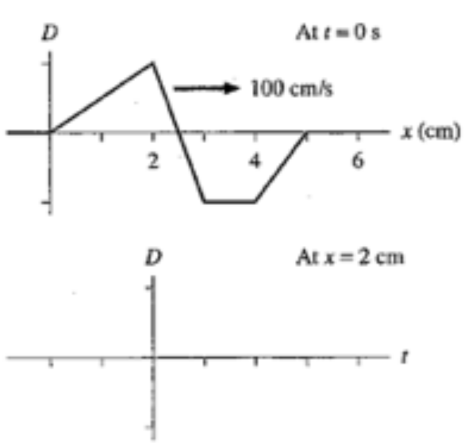
Physics 132
Homework 3 Worksheet · Traveling Waves

1. The wave shown at time $t = 0$ s is traveling to the right at a speed of 25 cm/s.
   a. Draw snapshot graphs of this wave at times $t = 0.1$ s, $t = 0.2$ s, $t = 0.3$ s, and $t = 0.4$ s.
   b. What is the wavelength of the wave?
   c. Based on your graphs, what is the period of the wave?
   d. What is the frequency of the wave?
   e. What is the value of the product λf?
   f. How does this value of λf compare to the speed of the wave?

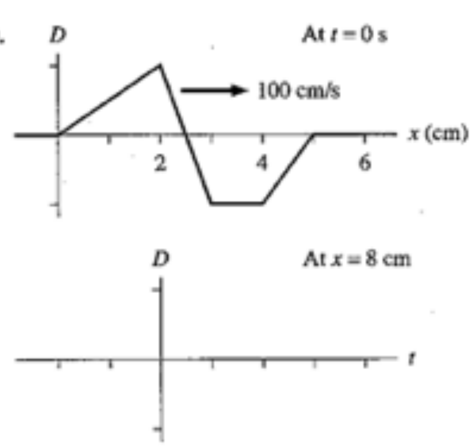


2. Below are snapshot graphs of wave pulses on a string. For each, draw the history graph at the specified point on the x-axis. No time scale is provided on the t-axis, so you must determine an appropriate time scale and label the t-axis appropriately.

a.



b.



Continued on back

3. A traveling wave is described by the equation. Answer each question and describe your reasoning.

$$y(x, y) = (7.5\text{ cm})\ \cos\left((5\,\text{m}^{-1})\,x + (20\,\text{s}^{-1})\,t\right)$$

a) What is the speed of this wave?

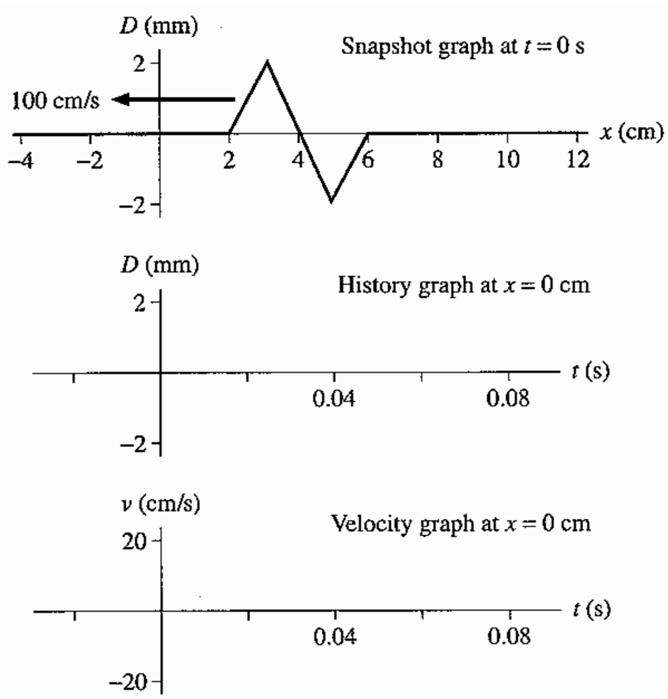
b) In what direction does this wave propagate?

c) What are the maximum speed and maximum acceleration of a particle in the medium in which this wave propagates?

3. a. Draw the history graph $D(x = 0\text{ cm}, t)$ for this wave at the point $x = 0$ cm.

b. Draw the *velocity*-versus-time graph for the piece of the string at $x = 0$ cm. Imagine painting a dot on the string at $x = 0$ cm. What is the velocity of this dot as a function of time as the wave passes by?

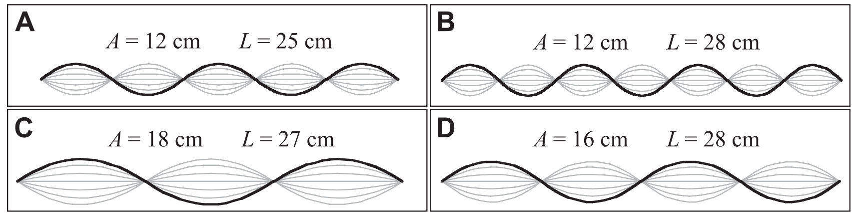
c. As a wave passes through a medium, is the speed of a particle in the medium the same as or different from the speed of the wave through the medium? Explain.



Name: ______________________________

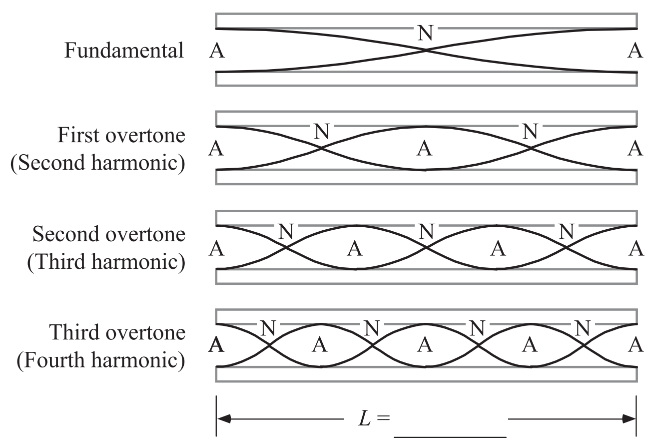
Physics 132
Homework 4 Worksheet · Standing Waves & Interference

1. A string is stretched so that it is under tension and is tied at both ends so that the endpoints don't move. A mechanical oscillator then vibrates the string so that a standing wave is created. The dark line in each diagram represents a snapshot of a string at an instant in time when the amplitude of the standing wave is a maximum. The lighter lines represent the string at other times during a complete cycle. All of the strings are identical except for their lengths, and all strings have the same tension. The number of nodes and antinodes in each standing wave is different. The lengths of the strings (L) and the amplitudes at the antinodes (A) are given in each figure. **Rank the frequencies of the waves. Explain your reasoning.**



				OR	
1 Greatest	2	3	4 Least		All the same

2. A pipe of length L is open at both ends. Sound is created in the pipe at four different frequencies. The diagram shows the location of nodes (N) and antinodes (A) in the pipe for the four different modes. The table to the right has an entry for wave speed of the first overtone, and an entry for the wavelength of the second overtone. **Use the given information to find the length L of the pipe. Then complete the table of frequencies, wavelengths, and wave speeds for the four modes. Explain your reasoning.**

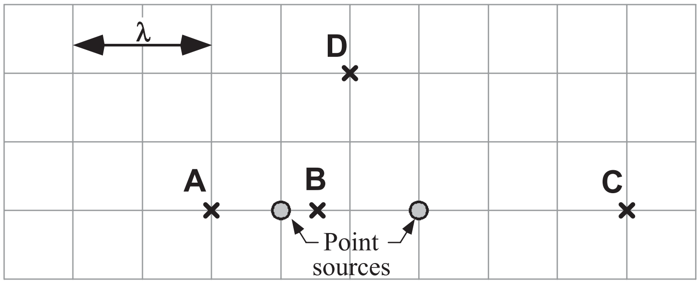


Frequency	Wavelength	Wave speed
		340 m/s
	40 cm	

Continued on back

3. Two pulses travel toward each other along a long stretched spring as shown. Pulse A is wider than pulse B, but not as high. **Is the speed of pulse A (i) larger than, (ii) smaller than, or (iii) equal to the speed of pulse B? If there is not enough information to tell, state that explicitly. Explain your reasoning.**

4. Two identical point sources are generating waves with the same frequency and amplitude. The two sources are out of phase with each other, so at the instant that one source is creating a crest, the other source is creating a trough. The wavelength of the waves is equal to the distance between the two sources.



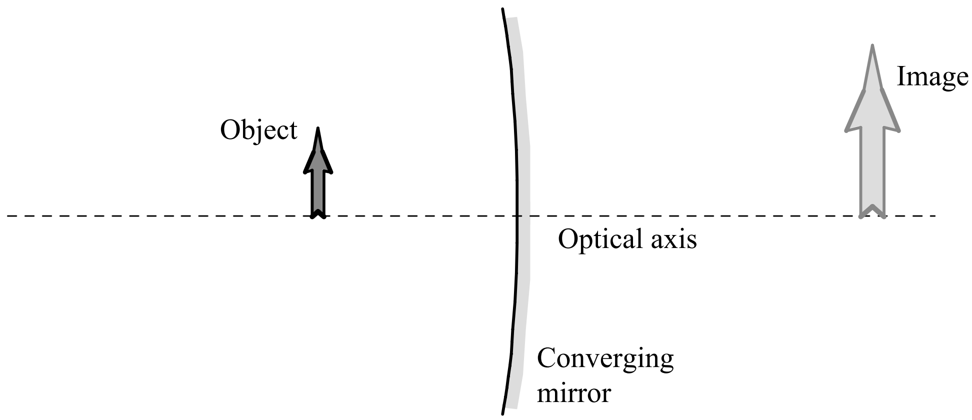
List all the labeled points where the waves from the two sources constructively interfere. If there are no such points, indicate that by stating "none of them." Explain your reasoning.

List all the labeled points where the waves from the two sources destructively interfere. If there are no such points, indicate that by stating "none of them." Explain your reasoning.

Name: ______________________________

Physics 132
Homework 7 Worksheet · Imaging

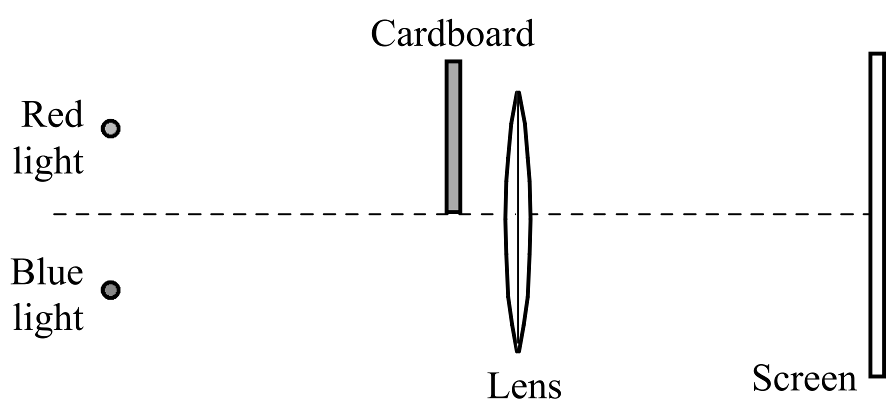
1. An object is placed in front of a converging mirror. An upright image of the object is formed behind the mirror at the location shown. Based on the image and object locations above, find the focal point for this mirror. Explain your reasoning.

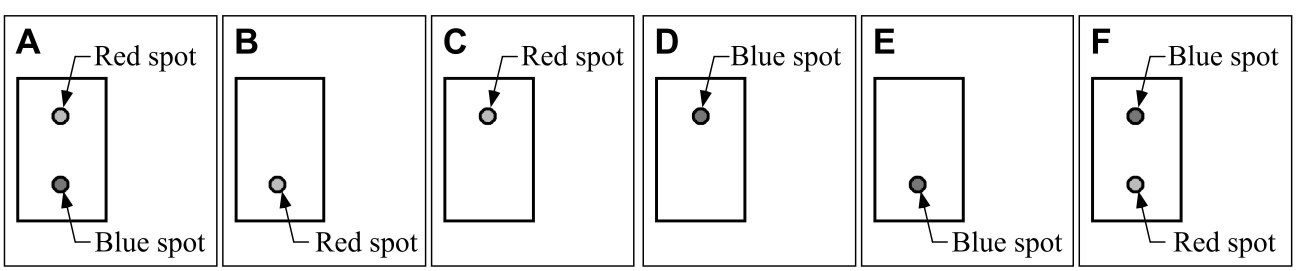


2. Light from two small bulbs, one red and one blue, passes through a lens to form an image of the bulbs on a screen. Without changing the location of the bulbs, the lens, or the screen, a piece of cardboard is placed so that it covers half of the lens, as shown in the side view diagram.

Which of the depictions below (A-F) best represents what will appear on the screen?

Draw at least four rays directly on the figure to justify your answer

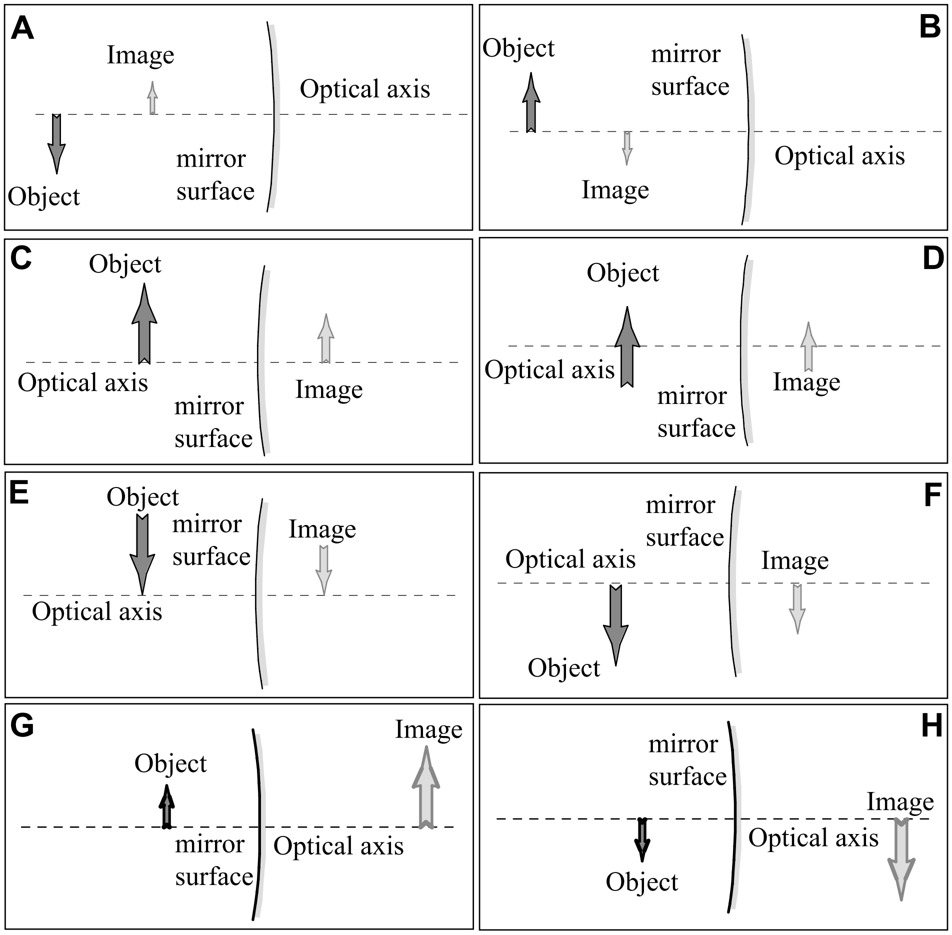




Explain your reasoning:

Continued on back

3. Consider the image positions for the mirrors arranged as shown to the left, with the objects placed on the left side.

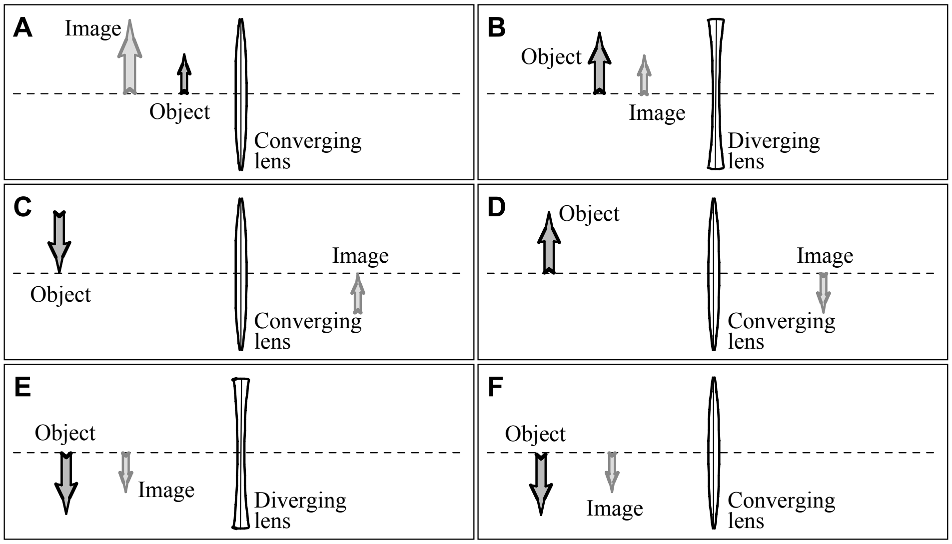


(a) List all the cases that produced a virtual image of the object:

(b) List all the cases that produced an inverted image of the object:

(c) List all the cases that produced a reduced size image of the object

4. Consider the image positions for the lenses arranged as shown with the objects placed on the left side.



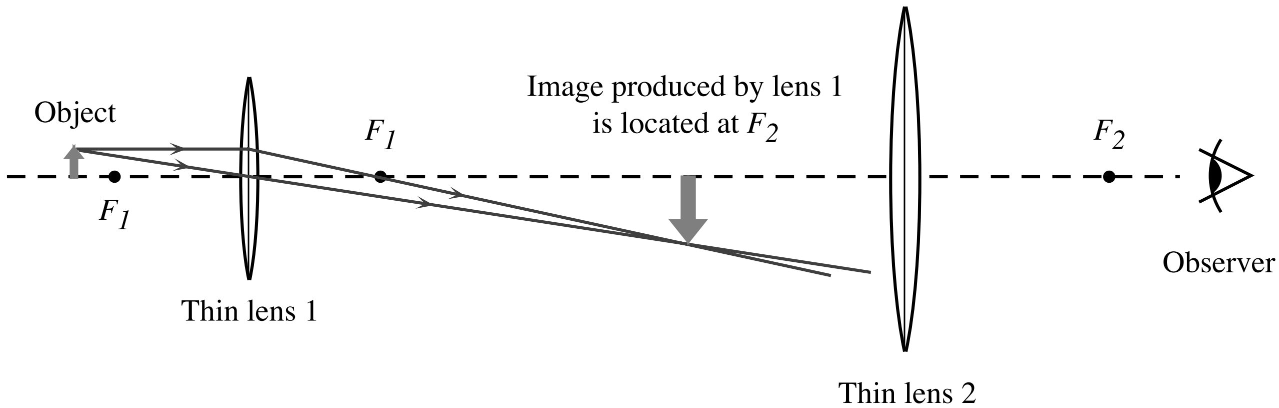
(a) List all the cases that produced a virtual image of the object:

(b) List all the cases that produced an inverted image of the object:

(c) List all the cases that produced a reduced size image of the object:

Continued on next page ☞

5. Two thin convex lenses and an object are arranged as shown below. Two rays from the tip of the object are drawn in order to determine the location of the image produced by lens 1. Lens 2 is placed so that one of its focal points coincides with the location of the image produced by lens 1.



a) Treating the image produced by lens 1 as an object for lens 2, draw two principal rays from the tip of this image that pass through lens 2. (Note that one of the principal rays cannot be drawn in this case.) Using either geometry or trigonometry, show that these two principal rays are *parallel* on the right side of lens 2. (Hint: Look for congruent right triangles in your ray diagram.)

b) Where is the tip of the image seen by the observer located? Explain. (Hint: From where do the rays on the right side of lens 2 *appear* to have come?)

c) On the diagram above, clearly indicate:

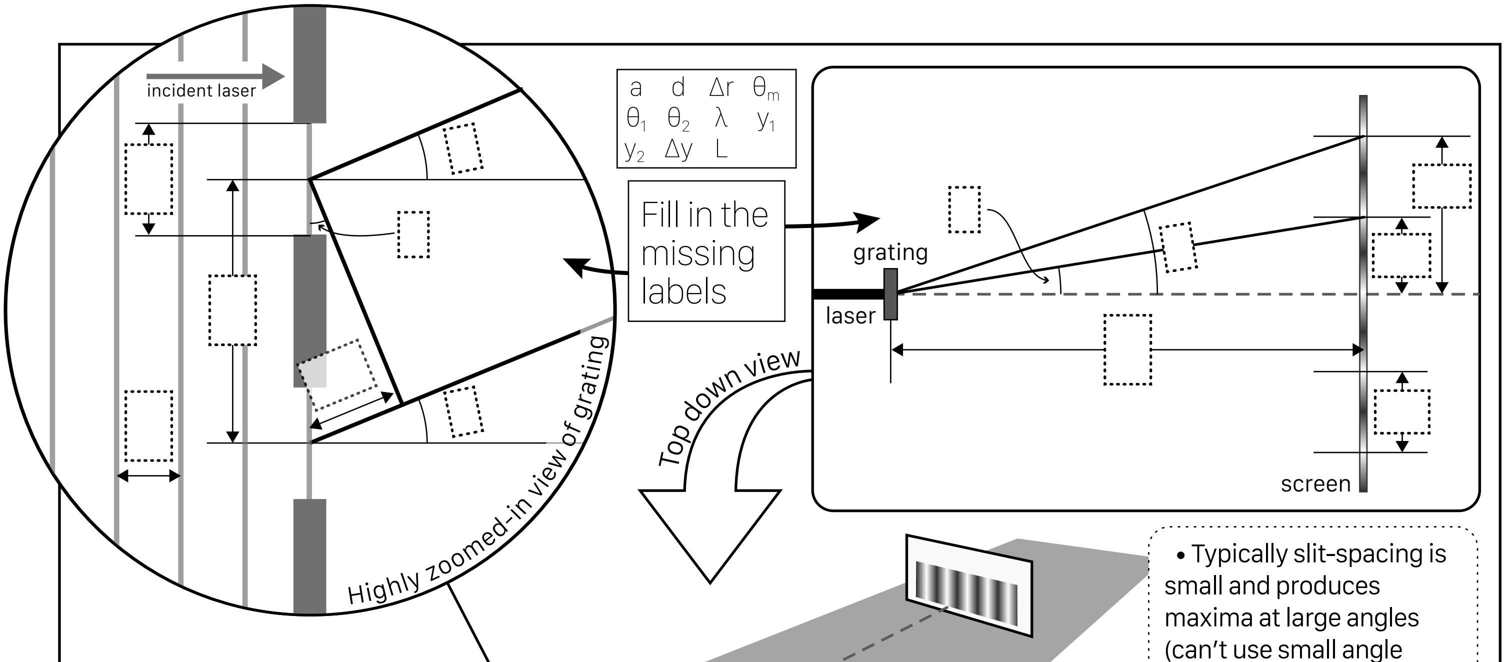
the direction in which the observer must look to see the tip of the image,
the direction in which the observer must look to see the tail of the image, and
an angle that represents the angular size of the entire image seen by the observer.

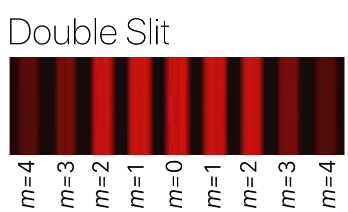
d) On the basis of your results in parts a–c, which would appear larger: the image seen by the observer (with both lenses present) or the object itself (with the lenses removed)? Explain.

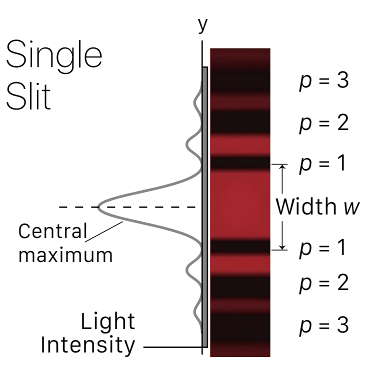
e) The diagram in this problem illustrates a compound microscope. Lens 1, called the objective, is placed near the object of interest. Lens 2, known as the eyepiece, is placed so that one of its focal points coincides with the image produced by the objective. In order to improve the angular magnification (magnification of the apparent size of the image) of the microscope shown above, would you replace the eyepiece (lens 2) with another lens that has a smaller focal length or a larger focal length? Explain your reasoning.

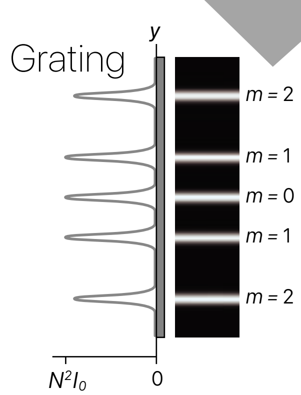
Name: ______________________________

Physics 132 Wave Optics Worksheet and Cheatsheet









2-Slit & Multi-Slit Gratings

- Specified by **constructive** interference condition ($\Delta r = m\lambda$)
- m is an integer 0, 1, 2, 3...
- The center maxima corresponds to m=0.
- The first maxima either side of center both correspond to m=1, the next symmetric pair of maxima away from the center is m=2, etc.
- θ_m and y_m represent the angle and distance measured along the screen to each maxima, respectively. θ_3 is the angle from the center maximum to the third maxima out from center on either side. Similarly, y_3 is the distance from the center maximum to the third maxima (on either side) as measured along the screen.

Provided on Equation Sheet

$$d\sin\theta_m = m\lambda \qquad d\sin\theta_m = \left(m + \frac{1}{2}\right)\lambda$$

Prominent Equation Sheet Ommissions

$$\theta_m = \frac{m\lambda}{d} \qquad \Delta y = \frac{\lambda L}{d} \qquad y_m = L\tan\theta_m \qquad y_m = \frac{m\lambda L}{d}$$

Any equation used on an exam that is not provided on the equation sheet must be derived or justified from the provided equation set. This list is not comprehensive.

Single Slit Interference

- Specified by **destructive** interference condition $\Delta r = (a/2)\sin\theta_p = (p/2)\lambda$
- p is an integer 1, 2, 3...
- The first minima on either side of center both correspond to p=1, the next symmetric pair of minima away from the center is p=2, etc
- Destructive interference from each single-slit is responsible for groupings or missing maxima observed with 2-slit pattern.

Provided on Equation Sheet $\quad d\sin\theta_p = p\lambda$

Name: ______________________________

Physics 132
Homework 5 Worksheet · Wave Optics

1. In the lab, monochromatic light is passed through a two-slit grating onto a screen and produces the interference pattern shown below. For each change listed in the table, **indicate whether the spacing between the bight spots *increases, decreases,* or *remains the same* and explain your reasoning.**

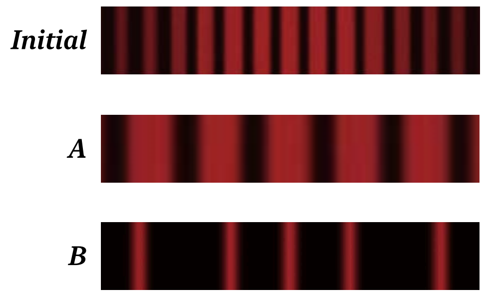
Initial Pattern

Consider each scenario independently as changes to the initial pattern. Assume that all parameters remain constant other than the specified change

	Change to system	**Spacing between the bright spots observed on the screen**		
		Increases	*Decreases*	*Stays the Same*
a	the slit separation is increased			
	Explain your reasoning			
b	the color of the light is switched from red to blue			
	Explain your reasoning			
c	the whole apparatus is submerged in water			
	Explain your reasoning			
d	the screen is moved closer to the grating			
	Explain your reasoning			
e	the width of each slit is halved			
	Explain your reasoning			
f	the width of each slit is halved			
	Explain your reasoning			

Continued on back

2. The figure to the right shows three interference patterns. Initially we observe the pattern at the top of the figure and make changes to the system to produce patterns *A* and *B*.



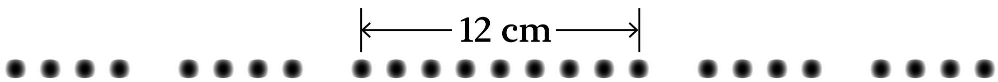
c) Can pattern ***A*** be produced by making changes to the initial setup that retain the *same grating* and also maintain the *same position relative to the screen* as the initial case? **Explain how, or why not.**

d) Can pattern ***B*** be produced by making changes to the initial setup that retain the *same grating* and also maintain the *same position relative to the screen* as the initial case? **Explain how, or why not.**

e) Is it possible to observe all three patterns using only gratings with the same slit spacing and slit width? **Explain how, or why not.**

Continued on next page

3. A laser is incident on two narrow slits that are positioned 1.5 meters from a screen. At the screen, light from the two slits produces the pattern of bright spots shown below. Each of the two slits has a width of 0.01 mm, but the distance between the slits unknown.
For good practice, complete this problem without using a calculator



a) **Use the information above to determine the spacing between the two slits (to the nearest 0.01 mm).**

d) **Determine the wavelength of the laser light incident on the double slit grating. For full credit, use the small-angle approximation to determine a numeric answer.**

Name: ______________________________

Physics 132
Homework 5 Worksheet · Wave Optics

1. In the lab, monochromatic light is passed through a two-slit grating onto a screen and produces the interference pattern shown below. For each change listed in the table, **indicate whether the spacing between the bight spots *increases, decreases,* or *remains the same* and explain your reasoning.**

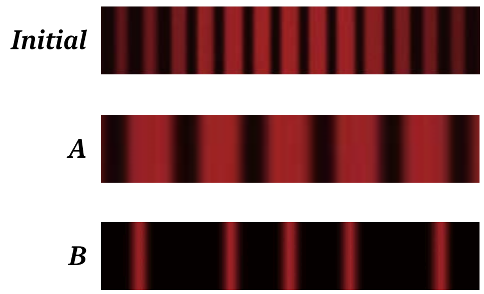
Initial Pattern

Consider each scenario independently as changes to the initial pattern. Assume that all parameters remain constant other than the specified change

	Change to system	Spacing between the bright spots observed on the screen		
		Increases	*Decreases*	*Stays the Same*
a	the slit separation is increased			
	Explain your reasoning			
b	the color of the light is switched from red to blue			
	Explain your reasoning			
c	the whole apparatus is submerged in water			
	Explain your reasoning			
d	the screen is moved closer to the grating			
	Explain your reasoning			
e	the width of each slit is halved			
	Explain your reasoning			
f	the width of each slit is halved			
	Explain your reasoning			

Continued on back

2. The figure to the right shows three interference patterns. Initially we observe the pattern at the top of the figure and make changes to the system to produce patterns *A* and *B*.



   c) Can pattern ***A*** be produced by making changes to the initial setup that retain the *same grating* and also maintain the *same position relative to the screen* as the initial case? **Explain how, or why not.**

   d) Can pattern ***B*** be produced by making changes to the initial setup that retain the *same grating* and also maintain the *same position relative to the screen* as the initial case? **Explain how, or why not.**

   e) Is it possible to observe all three patterns using only gratings with the same slit spacing and slit width? **Explain how, or why not.**

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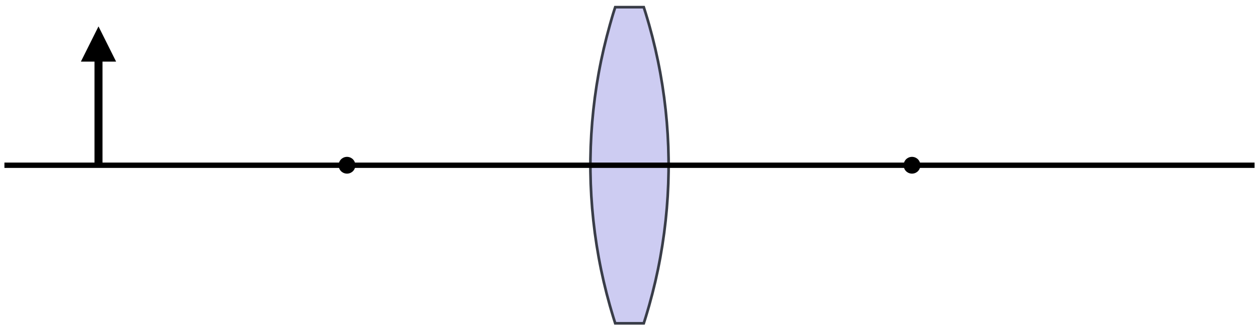
Name: ______________________________

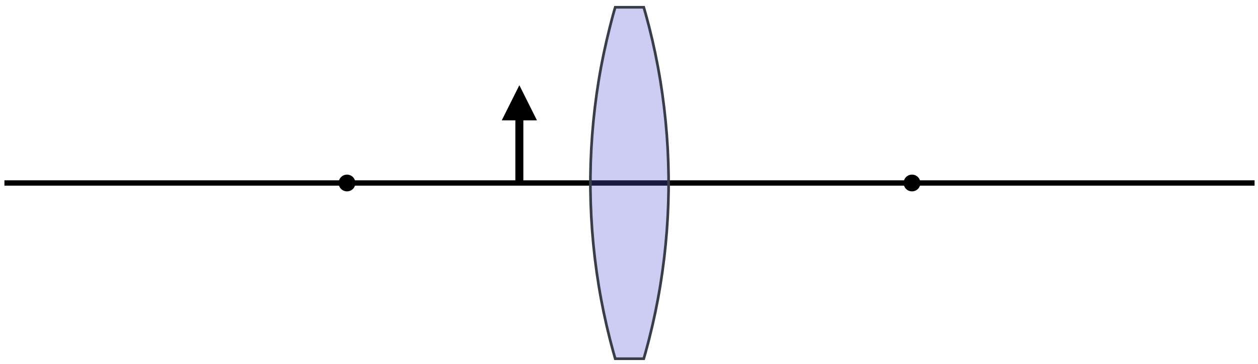
Physics 132
Ray Tracing Thin Lenses and Spherical Mirrors

Scenario I



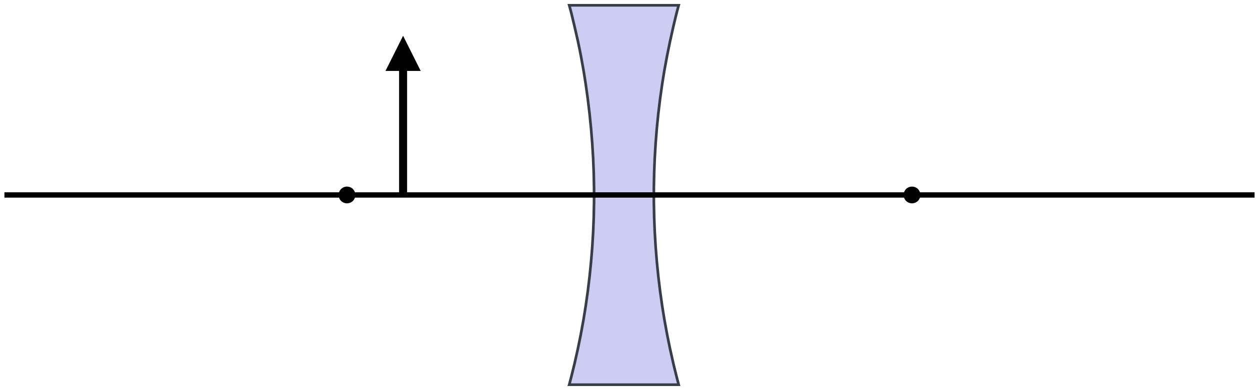
❐ $m < 0$ ❐ $m > 0$ ❐ $|m| > 1$ ❐ $|m| < 1$ ❐ $s' > 0$ ❐ $s' < 0$ ❐ $f > 0$ ❐ $f < 0$

Scenario II

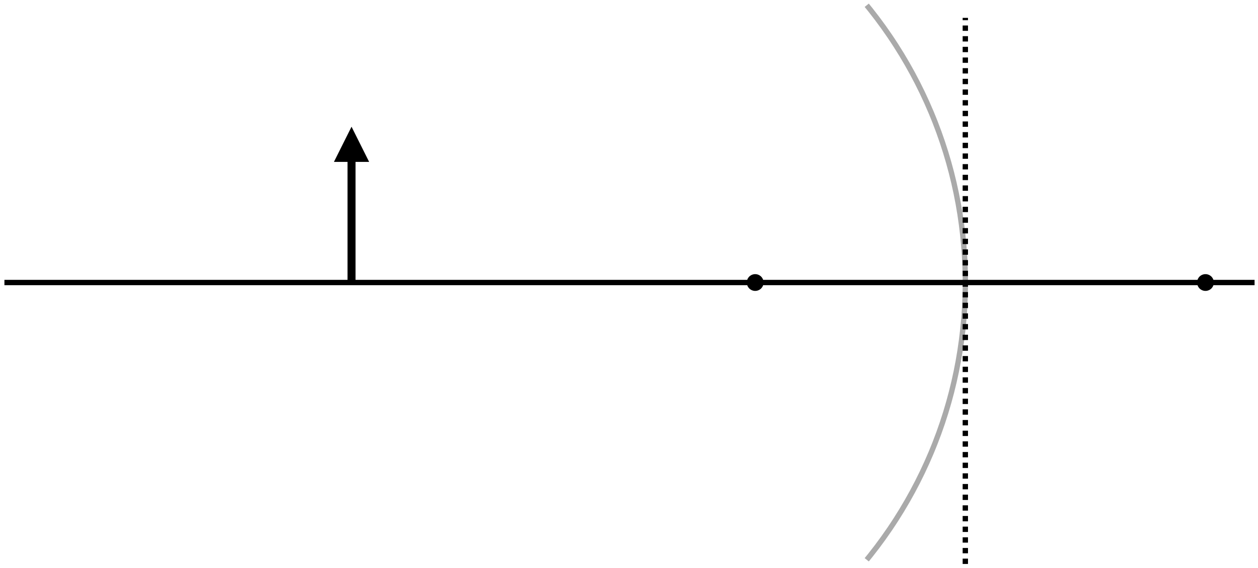


❐ $m < 0$ ❐ $m > 0$ ❐ $|m| > 1$ ❐ $|m| < 1$ ❐ $s' > 0$ ❐ $s' < 0$ ❐ $f > 0$ ❐ $f < 0$

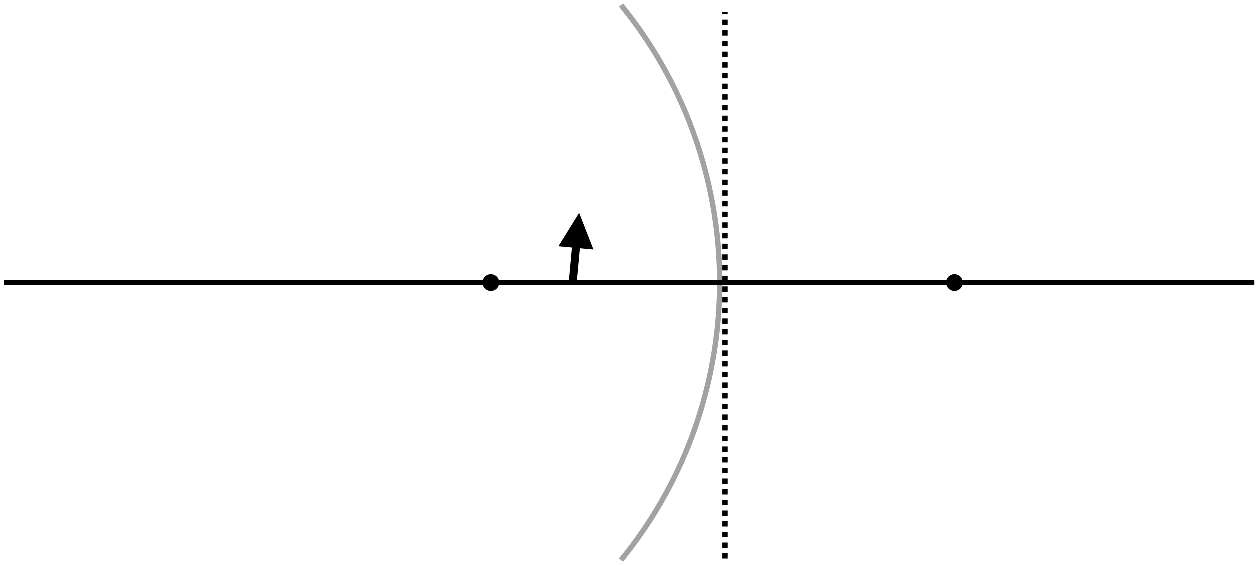
Scenario III



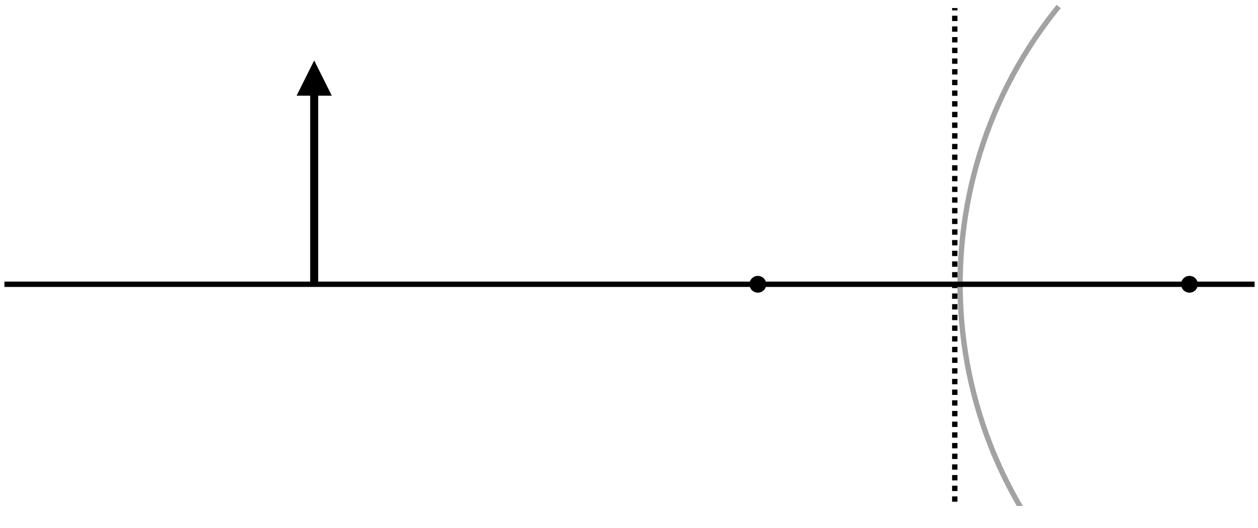
❐ $m < 0$ ❐ $m > 0$ ❐ $|m| > 1$ ❐ $|m| < 1$ ❐ $s' > 0$ ❐ $s' < 0$ ❐ $f > 0$ ❐ $f < 0$



❐ $m < 0$ ❐ $m > 0$ ❐ $|m| > 1$ ❐ $|m| < 1$ ❐ $s' > 0$ ❐ $s' < 0$ ❐ $f > 0$ ❐ $f < 0$



❐ $m < 0$ ❐ $m > 0$ ❐ $|m| > 1$ ❐ $|m| < 1$ ❐ $s' > 0$ ❐ $s' < 0$ ❐ $f > 0$ ❐ $f < 0$



❐ $m < 0$ ❐ $m > 0$ ❐ $|m| > 1$ ❐ $|m| < 1$ ❐ $s' > 0$ ❐ $s' < 0$ ❐ $f > 0$ ❐ $f < 0$

PHYSICS 132 IMAGING PRACTICE PROBLEMS

The problems below are from a couple of my previous PHYS 132 exams. I used them as example problems at the Midterm Review Session, and want to make them available to anyone who was unable to attend.

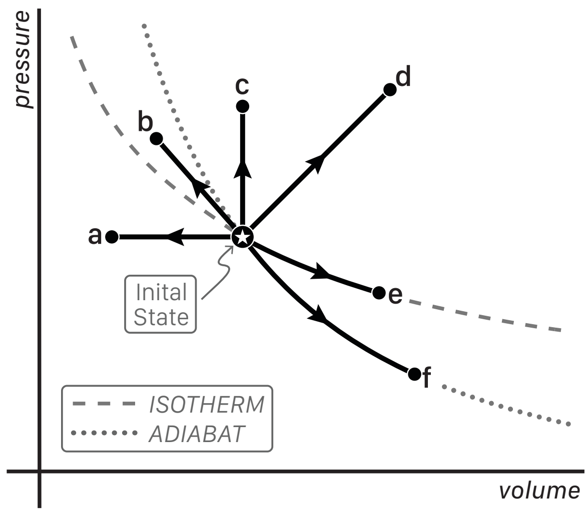
1. Ralph is excited to try out his new magnifying glass whose box prominently advertises to make objects "5 times life size when placed 4cm from the lens!" Eager to observe his collection of bottle caps Ralph rushes home and holds the magnifying glass 4 cm above the bottle cap he wants to observe.
    a) On a separate sheet, determine s, s', and f for this system.
    b) Use a ruler and the grid below to ray-trace the system. Include at least three primary rays. Make the object 1 square tall.
    a) Ralph looks through the magnifying glass, positioning is eye 20cm from the lens. Ralph's reading glasses (which he isn't wearing) have a prescription of +⅔ diopters, and allow him to read at a distance of 25cm. Will Ralph be able to see the bottle cap (through the magnifying glass) without his glasses? (answer on a separate sheet)

3. A light source is positioned 30 cm in front of an unknown lens. A converging lens with a focal length of 20cm is placed 50 cm behind the unknown lens. An image is formed on a screen 30 cm behind the converging lens.
    a) Determine the focal length of the unknown lens and the total magnification of the system.
    b) Is the unknown lens converging or diverging?
    c) Is the image inverted or upright, real or virtual ? (20 points)

PHYSICS 132 CHAPTER 18/19 QUIZ REVIEW

The problems below are from a couple of my previous PHYS 132 exams. I used them as example problems at the Midterm Review Session, and want to make them available to anyone who was unable to attend.

1. A cylinder contains a sample of an ideal gas, initial at a pressure and volume corresponding to the initial state point ✪ in the PV diagram to the right. The points *a-f* each depict six distinct processes that originate from the initial state. The final state for each scenario is indicated by the labeled point (*a* through *f*). In the table below determine whether each term in the first law of thermodynamics (***Q, W,*** ΔE_{th}) is ***positive*** (greater than 0J) ***negative*** (less than 0J) or ***zero***

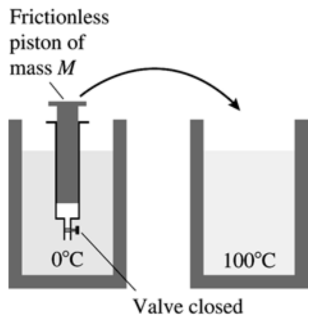


	Q			**W** (work *on* gas)			**ΔE_{th}**		
	positive $Q>0$	*negative* $Q<0$	*zero* $Q=0$	*positive* $W>0$	*negative* $W<0$	*zero* $W=0$	*positive* $\Delta E_{th}>0$	*negative* $\Delta E_{th}<0$	*zero* $\Delta E_{th}=0$
a									
b									
c									
d									
e									
f									
	Check three boxes in each row (one for each *Q, W,* ΔE_{th})								

1b. Which final state *a-f* has the highest temperature?

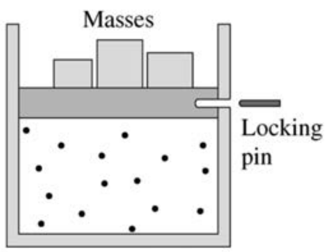
1c. For which process *a-f* is the work done on the gas the greatest?

6. A vertical syringe with a frictionless piston of mass M is initially at thermal equilibrium in ice water and then transferred to boiling water, and allowed to come to thermal equilibrium. (15 points)



a) Does the volume of the gas increase, decrease or stay the same? Explain.

b) Does the pressure of the gas increase, decrease or stay the same? Explain.



7. The cylinder of gas shown has a piston that can float up and down. You can:
   - Lock or unlock the piston in place with a pin
   - Add or remove masses from the piston
   - Place the entire cylinder in a hot or cold liquid.

a) Can you increase the gas temperature without changing the pressure? If so, describe how you would do it. If not, explain why not.

b) Can you increase the gas pressure without changing the temperature? If so, describe how you would do it. If not, explain why not.

7. A block of mass M is dropped into a cylinder with a cross-sectional area A and a height L forming a frictionless, air-tight seal. (20 points)

a) Determine an expression h for the height above the bottom of the cylinder that the block comes to rest.

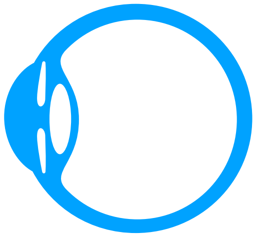
b) With the block at height h, you apply a flame and increase the temperature of the gas from 27˚C to 127˚C, and the block moves to a new height h_1.
What is h_1/h ?

Name: ____________________

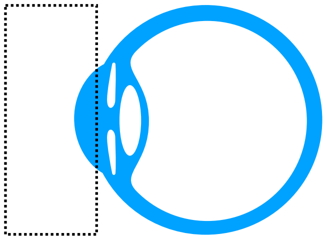
Phys 132 • Vision Correction Exam Problems

1. Ralph has myopia (he's *nearsighted*) and wears glasses to correct his vision.

a) Draw at least two rays that demonstrate how incoming rays travel through Ralph's uncorrected eye. The incoming rays should be incident on the cornea at an angle consistent with an object distance that Ralph struggles to see without correction. Explanation why the image isn't sharp



b) Draw at least two rays that demonstrate how incoming rays travel through Ralph's with the addition of on an appropriate corrective lens, and explain what about the rays makes he image sharp.



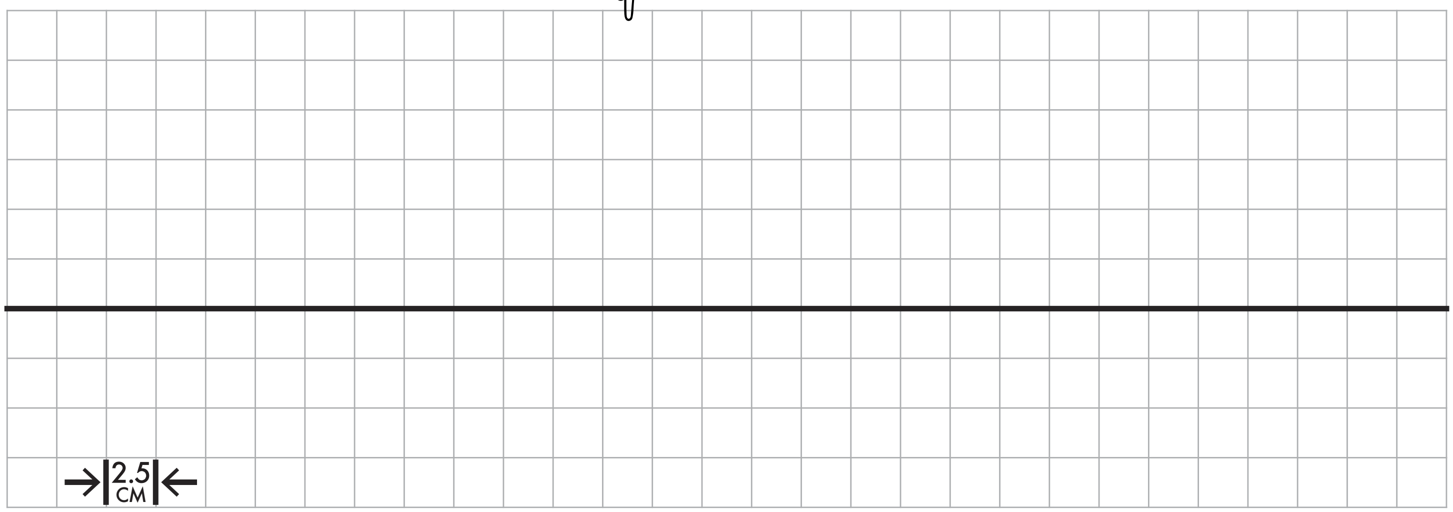
Corrective
Lens

2. Bart is excited to try out his new cosmetic mirror whose box prominently advertises to make his face "3 times life size when placed 10cm from the mirror!" Eager to observe his newly grown mustache, Bart rushes home and places his face 10cm from the mirror
   a) Determine s, s', and f for this system.

   b) Use a ruler and the grid on the back of this page to ray-trace the system. Include at least three primary rays
   c) If Bart's eyeglasses have a prescription of -3⅓ diopters. Can he clearly see his image in the mirror without his glasses on?

Continued on back

This grid goes with № 2 from the front



Name: ______________________________

Physics 132
Worksheet · Calorimetry

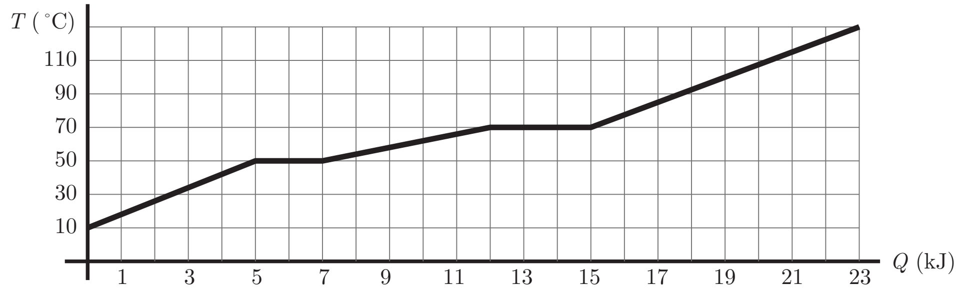
1. 1.0 kg of water is initially at 370K in an open container at atmospheric pressure when a flame is used to heat the water, adding 21 kJ of energy. What is the final temperature of the water?

2. It is a well-known fact that water has a higher specific heat than iron. Now, consider equal masses of water and iron that are initially in thermal equilibrium. The same amount of heat, 30 calories, is added to each one. Which statement is true?
   ❐ They remain in thermal equilibrium.
   ❐ They are no longer in thermal equilibrium; the iron is warmer.
   ❐ They are no longer in thermal equilibrium; the water is warmer.
   ❐ It is impossible to say without knowing the exact mass involved.
   ❐ It is impossible to say without knowing the exact specific heats.

Explain your reasoning:

3. When a liquid freezes,
   ❐ the temperature of the substance increases.
   ❐ the temperature of the substance decreases.
   ❐ heat energy leaves the substance.
   ❐ heat energy enters the substance.

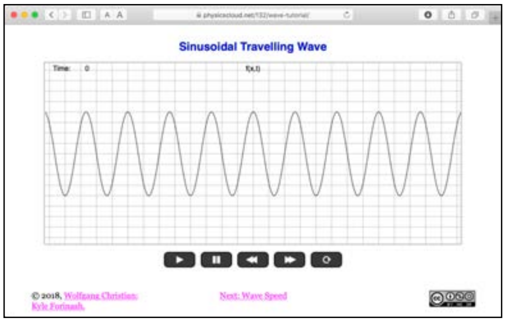
4. You heat 2 kg of Kryptonite and measure the temperature, which is plotted to the right. Determine the values in the table below. Include units. Complete calculations in the space provided and record answers in the table below.



T_{melting}	T_{boiling}	c_{solid}	c_{liquid}	c_{gas}	L_f	L_v

NAMES:____

Studio 132 Tutorial: Traveling Waves



In this exercise, we will use open-source animations and interactive physics demonstrations available through a link on the course website, or accessed directly at **physicscloud.net/132/wave-tutorial**

If the page loads correctly. you should see a graph of a sinusoidal traveling wave and controls animate its motion. For each section below, refer to the corresponding animation and complete the guided worksheet. Report any requested quantities in the space provided.

Part I: Determine the properties of the traveling wave

1. Click anywhere on the graph to enable the on-screen cursor. Using this functionality, measure the frequency, wavelength, amplitude and period of the wave. ***The reported position is given in centimeters and the time in seconds.***

2. Reset the animation and then use the step buttons to advance the time to 2.0s. Identify the position of at least two points on the string that have *maximum acceleration* at t=2.0s.

3. Using this information, write down an expression for the displacement of this wave $D(x,t)$.

4. In your own words, explain *why* your displacement expression correctly describes the propagation direction of the wave observed in the animation.

*Click **Next: Wave Speed** to continue*

Part II: Speed of a Wave

The velocity of the wave v, is a constant determined by the *properties of the medium* in which the wave is moving. The velocity is a vector which gives the forward speed of the wave and the direction the wave is traveling. For now we will not worry about direction since the waves being discussed will all be assumed to travel along the x-axis. In this simulation, the original wave will remain in the window so that as you make changes to $f(x,t)$ you can see how the new wave (in red) compares to the original ($g(x,t)$, in blue).

In the displacement equation for a sinusoidal traveling the wave, the quantity $2\pi/\lambda$, is often called the *wave number*. Unfortunately the standard symbol assigned to the *wave number* is *k,* a seemingly arbitrary and undoubtedly poor choice.

$$D(x,t) = A\sin\left(\frac{2\pi}{\lambda}x - \omega t + \phi_0\right) = D(x,t) = A\sin\left(kx - \omega t + \phi_0\right)$$

You'll have to be careful not confuse the many meanings of *k.* In the context of a traveling wave it's $k = 2\pi/\lambda$ and has units of [rad] / [m] or $m^{-1.}$ **Watch out:** this is not the same *k* as the spring constant, (units [N] / [m])*.

5. Determine the speed of the wave in the simulation using v = λ /T where wavelength and period are determined from the simulation as you did in the previous exercise using the mouse to find the wavelength and the time to find the period. What is the forward speed of this wave?

6. The speed of this wave is also given mathematically by v = ω/k since ω = 2π f = 2π/T and k = 2π/λ. What is the speed of this wave based on the values of ω and k in the equation? Does this match the speed you got from the simulation?

7. Reload the initial conditions and experiment with values of the wavenumber both smaller and larger than 2.0 rad/m keeping the angular frequency fixed. How does the wavenumber change the speed of the wave?

8. Reload the initial conditions and experiment with values of the angular frequency both smaller and larger than 0.8 rad/s keeping the wavenumber fixed. How does the angular frequency change the speed of the wave?

This simulation is misleading in one important way. *In the simulation you can set any combination of angular frequency and wavenumber you choose and so have any speed you want for the wave. But for mechanical and acoustic waves the speed is determined by the medium in which the wave travels. As we will see, for these waves it is often the case that v = ω/k so that the angular frequency and wavenumber are inversely proportional with v constant.*

---

* This *k* doesn't mean translational kinetic energy *(K),* either. The wavenumber can't it be used to measure temperature, like the K known as Kelvin. It isn't the same k we to calculate the force between charges ($k = 1/(4\pi\varepsilon_0)$). We're also not referring to the SI-prefix for 10^3 (kg, kW, kPa…), the z-directed unit vector $\hat{k}$, Boltzmann's Constant (*k* or sometimes *k_B),* nor is it the K found on the periodic table (Potassium). Why, then is k the symbol for *wave number*? 🤯 I don't know—I'm not even sure which physicist to blame— but I do wish they'd been a little more creative.

*Click **Next: Transverse Waves** to continue*

Part III: Transverse Waves

The following simulation shows a graph of the motion of one location, the red circle, on a string which has a transverse wave on it. Since we're dealing with specific case of transverse waves, we'll choose the more familiar symbol *y* to represent the displacement. Therefore, the vertical location of points on the string (represented by the circles) as a function of horizontal location along the x-axis and time is described mathematically by$y(x,t) = A\sin(kx - \omega t + \phi_0)$.

9. Play the animation (lower left button). From the graph, what are the amplitude and period of the motion of the red dot?

10. Determine the wavelength and propagation speed.

A second velocity associated with a wave is how fast the material of the wave moves up and down at a single location (the vertical speed of the circles in the simulation). This velocity, the transverse velocity, is not a constant but is a function of location and time (different places on the wave move upward or downward at different speeds at different times). Since velocity is the rate of change of position, this second speed (in the *y* direction) is given by the derivative of the *y*-displacement with respect to time:

$$v(x,t) = \frac{\partial y}{\partial t} = -A\omega\cos(kx - \omega t + \phi_0)$$

Notice that the maximum speed of a section of the wave at location x and time t will be given by $v_{\text{max}} = A\omega$ We use a partial derivative here because *y(x,t)* is a function of two variables.

11. Click on the 'Velocity' button and then 'play'. The upper graph now gives the speed of the red circle in the y-direction as a function of time. Using v_{max} from the graph and the amplitude from (9) determine is the angular frequency? How does this compare with the value calculated from the period?

12. State in your own words the difference between wave speed and transverse speed of a wave.

*Click **Next: Reflection from ideal boundaries** to continue*

Part IV: Reflection from Ideal Boundaries

In the previous simulation we did not take the wave nature of reflected waves into account; the waves were assumed to be exactly the same after reflection. However the phase of the wave may be different after reflection, depending on the surface from which they reflect. The example below is for strings but a similar effect occurs when light or sound reflect off of different types of surfaces or boundaries.

Waves reflect from a boundary in two basic ways depending on whether the boundary is *hard* or *soft*. In the case of waves on a string an ideal *hard* boundary is where the string is completely fixed at one end attached and an ideal *soft* boundary is when the end of the string can slide up and down without friction. To accurately model the dynamics, the string in this animation is simulated as a row of individual masses connected by invisible springs.

In the case of strings a boundary where the end is free is called a free boundary condition. If the end is fixed it is called a rigid or fixed boundary condition. A third possible boundary is circular boundary condition, or periodic boundary condition, where the right end of the string loops around to smoothly connect to the left end. With a circular boundary condition, a pulse moving the the right would re-appear at the left after it leaves the right hand side of the simulation.

13. Describe the similarities and differences between the two animations shown. What are their boundary conditions? How does this affect the reflected pulse?

14. For the lower pulse, what is the direction of the force, if any, that is *exerted by the string* on the fixed green ring? Explain.

15. For the lower pulse, what is the direction of the force, if any, that is *exerted by the green ring* on the string? Explain.

16. Are your observations about the forces on the end of the string helpful in explaining the behavior of the reflected pulses? Explain.

*Click **Next: Reflection upon entering a new medium** to continue*

Part V: Reflections dues to changing media

Generally the term impedance refers to how easily oscillating energy is transferred from one location to another. There are many kinds of impedance; mechanical, electrical, acoustic and wave impedances all have definitions specific to their use in different fields. Here we will briefly investigate the mechanical energy transferred from one medium to another.

17. **Predict:** What reflection to you expect to see, if any, as the pulse travels from the heavy string to the light string? What about the reflection in the light-to-heavy case?

18. For each case, how does the *tension* in one string compare to the tension in the other? Explain.

19. How does the linear mass density μ for one string compare to the linear mass density of the other? Explain.

20. **Watch both animations** and describe the behavior of the reflected (and transmitted) pulses. Can your observations about the tension and linear mass density be used to explain the behavior of the reflected pulses? Explain.

In this simulation the change in mass of the string affects the amount of reflected and transmitted energy and the speeds of the waves. If the string had the same mass on both sides there would be no reflection. different values.

Impedance matching is an important consideration whenever energy is transferred across a boundary. You end up with reflections and partial transmission whenever the systems are not perfectly matched across the boundary. Understanding impedance is important to many areas of physics and engineering. Here are a few tidbits:

- When two electrical devices are hooked together and one device is sending energy to the second one (for example signals going from a stereo system to a set of speakers), when the electrical impedance of the two devices is different, some energy is reflected rather than being transmitted to the second device—This reason why your car's subwoofer needs a big amplifier, those low frequency speakers have a very low electrical impedance.
- One way to try to match impedances is to gradually change the medium between two different values. This is the purpose of the bell on brass and woodwind instruments. An instrument such as a trumpet would not produce as much sound if it ended abruptly with no flared bell on the end. This is because there is an impedance mismatch for the waves inside the instrument (where the pressure is constrained by the sides of the instrument) and the pressure outside.

Click ***Next: Two Dimensional Waves*** *to continue*

Part VI: Waves propagating in two dimensions

21. Click on the 'play' button with the plane wave selected. Experiment with wavelength and period. Is the simulation accurate in representing a fixed speed for a real wave? How do you know?

22. Can this representation be used to describe longitudinal waves as well as transverse waves? Why or why not? Explain.

23. With an appropriate choice of variables, can we use the same form of our displacement equation to describe the circular waves shown in the animation? Are the there still two independent variables? Explain.

24. The circular wave simulation is *unphysical* in one sense because the amplitude of the circular wave does not change as the diameter gets bigger. Why is this unrealistic? Would you expect the amplitude of a circular wave to be the same once it has spread out over a very large distance from the source? Explain.

Name ____________________ Name ____________________

Name ____________________

Physics 132 Lab Activity 4

Interference and Diffraction of Light Part I

Goal: *Observe the light patterns formed when a laser passes through various slit masks and identify trends, similarities and differences between the patterns. Use interference measurements, and the small angle approximation when appropriate to calculate grating parameters.*

Procedure: Carefully set the laser at one end of your table, and, if possible, point it away from your neighbors' table. Place the mount right in front of the laser. Place the screen on your table as far away from the mount as possible. If you need to draw or mark parts of the pattern on the screen, clip a piece of white paper onto the screen. *Please do not draw on the screen.*

To observe the patterns, walk up closely to the screen and look at them up close-up. The whole point of this lab is to discover all the features of these patterns and start thinking about how they might be related. Seriously – get up and look!

You have the following slit masks available (details of the approximate size and distance of the slits are indicated on the frame of the mask):
Single slit mask, Double slit mask, Multiple slit mask, Gratings (various slit densities)

Experiment 1: Double slit

Place the double slit mask on the mount and shine the laser through one of the slit pairs (pairs (I recommend 0.04 mm width slits at 0.25 mm spacing).For best results, try to have it as upright and as perpendicular to the laser beam as possible. Look closely at the pattern formed on the screen. Describe the features you see to each other, and make sure you all see them. Sketch what you see here.

Slit spacing (from label): _____________ Slit width (from label): _____________

Sketch the pattern observed on the screen in are area below. Include a scale bar on your drawing and try to include all of the salient features in your drawing.

Brightness corresponds directly to the intensity of light. Make a plot (by hand) of intensity vs. position along an imaginary line through the pattern you see on the screen.

Try the other double slits and compare the patterns. Describe the effect of increasing or decreasing the slit spacing on the pattern.

Why does the pattern look the way it does? Try to explain as many of the features you are seeing using your knowledge of waves, and the results from your investigation thus far. Are there any (so far) unexplainable features in the observed pattern? [Hint: The “ideal” double slit diffraction pattern consists of interference maxima, which are all equally bright]

How does the pattern change as the distance between the grating and viewing screen changes? Does the changes in the pattern suggest a wave or particle model for light? Explain your reasoning.

Experiment 2: Slit spacing of a double slit

Place the 0.04 mm double slit with the 0.25 mm spacing into the path of the laser beam and observe the pattern on the screen. Make appropriate measurements to calculate the actual slit spacing and compare with the manufacturer's value. Record all relevant values, measurements, and calculations here. In the space provided, make a sketch of the pattern on the screen and in it show from where to where you are measuring. Use 632.8 nm for the wavelength of the laser.

Hint № 1: Your measurement precision is higher if you choose to measure a larger distance with the ruler. Instead of measuring the distance from the central fringe to the next one, measure the distance of a number of fringes, and then divide by the appropriate number.

Hint № 2: It is easier and more accurate to discern dark spots than to pinpoint the brightest spot of a wide bright fringe. Here, you can safely use the small angle approximation (check this yourself).

Verify with your instructor that you're making sound measurements before moving on.

In the space below, verify that you are safely able use the small angle approximation in these calculations.

Experiment II: Measurements, Calculations and Sketch

Experiment 3: Grating

Next, place the multi-slit grating. Typically diffraction gratings are labeled in *lines/mm* which specifies the number of slit-openings (lies) in the span of 1 mm in the grating region. You will need to calculate the slit spacing from the provided specification. Once again, look closely at the pattern formed on the screen. Describe the features you see to each other, and make sure you all see them. Sketch what you see here:

Slit width (from label): ________ , Slit spacing (from label): ________, # slits: ________

What is the effect of increasing or decreasing the line density (#lines/mm) on the pattern?

Can the small angle approximation be used if calculating the wavelength or slit spacing from measurements of the bright-spot to bright-spot distance (and screen-grating distance)? Explain why or why not, and show any calculations.

Observe the diffraction pattern created by reflecting the laser off of the back surface of a CD. Measure the spacing between maxima and use this to experimentally determine the pit spacing. The reflection pattern is similar to that of a diffraction grating. Look up the average pit spacing for CDs and compare with your measurement. How would your results change if you were to use a DVD or Blu-ray disc instead?

Name ____________ Name ____________

Name ____________

Physics 132 Lab Activity 6

Thin Lenses *Rev 3*

Goal: *Observe and measure the image produced by a single-lens and two-lens imaging arrangement. Verify the thin-lens equation and magnification relationship. Measure the focal length of both a converging and a diverging lens.*

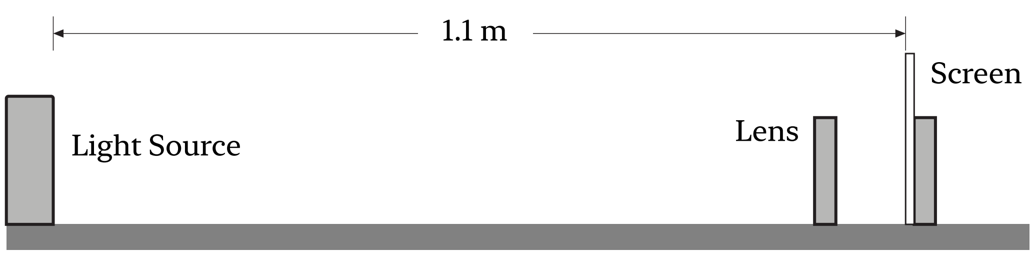
Experiment 1: Distant Object and Converging Lens

1. Use the converging lens to form a sharp image of a distant object (lamp from across the room or something outside the window) on the screen. Measure the distance from the center-plane of the lens to the image formed on the screen. Use this measurement to calculate the focal length of the lens[1] [hint: it should be reasonable to say that the object is infinitely far away if compared to image distance]. Show you work.

2. How does your measured and calculated value for the focal length of the lens compare to the manufacturer's value printed on the lens holder?

Experiment 2: Single Lens Imaging

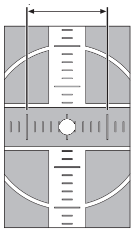
1. Place the light source and the screen at either end of the optics bench with the light source's crossed-arrow object toward the screen. Place the converging lens between them as shown in the figure (somewhat less that 1.1m is fine, if that's all that fits).



[1] In practice, this method is regularly used by scientists and engineers to get an approximate value for the focal length of an unknown covering lens, typically using the image on the table of the overhead lights above.

2. Starting with the lens close to the screen, slide the lens away from the screen to a position where a sharp image of the crossed-arrow object is formed on the screen. Describe the image: Is it larger or smaller than the object? Upright or inverted? Real or virtual? How do you know?

3. Measure the image distance and the object distance, as well as the object size and the image size and record them here.



Measure the same feature (the height of the arrow or the tick marks shown above) on both the object and in the image formed so that their sizes can be meaningfully compared

4. Find the focal length of the lens and compare it with the manufacturer's value.

5. Check the magnification equation by comparing the magnification found (i) from the object and image distances, and (ii) from the object and image heights. Show your work.

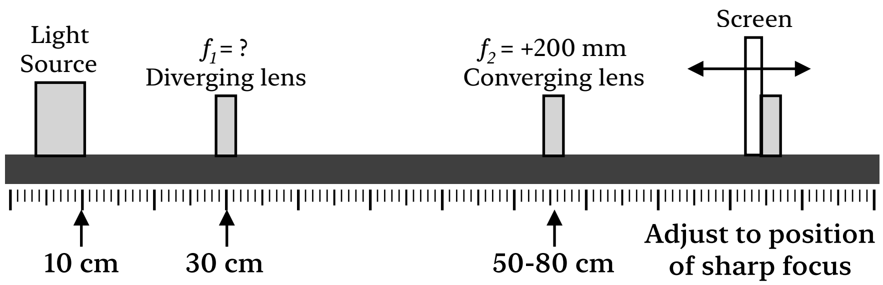
6. In the space below, predict what will happen to the image if you cover the lower half of the lens with a sheet of paper.

7. Using a sheet of paper, cover the lower half of the lens. Then, continue to raise the paper held against the lens until only a sliver of glass remains for the light to pass through. Record your observations of the image below.

8. Now move the lens along the track until you see another sharp image form on the screen. Record the object and image distances, and also the image height here. What relationships do you notice for these values, compared to those in step 5?

Experiment 3: Two lens imaging

1. Why can't you determine the focal length of a diverging lens using either of the methods from Experiment 1 or Experiment 2 above?



2. As shown above, place the diverging lens on the bench at the 30 cm mark. Place the light source at the 10 cm mark with the crossed-arrow object toward the lens. Place the converging lens with focal length +200 mm on the bench anywhere between the 50 cm and 80 cm marks. Place the viewing screen behind the converging lens. Slide the screen to a position where a clear image is formed on it—The real image you see on the screen is formed by the converging lens with the virtual image (formed by the diverging lens) acting as the object— In the space below, record the diverging lens object distance, s_1, and the converging lens image distance s_2'.

3. Use s_2', the thin lens equation and your value of f_2 from experiment II to calculate the object distance for the converging lens s_2 . Show your work here.

4. In the space below, make a sketch of the location of each optical component, (similar to the figure above № 2), and mark the location of the image/object for both lenses. Use your calculated value of of the converging-lens object distance s_2 and your sketch to determine the diverging lens' image distance s_1'. Be careful with your signs.

5. Use s_1 and s_1' to calculate the focal length of the diverging lens f_1 Compare your calculated value to the manufacturer's value, including a percent difference. Show your work here.

Experiment ★: Virtual Object

1. With the light source at 0 cm, place the converging lens on the optical rail at 30 cm. Slide the screen along the optical rail until you find a clear image. Measure the object and image distances for the converging lens and record them here.

2. Draw a diagram depicting the optical rail setup and the *marginal rays* that pass from the top of the object (represented by the tip of an arrow) to the image on the screen. The marginal rays are the two rays emitted from the object that reach the top and bottom of the lens. Try and make the horizontal distances roughly to scale.

3. Now place the screen at 110 cm and put the diverging lens between the converging lens and the screen. Slide the lens until you see a clear image on the screen. Record the position of the diverging lens. Draw a diagram depicting the optical rail setup and the *marginal rays* that pass from the top of the object (represented by the tip of an arrow) to the first image image, and the marginal rays from the diverging lens to the screen.

4. Use the location of the diverging lens and your diagram to determine the object and image distances for the diverging lens. Note the signs here are unusual, and not like any problem we've attempted so far.

5. Now that you know the object and the image distances for the diverging lens, use them (be careful with the signs of your object and image distances) to find the focal length of the diverging lens and compare it to the focal length provided by the manufacturer by finding the % Error.

6. In terms of the rays entering the lens, under what circumstances does it make sense to use a negative object distance *s?* In other words, what property do the the rays entering the diverging lens in this scenario have that make it impossible for their source to have been a real object directly? [Hint: A real object produces infinitely many rays from every point that *diverge* as they leave the source]

Physics 132 | Fall 2021

Dr. Culbreath | Cal Poly Physics

Office Hours NA
zoom.us

Syllabus	Objectives	YouTube	Zoom

Important Links

- Course Syllabus
- Course Objectives
- Email assignment submission procedure
- Zoom Meeting Room
  - (Use this link or through the zoom app, use the "Join" button with meeting id `drculbreath` to join class meetings or office hours)
- Physics Cloud log-in page
  - Note that Physics Cloud usernames do *not* include `@calpoly.edu`
  - Access directly at `https://physicscloud.net` and click "Log in" in the upper right

Handouts and Homework

Due Date	Email Subject	Type	Topic	Details	Solutions
F 12/31	---	Homework	**Thermodynamics Exam Problems:** Includes Exam 6 and Exam 7 material	Details	
W 12/08	---	Homework	**Homework 8:** Ch 19 and Ch 21: Thermodynamic Cycles	Assignment	PDF
M 11/29	HW7	Homework	**Homework 7:** Properties of Matter and Ideal Gas Law	Assignment	PDF
M 11/29	---	Assessment	**Exam 6:** Chapter 18 and Chapter 20 (§3-4 only)	Equation Sheet 3	PDF
F 11/19	---	Worksheets and Lab	**First Law Tutorial**	PDF (login required)	PDF
W 11/17	---	Worksheets and Lab	**Ideal Gas Law Tutorial**	PDF (login Required)	PDF
M 11/15	HW6	Homework	**Homework 6:** Imaging and Vision Correction	Assignment	PDF
M 11/15	HW6W	Homework	**Homework 6 Worksheet:** Imaging Worksheet	Worksheet	PDF

M 11/15	---	Worksheets and Lab	**Lab 6:** Thin Lenses	Handout	
M 11/15	---	Assessment	**Exam 5:** Imaging and Vision Correction	Equation Sheet 2	PDF
W 11/10	---	Worksheets and Lab	**Lab 5: Snell's Law**	Handout	
F 11/05	---	Worksheets and Lab	**Lab 4:** Interference and Diffraction	Handout	
F 11/05	HW5	Homework	**Homework 5**	Assignment	PDF
F 11/05	HW5W	Homework	**Homework 5 Worksheet**	Worksheet	PDF
F 11/05	---	Assessment	**Exam 4:** Refraction and Reflection	Equation Sheet 2	PDF
F 11/05	G5	Worksheets and Lab	**Group Assignment 5:** Snell's Law Prelab Worksheet	Worksheet	
W 10/27	---	Worksheets and Lab	**Wave Optics Worksheet**	Worksheet	
M 10/25	HW4	Homework	**Homework 4:** Superposition of Waves	Assignment	PDF
M 10/25	HW4W	Homework	**Homework 4 Worksheet:** Standing Waves Worksheet	Worksheet	PDF
M 10/25	---	Assessment	**Exam 3:** Superposition and Interference	Equation Sheet 2	PDF
M 10/18	---	Worksheets and Lab	**Lab 3:** Standing Waves on a String	Handout	
F 10/15	---	Worksheets and Lab	**Tutorial:** Wave Simulation Tutorial	Handout	
W 10/13	---	Assessment	**Exam 2:** Traveling Waves	Equation Sheet	PDF
M 10/11	HW3	Homework	**Homework 3:** Chapter 16	Assignment	
M 10/11	HW3W	Homework	**Homework 3 Worksheet:** Wave Representations	Worksheet	
M 10/11	---	Assessment	**Exam 1:** Oscillations		PDF
M 10/04	---	Worksheets and Lab	**Course Syllabus:** Online Quiz	Quiz Link (Physics Cloud login required)	
F 10/01	HW2	Homework	**Homework 2:** Chapter 15b / Oscillations	Assignment	PDF
F 10/01	HW2W	Homework	**Homework 2 Worksheet:** Dynamics of SHM	Worksheet	PDF
W 9/29	HW1	Homework	**Homework 1:** Chapter 15a / Oscillations	Assignment	PDF

T 9/28	---	Worksheets and Lab	**Group Assignment 2:** Dynamics of SHM	Worksheet	PDF
M 9/27	---	Worksheets and Lab	**Lab 1:** Simple Harmonic Motion of a Mass Suspended from a Spring	Handout	
W 9/22	---	Worksheets and Lab	**Group Assignment 1:** Kinematics of SHM	Worksheet	PDF

Exams

Nº 7: Thermodynamics I
Ch 18
Ch 19 §1–4
Ch 20 §3–4

R & F 3/12–3/13
(in lab)

Equation Sheet 3

Nº 6: Imaging
Ch 34 §5–7
Ch 35 §1–3

R & F 3/5–3/6
(in lab)

Solution

Nº 7: Thermodynamic Cycle
Ch 19 §1–5 and §7
Ch 21 §1–3 and §6

M12/6/21
or **F 12/10/21**

Equation Sheet 3

Nº 6: Ideal Gasses
Ch 18 (all sections)
Ch 20 §3–4 only

M 11/29/21

Equation Sheet 3

Nº 5: Optics II · Imaging
Ch 34 §5–7
Ch 35 §1 and §3

W 11/17/21

Solution
Equation Sheet 2

Nº 4: Optics I
Ch 33 §1–4
Ch 34 §1–4
Ch 35 §5

F 11/5/21

Equation Sheet 2

Nº 3: Superposition & Interference
Ch 17 (all sections)

~~F 10/22/21~~
M 10/25/21

Solution
Equation Sheet 2

Nº 2: Traveling Waves
Ch 16

W 10/13/21

Solution
Equation Sheet 1

Virtual Instruction Recordings

Content available through zoom video player is password protected. Get the password by logging in or by emailing your instructor.

Date	Format	Topic	Details	🧪

Suplemental Lecture Material

Chapter 15 Oscillations	Introduction to Exponential Decay (Damped Oscillations) Damped Oscillator Example Problem

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Slide Deck

Spring 2021 Keynote Slides	Cloud Viewer

Due: Monday 11/15/21

Assignment 6

Physics for Scientists and Engineers, A Strategic Approach 4th Edition. Randall Knight.

Due Monday 11/15

- HW6 — PDF problems | 🧪 Solution
  - Chapter 34 Exercises and Problems: 24, 27, 32, 38, 39, 40, 65, 77
  - Chapter 35 Exercises and Problems: 11, 12, 30, 31, 33, 34, ~~41~~
- HW6W Worksheet: Imaging and Vision Correction — Worksheet | 🧪 Solution

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Extra Resources

- Previous Exam Problems
- In-class Ray Tracing Worksheet | 🧪 Solution
- **Slide Tutorial:** When images are objects
- **Slide Tutorial:** Primary rays in two lens problems
- **Extra content:** Vision Correction Lecture Slides (extended version) Web Viewer

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Chapter Exams

I've heard the experiences of a few colleagues who have tried a more-frequent assessment scheme based around weekly, more bite-sized exams. For my first experience in Studio Physics, I decided to put the assessment question to an anonymous, online vote (supported by Physics Cloud) to determine the overall exam scheme for the course. Students were the choice of i) two midterms ii) three midterms, lowest score dropped, with the third midterm held on the last regular day of class or iii) eight chapter tests, drop lowest, and final exam limited to the chapters corresponding to a student's two lowest exams. Frequent tests won over three midterms (which bested the two midterms option) by a vote of 14 to 10 to 6.

Virtual
Physics 132 Syllabus
Spring 2021

Instructor: Dr. Christopher Culbreath (he/him/his)
Office Hours: MWF and Sunday 2:10-3:00 via Zoom

Lecture: MWF 1:10–2:00 **Lab:** Tue 12:10-3:00 Thurs 3:10-6:00
Email: cculbrea@calpoly.edu **Web:** physicscloud.net/132 **Mobile:** (805) 234-0847
Zoom Meeting ID: drculbreath **Zoom Passcode:** newtonwins **Video Passcode:** phys_132

Virtual Instruction: This offering of Physics 132 is structured so that it can be attended completely *asynchronously*, except for exam periods. All lecture content, exercises and handouts that cover exam-eligible material will be provided digitally on the course website. **If you plan on regular asynchronous participation (more than one class meeting per week on average) you must email the instructor to setup a meeting to discuss how labs and in-class activities will be made up.** Students who do not meet with the instructor regarding their asynchronous attendance will not be excused from mandatory (virtual) lab exercises. Synchronous attendance is optional, but encouraged. A listing of live lecture recording times, recitation groups and related course exercises will be maintained on the course website. Due to Zoom's varying video processing times, some lecture videos may not be posted until the following class meeting. Whenever possible, webcam proctored exams are mandatory and administered during laboratory meetings. Students requiring an alternate time or an adjustment to their designated time slot should contact the instructor by email. Special accommodation less than 24 hours in advance of a scheduled exam will only be made for extenuating circumstances, at the discretion of the instructor.

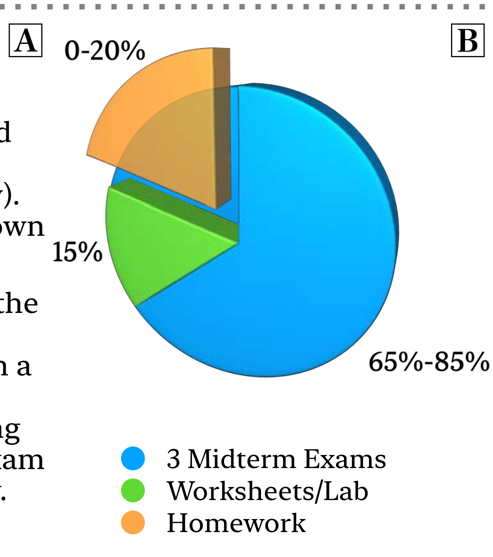
Course Objectives: Physics 132 is the second course in the series of calculus-based introductory physics classes. Unlike the other courses in the introductory physics series, Physics 132 covers three broad topics: Waves, Optics and Thermodynamics. A full outline of the course objectives is posted on the course website.

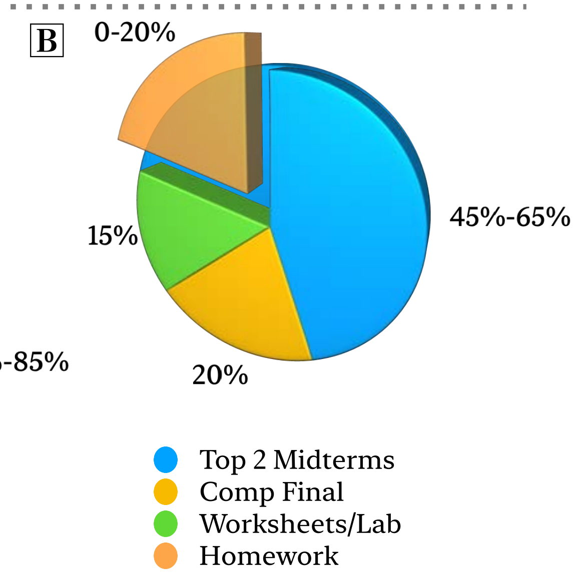
Textbook: *Physics for Scientists and Engineers: A Strategic Approach with Modern Physics*, by Randall D. Knight, 4th Edition. The textbook is well-written and accessible, and my lecture notes generally align with the textbook presentation. Handouts will be distributed digitally on the course website.

Course Website: The course website is https://physicscloud.net/132/ ***The website is a source of essential information for this course.*** Assignments, solutions, the syllabus, course objectives, course schedule, lab handouts and exam solutions will all be posted to the site. A login is not required to access the main course site (grades and other sensitive content require login access). Please check the course website regularly. **I do not use the campus Canvas or Poly Learn systems.**

Prerequisites: Prior completion of PHYS 141 (or equivalent) is a required prerequisite.

Grading: Course grades will be tabulated according to a weighted average. The specific weighting of assignment types will be determined by the outcome of the assessment scheme class vote (see details below). Each of the schemes (A or B) is shown to the right. In either scheme, homework is weighted at 0–20% of the overall course grade, according to individual student preference. When a student chooses a homework weighting less than 20%, the grading weight assigned to their midterm exam scores is increased commensurately. The default weight assigned to





homework (without student intervention) is 15%. The page for adjusting your individual homework grading weight will be first be available on Physics Cloud after the first homework assignment has been graded. The last opportunity to adjust your homework grading weight will be just after grades for the first exam have been posted (the specific cutoff date will be announced in class and by email at least 48 hours in advance).

At the end of the term, every student's weighted point total will be ranked with letter grades assigned using a normal (Gaussian) distribution with the median score assigned a C+ and the width of the distribution adjusted such that the number of students earning an *A* or *A-* is no fewer than 10% of enrolled students. *The curve will never require a level of performance that exceeds standard 10%-per-letter-grade thresholds.* Specifically, the minimum score required for an *A-* shall never exceed 90%, scores above 80% will always be awarded a *B-* or better and scores above 70% earn a *C-* or better regardless of class performance and the specific distribution of grades. Stated another way, *the curve cannot hurt you.* No individual assignments will be curved, nor will point totals be manipulated to offset performance. C, C+ and C- grades indicate overall scores not far from the average. *A*s are reserved for scores reflecting significantly above-average performance and are typically awarded to 10-15% of the class.

physicscloud.net At the beginning of the quarter you will receive email to signup for my course-management system at physicscloud.net. In addition to viewing your course grade and assignment statistics, physicscloud.net is used for scheduling review sessions, and for voting on important *course options* such as the schemes for assessment and homework grading.

Homework: Homework will be collected weekly. Homework is due as indicated for the assignment on the course website. ***Late homework is accepted (until Friday of Week 10), subject to a 33% deduction, graded as credit/no-credit.***

Homework Presentation: Assigned book problems should be worked on blank, unruled, paper or quad-ruled, engineering-type graph paper. *Do not use regular lined notebook paper.* Blank printer paper is everywhere; use that instead. Clearly indicate the problem number for each provided solution. Number the pages in the upper right corner. Whenever possible, the solution should *include a figure or sketch* that illustrates the key parameters of the problem. Answers must be reported using a reasonable number of significant figures. Try to make your calculation as clear and tidy as possible; little effort will be made to decipher sloppy work. *Work problems symbolically until the last step*, at which point you can plug-in actual numbers and recover a numeric answer. ***All numeric values must include units:*** if you write down a number, it must include appropriate units, even in intermediate calculation steps. In contrast to the calculator-ready-expression policy applied to exams, when completing homework you are expected to use your calculator to compute the numeric result of your calculator-ready expression. A full-credit homework response should include the correct numeric value (with appropriate units!) whenever appropriate.

Homework Grading: As decided by class vote, homework will either be graded using a 1-2-3 grading scheme. Under the 1-2-3 scheme, each problem is worth three points. 1 point is awarded for submitting a reasonable solution *on time*, and the remaining 2 points are awarded with crude precision: 2 points for a correct, complete solution that fully adheres to the presentation guidelines above, 0 points for a solution obviously less than 50% complete/correct, and 1 point for any solution in between. When turning in assignments containing both book problems and a worksheet, staple each portion separately. Students should form a separate stacks for each portion when submitting their work at the beginning of class. In some weeks, both portions will not be graded and the assignment's grade will be determined from a 1-2-3 scoring of the worksheet or book problems alone.

Lab: It is not possible to completely replicate the hands-on, collaborative nature of the teaching laboratory through virtual instruction. When it's practical, appropriate and educationally valuable, simulated laboratory exercises will be assigned to augment the curriculum in the course. In most cases, the simulation will be started during a recitation period and completed asynchronously as homework. Reports from lab simulation exercises will be assigned to the Worksheets grading category. I teach two sections of PHYS-132 Lab this quarter. Tuesday 12:10-3:00 and Thursday 3:10-6:00. **Each week, you may choose to attend either lab meeting at your discretion. Unless you have made arrangements to take this class asynchronously, weekly lab attendance is required;** lab absences will only be accommodated for a single infraction, on a case-by-case basis, with a valid excuse.

Name: ___________________________

Physics 132 • In Class Exam 1 • Spring 2021

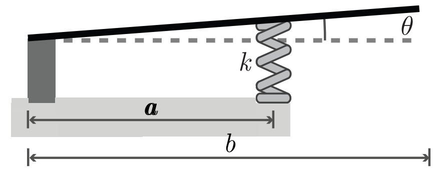
No calculators. No notes. Only this document, blank paper and a pencil are allowed. 50 minutes · 60 points

Section 1 • Short Answer

For each response below you must explain your reasoning using mathematics, sketches or written explanation. ***You may attach a separate sheet of paper if necessary.***

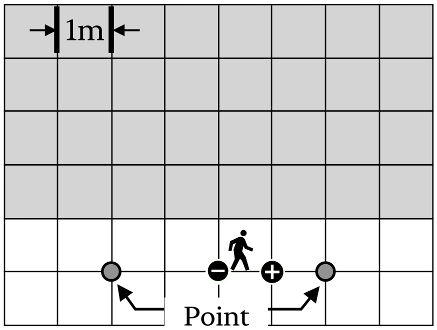
1. A spring loaded diving board is shown in the figure to the right. For small displacements, the torque about the pivot is given by

$$\Sigma\tau = -a^2k\theta = I\alpha$$
$$\Sigma\tau = -a^2k\theta = (\tfrac{1}{3}mb^2)\alpha$$



a) Determine the equation of motion (differential equation) for this system in terms of the variables *a, b, k, m,* and *θ*

b) What is the expression for the angular frequency ω in the solution to this equation of motion?



2. In the figure to the left, two point-source speakers are generating waves with the same amplitude at an unknown frequency. Take the speed of sound to be 340 m/s. As shown in the figure, an observer initially stands at the location marked ⊖ and identifies a point of minimum sound intensity. The observer then walks to the right and notices the intensity steadily increase reaching a maximum at the location marked ⊕

a) Using the information provided and the locations depicted in the figure, determine the initial phase difference between the two sources and their frequency of oscillation.

b) Notably, as the observer walks from ⊖ to ⊕ there's one speaker directly in front of her while the other is directly behind her; that means that she is walking through a region of overlapping *counter-propagating waves.* Is your answer in part a) consistent with the pattern of quiet and loud regions that you would expect to arise from the superposition of counter-propagating waves? Explain why or why not.

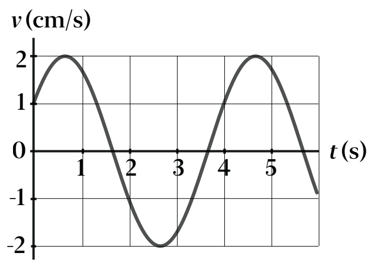
c) Directly on the figure provided above, indicate a location *in the shaded region* where a listener would observe **maximum** intensity (maximum constructive interference). Label this point A.

d) Indicate a second location *in the shaded region* where a listener would observe **minimum** intensity (total destructive interference). Label this point B.

Continued on back ☞

Section 2: Calculations

Show your work and all steps. Provide written explanations as needed that clearly show how you arrived at your answer. ***You may attach a separate sheet if necessary.***

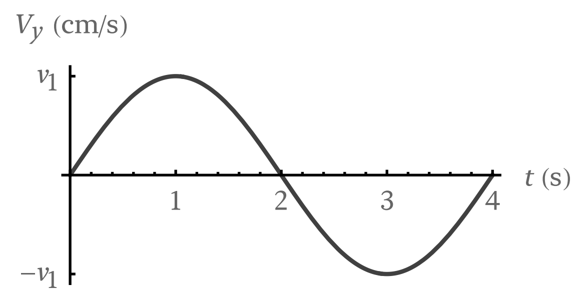


3. The plot to the left shows the velocity of a frictionless, horizontal 2 kg mass on a spring as a function of time.
   a) Using the information given on the plot, determine a function for the oscillator's position as a function of time *x(t)*. Determine all values of the function such that a position in centimeters is returned for a single input *t*.

b) What is the instantaneous phase of the oscillator at $t = 4$ s?

c) What is the spring constant for this mass-spring system?

4. A certain transverse sinusoidal wave has a wavelength of 20 cm and is moving in the positive x direction. The *transverse* velocity $v_y(t)$ of the particle at $x = 0$ is plotted to the right. The plot's scale on the vertical axis is set by $v_1 = \pi$ cm/s
   a) Determine an expression $D(x, t)$ for this system that depends only on x and t, and not on other unknown quantities



b) Sketch the wave's displacement as determined in part a, between $x = 0$ cm and $x = 20$ cm at the time t = 0 s.

PHYSICS 132 MIDTERM 1
EQUATION SHEET

SIMPLE HARMONIC MOTION

$x(t) = A\cos(\omega t + \phi_0)$ $\quad \omega = 2\pi f$ $\quad T = \dfrac{1}{f}$ $\quad E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2 = \frac{1}{2}m(v_{\max})^2$

$v(t) = -\omega A\sin(\omega t + \phi_0) = -v_{\max}\sin(\omega t + \phi_0)$ $\quad x(t) = Ae^{\frac{-bt}{2m}}\cos(\omega t + \phi_0)$

$\omega_{\text{spring}} = \sqrt{\dfrac{k}{m}}$ $\quad \omega_{\text{pendulum}} = \sqrt{\dfrac{g}{L}}$ $\quad \omega_{\text{phys-p}} = \sqrt{\dfrac{Mgl}{I}}$ $\quad \omega_{\text{damp}} = \sqrt{\omega_0^2 - \frac{b^2}{4m^2}}$ $\quad \tau = \dfrac{m}{b}$

TRAVELING WAVES

$v = \frac{\lambda}{T} = \lambda f$ $\quad k = \frac{2\pi}{\lambda}$ $\quad D(x,t) = A\sin(kx - \omega t + \phi_0)$ $\quad \Delta\phi_{\text{const.}} = 2\pi\frac{\Delta r}{\lambda} + \Delta\phi_0 = m \cdot 2\pi$

$v_{\text{string}} = \sqrt{T_s/\mu}$ $\quad n = \frac{c}{v}$ $\quad f_{\text{beat}} = f_2 - f_1$ $\quad \Delta\phi_{\text{destr.}} = 2\pi\frac{\Delta r}{\lambda} + \Delta\phi_0 = \left(m + \frac{1}{2}\right)2\pi$

$D(x,t) = A(x)\cos\omega t = 2a\sin kx\cos\omega t$ $\quad I = \frac{P}{a}$ $\quad I_1/I_2 = r_2^2/r_1^2$ $\quad \beta = (10\text{dB})\log_{10}\left(\frac{I}{I_0}\right)$

$\lambda_m = \frac{2L}{m}$ $\quad D_{\text{net}} = \sum_i D_i$ $\quad \lambda' = \lambda_0\sqrt{\dfrac{1 \pm v_s/c}{1 \mp v_s/c}}$ $\quad f_\pm = \dfrac{f_0}{1 \mp v_s/v}$ $\quad f_\pm = (1 \pm v_o/v)f_0$

KINEMATICS

$s = \frac{1}{2}a_s\Delta t^2 + v_{0s}\Delta t + s_0$ $\quad v_s = \dfrac{ds}{dt}$

$v_s = v_{0s} + a_s\Delta t$

$v_s^2 = v_{0s}^2 + 2a_s\Delta s$ $\quad a_s = \dfrac{dv_s}{dt}$

DYNAMICS

$\Sigma\vec{F} = m\vec{a}$

$\vec{F}_{A\text{ on }B} = -\vec{F}_{B\text{ on }A}$

$\vec{F}_{\text{spring}} = -k\vec{x}$

$f_s \le \mu_s n$ $\quad f_k = \mu_k n$

CIRCULAR MOTION

$s = \theta r$

$v_t = \omega r$ $\quad \omega = \dfrac{d\theta}{dt}$ $\quad \alpha = \dfrac{d\omega}{dt}$

$a_t = \alpha r$

$a_r = a_{\text{centrip}} = \dfrac{v^2}{r} = r\omega^2$

CONSERVATION LAWS

$W_{\text{ext}} = \Delta K + \Delta U + \Delta E_{\text{th}}$ $\quad K_{\text{trans}} = \dfrac{1}{2}mv^2$ $\quad K_{\text{rot}} = \dfrac{1}{2}I\omega^2$ $\quad \vec{p} = m\vec{v}$ $\quad \vec{p}_i = \vec{p}_f$ $\quad \vec{J} = \Delta\vec{p}$

$\Delta E_{\text{th}} = f_k d$ $\quad U_g(y) = mgy$ $\quad U_s(x) = \dfrac{1}{2}kx^2$ $\quad W = \displaystyle\int_{x_1}^{x_2} F_x(x)dx$ $\quad \vec{J} = \displaystyle\int_{t_1}^{t_2}\vec{F}(t)dt = F_{\text{avg}}\Delta t$

ROTATION OF A RIGID BODY

$\tau = rF\sin\phi = rF_\perp = r_\perp F$ $\quad \vec{\tau}_{\text{net}} = I\vec{\alpha}$ $\quad \vec{\ell} = \vec{r} \times \vec{p} = m(\vec{r} \times \vec{v})$ $\quad \ell = I\omega$ $\quad \vec{\ell}_i = \vec{\ell}_f$

$I_{\text{point}} = \displaystyle\sum_i^N m_i r_i^2$ $\quad I_{\text{sphere}} = \frac{2}{5}MR^2$ $\quad I_{\text{pipe}} = \frac{1}{2}MR_1^2 + R_2^2$ $\quad I_{\text{log or disk}} = \frac{1}{2}MR^2$ $\quad I_{\text{hoop}} = MR^2$

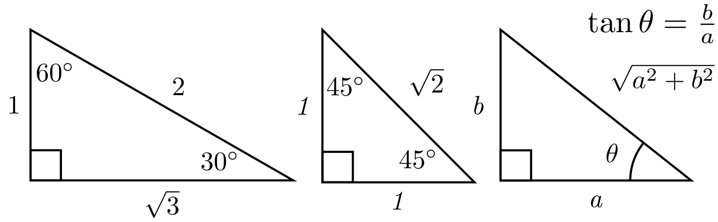
$I_{\text{baton}} = \frac{1}{12}ML^2$ $\quad I_\parallel = I_{\text{com}} + Md^2$

$n_{\text{air}} = 1.003$ $\quad n_{\text{water}} = 1.33$ $\quad n_{\text{glass}} = 1.5$

$v_{\text{sound}} = 343\,\frac{\text{m}}{\text{s}}$ $\quad g = 9.8066\,\frac{\text{m}}{\text{s}^2}$ $\quad I_0 = 10^{-12}\,\frac{\text{W}}{\text{m}^2}$

$c = 2.99782 \times 10^8\,\frac{\text{m}}{\text{s}}$ $\quad \tan\theta \approx \sin\theta \approx \theta$ (small θ)

$\tan\theta = \frac{b}{a}$

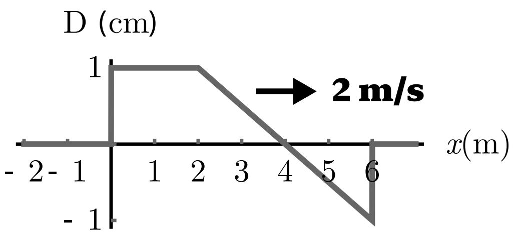


Physics 132 Final Exam • Spring 2021 **Name:**____________________

No calculators. One page of handwritten notes and an equation sheet allowed . 170 minutes

Section 1 • Choose four *(40% of total points)*

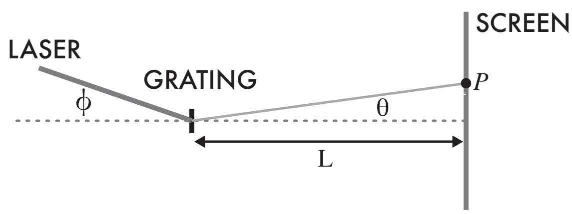
Choose four of the calculations below and solve on a separate sheet of paper (unless indicated otherwise). Clearly indicate the problems you would like graded by checking no more than four boxes.



1. Shown to the left is a snapshot graph at ***t* = 1s** of a wave traveling the right at **2 m/s**. Draw the history graph for (x=6m).

   ❒ Grade this problem

2. A laser pointer is incident at an angle ϕ on a diffraction grating with slit spacing d, as shown in the figure to the right.
   a) What is the path length difference between two waves passing through adjacent grating slits and arriving at the screen at point P? Include a sketch of the grating to justify your answer.
   b) Is there a maximum at $\theta = 0$?
   c) For what θ is the path length difference zero?

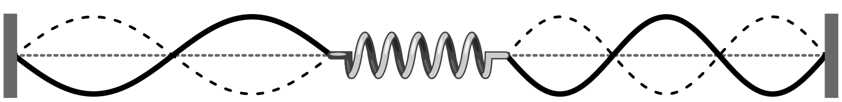


   ❒ Grade this problem.

3. During takeoff, the sound intensity level of a jet engine at a distance of 1.0-m is 150dB. What is the sound intensity level at a distance 1.0km? ❒ Grade this problem

4. A physics professor demonstrates the Doppler effect by tying a 600 Hz sound generator to a 1.0-m-long rope and whirling it around his head in a horizontal circle at 120 rpm. What are the highest and lowest frequencies heard by a student in the classroom?

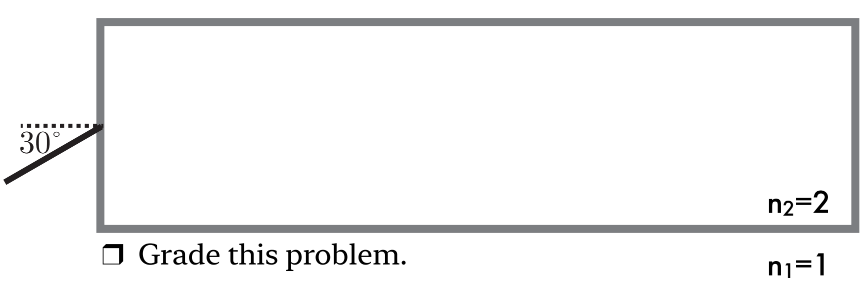
   ❒ Grade this problem.



5. The two strings in the figure to the left are of equal length and are being driven at equal frequencies. The linear density of the left string is 4.0 g/m. What is the linear density of the right string?

   ❒ Grade this problem.

6. A laser pointer is incident on a crystal with $n = 2$ as shown to the right. On the figure to the right, draw the path the laser takes in the crystal (and leaves the crystal). Exact angles are not important, just make the relative direction of the ray at each interface clear. (Note: arcsin(½)=30˚)



   ❒ Grade this problem.

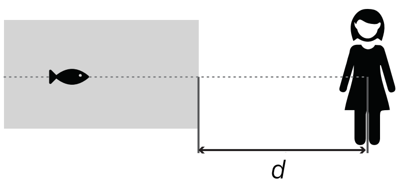
7. A block of mass M is dropped into a cylinder with a cross-sectional area A and a height L forming a frictionless, air-tight seal. Assume the process happens slowly. a) Determine an expression h for the height above the bottom of the cylinder that the block comes to rest. b) With the block at height h, you apply a flame and increase the temperature of the gas from 27˚C to 127˚C, and the block moves to a new height h_1. What is h_1/h?

   ❒ Grade this problem.

Continued on back

Section 2 • Choose three *(60% of total points)*

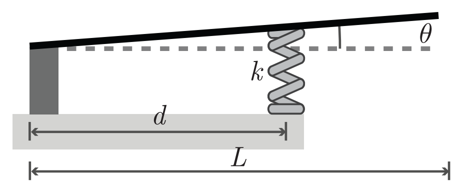
Choose three of the calculations below and solve on a separate sheet of paper (unless indicated otherwise). Clearly indicate the problems you would like graded by checking no more than four boxes.



8. A fish is inside an aquarium observes a person standing distance d from the aquarium's edge, as shown in the figure to the right. Where does the the person appear to the fish? Is the image real or virtual, magnified or demagnified? Draw a sketch to justify your answer. For full credit, use the small-angle approximation to find an expression for the image distance in terms of d, n_{air} and n_{water} ❒ Grade this problem.

9. An ideal gas has an initial pressure of 10 kPa and initial volume of 0.2 m³. The gas is in an insulated cylinder that allows the volume, pressure and temperature to change or be held constant. The gas undergoes the following three-step cycle.
   i. With the volume fixed, the gas is heated until the pressure increases to 20 kPa.
   ii. Allowing the volume to change, the gas is isothermally expanded until the volume is 0.7 m³ and the pressure is 10 kPa—a process in which 7kJ of heat flows into the gas.
   iii. The gas is isobarically compressed until the volume is 0.2 m³.
   a) Draw a *p-V* diagram for this cycle.
   b) What is the net work done on the gas in this cycle?
   c) Is this device a heat engine or refrigerator or neither? Why? ❒ Grade this problem.

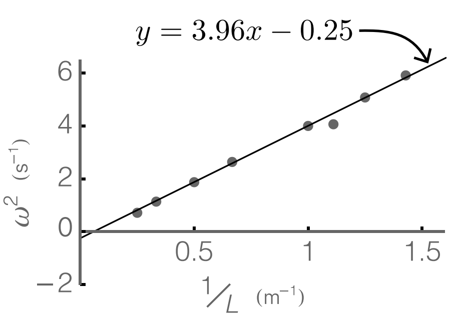
10. A spring loaded diving board is shown in the figure to the left. The torque about the pivot is given by



$$\sum \tau = -d^2 k \sin\theta = I\alpha$$
$$-d^2 k \sin\theta = \tfrac{1}{3} m L^2 \alpha$$

   a) What is the equation of motion (differential equation) for this system in terms of *d, k, m, L, θ*, and their derivatives?
   b) Using the small angle approximation, determine the angular frequency ω in the solution to this equation of motion. ❒ Grade this problem.

11. Ralph is excited to try out his new magnifying glass whose box advertises to make objects "5 times life size when placed 4cm from the lens!" Ralph rushes home and holds the magnifying glass 4 cm above a bottle cap he is eager to observe.
   a) On a separate sheet, determine *s, s'*, and *f* for this system.
   b) Use a ruler and the graph paper to ray-trace the system. Include at least three primary rays. Make the object 1 square tall.
   c) Ralph looks through the magnifying glass, positioning is eye 20cm from the lens. Ralph's reading glasses (which he isn't wearing) have a prescription of +⅔ diopters, and allow him to read at a distance of 25cm. Will Ralph be able to see the bottle cap (through the magnifying glass) without his glasses? ❒ Grade this problem.



❒ Grade this problem.

12. You're on the planet Krypton and would like to measure the acceleration due to gravity *g*. So, you measure the angular frequency of ω a heavily damped pendulum, repeating the measurement for several different strings of length *L*. The mass of the pendulum is ¼ kg. Your results are plotted (along with a best-fit line) in the figure to the right.
   a) determine *g*, the acceleration due to gravity on Krypton
   b) determine *b*, the damping constant for this pendulum.

For both parts include a complete explanation of how you determined your answer from the plot and best-fit line provided.

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PHYSICS 132 LAB GROUP QUIZ 1 - KINEMATICS OF SHM

Work with your lab group to complete the problems below. Unless indicated, submit one solution to each problem that the group agrees is correct. You may consult your notes, the textbook or your instructor for help.

For problems marked with a star (★), each group member must submit their own written solution, but collaboration is encouraged.

1. **FIGURE Q14.8** shows a velocity-versus-time graph for a particle in SHM.

   a. What is the phase constant ϕ_0? Explain.

   b. What is the phase of the particle at each of the three numbered points on the graph?

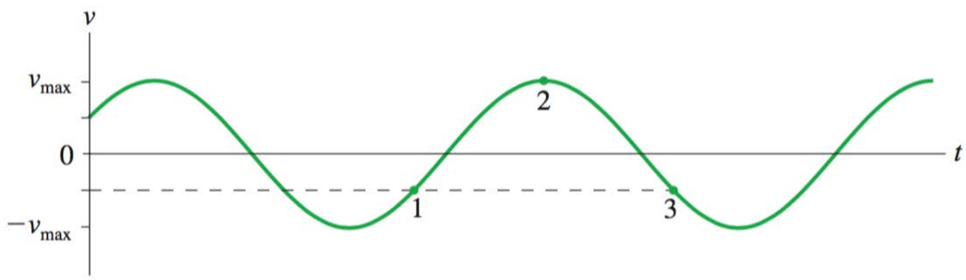

FIGURE Q14.8

2. A 200g block attached to a horizontal spring is with an amplitude of 2.0cm and a frequency of 2.0 Hz Just as it passes through the equilibrium point, moving to the right, a sharp blow, directed to the left exerts a 20N force for 1.0ms What are the new a) frequency and b) amplitude?

★3. An object in simple harmonic motion has an amplitude of 3.0cm a frequency of 2.0 Hz and a phase constant of 2π/3 rad. Draw a position graph showing two cycles of the motion.

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Name: ______________________________

PHYSICS 132 LAB GROUP QUIZ WEEK 2 - DYNAMICS & ENERGY OF SHM

Work with your lab group to complete the problems below. Unless indicated, submit one solution to each problem that the group agrees is correct. You may consult your notes, the textbook or your instructor for help.

1. ‖ A block on a frictionless table is connected as shown in **FIGURE P14.73** to two springs having spring constants k_1 and k_2. Show that the block's oscillation frequency is given by

$$f = \sqrt{f_1^2 + f_2^2}$$

where f_1 and f_2 are the frequencies at which it would oscillate if attached to spring 1 or spring 2 alone.

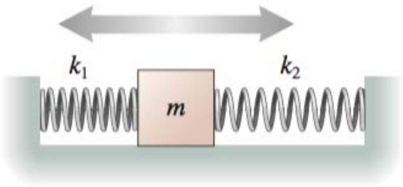
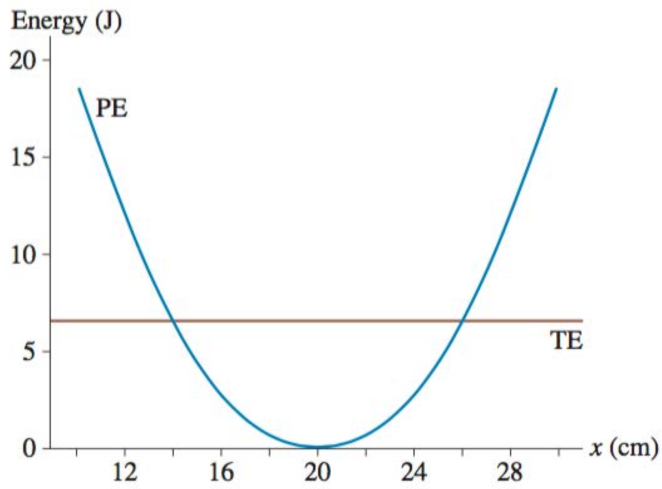


FIGURE P14.73

2. **FIGURE Q14.9** shows the potential-energy diagram and the total energy line of a particle oscillating on a spring.
   a. What is the spring's equilibrium length?
   b. Where are the turning points of the motion? Explain.
   c. What is the particle's maximum kinetic energy?
   d. What will be the turning points if the particle's total energy is doubled?



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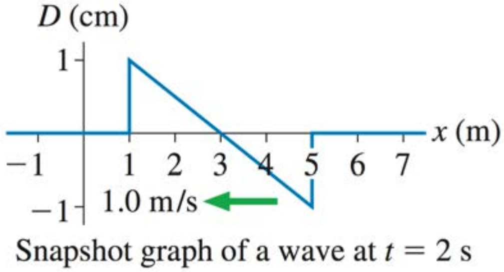
PHYSICS 132 LAB GROUP QUIZ 3 - TRAVELING WAVE GRAPHS

Work with your lab group to complete the problems below. Unless indicated, submit one solution to each problem that the group agrees is correct. You may consult your notes, the textbook or your instructor for help.

For problems marked with a star (★), each group member must submit their own written solution, but collaboration is encouraged.

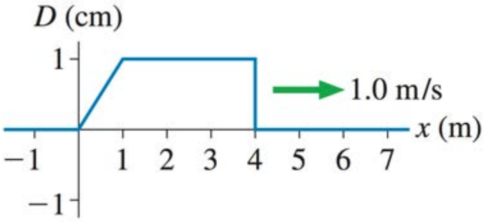
1. ‖ Draw the history graph $D(x = 0 \text{ m}, t)$ at $x = 0$ m for the wave shown in **FIGURE EX20.4**.



Snapshot graph of a wave at $t = 2$ s

FIGURE EX20.4

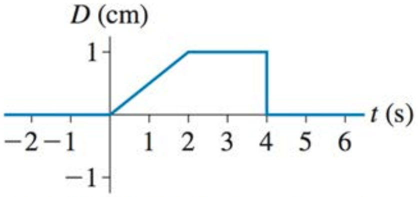
2. ‖ Draw the history graph $D(x = 5.0 \text{ m}, t)$ at $x = 5.0$ m for the wave shown in **FIGURE EX20.5**.



Snapshot graph of a wave at $t = 0$ s

FIGURE EX20.5

3. ‖ Draw the snapshot graph $D(x, t = 0 \text{ s})$ at $t = 0$ s for the wave shown in **FIGURE EX20.6**.



History graph of a wave at $x = 2$ m
Wave moving to the left at 1.0 m/s

FIGURE EX20.6

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PHYSICS 132 LAB QUIZ GROUP WEEK 4 - SUPERPOSITION

Work with your lab group to complete the problems below. Unless indicated, submit one solution to each problem that the group agrees is correct. You may consult your notes, the textbook or your instructor for help.

For problems marked with a star (★), each group member must submit their own written solution, but collaboration is encouraged.

1. As the captain of the scientific team sent to Planet Physics, one of your tasks is to measure g. You have a long, thin wire labeled 1.00 g/m and a 1.25 kg weight. You have your accurate space cadet chronometer but, unfortunately, you seem to have forgot- ten a meter stick. Undeterred, you first find the midpoint of the wire by folding it in half. You then attach one end of the wire to the wall of your laboratory, stretch it horizontally to pass over a pulley at the midpoint of the wire, then tie the 1.25 kg weight to the end hanging over the pulley. By vibrating the wire, and measuring time with your chronometer, you find that the wire's second-harmonic frequency is 100 Hz. Next, with the 1.25 kg weight still tied to one end of the wire, you attach the other end to the ceiling to make a pendulum. You find that the pendulum requires 314 s to complete 100 oscillations. Pulling out your trusty calculator, you get to work. What value of g will you report back to headquarters?

2. || The three identical loudspeakers in **FIGURE P21.69** play a 170 Hz tone in a room where the speed of sound is 340 m/s. You are standing 4.0 m in front of the middle speaker. At this point, the amplitude of the wave from each speaker is a.
   a. What is the amplitude at this point?
   b. How far must speaker 2 be moved to the left to produce a maximum amplitude at the point where you are standing?
   c. When the amplitude is maximum, by what factor is the sound intensity greater than the sound intensity from a single speaker?

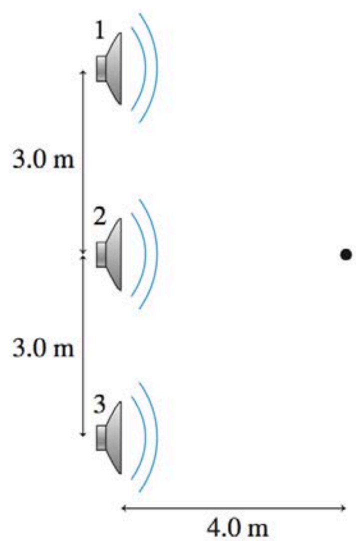

FIGURE P21.69

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PHYSICS 132 LAB QUIZ GROUP WEEK 6 - REFLECTION AND REFRACTION

Work with your lab group to complete the problems below. Unless indicated, submit one solution to each problem that the group agrees is correct. You may consult your notes, the textbook or your instructor for help.

1. ‖ The meter stick in **FIGURE P23.45** lies on the bottom of a 100-cm-long tank with its zero mark against the left edge. You look into the tank at a 30° angle, with your line of sight just grazing the upper left edge of the tank. What mark do you see on the meter stick if the tank is (a) empty, (b) half full of water, and (c) completely full of water?

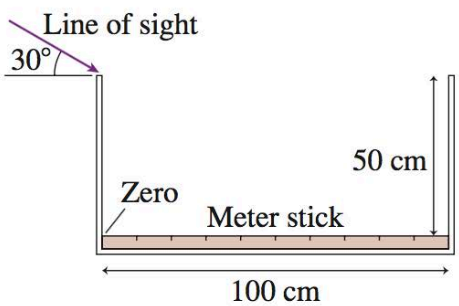

FIGURE P23.45

2. ‖ The place you get your hair cut has two nearly parallel mirrors 5.0 m apart. As you sit in the chair, your head is 2.0 m from the nearer mirror. Looking toward this mirror, you first see your face and then, farther away, the back of your head. (The mirrors need to be slightly nonparallel for you to be able to see the back of your head, but you can treat them as parallel in this problem.) How far away does the back of your head appear to be? Neglect the thickness of your head.

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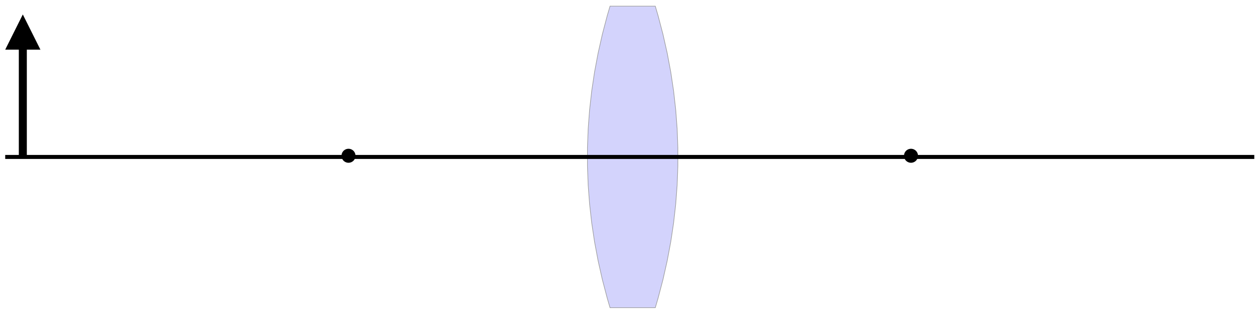
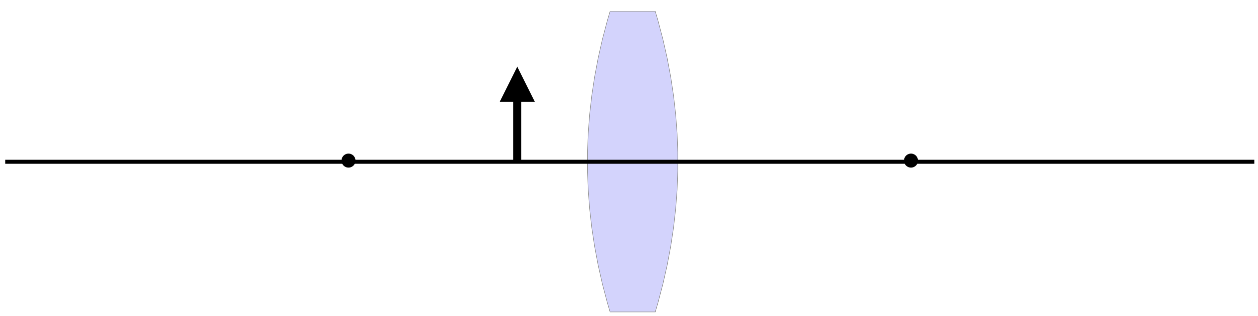
PHYSICS 132 LAB QUIZ WEEK 7

Turn in one ray tracing sheet per student.

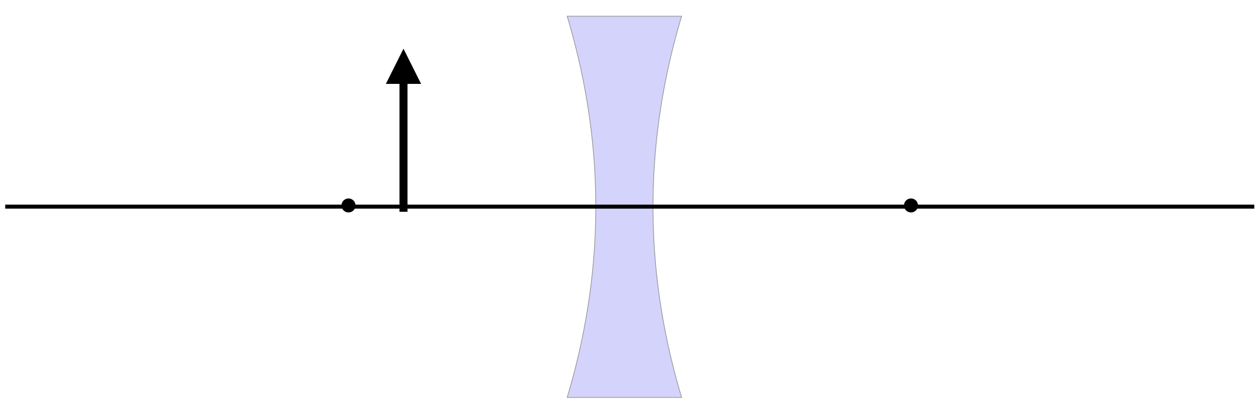
1. *Draw the three principle rays for each of the situations shown.*
2. *Determine the image properties*
3. *Choose one system and use the thin-lens equation to verify your result.*



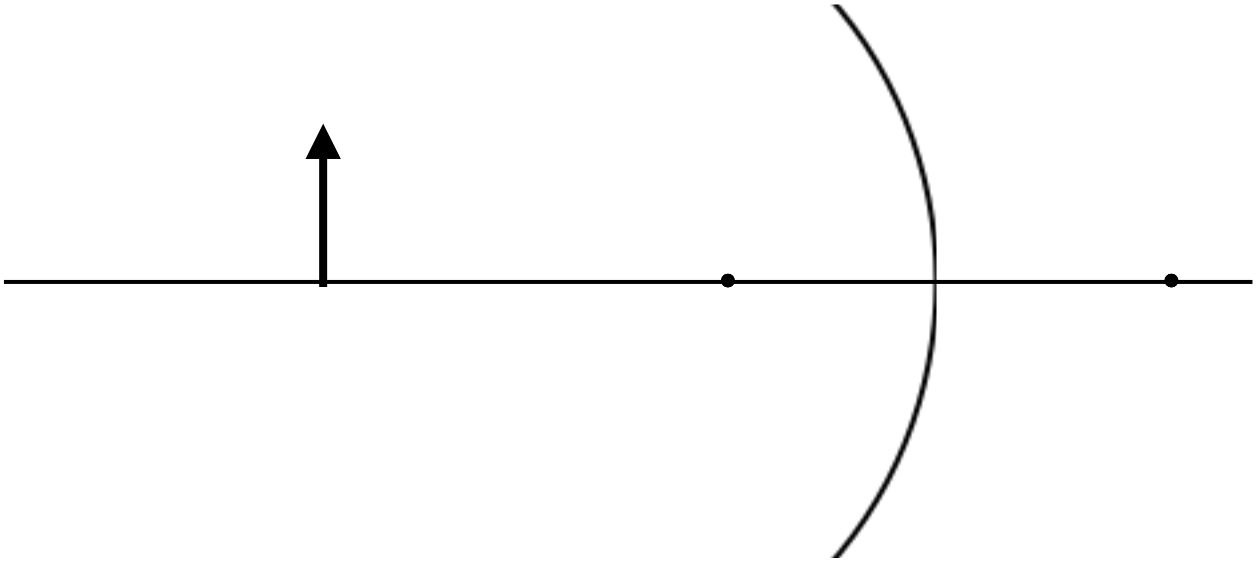
❒ $m < 0$ ❒ $m > 0$ ❒ $|m| < 1$ ❒ $|m| > 1$ ❒ $s' > 0$ ❒ $s' < 0$ ❒ $f < 0$ ❒ $f > 0$



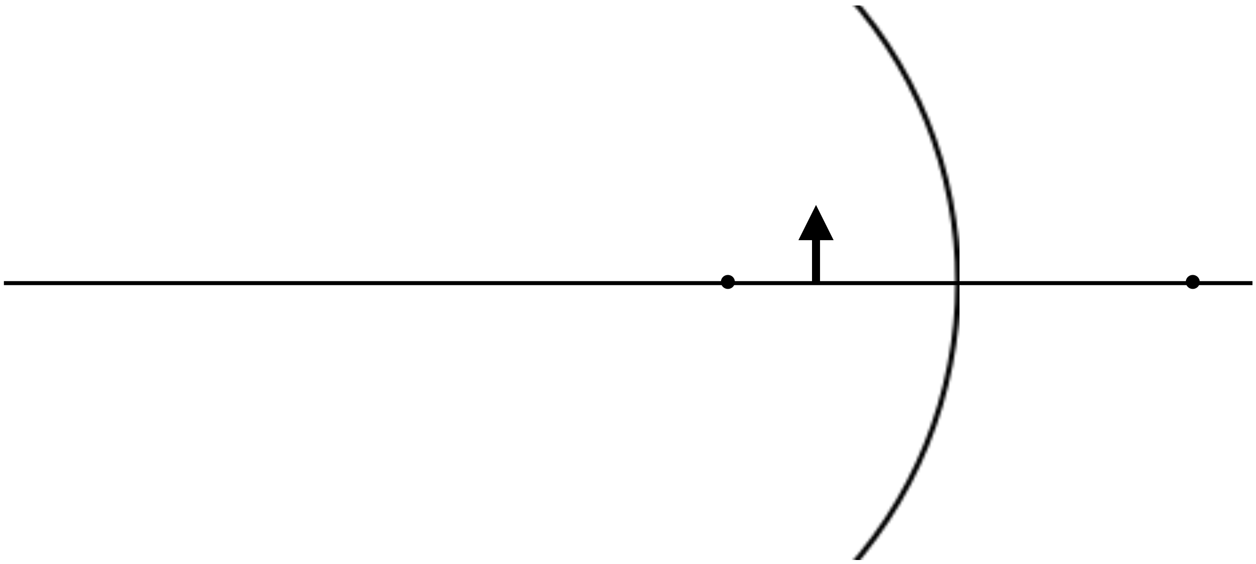
❒ $m < 0$ ❒ $m > 0$ ❒ $|m| < 1$ ❒ $|m| > 1$ ❒ $s' > 0$ ❒ $s' < 0$ ❒ $f < 0$ ❒ $f > 0$



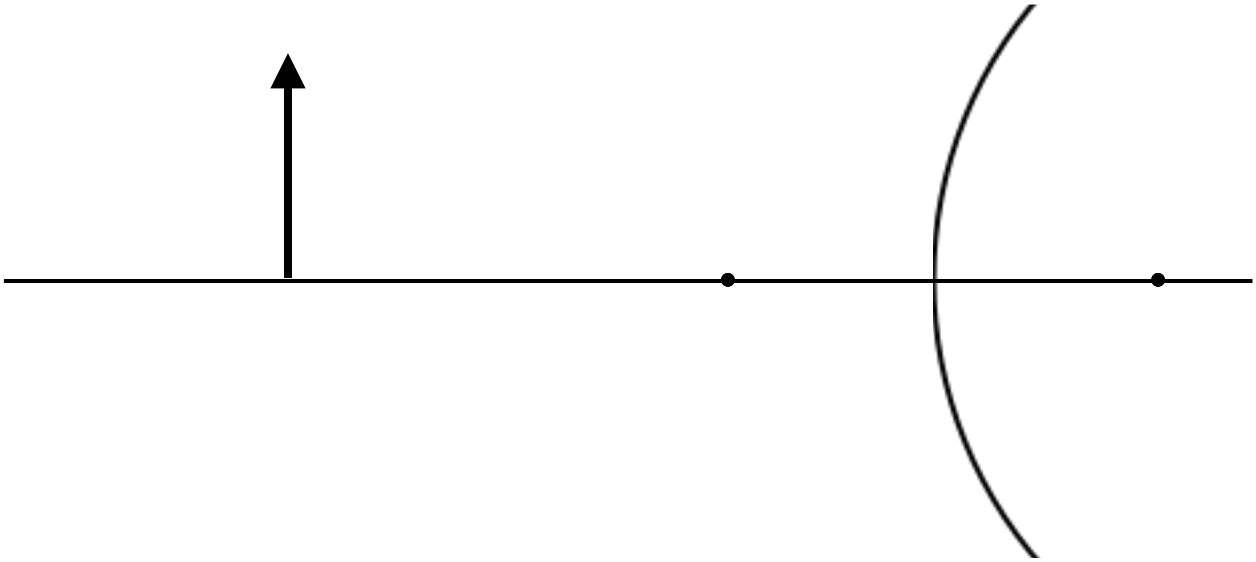
❒ $m < 0$ ❒ $m > 0$ ❒ $|m| < 1$ ❒ $|m| > 1$ ❒ $s' > 0$ ❒ $s' < 0$ ❒ $f < 0$ ❒ $f > 0$



❒ $m < 0$ ❒ $m > 0$ ❒ $|m| < 1$ ❒ $|m| > 1$ ❒ $s' > 0$ ❒ $s' < 0$ ❒ $f < 0$ ❒ $f > 0$



❒ $m < 0$ ❒ $m > 0$ ❒ $|m| < 1$ ❒ $|m| > 1$ ❒ $s' > 0$ ❒ $s' < 0$ ❒ $f < 0$ ❒ $f > 0$



❒ $m < 0$ ❒ $m > 0$ ❒ $|m| < 1$ ❒ $|m| > 1$ ❒ $s' > 0$ ❒ $s' < 0$ ❒ $f < 0$ ❒ $f > 0$

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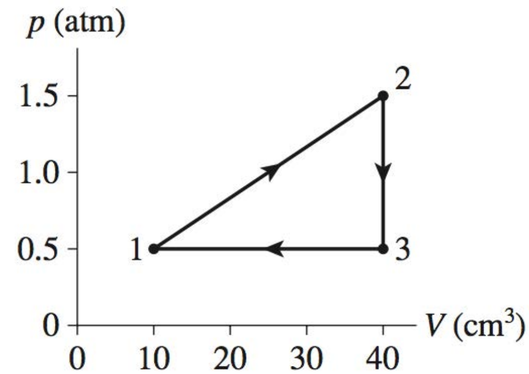
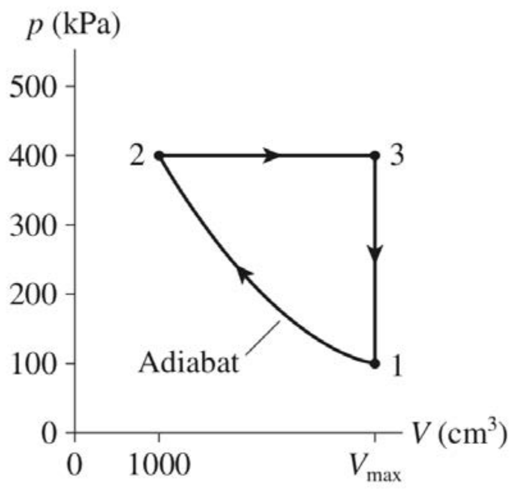
PHYSICS 132 LAB GROUP QUIZ 8 - IDEAL GAS CYCLES

Work with your lab group to complete the problems below. Unless indicated, submit one solution to each problem that the group agrees is correct. You may consult your notes, the textbook or your instructor for help.

For problems marked with a star (★), each group member must submit their own written solution, but collaboration is encouraged.

1. || A heat engine using a diatomic gas follows the cycle shown in **FIGURE P19.53**. Its temperature at point 1 is 20°C.
   a. Determine W_s, Q, and ΔE_{th} for each of the three processes in this cycle. Display your results in a table.
   b. What is the thermal efficiency of this heat engine?
   c. What is the power output of the engine if it runs at 500 rpm?





63. || The heat engine shown in **FIGURE P21.63** uses 0.020 mol of a diatomic gas as the working substance.
   a. Determine T_1, T_2, and T_3.
   b. Make a table that shows ΔE_{th}, W_s, and Q for each of the three processes.
   c. What is the engine's thermal efficiency?

PHYSICS 132 MIDTERM 1

EQUATION SHEET

SIMPLE HARMONIC MOTION

$x(t) = A\cos(\omega t + \phi_0)$ $\quad \omega = 2\pi f$ $\quad T = \dfrac{1}{f}$ $\quad E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2 = \frac{1}{2}m(v_{\max})^2$

$v(t) = -\omega A \sin(\omega t + \phi_0) = -v_{\max}\sin(\omega t + \phi_0)$ $\quad x(t) = Ae^{\frac{-bt}{2m}}\cos(\omega t + \phi_0)$

$\omega_{\text{spring}} = \sqrt{\dfrac{k}{m}}$ $\quad \omega_{\text{pendulum}} = \sqrt{\dfrac{g}{L}}$ $\quad \omega_{\text{phys-p}} = \sqrt{\dfrac{Mgl}{I}}$ $\quad \omega_{\text{damp}} = \sqrt{\omega_0^2 - \frac{b^2}{4m^2}}$ $\quad \tau = \dfrac{m}{b}$

TRAVELING WAVES

$v = \frac{\lambda}{T} = \lambda f$ $\quad k = \frac{2\pi}{\lambda}$ $\quad D(x,t) = A\sin(kx - \omega t + \phi_0)$ $\quad \Delta\phi_{\text{const.}} = 2\pi\frac{\Delta r}{\lambda} + \Delta\phi_0 = m \cdot 2\pi$

$v_{\text{string}} = \sqrt{T_s/\mu}$ $\quad n = \frac{c}{v}$ $\quad f_{\text{beat}} = f_2 - f_1$ $\quad \Delta\phi_{\text{destr.}} = 2\pi\frac{\Delta r}{\lambda} + \Delta\phi_0 = \left(m + \frac{1}{2}\right)2\pi$

$D(x,t) = A(x)\cos\omega t = 2a\sin kx\cos\omega t$ $\quad I = \frac{P}{a}$ $\quad I_1/I_2 = r_2^2/r_1^2$ $\quad \beta = (10\text{dB})\log_{10}\left(\frac{I}{I_0}\right)$

$\lambda_m = \frac{2L}{m}$ $\quad D_{\text{net}} = \sum_i D_i$ $\quad \lambda' = \lambda_0\sqrt{\dfrac{1 \pm v_s/c}{1 \mp v_s/c}}$ $\quad f_\pm = \dfrac{f_0}{1 \mp v_s/v}$ $\quad f_\pm = (1 \pm v_o/v)f_0$

KINEMATICS

$s = \frac{1}{2}a_s\Delta t^2 + v_{0s}\Delta t + s_0$ $\quad v_s = \dfrac{ds}{dt}$

$v_s = v_{0s} + a_s\Delta t$

$v_s^2 = v_{0s}^2 + 2a_s\Delta s$ $\quad a_s = \dfrac{dv_s}{dt}$

DYNAMICS

$\Sigma\vec{F} = m\vec{a}$

$\vec{F}_{A\text{ on }B} = -\vec{F}_{B\text{ on }A}$

$\vec{F}_{\text{spring}} = -k\vec{x}$

$f_s \le \mu_s n$ $\quad f_k = \mu_k n$

CIRCULAR MOTION

$s = \theta r$

$v_t = \omega r$ $\quad \omega = \dfrac{d\theta}{dt}$ $\quad \alpha = \dfrac{d\omega}{dt}$

$a_t = \alpha r$

$a_r = a_{\text{centrip}} = \dfrac{v^2}{r} = r\omega^2$

CONSERVATION LAWS

$W_{\text{ext}} = \Delta K + \Delta U + \Delta E_{\text{th}}$ $\quad K_{\text{trans}} = \dfrac{1}{2}mv^2$ $\quad K_{\text{rot}} = \dfrac{1}{2}I\omega^2$ $\quad \vec{p} = m\vec{v}$ $\quad \vec{p}_i = \vec{p}_f$ $\quad \vec{J} = \Delta\vec{p}$

$\Delta E_{\text{th}} = f_k d$ $\quad U_g(y) = mgy$ $\quad U_s(x) = \dfrac{1}{2}kx^2$ $\quad W = \displaystyle\int_{x_1}^{x_2} F_x(x)dx$ $\quad \vec{J} = \displaystyle\int_{t_1}^{t_2}\vec{F}(t)dt = F_{\text{avg}}\Delta t$

ROTATION OF A RIGID BODY

$\tau = rF\sin\phi = rF_\perp = r_\perp F$ $\quad \vec{\tau}_{\text{net}} = I\vec{\alpha}$ $\quad \vec{\ell} = \vec{r}\times\vec{p} = m(\vec{r}\times\vec{v})$ $\quad \ell = I\omega$ $\quad \vec{\ell}_i = \vec{\ell}_f$

$I_{\text{point}} = \displaystyle\sum_i^N m_i r_i^2$ $\quad I_{\text{sphere}} = \frac{2}{5}MR^2$ $\quad I_{\text{pipe}} = \frac{1}{2}MR_1^2 + R_2^2$ $\quad I_{\text{log or disk}} = \frac{1}{2}MR^2$ $\quad I_{\text{hoop}} = MR^2$

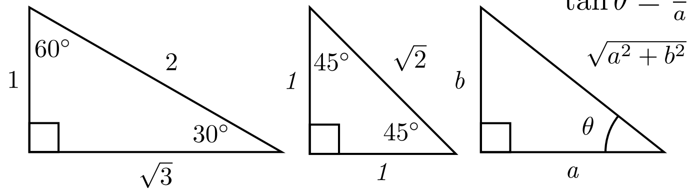
$I_{\text{baton}} = \frac{1}{12}ML^2$ $\quad I_{\parallel} = I_{\text{com}} + Md^2$

$n_{\text{air}} = 1.003$ $\quad n_{\text{water}} = 1.33$ $\quad n_{\text{glass}} = 1.5$

$v_{\text{sound}} = 343\,\frac{\text{m}}{\text{s}}$ $\quad g = 9.8066\,\frac{\text{m}}{\text{s}^2}$ $\quad I_0 = 10^{-12}\,\frac{\text{W}}{\text{m}^2}$

$c = 2.99782 \times 10^8\,\frac{\text{m}}{\text{s}}$ $\quad \tan\theta \approx \sin\theta \approx \theta$ (small θ)

$\tan\theta = \frac{b}{a}$



PHYSICS 132 MIDTERM 2
EQUATION SHEET

SIMPLE HARMONIC MOTION

$x(t) = A\cos(\omega t + \phi_0)$ $\quad \omega = 2\pi f$ $\quad T = \dfrac{1}{f}$ $\quad E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2 = \frac{1}{2}m(v_{\max})^2$

$v(t) = -\omega A\sin(\omega t + \phi_0) = -v_{\max}\sin(\omega t + \phi_0)$ $\quad x(t) = Ae^{\frac{-bt}{2m}}\cos(\omega t + \phi_0)$

$\omega_{\text{spring}} = \sqrt{\dfrac{k}{m}}$ $\quad \omega_{\text{pendulum}} = \sqrt{\dfrac{g}{L}}$ $\quad \omega_{\text{phys-p}} = \sqrt{\dfrac{Mgl}{I}}$ $\quad \omega_{\text{damp}} = \sqrt{\omega_0^2 - \frac{b^2}{4m^2}}$ $\quad \tau = \dfrac{m}{b}$

TRAVELING WAVES

$v = \frac{\lambda}{T} = \lambda f$ $\quad k = \frac{2\pi}{\lambda}$ $\quad D(x,t) = A\sin(kx - \omega t + \phi_0)$ $\quad \Delta\phi_{\text{const.}} = 2\pi\frac{\Delta r}{\lambda} + \Delta\phi_0 = m\cdot 2\pi$

$v_{\text{string}} = \sqrt{T_s/\mu}$ $\quad n = \frac{c}{v}$ $\quad f_{\text{beat}} = f_2 - f_1$ $\quad \Delta\phi_{\text{destr.}} = 2\pi\frac{\Delta r}{\lambda} + \Delta\phi_0 = \left(m + \frac{1}{2}\right)2\pi$

$D(x,t) = A(x)\cos\omega t = 2a\sin kx\cos\omega t$ $\quad I = \frac{P}{a}$ $\quad I_1/I_2 = r_2^2/r_1^2$ $\quad \beta = (10\text{dB})\log_{10}\left(\frac{I}{I_0}\right)$

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OPTICS

$n = \dfrac{c}{v}$ $\quad \lambda = \dfrac{\lambda_0}{n}$ $\quad \theta_i = \theta_r$ $\quad n_1\sin\theta_1 = n_2\sin\theta_2$ $\quad d\sin\theta_m = m\lambda$ $\quad a\sin\theta_p = p\lambda$

$\dfrac{1}{s} + \dfrac{1}{s'} = \dfrac{1}{f}$ $\quad m = \dfrac{h'}{h} = -\dfrac{s'}{s}$ $\quad f = \dfrac{R}{2}$ $\quad \sin\theta_{\text{crit}} = \dfrac{n_2}{n_1}$ $\quad d\sin\theta_m = \left(m + \frac{1}{2}\right)\lambda$

$1/f = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ $\quad \dfrac{n_1}{s} + \dfrac{n_2}{s'} = \dfrac{n_2 - n_1}{R}$

KINEMATICS

$s = \frac{1}{2}a_s\Delta t^2 + v_{0s}\Delta t + s_0$ $\quad v_s = \dfrac{ds}{dt}$

$v_s = v_{0s} + a_s\Delta t$

$v_s^2 = v_{0s}^2 + 2a_s\Delta s$ $\quad a_s = \dfrac{dv_s}{dt}$

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$\vec{F}_{A\text{ on }B} = -\vec{F}_{B\text{ on }A}$

$\vec{F}_{\text{spring}} = -k\vec{x}$

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$a_t = \alpha r$

$a_r = a_{\text{centrip}} = \dfrac{v^2}{r} = r\omega^2$

CONSERVATION LAWS

$W_{\text{ext}} = \Delta K + \Delta U + \Delta E_{\text{th}}$ $\quad K_{\text{trans}} = \dfrac{1}{2}mv^2$ $\quad K_{\text{rot}} = \dfrac{1}{2}I\omega^2$ $\quad \vec{p} = m\vec{v}$ $\quad \vec{p}_i = \vec{p}_f$ $\quad \vec{J} = \Delta\vec{p}$

$\Delta E_{\text{th}} = f_k d$ $\quad U_g(y) = mgy$ $\quad U_s(x) = \dfrac{1}{2}kx^2$ $\quad W = \displaystyle\int_{x_1}^{x_2} F_x(x)dx$ $\quad \vec{J} = \displaystyle\int_{t_1}^{t_2}\vec{F}(t)dt = F_{\text{avg}}\Delta t$

ROTATION OF A RIGID BODY

$\tau = rF\sin\phi = rF_\perp = r_\perp F$ $\quad \vec{\tau}_{\text{net}} = I\vec{\alpha}$ $\quad \vec{\ell} = \vec{r}\times\vec{p} = m(\vec{r}\times\vec{v})$ $\quad \ell = I\omega$ $\quad \vec{\ell}_i = \vec{\ell}_f$

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$I_{\text{baton}} = \frac{1}{12}ML^2$ $\quad I_{\parallel} = I_{\text{com}} + Md^2$

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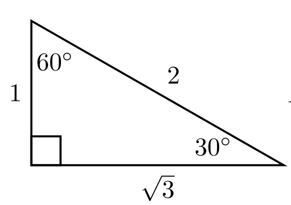
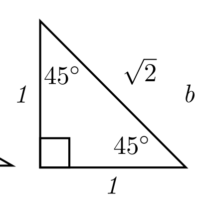
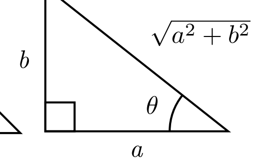
$v_{\text{sound}} = 343\,\frac{\text{m}}{\text{s}}$ $\quad g = 9.8066\,\frac{\text{m}}{\text{s}^2}$ $\quad I_0 = 10^{-12}\,\frac{\text{W}}{\text{m}^2}$

$c = 2.99782\times 10^8\,\frac{\text{m}}{\text{s}}$ $\quad \tan\theta \approx \sin\theta \approx \theta$ (small θ)





$\tan\theta = \frac{b}{a}$



PHYSICS 132 MIDTERM 3

EQUATION SHEET

SIMPLE HARMONIC MOTION

$x(t) = A\cos(\omega t + \phi_0)$ $\quad \omega = 2\pi f$ $\quad T = 1/f$ $\quad E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2 = \frac{1}{2}m(v_{\max})^2$

$v(t) = -\omega A \sin(\omega t + \phi_0) = -v_{\max}\sin(\omega t + \phi_0)$ $\quad x(t) = Ae^{\frac{-bt}{2m}}\cos(\omega t + \phi_0)$ $\quad \tau = m/b$

$\omega_{\text{spring}} = \sqrt{k/m}$ $\quad \omega_{\text{pendulum}} = \sqrt{g/L}$ $\quad \omega_{\text{phys-p}} = \sqrt{Mgl/I}$ $\quad \omega_{\text{damp}} = \sqrt{\omega_0^2 - b^2/(4m^2)}$

TRAVELING WAVES

$v = \frac{\lambda}{T} = \lambda f$ $\quad k = \frac{2\pi}{\lambda}$ $\quad D(x,t) = A\sin(kx - \omega t + \phi_0)$ $\quad \Delta\phi_{\text{const.}} = 2\pi\frac{\Delta r}{\lambda} + \Delta\phi_0 = m \cdot 2\pi$

$v_{\text{string}} = \sqrt{T_s/\mu}$ $\quad n = c/v$ $\quad f_{\text{beat}} = f_2 - f_1$ $\quad \Delta\phi_{\text{destr.}} = 2\pi\frac{\Delta r}{\lambda} + \Delta\phi_0 = \left(m + \frac{1}{2}\right)2\pi$

$D(x,t) = A(x)\cos\omega t = 2a\sin kx\cos\omega t$ $\quad I = \frac{P}{A}$ $\quad I_1/I_2 = r_2^2/r_1^2$ $\quad \beta = (10\text{dB})\log_{10}\left(\frac{I}{I_0}\right)$

$\lambda_m = \frac{2L}{m}$ $\quad D_{\text{net}} = \sum_i D_i$ $\quad \lambda' = \lambda_0\sqrt{\frac{1 \pm v_s/c}{1 \mp v_s/c}}$ $\quad f_\pm = \frac{f_0}{1 \mp v_s/v}$ $\quad f_\pm = (1 \pm v_o/v)f_0$

OPTICS

$d\sin\theta_m = \left(m + \frac{1}{2}\right)\lambda$

$n = c/v$ $\quad \lambda = \lambda_0/n$ $\quad \theta_i = \theta_r$ $\quad n_1\sin\theta_1 = n_2\sin\theta_2$ $\quad \sin\theta_{\text{crit}} = n_2/n_1$ $\quad d\sin\theta_m = m\lambda$

$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$ $\quad m = \frac{h'}{h} = -\frac{s'}{s}$ $\quad \frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R}$ $\quad \frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ $\quad a\sin\theta_p = p\lambda$

FLUIDS AND THERMODYNAMICS

$\Delta E_{\text{th}} = W + Q$ $\quad pV = nRT = Nk_BT$ $\quad T_K = T_C + 273$

$p = F/A$ $\quad p = p_0 + \rho gh$ $\quad F_B = m_f g = \rho_f V_f g$ $\quad W = -\int_{V_i}^{V_f} p\,dV$ $\quad C_p = C_V + R$

$W_{\text{isobaric}} = -p\Delta V$ $\quad Q = Mc\Delta T$ $\quad Q = \pm ML$ $\quad Q = nC\Delta T$ $\quad \Delta E_{\text{th}} = nC_V\Delta T$

$W_{\text{isothermal}} = -nRT\ln(V_f/V_i)$ $\quad W_{s\text{ (gas on environment)}} = -W$ $\quad E_{\text{per DOF}} = \frac{1}{2}Nk_BT = \frac{1}{2}nRT$ $\quad \gamma = C_P/C_V$

$W_{\text{adiabatic}} = \Delta E_{\text{th}} = -\left(\frac{p_fV_f - p_iV_i}{1-\gamma}\right)$ $\quad pV^\gamma = \text{const.}$ $\quad \eta = W_{\text{out}}/Q_H$ $\quad \eta_{\text{Carnot}} = 1 - T_C/T_H$

KINEMATICS

$s = \frac{1}{2}a_s\Delta t^2 + v_{0s}\Delta t + s_0$

$v_s = v_{0s} + a_s\Delta t$ $\quad v_s = \frac{ds}{dt}$

$v_s^2 = v_{0s}^2 + 2a_s\Delta s$ $\quad a_s = \frac{dv_s}{dt}$

DYNAMICS

$\Sigma\vec{F} = m\vec{a}$ $\quad \vec{F}_{\text{A on B}} = -\vec{F}_{\text{B on A}}$

$f_s \le \mu_s n$ $\quad f_k = \mu_k n$

$\vec{F}_{\text{spring}} = -k\vec{x}$

CIRCULAR MOTION

$s = \theta r$ $\quad \omega = \frac{d\theta}{dt}$ $\quad \alpha = \frac{d\omega}{dt}$

$v_t = \omega r$ $\quad a_t = \alpha r$

$a_r = a_{\text{centrip}} = \frac{v^2}{r} = r\omega^2$

CONSERVATION LAWS

$W_{\text{ext}} = \Delta K + \Delta U + \Delta E_{\text{th}}$ $\quad K_{\text{trans}} = \frac{1}{2}mv^2$ $\quad K_{\text{rot}} = \frac{1}{2}I\omega^2$ $\quad \vec{p} = m\vec{v}$ $\quad \vec{p}_i = \vec{p}_f$ $\quad \vec{J} = \Delta\vec{p}$

$\Delta E_{\text{th}} = f_kd$ $\quad U_g(y) = mgy$ $\quad U_{\text{spring}} = \frac{1}{2}kx^2$ $\quad W = \int_{x_1}^{x_2} F_x(x)dx$ $\quad \vec{J} = \int_{t_1}^{t_2}\vec{F}(t)dt = F_{\text{avg}}\Delta t$

ROTATION OF A RIGID BODY

$\tau = rF\sin\phi = rF_\perp = r_\perp F$ $\quad \vec{\tau}_{\text{net}} = I\vec{\alpha}$ $\quad \vec{\ell} = \vec{r} \times \vec{p} = m(\vec{r} \times \vec{v})$ $\quad \ell = I\omega$ $\quad \vec{\ell}_i = \vec{\ell}_f$

$I_{\text{point}} = \sum_i^N m_ir_i^2$ $\quad I_{\text{sphere}} = \frac{2}{5}MR^2$ $\quad I_{\text{baton}} = \frac{1}{12}ML^2$ $\quad I_{\text{log or disk}} = \frac{1}{2}MR^2$ $\quad I_\parallel = I_{\text{com}} + Md^2$

$k_B = 1.38064 \times 10^{-23}$ J/K $\quad R = 8.314598$ J/mol K $\quad N_{\text{A}} = 6.02214 \times 10^{23}$ particles/mol

$c_{\text{ice}} = 2090$ J/kg K $\quad c_{\text{water}} = 4190$ J/kg K $\quad c_{\text{steam}} = 1996$ J/kg K $\quad L_{f,\text{ water}} = 334$ kJ/kg $\quad L_{v,\text{ water}} = 2265$ kJ/kg

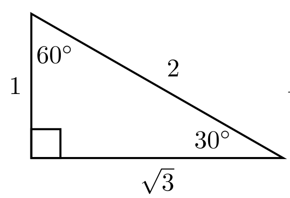
$C_{v,\text{mono}} = 12.5$ J/mol K $\quad C_{v,\text{dia}} = 20.8$ J/mol K

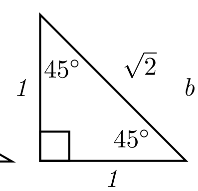
1 atm $= 101,300$ Pa $\quad \gamma_{\text{mono}} = 1.67$ $\quad \gamma_{\text{dia}} = 1.4$

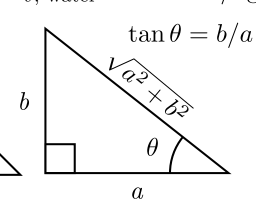
$n_{\text{air}} = 1.003$ $\quad n_{\text{water}} = 1.33$ $\quad n_{\text{glass}} = 1.5$

$v_{\text{sound}} = 343\frac{\text{m}}{\text{s}}$ $\quad g = 9.8066\frac{\text{m}}{\text{s}^2}$ $\quad I_0 = 10^{-12}\frac{\text{W}}{\text{m}^2}$

$c = 2.99782 \times 10^8\frac{\text{m}}{\text{s}}$ $\quad \tan\theta \approx \sin\theta \approx \theta$ (small θ)







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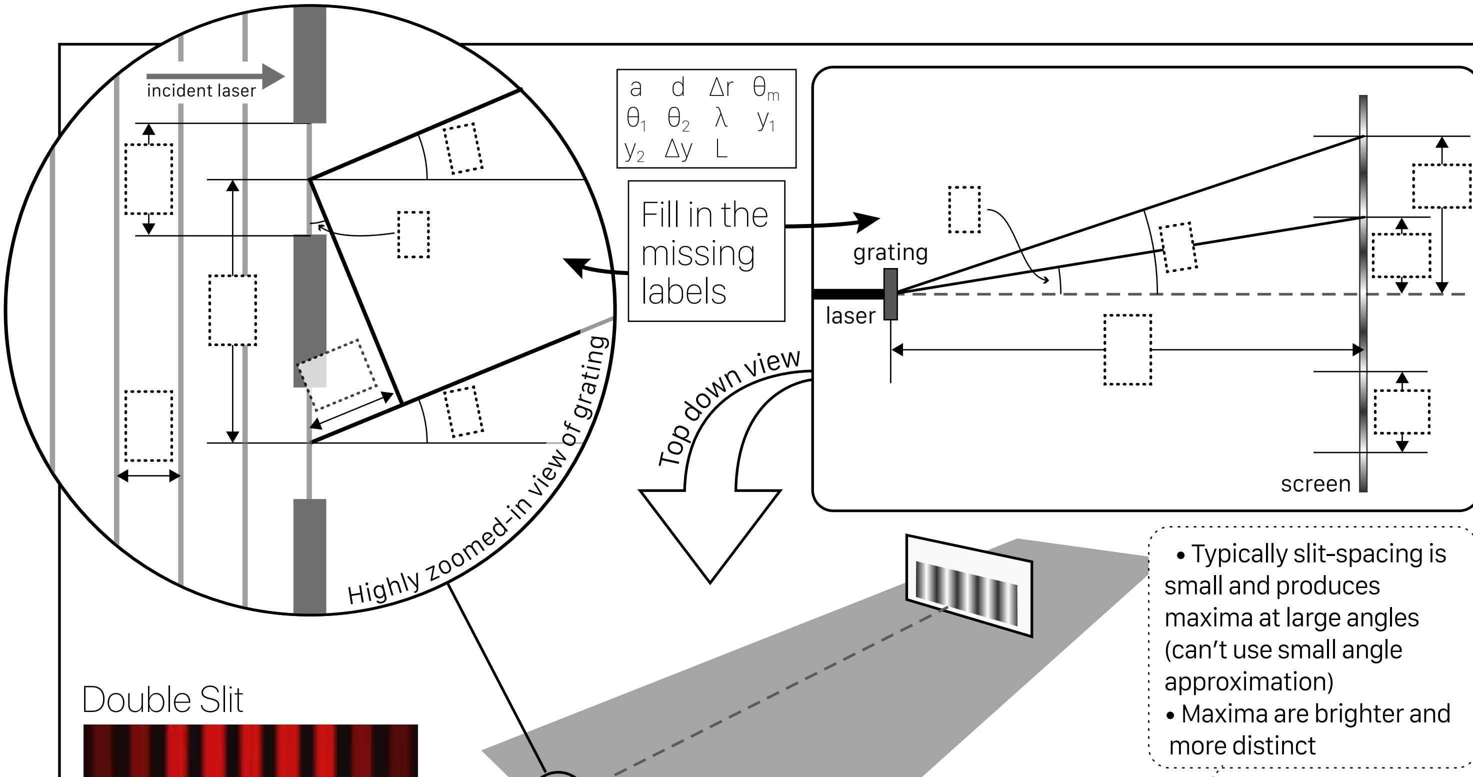
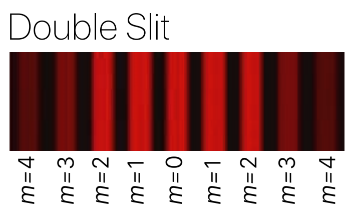
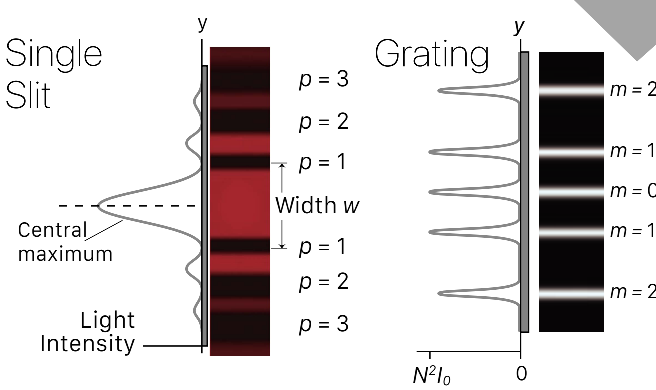
Physics 132 Wave Optics Worksheet and Cheatsheet







2-Slit & Multi-Slit Gratings

- Specified by **constructive** interference condition ($\Delta r = m\lambda$)
- m is an integer 0, 1, 2, 3...
- The center maxima corresponds to m=0.
- The first maxima either side of center both correspond to m=1, the next symmetric pair of maxima away from the center is m=2, etc.
- θ_m and y_m represent the angle and distance measured along the screen to each maxima, respectively. θ_3 is the angle from the center maximum to the third maxima out from center on either side. Similarly, y_3 is the distance from the center maximum to the third maxima (on either side) as measured along the screen.

Provided on Equation Sheet

$$d\sin\theta_m = m\lambda \qquad d\sin\theta_m = \left(m+\frac{1}{2}\right)\lambda$$

Prominent Equation Sheet Ommissions

$$\theta_m = \frac{m\lambda}{d} \qquad \Delta y = \frac{\lambda L}{d} \qquad y_m = L\tan\theta_m \qquad y_m = \frac{m\lambda L}{d}$$

Any equation used on an exam that is not provided on the equation sheet must be derived or justified from the provided equation set. This list is not comprehensive.

Single Slit Interference

- Specified by **destructive** interference condition $\Delta r = (a/2)\sin\theta_p = (p/2)\lambda$
- p is an integer 1, 2, 3...
- The first minima on either side of center both correspond to p=1, the next symmetric pair of minima away from the center is p=2, etc
- Destructive interference from each single-slit is responsible for groupings or missing maxima observed with 2-slit pattern.

Provided on Equation Sheet $\quad d\sin\theta_p = p\lambda$

Experiment 1

Uncertainty in Measurement

References: Many sections of this text adapted and summarized from *An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements* by John R. Taylor. University Science Books. 2007.

Introduction

Since the analysis of uncertainties is essential to any scientific measurement, many of the laboratory exercises in undergraduate physics labs emphasize the estimation and propagation of experimental uncertainty. In this lab, we investigate what is meant by experimental uncertainty, we develop techniques for estimating uncertainty and for using uncertainties in calculations.

What is uncertainty?

If you were to measure the width of this piece of paper using a ruler, you would likely find it to be around 21.6cm. But, is the paper *exactly* 21.6 cm? A careful ruler-user can probably consistently distinguish 21.6 cm from 21.7 cm, but can unlikely tell a 21.60 cm sheet from 21.61 cm. It would be foolish, using the same ruler, to say that the sheet of paper is 21.6030524 cm wide. The best we can say (with a ruler) is that the the width of the paper is closer to the 21.6 cm mark than any other mark. It's our best guess for the width. Taking the resolution of the ruler to be 0.1cm, we can say explicitly that the width is between 21.55 cm and 21.65 cm.

When stating measured values, we state our best guess for the measurement x_{best} and its uncertainty δx as

$$x_{\text{best}} \pm \delta x$$

The quantity δx is called the *uncertainty* of the measurement.

For the width w of this paper, the measurement is correctly written as

$$w = 21.6 \pm 0.05 \text{ cm}$$

If a careful experimenter wanted to make a better measurement, she could use a better instrument, and get a result with a smaller uncertainty. But does she know how wide the sheet of paper is *exactly*? That's a tough question. The width is likely to be different at the top of the sheet than at the bottom, or near the middle. With very precise measurements, mechanical vibrations cause trouble. Variations in humidity and temperature cause the sheet to grow and shrink. Microscopically, thermal energy keeps the atoms in the paper constantly vibrating and moving. It's *impossible* to define exactly what we mean by the *width* of the paper— it's not a well-defined quantity. So, we say what we know: our best guess and its uncertainty: $w = 21.6 \pm 0.05$ cm. Uncertainties are usually rounded to one significant figure.

Another source of uncertainty, *systematic errors*, are caused by mis-calibrated measurement equipment or a improper measurement technique. Anytime an instrument has an out-of-date calibration, or is otherwise unverified, the experimenter runs the risk of taking inaccurate measurements. In the undergraduate lab, systematic errors are not typically encountered. But in the real world, systematic errors happen and must carefully be avoided in experimental measurements.

Key ideas

1. No measurement can be made with absolute certainty.

It's all about comparisons

If I say that it's 311 Kelvin outside today, that my dog has a mass of 1.3 slugs and that I ate a 2.5 megajoule breakfast today, it probably doesn't mean much to you. These unfamiliar units illustrate an important point about measurements: they allow us to make comparisons. Using familiar units, I'd say it is 100°F today, my dog weighs 41 lbs, and I ate a 600 Calorie breakfast. This allows you to make a comparison to warmer or colder days, bigger or smaller dogs and to conclude that I should eat a healthier breakfast. Comparisons are the reason that we take any measurement. Any single measured quantity is completely uninteresting.

In lab, we compare our measurements to accepted values or to a value predicted by a physical model. Two measurements correctly stated with uncertainty, are *consistent* with one another when they are equal within their uncertainties. For two values p and q, does

$$p_{\text{best}} \pm \delta p = q_{\text{best}} \pm \delta q \,?$$

If this equality is true, p and q are said to be consistent.

As experimenters, we strive to make measurements of high precision. We want to be *certain* that measurements are consistent with predictions. So, measurements of low uncertainty are preferred. But avoid the temptation to underestimate uncertainty, it's better to be unsure than wrong.

Key ideas

1. Any single measured quantity is completely uninteresting.
2. We use a measurement and its uncertainty to *make a comparison* between the measurement and the accepted value or prediction.
3. It is better to be accurate than precise.

Today's Game

Game rules

In today's lab, we will be playing a game. The goal of the game is to make *accurate* measurements with the *lowest possible uncertainty* for the instrument and technique used. You will be instructed to make several measurements using different techniques. With your lab group, make your best measurement and estimate its uncertainty. Higher precision answers are rewarded with more points, while inaccurate answers receive no points. You will then bring your measurement to the lab instructor, where it will be compared against a very high precision measurement. Consistent measurements will be awarded using the formula

$$\text{awarded points} = \sqrt{\frac{x_{\text{best}}}{\delta x}} - 1 \qquad (1)$$

Accurate measurements of higher precision receive more points. Measurements with a relative uncertainty $\delta x / x_{\text{best}}$ of 25% receive 1 point. 10% → 2 points, 5% → 3 points, 1% → 9 points, 0.1% → 30 points.

- **Measurements inconsistent with the high-precision standard measurement will receive 0 game points.**
- **Explicitly follow the instructions for each measurement technique.**
- **Do not use measurement tools until instructed to do so.**
- **Chip Values:** White: 1 point, Red: 5 points, Blue 10 points, Green: 25 points, Black: 50 points

⋆ The lab group with the most points at the end of the lab-period will win a prize ⋆

Game Round 1: Estimating instrument uncertainty

Metal block

The uncertainty of a measurement depends on the tool used and the skill of the experimenter. Work as a group to estimate the uncertainty in the length offered by three measurement techniques.

SUBMISSION B1: State the length (with uncertainty) of the longest side of the block with **no external tools or objects used for scale**. You may handle the block if you like. Submit your measurement on a post-it note. Inches or centimeters are acceptable units. Calculate the payout (using Equation 1) you will receive if your measurement and uncertainty are consistent with the accepted value. The submission should include the block letter, your estimate of the length, the uncertainty, and the payout amount.

SUBMISSION B2: Measure the length of the longest side of the block in centimeters using the ruler. Calculate the payout (using Equation 1) you will receive if your measurement and uncertainty is consistent with the accepted value. Submit your measurement and its uncertainty on a post-it note. The submission should include the block letter, your measurement of the length, the uncertainty, and the payout amount.

SUBMISSION B3: Measure the length of the longest side of the block using the vernier calipers. Calculate the payout (using Equation 1) you will receive if your measurement and uncertainty is consistent with the accepted value. Submit your measurement and its uncertainty on a post-it note. The submission should include the block letter, your measurement of the length, the uncertainty, and the payout amount.

Unknown mass

SUBMISSION M1: State the mass (with uncertainty) of the provided mass with **no external tools or objects used for scale**. You may handle the mass if you like. Submit your measurement on a post-it note. Grams, kilograms, ounces or pounds are acceptable units. The submission should include the block letter, your estimate of the mass, the uncertainty, and the payout amout.

SUBMISSION M2: Measure the mass provided in grams using the triple beam balance. Submit your measurement and its uncertainty on a post-it note. The submission should include the mass letter, your measurement of the mass, the uncertainty, and the payout amount.

Lens focal length

Sometimes the uncertainty of a measurement is not limited by the scale of the instrument used. For example, when a lens forms an in-focus image of a distant object onto a screen, the distance between the screen and the lens is called the *focal length*. When we try to measure this focal length, it may be difficult to identify the center of the lens, or determine exact in-focus position for the screen.

SUBMISSION L1: Place a piece of white paper on the table. Position the lens above the paper, and adjust the paper-to-lens distance required to form an image (on the paper) of the fluorescent lights overhead. Using a ruler, measure the this paper-to-lens distance in centimeters. Submit your measurement and its uncertainty on a post-it note. The submission should include your measurement of the length, the uncertainty, and the payout amount.

Key ideas

1. It is important to make a reasonable estimate of the uncertainty of the measurement technique used.
2. A measurement is often more uncertain than the scale on an instrument suggests

---

Using uncertainties in calculations

The following formulas are reproduced, without proof, from Taylor (2007) cited above. **These formulas are shown for three variables x, y, z but can easily be generalized for more (or fewer) variables.** If the various quantities x, y, z are measured with small uncertainties $\delta x, \delta y, \delta z$, and the measured values are used to calculate some quantity q, then the uncertainties in x, y, z cause an uncertainty in q as follows:
When q is a **sum or difference** like $q = x + y - z$,

$$\delta q^* = \sqrt{(\delta x)^2 + (\delta y)^2 + (\delta z)^2} \tag{2}$$

If q is a **product or quotient** like $q = \frac{xz}{y}$,

$$\delta q = |q|\sqrt{\left(\frac{\delta x}{x}\right)^2 + \left(\frac{\delta y}{y}\right)^2 + \left(\frac{\delta z}{z}\right)^2}. \tag{3}$$

If q is a **power** of x and y like $q = \frac{zx^m}{y^n}$,

$$\delta q = |q|\sqrt{\left(m\frac{\delta x}{x}\right)^2 + \left(n\frac{\delta y}{y}\right)^2 + \left(\frac{\delta z}{z}\right)^2}. \tag{4}$$

If q is related to x by an **exactly-known coefficient** B then $q = Bx$ and

$$\delta q = |B|\delta x. \tag{5}$$

Example 1

The total mass of a bag of apples is $m_t = 2.1 \pm 0.1$ kg. The grocer tells you that the mass of the bag is $m_b = 0.22 \pm 0.03$ kg. What is the mass (and uncertainty) of the apples alone (m_a)?

$$m_a = m_t - m_b = 2.1\text{ kg} - 0.22\text{ kg} = 1.88\text{ kg}$$

From Equation 2 we calculate the uncertainty in the apple mass to be

$$\delta m_a = \sqrt{(\delta m_t)^2 + (\delta m_b)^2} = \sqrt{(0.1)^2 + (0.03)^2} = 0.104\text{kg}$$

With the correct number of significant figures,

$$m_a \pm \delta m_a = 1.8 \pm 0.1\text{ kg}.$$

Example 2

If a certain object has a mass m of 50.0 ± 0.2 kg and a volume V of 0.250 ± 0.005 m^3, the density ρ is given by

$$\rho = \frac{m}{V} = \frac{50\text{ kg}}{0.250\text{ m}^3} = 200\frac{\text{kg}}{\text{m}^3}.$$

According to Equation 3, the uncertainty in the density $\delta\rho$ is given by

$$\delta\rho = \rho\sqrt{\left(\frac{\delta m}{m}\right)^2 + \left(\frac{\delta V}{V}\right)^2} = \left(200\frac{\text{kg}}{\text{m}^3}\right)\sqrt{\left(\frac{0.2}{50}\right)^2 + \left(\frac{.005}{0.250}\right)^2} = 4.1\frac{\text{kg}}{\text{m}^3}.$$

The density is calculated to be

$$\rho = 200. \pm 4\frac{\text{kg}}{\text{m}^3}.$$

Key ideas

1. When uncertain measured values are used in calculations, *error propagation* is the set of tools used to determine the uncertainty in the calculated result.

Game Round 2: Calculated Uncertainties

Area of a metal block

SUBMISSION A1: Using the vernier calipers, measure, in mm, the two longest sides of the the metal block and calculate its area (mm^2), and the uncertainty in the area calculation. Submit your measurement and its uncertainty on a half sheet of paper. The submission should include your calculation of the area, the calculation of the uncertainty (with all details), and the payout amount.

Period of a turntable

SUBMISSION T1: Using the stopwatch, measure, in seconds, the amount of time it takes for the turn table to make one rotation. Measure the duration of one rotation directly, stopping the watch after exactly one rotation. Note: although the stopwatch measures in increments of 0.01 s, the uncertainty in this measurement is much greater that 0.01 s, and is limited by the inconsistencies in human reaction time. With your group, discuss the best approach for estimating the uncertainty in the time measurement process. Submit your measurement and its uncertainty on a post-it note. The submission should include your measurement of the period, estimate of uncertainty, and the payout amount.

SUBMISSION T2: If we measure the duration of several rotations of the turntable, we can significantly reduce the uncertainty in the duration of one rotation. Use this technique, along with Equation 5 to make a better measurement of the single-rotation duration. Submit your measurement and its uncertainty on a post-it note. The submission should include your measurement of the period, estimate of uncertainty, and the payout amount.

Repeated Measurements

When measuring the period of the turntable above, we identified the greatest source of uncertainty as the reaction-time of the experimenter. Even a careful experimenter is just as likely to overshoot her measurement as undershoot. Reaction-time is a source of *random error* in an experiment. There are many sources of random errors in any particular measurement.

Suppose we need to measure some quantity x and have determined the systematic errors to be negligible. The remaining sources of uncertainty are random, so we should be able to detect them by repeating the measurement several times. Suppose we repeat the measurement five times, and record the (unitless) values

$$45, 46, 46, 49, 43$$

What should we take for our best estimate x_{best} of the quantity x?

Reasonably, we can use the *average* or mean $\overline{x}$ of the five values as an estimate of x_{best}

$$x_{\text{best}} = \overline{x} = \sum_{i=1}^{N} \frac{x_i}{N} \tag{6}$$

For the five values above, we find

$$x_{\text{best}} = \overline{x} = \sum_{i=1}^{N} \frac{x_i}{N} = \frac{45+46+46+49+43}{5} = 45.8.$$

By taking several measurements we can also get a sense of the uncertainty in our experiment. The *standard deviation*

$$\sigma = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (x_i - \overline{x})^2}$$

is a measure that is used to quantify the amount of variation in a set of data. Data sets with large variations have a larger uncertainty than those with small variations. σ measures how much uncertainty is in *any one data point* x_i. But, when we combine several (N) measurements x_i to make an improved estimate of the measurement $x_{\text{best}} = \overline{x}$, we expect x_{best} to be closer to the true value than one measurement taken alone. When several individual measurements are combined as an average, we estimate the uncertainty using the *standard deviation of the mean*, given by

$$\sigma_{\overline{x}} = \frac{\sigma}{\sqrt{N}} = \sqrt{\frac{1}{N(N-1)} \sum_{i=1}^{N} (x_i - \overline{x})^2} \tag{7}$$

Note the factor of $\sqrt{N}$ in the denominator: If we collect more data points, the uncertainty is reduced.

For the five data points shown above the uncertainty is given by

$$\begin{aligned} \sigma_{\overline{x}} &= \sqrt{\frac{1}{N(N-1)} \sum_{i=1}^{N} (x_i - \overline{x})^2} \\ &= \sqrt{\frac{1}{5(5-1)} \left((45-45.8)^2 + (46-45.8)^2 + (46-45.8)^2 + (49-45.8)^2 + (43-45.8)^2\right)} = 1.6 \end{aligned}$$

The measurement is correctly reported as 45.8 ± 1.6.

Game Round 3: Repeated Measurements

Falling time of an Atwood machine

SUBMISSION P1: Using a stop watch, measure the amount of time it takes for the left block of the Atwood machine to fall between the two arrows. Start and stop the timer when the bottom edge of the block passes the arrow. **Make the measurement only once**, and submit your best measurement for the fall time and its uncertainty. Submit your measurement and its uncertainty on a post-it note. The submission should include your measurement of the fall time, estimate of uncertainty, and the payout amount.

SUBMISSION P2: Using a stop watch, measure the amount of time it takes for the left block of the Atwood machine to fall between the two arrows. Start and stop the timer when the bottom edge of the block passes the arrow. **Make the measurement five times**, and submit your best measurement for the fall time and its uncertainty. Submit your measurement and its uncertainty on a half sheet of paper. The submission should include your calculation of the mean fall time, the calculation of the uncertainty, and the payout amount.

SUBMISSION P3: Using a stop watch, measure the amount of time it takes for the left block of the Atwood machine to fall between the two arrows. Start and stop the timer when the bottom edge of the block passes the arrow. **Make the measurement twenty times**, and submit your best measurement for the fall time and its uncertainty. Submit your measurement and its uncertainty on a half sheet of paper. The submission should include your calculation of the mean fall time, the calculation of the uncertainty, and the payout amount. You may use a graphing calculator or computer to assist in statistical calculations.

Key ideas

1. Measurements that can be repeated should be.
2. By taking repeated measurements, we can estimate the uncertainty in the measured value.
3. With *more* repeated measurements, we reduce the uncertainty.
4. We use *statistical analysis* to estimate the uncertainty of repeated measurements
5. *Error propagation* and *statistical analysis* are distinct tools, and both are important.

Weakest Link Rule

To make a rigorous measurements and comparisons, we must apply the tools of statistical analysis and propagate uncertainties described above. However, a full error analysis is laborious and time consuming and not appropriate for every task and measurement. In many cases, we can apply a simpler, short-hand technique called the *Weakest Link Rule.* In any measurement, the percent uncertainty in the calculated value of some quantity is at least as great as the greatest percentage uncertainty of the values used to make calculation. In many cases, the overall uncertainty is dominated by a single measurement—the weakest link. To apply weakest link analysis,

1. Estimate the absolute uncertainty in each measured quantity used to find the calculated quantity.
2. Calculate the relative uncertainty in each measured quantity.
3. Pick the largest relative uncertainty. We call this largest relative uncertainty the weakest link.
4. We say that the relative uncertainty in our calculated value is equal to the weakest link (the largest relative uncertainty in our measured values). We can then apply the relative uncertainty of the weakest link to the calculated quantity to determine its absolute uncertainty.

Example 3

Here's an example: You've been asked to estimate the volume of your laptop computer. First, you measure the length, width, and thickness with a meter stick (which has an absolute uncertainty of 0.05cm)

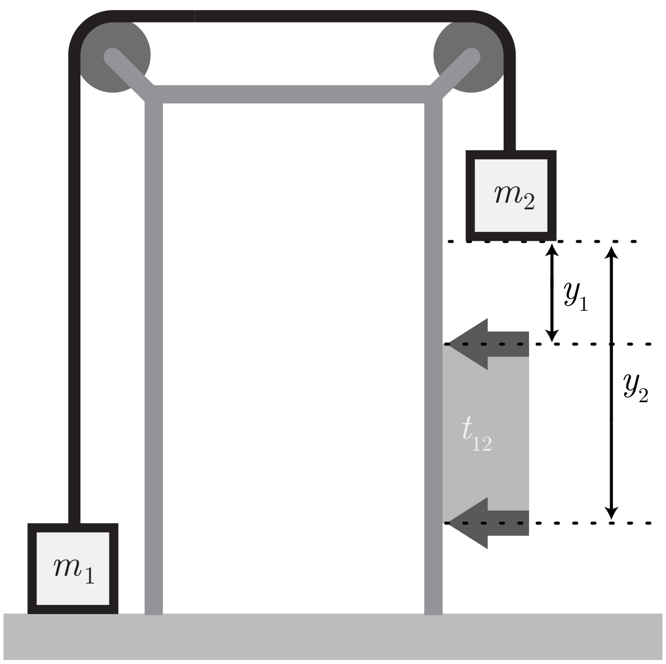
Measurement	Value	Relative Uncertainty
Length (L)	39.4 ± 0.05 cm	0.05 cm/39.4 cm = 0.00127 = 0.127%
Width (W)	28.7 ± 0.05 cm	0.05 cm/28.7 cm = 0.00174 = 0.174%
Thickness (T)	4.3 ± 0.05 cm	0.05 cm/4.3 cm = 0.0116 = 1.16%

From this table, you can see that the thickness has by far the largest relative uncertainty— the thickness measurement is our weakest link! The volume of the laptop is $V = LWT = (39.4\text{ cm})(28.7\text{ cm})(4.3\text{ cm}) = 4862\text{ cm}^3$. Since the thickness measurement has the largest relative uncertainty (1.16%) we say this is the relative uncertainty in our final calculated volume V. To determine the absolute uncertainty of our calculated volume, we multiply the volume by the relative uncertainty of the weakest link:

$$\Delta V = V \times (\text{Weakest Relative Uncertainty}) = (4862\text{ cm}^3)(0.0116) = 56\text{ cm}^3$$

So, the final estimate for the volume of the laptop is $4862 \pm 56\text{ cm}^3$.

Questions and Calculations

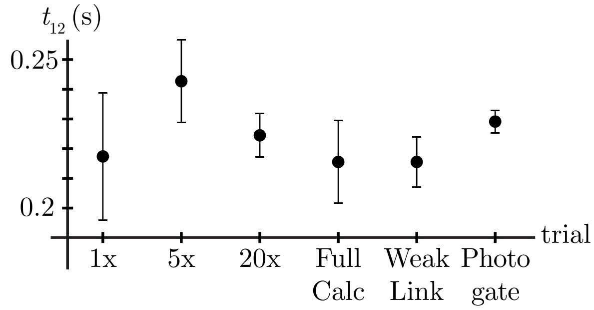


Newton's laws predict that the amount of time it should take for the right mass of the above Atwood machine to fall through the arrows in the figure above is given by

$$t_{12} = \sqrt{\frac{2(m_2 + m_1)}{g(m_2 - m_1)}}\left(\sqrt{y_2} - \sqrt{y_1}\right) \tag{8}$$

Assume $g = 9.81\frac{\text{m}}{\text{s}^2}$, with negligible uncertainty (pretend $\delta g = 0$). Carefully measure the distances y_1 and y_2 and the masses m_2 and m_1, with their uncertainties and calculate the predicted time t_{12}, that the mass will travel between the arrows.

1. Calculate the uncertainty in the fall time δt_{12}, by generalizing and applying equations 3 and 4.
2. Calculate the uncertainty in the fall time δt_{12} using the weakest link method. Is your result reasonable? Why or why not?
3. Is the value you calculated for t_{12} consistent with the measurements you made in Game Round 3? On graph paper, plot the measured values and calculated value with error bars, as shown in the figure below. Ask your instructor for the photogate measurement.



Uncertainty in Measurement: Original LabView Software

In order to aid in the administration of the *Uncertainty in Measurement* laboratory exercise detailed on the preceding pages, I wrote three LabView applications to automate the precision measurement of the turntable period (using a Vernier-branded rotation sensor) and the in-situ precision measurement of the Atwood machine fall time (using a pair Vernier photogates). These applications allow the automated and continous collection of the precision measurements required to check students' measurements for the game exercise incorporated into this lab. A third VI, the INSTRUCTOR CONSOLE references a spreadsheet of standard measurements and retrieves the precision measurements produced by the Turntable and Atwood VIs to streamline checking student measurements. The results are displayed on a chart with appropriate error bars. The application front panels are shown in figure 1.

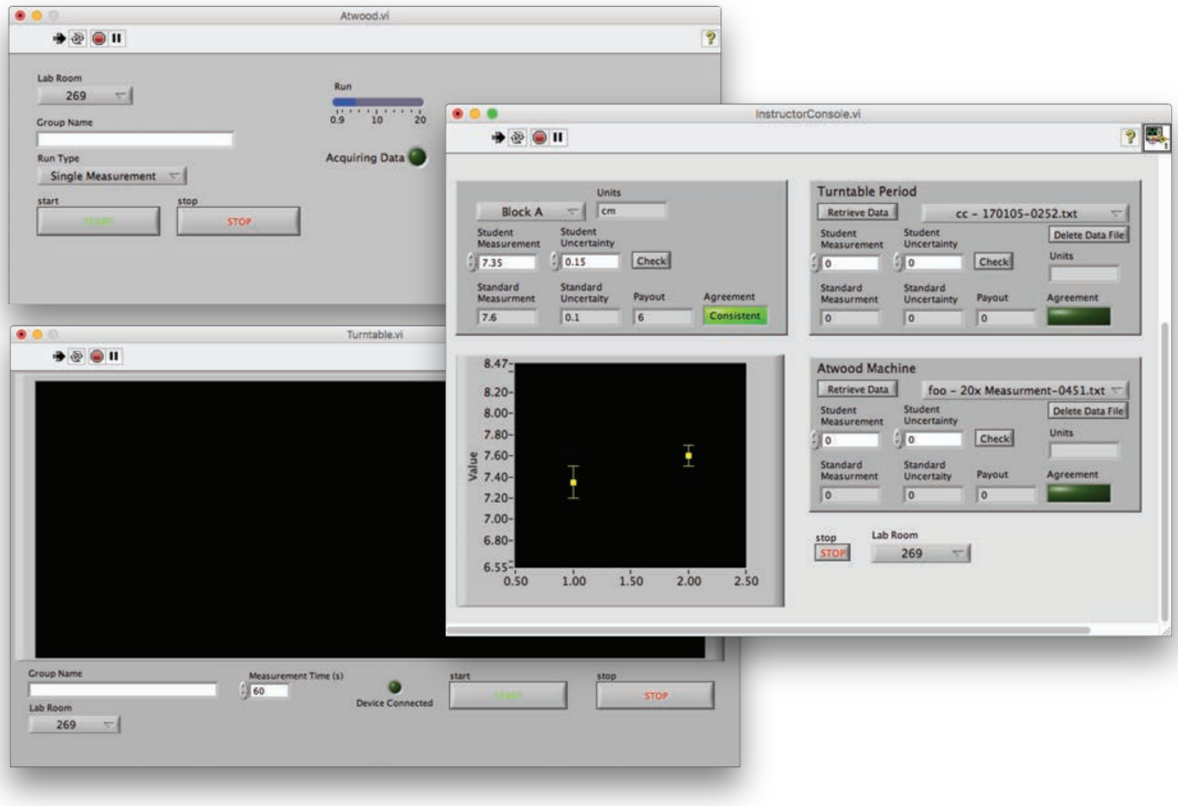


Figure 1: Custom LabView VIs automate the task of collecting standard measurements and reporting them to the instructor for the competition incorporated into my *Uncertainty in Measurement* laboratory exercise. The VIs aim to streamline the student and instructor experience and serve to facilitate the adoption of the exercise with other instructors.

Lecture Slides

I utilize slides as a multimedia accompaniment to my lecture presentation, not the focus. When an image, video, sound or animation can add to my explanation, I include it my slide deck. The slide deck is posted to the course website and updated regularly. For my most recent Physics 132 offering (Fall 2016), the slide deck contained 106 slides, including 29 original mathematica animations.

Mathematica Animations

A main topic of Physics 132 is oscillations and waves. Due to their dynamic nature—changing in both space and time—waves computer animations are an excellent tool to help students visualize and conceptually understand key wave properties. I have used Mathematica (figure 2) to develop versatile code for producing longitudinal and transverse animations. My Physics 132 Mathematica animation library contains 29 original animations, covering wave velocity, snapshot and history graphs, small angle approximation, standing waves and sound propagation.

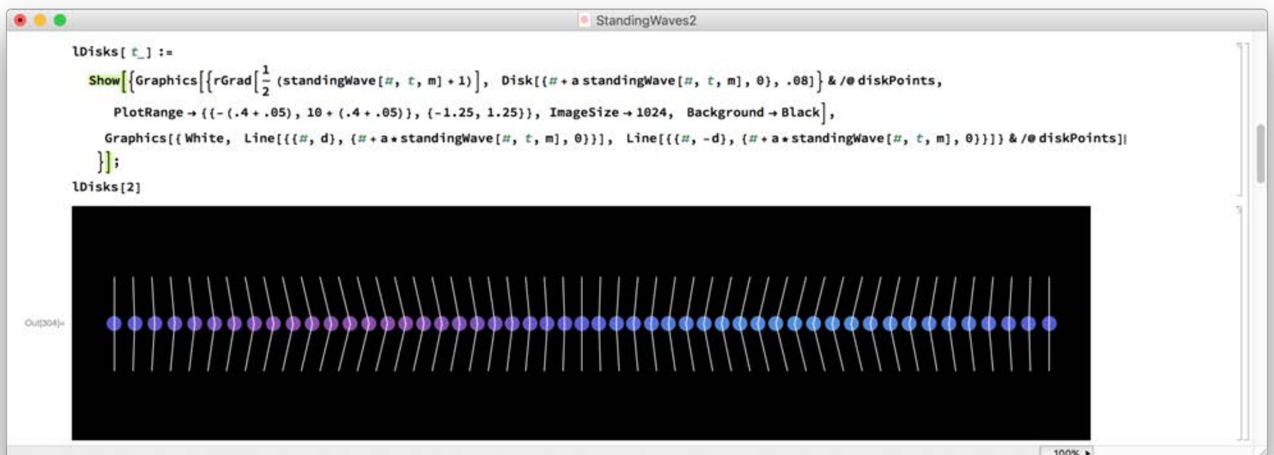


Figure 2: The dynamic nature of wave-phenomenon makes computer animations an excellent tool for illustrating their properties. I wrote a Mathematica notebook longitudinal and transverse wave animation generator for producing high-resolution animations integrated into my lecture.

Other slide content

In addition to animations, my Physics 132 presentation features many other multimedia elements, including photographs, videos, clicker-type questions, and book illustrations. Figure 3 shows a sample of several Physics 132 lecture slides.

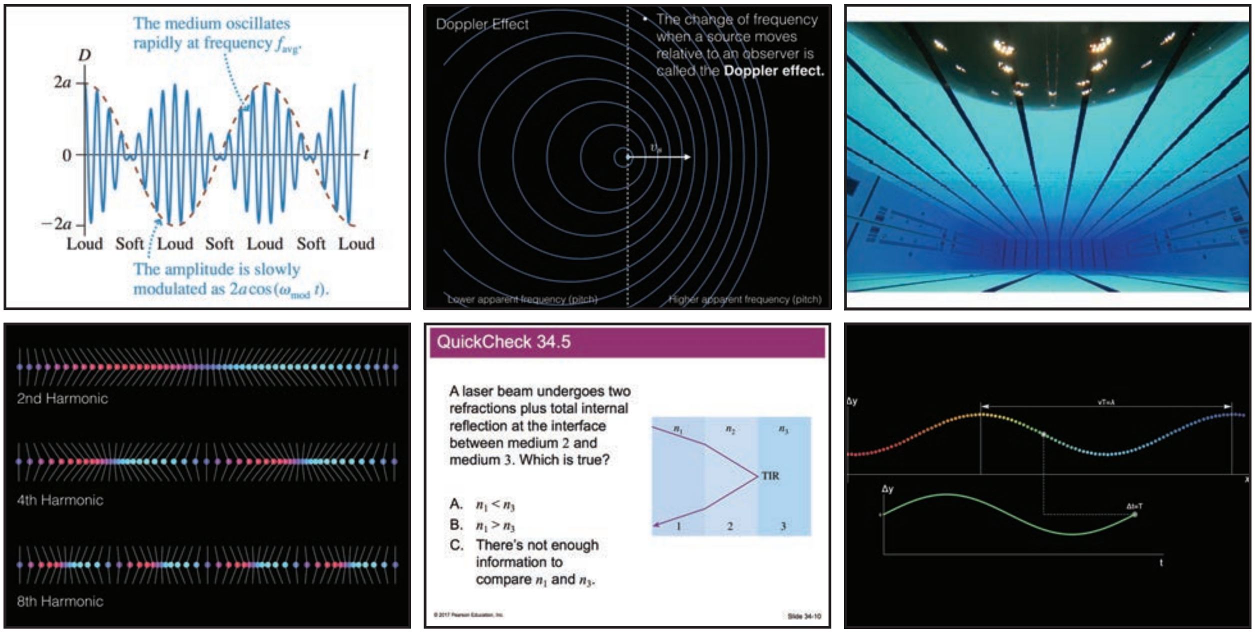


Figure 3: I use my slide deck as a multimedia accompaniment to lecture, incorporating photos, videos, original animations, clicker-type questions and book illustrations.

Course Website

The Physics 132 Course Website (`http://physicscloud.net/132`), shown above in figure 4 is the central communication hub for the class. The website provides student access to the course

- Syllabus
- Objectives
- Schedule
- Homework assignments
- Instructor-prepared homework solutions
- Equation sheets
- Midterm solutions
- Lab Manual
- Supplemental lecture videos
- Homework solution videos (select problems)

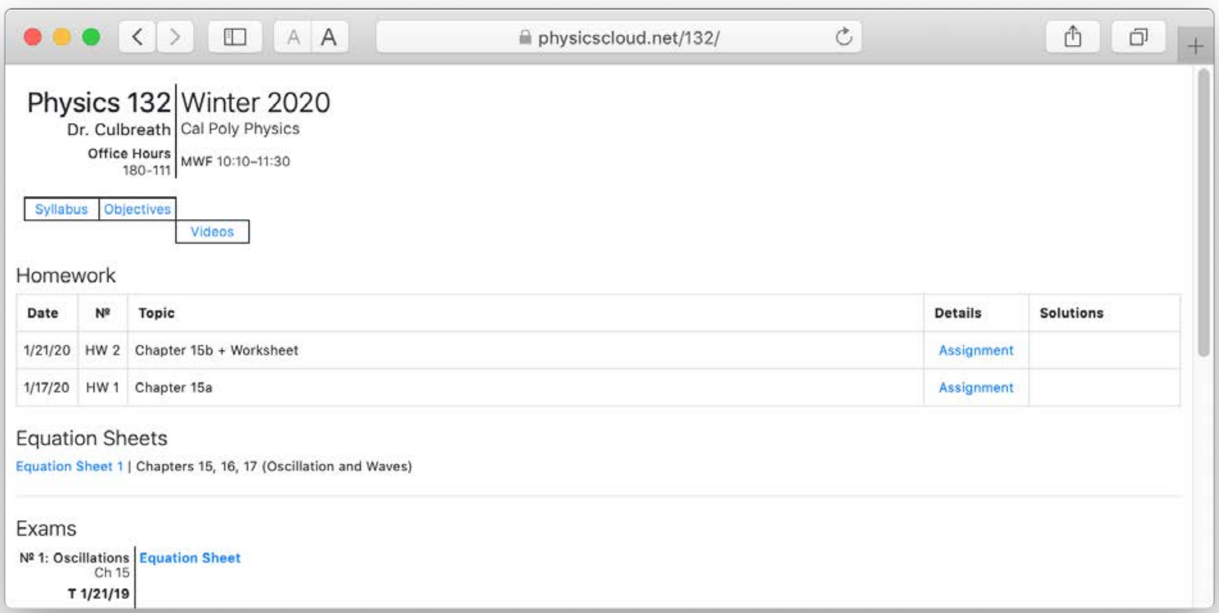


Figure 4: The course website is the central communication hub for the class and is updated several times per week. Visit the site at `http://physicscloud.net/132`

Homework Assignments are posted at least one week before their due date. Homework assignments (figure 5) often include links to one or two homework solution videos (see *Online Videos* on page 189). Changes to the course schedule are relayed by email and updated on the site.

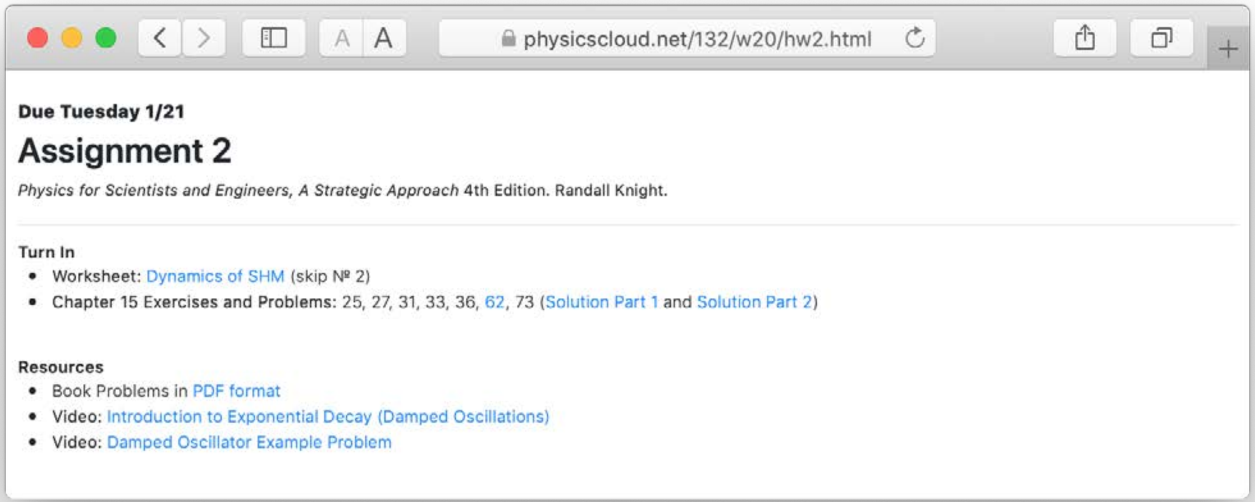


Figure 5: Homework assignments are posted to the course website at least one week before their due date and often include links to 1–3 instructor-prepared solution videos.

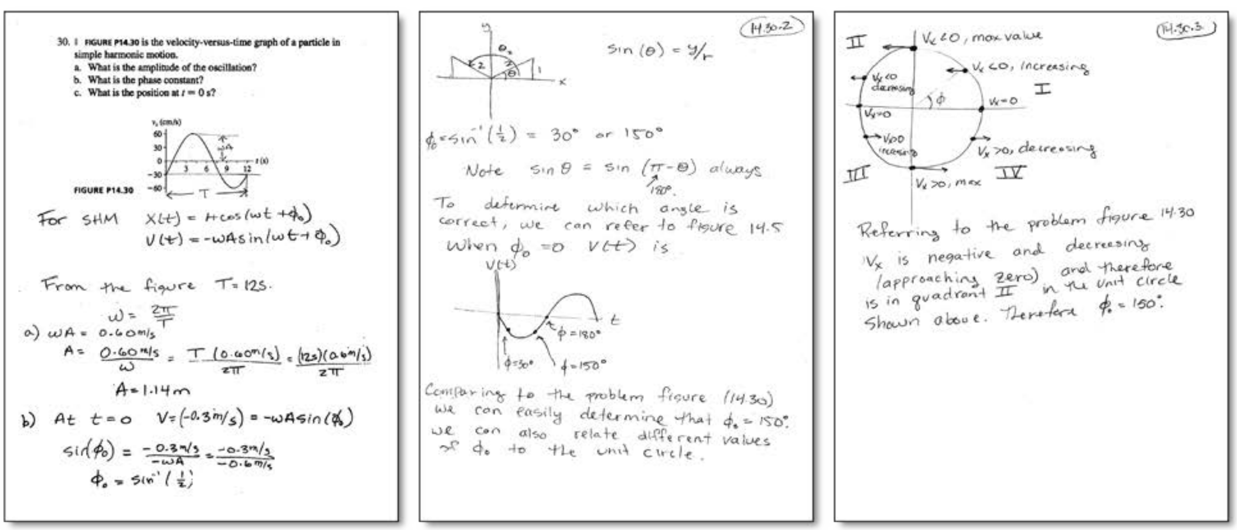


Figure 6: Instructor prepared homework solutions are posted to the course website the same day that homework is collected, and often contain explanatory notes and commentary. At the end of the Fall 2016 quarter, the Physics 132 Course Website contained 268 pages of handwritten instructor-prepared solutions.

Homework and Exam solutions

Instructor prepared homework solutions are posted to the course website on the same day that homework is collected. The homework solutions detail the step-by-step approach to solving the problem, and often include explanatory notes and commentary, as shown in figure 6. In addition, detailed exam solutions are posted after students receive their graded exams. For both exams and homework, I require students to submit corrections which reference the posted solutions and remedy mistakes in their original work†.

Self-paced slideshows

A full general description of my self-paced slideshow content can be found on page 259. Listed below is the content I produced and is available on my course website specifically for Physics 132.

Table 2: Physics 132 Self-paced Slideshow Presentations

Topic	URL
Initial Phase in Travelling Waves	physicscloud.net/132/phase
Images as Objects in two-lens systems	physicscloud.net/132/two-lens
What's with the rays between two lenses?	physicscloud.net/132/quick-two-lens

Course Videos

A full general description of my online video content can be found on page 241. Listed below is the content I produced and is available on my course website specifically for Physics 132.

Table 3: Physics 132 Step-by-step Solution Videos

Topic	Duration	URL
Ch 22 #36	6:05	youtube.com/watch?v=5zvtKxY-0Dg
Ch 22 #70	6:28	youtube.com/watch?v=I_JJ5bS-zzs
Ch 21 #74	5:29	youtube.com/watch?v=W_opX2byMwI
Ch 21 #77	6:15	youtube.com/watch?v=yzek8qJ6boA
Ch 14 #72	18:25	youtube.com/watch?v=-ziz7R3GijE
Ch 14 #62	5:20	youtube.com/watch?v=YQjk2831gvI
Ch 14 #49	7:19	youtube.com/watch?v=IGVrH1UBNRY
Conceptual 2D Interference	8:11	youtube.com/watch?v=bcx65yaYkLQ
Quantitative 2D Interference	7:51	youtube.com/watch?v=bcx65yaYkLQ
1D Interference	9:52	youtube.com/watch?v=FmwmjKRtt2w
Comparing Two Gases (Ch 16)	4:20	youtube.com/watch?v=vwYGx1VNt9Q
PV Diagram Example	3:34	youtube.com/watch?v=QO6zmI1LpOk

†The corrections policy is detailed in the course syllabus (page 155)

PHYSICS 133

Course Syllabus/Fall 2018

INSTRUCTOR: Dr. Christopher Culbreath **MAILBOX**: Physics Department Office (180-204)
OFFICE HOURS: M 9:10 AM—11 AM • M 12:10PM—1 PM • F 9:10 AM—11 AM (Baker 6th Floor Lobby)
EMAIL: cculbrea@calpoly.edu **WEB:** http://physicscloud.net/133
LECTURE: MWF 8:10-9:00 in Science North (53-202)
LAB: W 12:10-3:00 (180-270) • W 3:10-6:00 with Dr. Gillen (180-270)

COURSE DESCRIPTION: This course is the last module of the 3-quarter introductory physics sequence with calculus for science and engineering students. The course topic is electricity and magnetism. It requires calculus and will make use of quite a bit of trigonometry and algebra.

COURSE OBJECTIVES: The course objectives are: i) to understand concepts relevant to electrodynamics such as electric and magnetic fields, forces, potentials, electric circuits, and electromagnetic induction, and ii) to master problem-solving techniques related to these concepts.

TEXT: *Physics for Scientists and Engineers: A Strategic Approach with Modern Physics*, by Randall D. Knight, 4th Edition. Lab handouts are distributed digitally on the course website. Please read and print lab handouts ahead of time.

COURSE WEBSITE: The course website is **http://physicscloud.net/133/** ***The website is a source of essential information for this course.*** Assignments, solutions, the syllabus, course objectives, course schedule, lab handouts and exam solutions will all be posted to the site. Please check it regularly. I do not use the campus Poly Learn system.

PREREQUISITES: Prior completion of PHYS 141 (or equivalent) is a required prerequisite.

GRADING: Homework 10% • Exam Corrections 5% • Two Exams 25% each • Final 25% • Lab 10%
No individual assignments will be curved, and no letter grades will be assigned until the end of the term. At the end of the quarter, every student's weighted point total will be ranked and the distribution curved such that C, C+ and C- grades indicate performance not far from the average. *A*s are reserved for exceptional performance and are typically awarded to 18%-or-less of the class.

CLICKER QUESTIONS: During lecture, real-time feedback, and attendance will be provided by multiple-choice conceptual and discussion questions. Answers are registered through multi-colored answer cards passed out on the first day of class, and are expected at each class meeting.

HOMEWORK: Homework will be collected weekly. Homework is due at the beginning of class. Late homework will receive a 33% deduction, and be graded on a credit/no-credit basis.

HOMEWORK PRESENTATION: Homework problems should be worked on blank, unruled, paper or quad-ruled, engineering-type graph paper. ***Do not use regular lined notebook paper.*** Blank printer paper is everywhere; use that instead. Clearly indicate the problem number on each page. Bind all pages of the homework set with a single staple in the upper-left corner. Number the pages in the upper right corner. Whenever possible, the solution should ***include a figure or sketch*** that illustrates the key parameters of the problem. Answers must be reported using a reasonable number of significant figures. Try to make your calculation as clear and tidy as possible; little effort will be made to decipher sloppy work. ***Work problems symbolically until the last step***, at which point you can plug-in actual numbers and recover a numeric answer. ***All numeric values must include units:*** if you write down a number, it must include appropriate units, even in intermediate calculation steps. If you don't want to include units, work symbolically until the last step.

HOMEWORK GRADING: As decided by class vote, homework will either be graded using a 1-2-3 or lottery grading scheme. Under the 1-2-3 scheme, each problem is worth three points. 1 point is awarded for submitting a reasonable solution *on time*, and the remaining 2 points are awarded with crude precision: 2 points for a correct, complete solution that fully adheres to the presentation guidelines above, 0 points for a solution obviously less than 50% complete/correct, and 1 point for any solution in between. With a lottery-type grading scheme, 0-3 problems per assignment are chosen at random to be graded rigorously with 10 points possible per problem.

PHYSICSCLOUD.NET At the beginning of the quarter you will receive email to signup for my course-management system at physicscloud.net. In addition to viewing your course grade and assignment statistics, physicscloud.net is used for scheduling review sessions, and for voting on important ***course options*** such as the homework collection day and the homework grading scheme.

LAB: The three-hour lab meets weekly. Prepare for lab each week by reading the lab handout before coming to class. The lab schedule is attached to this syllabus. ***Attendance and participation for every lab exercise is required.*** If you miss a lab, your course performance will be considered Incomplete—and you must make up all missing lab assignments in a future quarter to receive a passing grade. If you must miss lab, you can make it up the same week in another section, but you must make arrangements with the appropriate lab instructor to participate in an alternate lab session. Exceptions to the lab attendance policy will only be made on a one-time basis, and only for a compelling reason. Specific lab requirements, assessment, and attendance are at the discretion of the individual lab instructor. Exceptional performance in lab can give an advantage to students whose performance is near the borderline of two grades. Lab report requirements are determined by the lab instructor and will be explained during the lab period. You may not leave before your lab group is done, you must be present for your work to be accepted.

EXAMS: Two midterm exams and a final exam will be given during the quarter as tentatively scheduled below. An equation sheet will be provided. The equation sheets for each midterm are available on the course website, and I encourage you to use them as a resource when working homework problems. Be aware that the equation sheet doesn't necessarily include the full form of every conceivable equation. Only the equations on the equation sheet should be considered as given, and any other relationships should be derived or justified from the relationships on the sheet. Solutions that arrive at an answer or equation without justification are not acceptable. **Calculators are not allowed on any exams in this course.** Exam solutions should always show *all* steps of the calculation and be worked *symbolically* until the last step, which should be a calculator-ready expression for the desired quantity. On an exam, it is the symbolic answer that counts, and you should avoid using exam time to perform tedious arithmetic. **Any time a number is used, anywhere on the exam, appropriate units are required.** Symbolic quantities do not require units.

EXAM CORRECTIONS: Exam corrections are due one week after exams are returned in class. Submit corrected solutions for all problems for which you did not receive full-credit. Small errors may be corrected in-place using an alternate pen color. Submit a new rewritten solution for problems with significant errors (scores below 70%). Missed multiple choice problems require a written or mathematical explanation that justifies the correct answer or remedies your misconception. Exam corrections should be stapled to the front of your midterm exam and resubmitted by the due date. The original midterm may be omitted if the corrected solution includes every problem on the exam. Corrections do not earn points back towards the original exam score, but are scored as a separate assignment. Exam corrections are worth 5% of your overall course grade.

LATE WORK: Late work is accepted as specifically described in this syllabus and on a case-by-case basis. All work in this course that is not submitted during the main submission period must be turned in to my *mailbox in the physics department office (180-206)*. **I do not regularly use my official office in Jesperson Hall. Please do not leave late work or other correspondence for me there.**

PHYSICS 133

Tentative Course Schedule

Fall 2018

Last Updated 9/20/18

WK	MONDAY	WEDNESDAY	FRIDAY	
0 Sep 16 Sep 22			**21** *Charges* Ch 25 1/4	**No Lab**
1 Sep 23 Sep 29	**24** Ch 25 2/4	**26** Ch 25 3/4	**28** Ch 26 4/4	**Lab:** Electrostatics
2 Sep 30 Oct 6	**1** *Electric Field* Ch 26 1/4	**3** Ch 26 2/4	**5** Ch 26 3/4	**Lab:** Electric Field I
3 Oct 7 Oct 13	**8** Ch 26 4/4	**10** *Gauss' Law* Ch 27 1/2	**12** Ch 27 2/2	**Lab:** Electric Field II
4 Oct 14 Oct 20	**15** *Potential* Ch 28 1/3	**17** Ch 28 2/3	**19** Ch 28 3/3	**Exam 1:** Electric Forces and Fields (During lab period)
5 Oct 21 Oct 27	**22** *Potential +Field* Ch 29 1/3	**24** Ch 29 2/3	**26** Ch 29 3/3	**Lab:** Electric Potential and Field
6 Oct 28 Nov 3	**29** *Current* Ch 30 1/2	**31** *Circuits* Ch 31 1/4	**2** Ch 31 2/4	**Lab:** Circuits I
7 Nov 4 Nov 10	**5** Ch 31 3/4	**7** Ch 31 4/4	**9** *B-Field* Ch 32 1/6	**Lab:** Circuits II
8 Nov 11 Nov 17	**12** **NO CLASS** Veteran's Day	**14** Ch 32 2/6	**16** Ch 32 3/6	**Lab:** Earth's Magnetic Field **Exam 2:** 9/14 location and time TBD
	**19**	**21**	**23**	Thanksgiving Break
9 Nov 25 Dec 1	**26** Ch 32 4/6	**28** Ch 32 5/6	**30** Ch 32 6/6	**Lab:** Current Balance
10 Dec 2 Dec 9	**3** Ch 33 1/3	**5** Ch 33 2/3	**7** Ch 33 3/3	**Lab:** Faraday's Law
FINAL Dec 10 Dec 17	**11**	**13**	**15** **FINAL EXAM** 7:30AM 53-202	

NAME: ______________________________

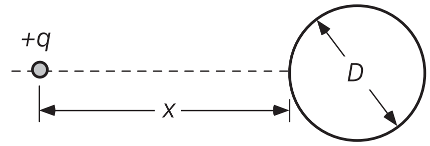
PHYSICS 133 MIDTERM 1 • CAL POLY • FALL 2018 • DR. CULBREATH

No calculators. No notes. Use only the provided paper and equation sheet. 110 minutes.

SECTION 1 • MULTIPLE CHOICE

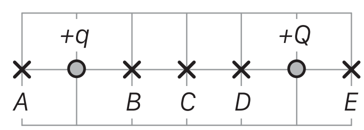
Choose the best answer from the provided choices (5 points each or as marked)

1. As shown to the right, a positive point charge is placed a distance x away from the closest surface of a neutral metal sphere that has a diameter D. For each change listed, state whether the magnitude of the force exerted on the point charge by the sphere *increases*, *decreases*, or *remains the same*. (Assume that all of the other given variables remain the same for each change given.) *(10 points)*

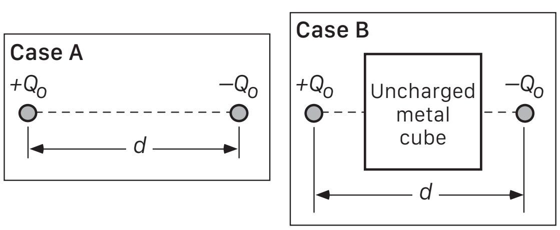


	Change to system	Effect on the force exerted on the particle			
		No Force	*Increases*	*Decreases*	*Stays the Same*
1	Increase the distance x				
2	Increase D, keeping the charge a distance x away				
3	Increase the charge of the particle				
4	Make the charge of the particle $-q$				
5	Add negative charge to the sphere				

2. Shown to the right are two charged particles that are fixed in place. The magnitude of the charge Q is greater than the magnitude of the charge q. A third charge is now placed at one of the points A–E. **The net force on this charge due to q and Q is zero.** At which point A–E is it possible that the third charge was placed?



❒ A ❒ B ❒ C ❒ D ❒ E



3. Shown the left, two particles with equal and opposite charges are fixed in place a distance d apart. The cases are identical, except that in Case B an uncharged metal cube is placed between the two particles. Is the net electric force on the positively charged particle

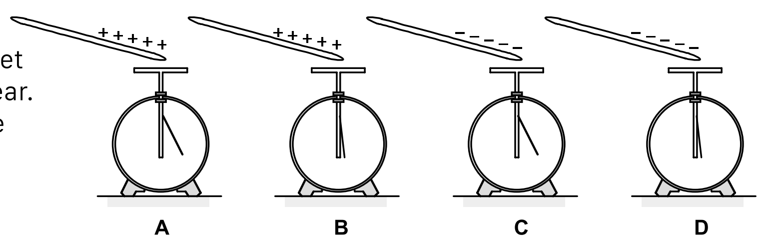
❒ greater in Case A ❒ greater in Case B

❒ the same in both cases

SECTION 2 • SHORT ANSWER

Answer the question in the space provided. 15 points each.

4. For the four situations depicted to the right, rank the net charge on the electroscope while the charged rod is near. (The net charge will be a negative value if there is more negative than positive charge on the electroscope.) **Explain your reasoning in the space below.**

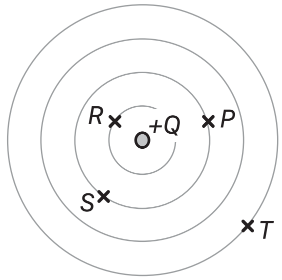


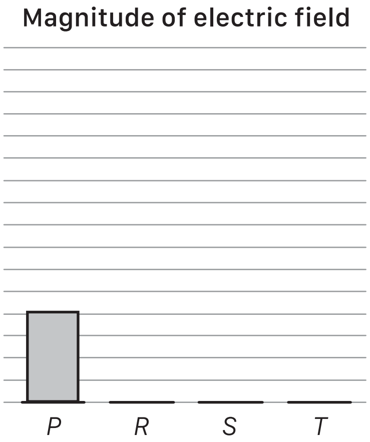
1 Greatest	2	3	4 Least

OR ☐ All the same ☐ All zero ☐ Cannot determine

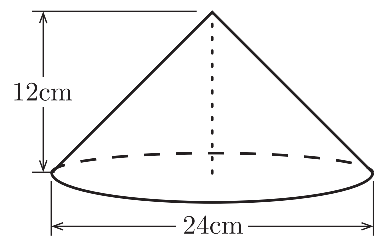
Continued on back ☞

5. Points P, R, S, and T lie close to a positive point charge. The concentric circles shown are equally spaced with radii of r, $2r$, $3r$, and $4r$. The magnitude of the electric field at point P due to the point charge is shown in the bar chart below. **Complete the bar chart to indicate the relative magnitude of the electric field at points *R*, *S*, and *T*.** Explain your reasoning in the space provided.





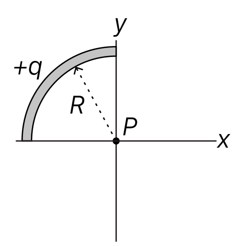
6. A cone is resting on a tabletop as shown in the figure to the right, with its face horizontal. A uniform electric field of magnitude 1000N/C points vertically upward. How much electric flux passes through the sloping side surface area of the cone? (There's no need to compute arithmetic that uses a decimal value of π; just include π in your final answer)



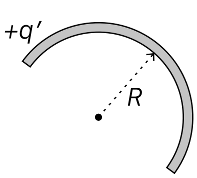
SECTION 3 • CALCULATION

Answer on a separate sheet of paper. 35 points.

7. As shown to the left, a thin glass rod forms a quarter of radius R. A total charge of $+q$ is uniformly distributed along the rod.



   a) Determine an expression for the electric field $\vec{E}$ produced at point P. State your answer in component form.



   b) Can a semicircular rod, also of radius R, but having total positive charge +q' (as depicted to the left) be added to the original configuration in such a way that the electric field at P is zero? If so, determine the magnitude of the charge q' in terms of q and provide a sketch that clearly indicates the required position and orientation of semicircular rod relative to the quarter-circular rod analyzed in part a.

NAME: ________________________________

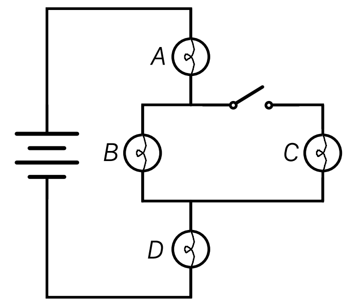
PHYSICS 133 MIDTERM 2 • CAL POLY • FALL 2018 • DR. CULBREATH

No calculators. No notes. Use only the provided paper and equation sheet. 110 minutes.

SECTION 1 • MULTIPLE CHOICE

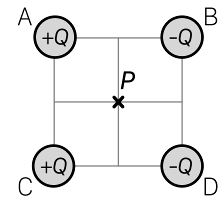
Choose the best answer from the provided choices (3 points each)

1. A battery is connected to four identical bulbs and a switch as shown. The current through each bulb determines its brightness.



   a) When the switch is closed, the brightness of bulb *C*
      ❐ increases. ❐ decreases. ❐ stays the same.
   b) When the switch is closed, the current out of the battery
      ❐ increases. ❐ decreases ❐ stays the same.
   c) When the switch is closed, the brightness of bulb *A*
      ❐ increases. ❐ decreases. ❐ stays the same.
   d) When the switch is closed, the brightness of bulb *D* is
      ❐ brighter than bulb *A*. ❐ dimmer than bulb *A*. ❐ the same as bulb *A*.

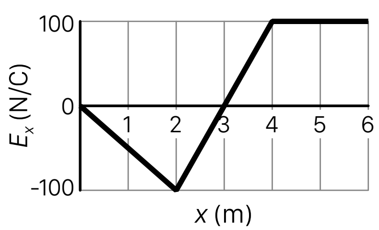
2. Four identical point charges are fixed at the same distance from point *P*. The charges are either $+Q$ or $-Q$. Each action described the table below is made to the situation shown in the diagram (i.e., "Change sign of charge D" means that charges A, C, and D will be positive and charge B will be negative). For each row in the table, **a)** indicate whether the electric potential at the origin *increases*, *decreases*, or *remains the same*. (Assume the electric potential is zero far from the charges.) **b)** Draw an arrow in the last column of each row that shows the direction of the electric field at the origin after the modification.



		Electric Potential at *P*	**Electric Field Direction** at *P*
1	Change the sign of charge A		
2	Change the sign of charge B		
3	Change the sign of charge C		
4	Change the signs of charges B and D		
5	Exchange charges A and D		

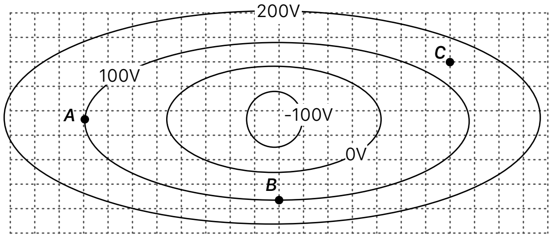
SECTION 2 • SHORT ANSWER

Answer the question in the space provided.



3. The graph shows the electric field as a function of position in a particular region of space. If the electric potential is 25V at $x = 1$ m what is the electric potential at $x = 6$ m? Explain your reasoning. (8 points)

Continued on back ☞



10 cm grid spacing

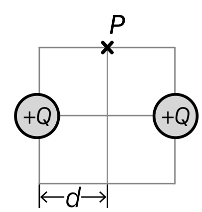
4. The figure to the left shows a series of equipotential curves.
   a) Is the electric field strength at point A larger than, smaller than, or equal to the field strength at point B? Explain. (3 points)
   b) From the information on the figure, estimate the electric field $\vec{E}$ at point C. (8 points)

5. A circuit contains seven resistors and a battery. The chart below gives the currents in each element, the potential difference across each element, and the resistance values of the resistors. **In the space below, draw an electric circuit that is consistent with the values of this chart. Label the resistors.** (12 points)

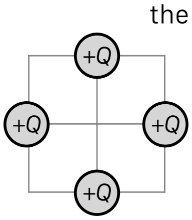
	ΔV	***I***	***R***
Battery	*64.0 V*	*12.0 A*	
R_1	*20.0 V*	*5.0 A*	*4.0 Ω*
R_2	*20.0 V*	*2.0 A*	*10.0 Ω*
R_3	*20.0 V*	*5.0 A*	*4.0 Ω*
R_4	*24.0 V*	*12.0 A*	*2.0 Ω*
R_5	*8.0 V*	*4.0 A*	*2.0 Ω*
R_6	*8.0 V*	*8.0 A*	*1.0 Ω*
R_7	*12.0 V*	*12.0 A*	*1.0 Ω*

SECTION 3 • CALCULATIONS

Answer on a separate sheet of paper.

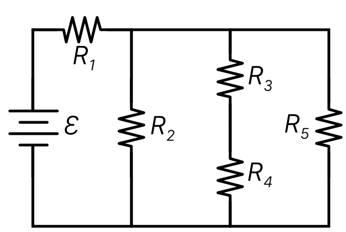


6. Two identical charged spheres, each with positive charge $+Q$ and mass m are positioned a distance $2d$ apart as shown in the figure to the right. (20 points)
   a) Determine an expression for the the **electric field** at the point P located a distance d above the midpoint of the two charges.
   b) Determine an expression for the value of the **electric potential** at point P? Assume that the value of the potential is zero when infinitely far from the charges.



   c) An additional identical charged sphere is held at point P and a forth identical sphere is positioned symmetrically below the centerpoint as shown in the figure to the left. Each of the four spheres a mass m and a net charge $+Q$. If all four spheres are released simultaneously and allowed to move away from each other, determine an expression for the the **speed of each sphere when they are very far apart.**

7. Four of the five resistance values for the circuit to the right are given in the table, as is the battery voltage and the current in resistor R_3. **On a seperate sheet, reproduce the table with the calculated value of R_1 and the currents in and voltages across all elements.** (22 points)



	ΔV	***I***	***R***
$\mathcal{E}$	*72.0 V*		
R_1			
R_2			*2.0 Ω*
R_3		*4.0 A*	*5.0 Ω*
R_4			*1.0 Ω*
R_5			*3.0 Ω*

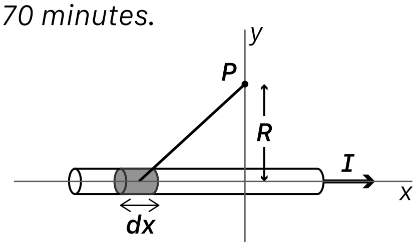
NAME: ______________________________

PHYSICS 133 FINAL EXAM • CAL POLY • FALL 2018 • DR. CULBREATH

No calculators. No notes. Use only the provided paper and equation sheet. 170 minutes.

SECTION 1 • MULTIPLE CHOICE

Choose the best answer from the provided choices (5 points each)



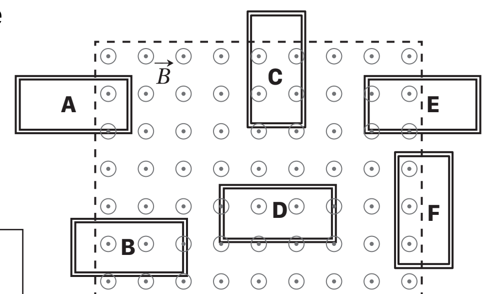
1. Shown to the right, a very long wire is positioned along the x-axis. The appropriate integral to determine the magnetic field at point P a distance R from the wire is

❒ $\vec{B} = \frac{\mu_0 I}{4\pi}\int_{-\infty}^{\infty}\frac{x\,dx}{(R^2+x^2)^{3/2}}\hat{k}$ ❒ $\vec{B} = \frac{\mu_0 I}{4\pi}\int_{-\infty}^{\infty}\frac{dx}{R^2+x^2}\hat{k}$ ❒ $\vec{B} = \frac{\mu_0 I}{4\pi}\int_{-\infty}^{\infty}\frac{R\,dx}{(R^2+x^2)^{3/2}}\hat{k}$

❒ $\vec{B} = \frac{\mu_0 I}{4\pi}\int_{-\infty}^{\infty}\frac{x\,dx}{(R^2+x^2)^{3/2}}(-\hat{k})$ ❒ $\vec{B} = \frac{\mu_0 I}{4\pi}\int_{-\infty}^{\infty}\frac{dx}{R^2+x^2}(-\hat{k})$ ❒ $\vec{B} = \frac{\mu_0 I}{4\pi}\int_{-\infty}^{\infty}\frac{R\,dx}{(R^2+x^2)^{3/2}}(-\hat{k})$

2. A 50-cm wire placed in an east-west direction is moved horizontally to the north with a speed of 2.0 m/s. The horizontal component of the earth's magnetic field at that location is 25 µT toward the north and the vertical component is 50µT downward. What is the emf induced between the ends of the wire?

❒ 10 µV ❒ 20 µV ❒ 30 µV ❒ 40 µV ❒ 50 µV



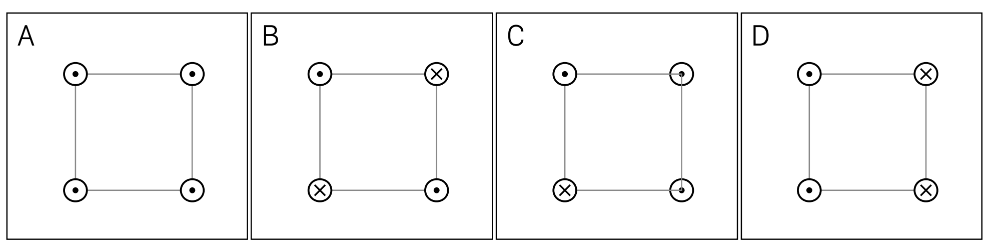
3. Six identical rectangular wire loops are moving to the right at the same constant speed. There is a uniform magnetic field coming out of the page in the region enclosed by the dashed line. The rectangular loops are all 5 cm by 10 cm. Rank the magnitude of the induced current in the rectangular loops at the instant shown. Assume there is no effect or interaction between the loops. (10 points)

						OR		
1 Greatest	2	3	4	5	6 Least		All the same	All zero

SECTION 2 • SHORT ANSWER

Answer the question in the space provided. (15 points each)

4. Current-carrying wires are positioned at the corners of a square. All of the currents have the same magnitude, but some are into the page and some are out of the page.



Rank the magnitude of the net magnetic field at the center of the square.

Explain your reasoning.

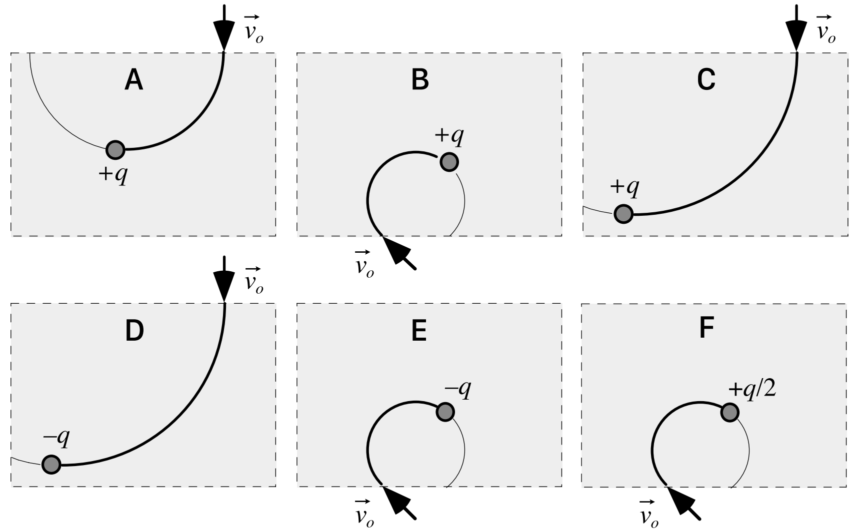
				OR		
1 Greatest	2	3	4 Least		All the same	All zero

Continued on back

5. In each case, the shaded region contains a uniform magnetic field that may point either into the page or out of the page. A charged particle moves through the region along the path indicated. All of the charged particles have the same mass and enter the region with the same initial speed.

Rank the magnetic field in the region. Fields directed out of the page (considered positive) are ranked higher than fields directed into the page (considered negative).

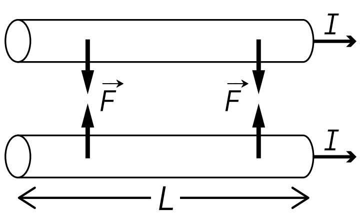
Explain your reasoning.



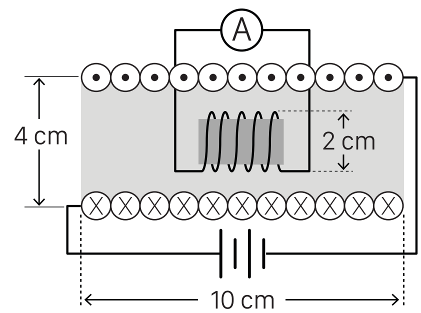
						OR		
1 Greatest	2	3	4	5	6 Least		All the same	All zero

SECTION 3 • CALCULATIONS

Answer on a separate sheet of paper. (25 points each)



6. Two parallel wires carrying current in the same direction are found to attract each other, as shown to the left
a) Our basic model is that magnetism is an interaction between moving charges. Give a step-by-step explanation, making explicit reference to the presence and properties of moving charges, of *how* the wires attract each other. Your explanation should consist of sentences and pictures, but no equations.
b) Suppose the wires have a linear mass density μ of 2.0 g/m and carry equal, parallel currents. The upper wire is fixed in position. What value of the current will allow the lower wire to "float" 1.0 cm below the upper wire? *(Linear mass density is mass per unit length, $m = \mu L$. For example, a wire with a length of 0.5 m and μ = 2.0 g/m would have a total mass of 1 gram)*



7. As shown to the right, an outer coil of wire is 10 cm long, 4.0 cm in diameter, with 200 turns of wire and has a total resistance of 2.0 Ω. It is attached to a battery, as shown, that steadily increases in voltage from 0 V to 12 V in 0.25 s. The inner coil has a length of 1.0 cm, is 2.0 cm in diameter has 20 turns of wire and has a total resistance of 0.020 Ω. It is connected, as shown, to a current meter Ⓐ
a) As the voltage to the outer coil begins to increase, in which direction (left-to-right or right-to-left) does current flow through the meter? Explain.
b) Determine an expression for the magnitude of the current through the meter

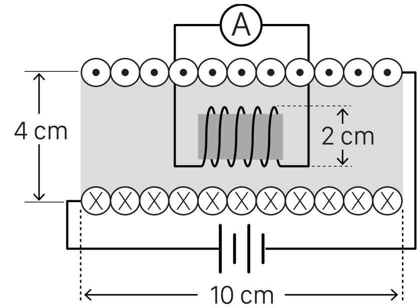
NAME: ______________________________

PHYSICS 133 FINAL EXAM • CAL POLY • FALL 2017 • DR. CULBREATH

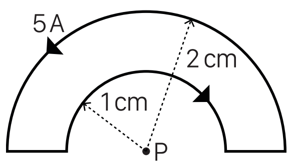
No Calculators. One page of hand-written notes and equation sheet allowed. 170 minutes.

CHOOSE EIGHT (8) PROBLEMS

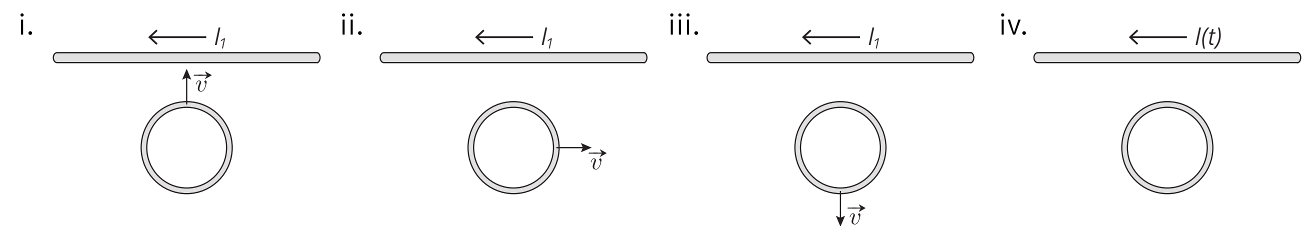
Choose nine of the calculations below and solve on a separate sheet of paper (unless indicated otherwise). Clearly indicate the problems you would like graded by checking no more than eight boxes.



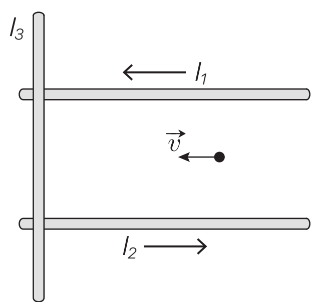
1. As shown to the right, an outer coil of wire is 10 cm long, 4.0 cm in diameter, with 200 turns of wire and has a total resistance of 2.0 Ω. It is attached to a battery, as shown, that steadily increases in voltage from 0 V to 12 V in 0.25 s, then remains at 12 V for t > 0.25 s. The inner coil of wire is 1.0 cm long, 2.0 cm in diameter, has 20 turns of wire, and has a total resistance of 0.020 Ω. It is connected, as shown, to a current meter Ⓐ
   a) As the voltage to the outer coil begins to increase, in which direction (left-to-right or right-to-left) does current flow through the meter? Explain.
   b) Determine an expression for the magnitude of the current through the meter ❐ Grade this problem



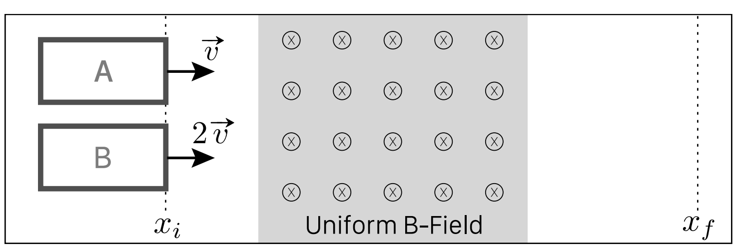
2. Using the Biot-Savart Law determine an expression for the strength and direction of the magnetic field at point *P* as shown in the figure to the left.
   ❐ Grade this problem



3. A long wire carries current I_1 to the left as shown in the figures below. ❐ Grade this problem
   a) For figures i, ii, iii, determine the direction of the induced current.
   b) In figure iv, the current varies as a function of time. Consider three scenarios for $I(t)$ (units omitted):
   $I_1(t) = (3.0)\cos(4t)$ $I_2(t) = (3.0t^2 - 5.0t)$ $I_3(t) = (1.5)e^{-2t}$
   Does $I_1(t)$, $I_2(t)$ or $I_3(t)$ produce the largest induced emf in the ring at t=0? Explain.



4. Two long wire carry equal currents I_1 to the left and I_2 to the right as shown in the figure. A positively charged particle travels to the left with velocity $\vec{v}$. At the instant shown in the figure, the net magnetic force due to all three wires is 0. A third wire carries current I_3, and is positioned perpendicular to the first two wires, in the same plane. **a)** Determine the direction of the current I_3
   b) A short time later, what is the direction of the force on the particle?
   ❐ Grade this problem



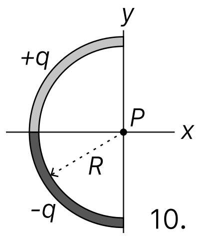
5. The two wire loops A and B shown to the right travel with speed *v* and 2*v*, respectively. They move into a region of uniform magnetic field directed into the page. Plot the current in each loop versus time as it moves from x_i to x_f. Specific values of *I* and *t* are not important, but the shape of the plots and the scale of the plots relative to each other are. ❐ Grade this problem

Continued on back

6. Use Gauss' Law to calculate the electric field **a)** inside and **b)** outside of a sphere of radius R with charge Q distributed uniformly throughout its volume. ❒ Grade this problem

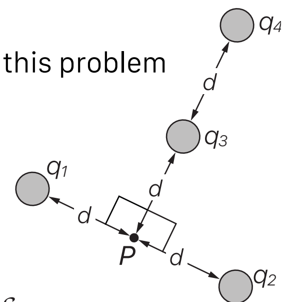
7. A parallel-plate capacitor consisting of two 2.0 cm × 2.0 cm square plates is connected to a battery with emf $\mathscr{E}$. There is a vacuum between the plates. An electron released from rest at the surface of the negative plate crosses the capacitor and strikes the positive plate with a speed of $v_1 = 2.0\times10^6$ m/s. **a)** What is the emf of the battery? **b)** Can you determine the electric field inside the capacitor? If so, what is it? If not, why not? ❒ Grade this problem

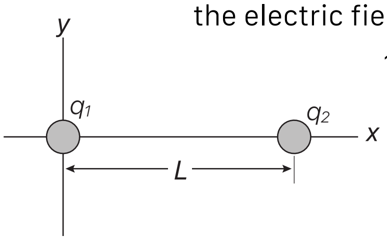
8. Two conducting spheres are far apart. The smaller sphere carries a total charge of Q. The larger sphere has a radius that is twice that of the smaller and is initially neutral. After the two spheres are connected by a conducting wire, what fraction of Q is on each sphere? ❒ Grade this problem



9. As shown to the left, a thin glass rod forms a semicircle of radius R. Charge is uniformly distributed along the rod, with +q on the upper half, and -q on the lower half. Determine an expression for the electric field $\vec{E}$ produced at point P.
❒ Grade this problem

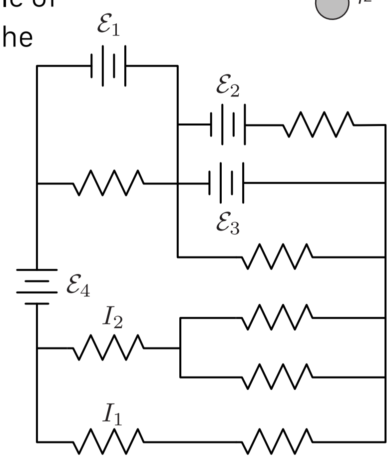
10. In the figure to the right, the four particles are fixed in place and have charges $q_1 = q_2 = +5e$, $q_3 = +3e$ and $q_4 = -12e$. d = 5µm. Establish a coordinate system and determine and expression for the electric field $\vec{E}$ at point P. ❒ Grade this problem



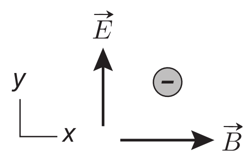


11. In the figure to the left, particles of charge $q_1 = -5.0q$ and $q_2 = +2q$ are fixed on an x-axis. As a multiple of the distance L, what coordinate on the axis is the net electric field of the particles zero?
❒ Grade this problem

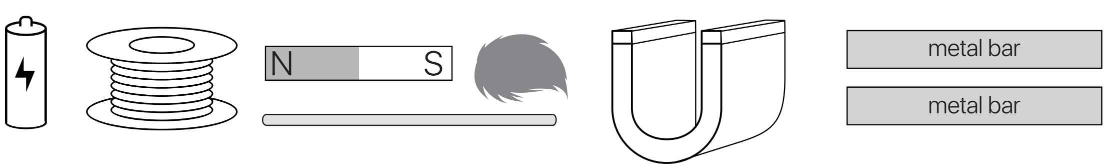
12. In the figure to the right, the ideal batteries have emfs $\mathscr{E}_1 = 20.0$V, $\mathscr{E}_2 = 10.0$V, $\mathscr{E}_3 = 5.0$V, and $\mathscr{E}_4 = 5.0$V, and the resistances are each 2.0Ω. **a)** What is the value and direction of the current I_1 and I_2? **b)** Draw a separate diagram illustrating how you would (in the lab) correctly connect an ammeter to measure the current I_1 and how you would connect a voltmeter to measure the voltage drop of the resistor labeled I_2. Make sure your diagram clearly shows both meters wired correctly. ❒ Grade this problem



13. An electron sits in a region of space with a uniform magnetic field that everywhere points in the +x-direction, and a uniform electric field that points everywhere in the +y-direction. Assume the strengths of the fields are such that any force exerted on the electron by either is of comparable magnitude. Sketch and/or describe with words the trajectory of the electron if it is **a)** initially at rest **b)** moving to the right (+x direction) with constant speed **c)** moving upwards (+y direction) with constant speed ❒ Grade this problem



14. Using only the materials below: a battery, a spool of wire (wire cutters and attachment clips), a bar magnet, a plastic rod, fur cloth, and a large bench horseshoe magnet, describe *three* distinct ways you can produce equal and opposite charges on two metal bars. **Extra Credit:** Describe a *forth* way to induce equal and opposite charge.



❒ Grade this problem

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Name: ______________________________

PHYSICS 133 LAB QUIZ GROUP QUIZ WEEK 1 - ELECTROSTATICS

Work with your lab group to complete the problems below. Unless indicated, submit one solution to each problem that the group agrees is correct. You may consult your notes, the textbook or your instructor for help.

||| Suppose the magnitude of the proton charge differs from the magnitude of the electron charge by a mere 1 part in 10^9.

a. What would be the force between two 2.0-mm-diameter copper spheres 1.0 cm apart? Assume that each copper atom has an equal number of electrons and protons.

b. Would this amount of force be detectable? What can you conclude from the fact that no such forces are observed?

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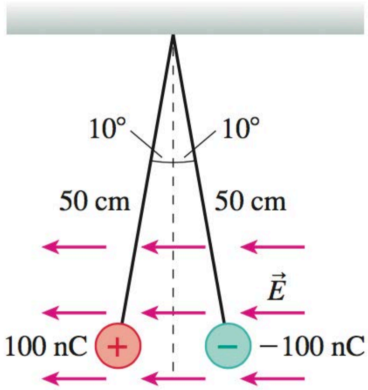
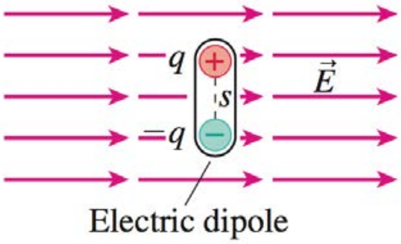
PHYSICS 133 LAB QUIZ GROUP QUIZ WEEK 2 - ELECTRIC FIELD

Work with your lab group to complete the problems below. Unless indicated, submit one solution to each problem that the group agrees is correct. You may consult your notes, the textbook or your instructor for help.

1. The identical small spheres shown in **FIGURE CP25.74** are charged to $+100$ nC and -100 nC. They hang as shown in a 100,000 N/C electric field. What is the mass of each sphere?



2. || An electric dipole consists of two opposite charges $\pm q$ separated by a small distance s. The product $p = qs$ is called the *dipole moment*. **FIGURE P25.56** shows an electric dipole perpendicular to an electric field $\vec{E}$. Find an expression in terms of p and E for the magnitude of the torque that the electric field exerts on the dipole.



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PHYSICS 133 LAB QUIZ GROUP QUIZ WEEK 3 - ELECTRIC FIELD

Work with your lab group to complete the problems below. Unless indicated, submit one solution to each problem that the group agrees is correct. You may consult your notes, the textbook or your instructor for help.

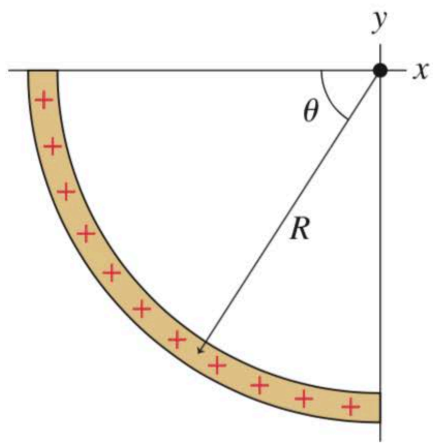

FIGURE P26.45

|| A plastic rod with linear charge density λ is bent into the quarter circle shown in **FIGURE P26.45**. We want to find the electric field at the origin.

a. Write expressions for the x- and y-components of the electric field at the origin due to a small piece of charge at angle θ.

b. Write, but do not evaluate, definite integrals for the x- and y-components of the net electric field at the origin.

c. Evaluate the integrals and write $\vec{E}_{\text{net}}$ in component form.

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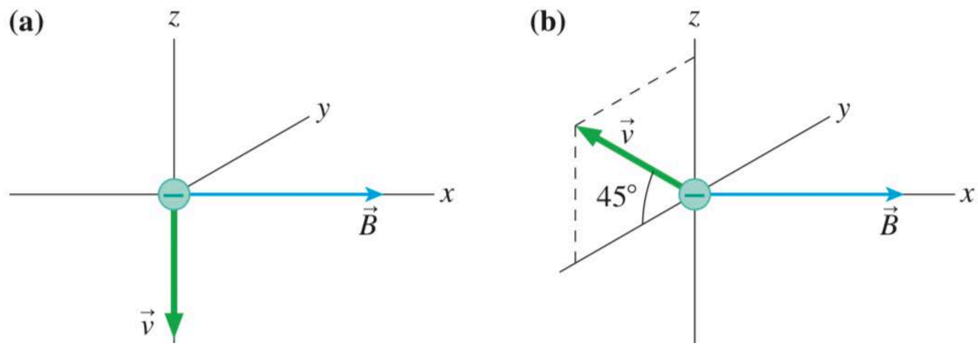
Name: ______________________________

PHYSICS 133 LAB QUIZ GROUP QUIZ WEEK 8 - MAGNETIC FORCES

Work with your lab group to complete the problems below. Unless indicated, submit one solution to each problem that the group agrees is correct. You may consult your notes, the textbook or your instructor for help.

1. || An electron moves in the magnetic field $\vec{B} = 0.50\,\hat{\imath}$ T with a speed of 1.0×10^7 m/s in the directions shown in **FIGURE EX32.27**. For each, what is magnetic force $\vec{F}$ on the electron? Give your answers in component form.



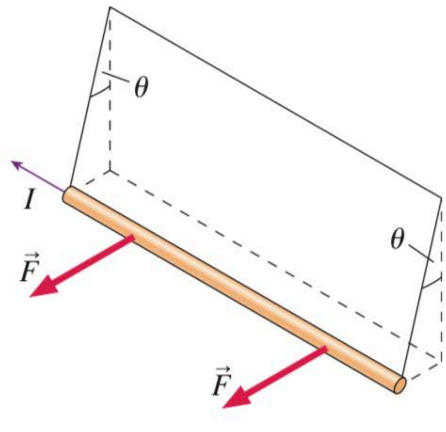


FIGURE P32.71

2. || a. In **FIGURE P32.71**, a long, straight, current-carrying wire of linear mass density μ is suspended by threads. A magnetic field perpendicular to the wire exerts a horizontal force that deflects the wire to an equilibrium angle θ. Find an expression for the strength and direction of the magnetic field $\vec{B}$.

   b. What $\vec{B}$ deflects a 55 g/m wire to a 12° angle when the current is 10 A?

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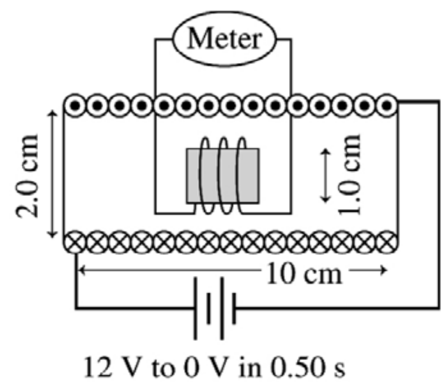
PHYSICS 133 LAB QUIZ GROUP QUIZ WEEK 10 - FARADAY'S LAW

Work with your lab group to complete the problems below. Unless indicated, submit one solution to each problem that the group agrees is correct. You may consult your notes, the textbook or your instructor for help.



1. The outer coil of wire is 10 cm long, 2.0 cm in diameter, wrapped tightly with one layer of 0.50-mm-diameter wire, and has a total resistance of 1.0 Ω. It is attached to a battery, as shown, that steadily decreases in voltage from 12 V to 0 V in 0.50 s, then remains at 0 V for t > 0.5 s. The inner coil of wire is 1.0 cm long, 1.0 cm in diameter, has 10 turns of wire, and has a total resistance of 0.010 Ω. It is connected, as shown, to a current meter.

   a. As the voltage to the outer coil begins to decrease, in which direction (left-to-right or right-to-left) does current flow through the meter? Explain.

   b. Draw a graph showing the current in the inner coil as a function of time for $0 \le t \le 1$ s. Include a numerical scale on the vertical axis.

PHYSICS 133

Midterm 1 Equation Sheet

ELECTROSTATICS

$$F_{\text{point}} = \frac{K|q_1||q_2|}{r^2} \qquad \lambda = \frac{Q}{L} \qquad E_{\text{plane}} = \frac{\eta}{2\varepsilon_0}$$

$$K = \frac{1}{4\pi\varepsilon_0} \qquad \eta = \frac{Q}{A} \qquad (E_{\text{disk}})_z = \frac{\eta}{2\varepsilon_0}\left[1 - \frac{z}{\sqrt{z^2+R^2}}\right]$$

$$\vec{E} = \frac{\vec{F}_{\text{on q}}}{q} \qquad \rho = \frac{Q}{V} \qquad \vec{p} = (qs, \text{from - to +})$$

$$\vec{E}_{\text{point}} = \frac{Kq}{r^2}\hat{r} \qquad |\vec{\tau}_{\text{dipole}}| = |\vec{p} \times \vec{E}| = pE\sin\theta$$

$$\vec{E}_{\text{net}} = \sum \vec{E}_i \qquad \Phi_e = \vec{E}\cdot\vec{A} \qquad \vec{E}_{\text{dipole bisecting plane}} = -\frac{K\,\vec{p}}{r^3}$$

$$dE_{\text{point}} = \frac{K\,dq}{r^2} \qquad \Phi_e = \oint \vec{E}\cdot d\vec{A} = \frac{Q_{\text{in}}}{\varepsilon_0} \qquad \vec{E}_{\text{dipole axis}} = \frac{K\,2\vec{p}}{r^3}$$

KINEMATICS

$$s = \tfrac{1}{2}a_s\Delta t^2 + v_{0s}\Delta t + s_0 \qquad v_s = \frac{ds}{dt}$$

$$v_s = v_{0s} + a_s\Delta t$$

$$v_s^2 = v_{0s}^2 + 2a_s\Delta s \qquad a_s = \frac{dv_s}{dt}$$

DYNAMICS

$$\Sigma\vec{F} = m\vec{a}$$

$$\vec{F}_{A\,\text{on}\,B} = -\vec{F}_{B\,\text{on}\,A}$$

$$\vec{F}_{\text{spring}} = -k\vec{x}$$

$$f_s \le \mu_s n \qquad f_k = \mu_k n$$

CIRCULAR MOTION

$$s = \theta r$$

$$v_t = \omega r \qquad \omega = \frac{d\theta}{dt} \qquad \alpha = \frac{d\omega}{dt}$$

$$a_t = \alpha r$$

$$a_r = a_{\text{centrip}} = \frac{v^2}{r} = r\omega^2$$

CONSERVATION LAWS

$$W_{\text{ext}} = \Delta K + \Delta U + \Delta E_{\text{th}} \qquad K_{\text{trans}} = \frac{1}{2}mv^2 \qquad K_{\text{rot}} = \frac{1}{2}I\omega^2 \qquad \vec{p} = m\vec{v} \qquad \vec{p}_i = \vec{p}_f \qquad \vec{J} = \Delta\vec{p}$$

$$\Delta E_{\text{th}} = f_k d \qquad U_g(y) = mgy \qquad U_s(x) = \frac{1}{2}kx^2 \qquad W = \int_{x_1}^{x_2} F_x(x)dx \qquad \vec{J} = \int_{t_1}^{t_2}\vec{F}(t)dt = F_{\text{avg}}\Delta t$$

ROTATION OF A RIGID BODY

$$\tau = rF\sin\phi = rF_\perp = r_\perp F \qquad \vec{\tau}_{\text{net}} = I\vec{\alpha} \qquad \vec{\ell} = \vec{r}\times\vec{p} = m(\vec{r}\times\vec{v}) \qquad \ell = I\omega \qquad \vec{\ell}_i = \vec{\ell}_f$$

$$I_{\text{point}} = \sum_i^N m_i r_i^2 \qquad I_{\text{sphere}} = \tfrac{2}{5}MR^2 \qquad I_{\text{pipe}} = \tfrac{1}{2}MR_1^2 + R_2^2 \qquad I_{\text{log or disk}} = \tfrac{1}{2}MR^2 \qquad I_{\text{hoop}} = MR^2$$

$$I_{\text{baton}} = \tfrac{1}{12}ML^2 \qquad I_{\parallel} = I_{\text{com}} + Md^2$$

CONSTANTS

$K = 8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$

$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2$

$e = 1.60 \times 10^{-19}\ \text{C}$

$m_p = 1.67 \times 10^{-27}\ \text{kg}$

$m_e = 9.11 \times 10^{-31}\ \text{kg}$

$g = 9.81\ \text{m/s}^2$

$N_A = 6.02 \times 10^{23}$ particles/mol

INTEGRALS

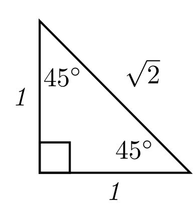
$$\int \frac{x\,dx}{(x^2 \pm a^2)^{3/2}} = -\frac{1}{\sqrt{x^2 \pm a^2}}$$

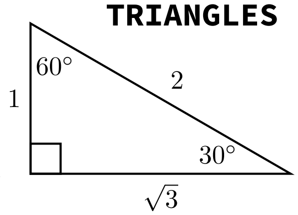
$$\int \frac{dx}{(x^2 \pm a^2)^{3/2}} = \frac{\pm x}{a^2\sqrt{x^2 \pm a^2}}$$

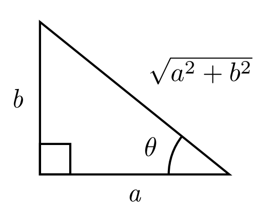
$$\int \frac{dx}{\sqrt{x^2 \pm a^2}} = \ln\left(x + \sqrt{x^2 \pm a^2}\right)$$

$$\int \frac{dx}{x^2 + a^2} = \frac{1}{a}\tan^{-1}\left(\frac{x}{a}\right)$$

TRIANGLES







$\tan\theta = \frac{b}{a}$

PHYSICS 133

Midterm 2 Equation Sheet

ELECTROSTATICS

$F_{\text{point}} = \frac{K|q_1||q_2|}{r^2}$ $\quad \vec{E} = \frac{\vec{F}_{\text{on q}}}{q}$ $\quad \vec{E}_{\text{point}} = \frac{Kq}{r^2}\hat{r}$ $\quad K = \frac{1}{4\pi\varepsilon_0}$ $\quad \lambda = \frac{Q}{L}$ $\quad \eta = \frac{Q}{A}$ $\quad \rho = \frac{Q}{V}$

$\Phi_e = \vec{E}\cdot\vec{A}$ $\quad \Phi_e = \oint \vec{E}\cdot d\vec{A} = \frac{Q}{\varepsilon_0}$ $\quad E_{\text{plane}} = \frac{\eta}{2\varepsilon_0}$ $\quad (E_{\text{disk}})_z = \frac{\eta}{2\varepsilon_0}\left[1 - \frac{z}{\sqrt{z^2+R^2}}\right]$

$\vec{p} = (qs,\ \ominus \text{ to } \oplus)$ $\quad \vec{E}_{\text{dipole axis}} = -\frac{K2\vec{p}}{r^3}$ $\quad \vec{E}_{\text{dipole bs plane}} = -\frac{K\vec{p}}{r^3}$ $\quad |\vec{\tau}| = |\vec{p}\times E| = pE\sin\theta$

$U_{q_1+q_2} = \frac{Kq_1q_2}{r}$ $\quad \Delta U = -W_{(i\to f)} = -\int_i^f \vec{F}\cdot d\vec{s}$ $\quad U_{\text{dipole}} = -\vec{p}\cdot\vec{E}$ $\quad U = qV$

$V_{\text{point}} = \frac{Kq}{r}$ $\quad \Delta V = -\int_i^f \vec{E}\cdot d\vec{s} = -\int_{s_i}^{s_f} E_s ds$ $\quad \vec{E} = -\nabla V$ $\quad E_s = -\frac{dV}{ds} \approx -\frac{\Delta V}{\Delta s}$

CIRCUITS

$\Delta V = IR$ $\quad \Delta V_{\text{loop}} = \sum(\Delta V_i) = 0$ $\quad \sum I_{\text{in}} = \sum I_{\text{out}}$ $\quad R = \frac{\rho L}{A}$ $\quad Q = I\Delta t$ $\quad J = \frac{I}{A}$

$P_{\text{bat}} = I\mathcal{E}$ $\quad P_{\text{R}} = \Delta V_R I$ $\quad C = \frac{Q}{\Delta V_C}$ $\quad C_{\text{plate}} = \frac{\varepsilon_0 A}{d}$ $\quad E_{\text{cap}} = \frac{\Delta V_c}{d}$

KINEMATICS

$s = \frac{1}{2}a_s\Delta t^2 + v_{0s}\Delta t + s_0$

$v_s = v_{0s} + a_s\Delta t$ $\quad v_s = \frac{ds}{dt}$

$v_s^2 = v_{0s}^2 + 2a_s\Delta s$ $\quad a_s = \frac{dv_s}{dt}$

DYNAMICS

$\Sigma\vec{F} = m\vec{a}$

$\vec{F}_{A\,\text{on}\,B} = -\vec{F}_{B\,\text{on}\,A}$ $\quad f_s \le \mu_s n$

$\vec{F}_{\text{spring}} = -k\vec{x}$ $\quad f_k = \mu_k n$

CIRCULAR MOTION

$s = \theta r$ $\quad \omega = \frac{d\theta}{dt}$ $\quad \alpha = \frac{d\omega}{dt}$

$v_t = \omega r$ $\quad a_t = \alpha r$

$a_r = a_{\text{centrip}} = \frac{v^2}{r} = r\omega^2$

CONSERVATION LAWS

$W_{\text{ext}} = \Delta K + \Delta U + \Delta E_{\text{th}}$ $\quad K_{\text{trans}} = \frac{1}{2}mv^2$ $\quad K_{\text{rot}} = \frac{1}{2}I\omega^2$ $\quad \vec{p} = m\vec{v}$ $\quad \vec{p}_i = \vec{p}_f$ $\quad \vec{J} = \Delta\vec{p}$

$\Delta E_{\text{th}} = f_k d$ $\quad U_g(y) = mgy$ $\quad U_s(x) = \frac{1}{2}kx^2$ $\quad W = \int_{x_1}^{x_2} F_x(x)dx$ $\quad \vec{J} = \int_{t_1}^{t_2}\vec{F}(t)dt = F_{\text{avg}}\Delta t$

ROTATION OF A RIGID BODY

$\vec{\ell} = \vec{r}\times\vec{p} = m(\vec{r}\times\vec{v})$ $\quad \ell = I\omega$ $\quad \vec{\ell}_i = \vec{\ell}_f$

$\tau = rF\sin\phi = rF_\perp = r_\perp F$ $\quad \vec{\tau}_{\text{net}} = I\vec{\alpha}$ $\quad I_{\parallel} = I_{\text{com}} + Md^2$ $\quad I_{\text{point}} = \sum m_i r_i^2$

$I_{\text{baton}} = \frac{1}{12}ML^2$ $\quad I_{\text{sphere}} = \frac{2}{5}MR^2$ $\quad I_{\text{pipe}} = \frac{1}{2}MR_1^2 + R_2^2$ $\quad I_{\text{log or disk}} = \frac{1}{2}MR^2$ $\quad I_{\text{hoop}} = MR^2$

CONSTANTS

$K = 8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$

$\varepsilon_0 = 8.85\times10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2$

$e = 1.60\times10^{-19}\ \text{C}$

$m_p = 1.67\times10^{-27}\ \text{kg}$

$m_e = 9.11\times10^{-31}\ \text{kg}$

$g = 9.81\ \text{m/s}^2$

$N_A = 6.02\times10^{23}$ particles/mol

INTEGRALS

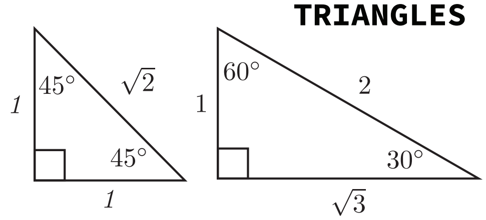
$$\int \frac{xdx}{(x^2\pm a^2)^{3/2}} = -\frac{1}{\sqrt{x^2\pm a^2}}$$

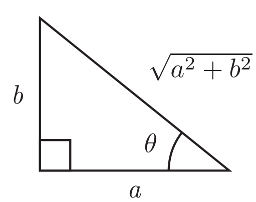
$$\int \frac{dx}{(x^2\pm a^2)^{3/2}} = \frac{\pm x}{a^2\sqrt{x^2\pm a^2}}$$

$$\int \frac{dx}{\sqrt{x^2\pm a^2}} = \ln\left(x+\sqrt{x^2\pm a^2}\right)$$

$$\int \frac{dx}{x^2+a^2} = \frac{1}{a}\tan^{-1}\left(\frac{x}{a}\right)$$

TRIANGLES





$\tan\theta = \frac{b}{a}$

PHYSICS 133

Midterm 3 Equation Sheet

ELECTROSTATICS

$F_{\text{point}} = \frac{K|q_1||q_2|}{r^2}$ $\quad \vec{E} = \frac{\vec{F}_{\text{on q}}}{q}$ $\quad \vec{E}_{\text{point}} = \frac{Kq}{r^2}\hat{r}$ $\quad K = \frac{1}{4\pi\varepsilon_0}$ $\quad \lambda = \frac{Q}{L}$ $\quad \eta = \frac{Q}{A}$ $\quad \rho = \frac{Q}{V}$

$\Phi_e = \vec{E}\cdot\vec{A}$ $\quad \Phi_e = \oint \vec{E}\cdot d\vec{A} = \frac{Q}{\varepsilon_0}$ $\quad E_{\text{plane}} = \frac{\eta}{2\varepsilon_0}$ $\quad (E_{\text{disk}})_z = \frac{\eta}{2\varepsilon_0}\left[1 - \frac{z}{\sqrt{z^2+R^2}}\right]$

$\vec{p} = (qs,\ \ominus \text{ to } \oplus)$ $\quad \vec{E}_{\text{dipole axis}} = -\frac{K2\vec{p}}{r^3}$ $\quad \vec{E}_{\text{dipole bs plane}} = -\frac{K\vec{p}}{r^3}$ $\quad |\vec{\tau}| = |\vec{p}\times\vec{E}| = pE\sin\theta$

$U_{q_1+q_2} = \frac{Kq_1q_2}{r}$ $\quad \Delta U = -W_{(i\to f)} = -\int_i^f \vec{F}\cdot d\vec{s}$ $\quad U_{\text{dipole}} = -\vec{p}\cdot\vec{E}$ $\quad U = qV$

$V_{\text{point}} = \frac{Kq}{r}$ $\quad \Delta V = -\int_i^f \vec{E}\cdot d\vec{s} = -\int_{s_i}^{s_f} E_s ds$ $\quad \vec{E} = -\nabla V$ $\quad E_s = -\frac{dV}{ds} \approx -\frac{\Delta V}{\Delta s}$

CIRCUITS

$\Delta V = IR$ $\quad \Delta V_{\text{loop}} = \sum(\Delta V_i) = 0$ $\quad \sum I_{\text{in}} = \sum I_{\text{out}}$ $\quad R = \frac{\rho L}{A}$ $\quad Q = I\Delta t$ $\quad J = \frac{I}{A}$

$P_{\text{bat}} = I\mathcal{E}$ $\quad P_{\text{R}} = \Delta V_R I$ $\quad C = \frac{Q}{\Delta V_C}$ $\quad C_{\text{plate}} = \frac{\varepsilon_0 A}{d}$ $\quad E_{\text{cap}} = \frac{\Delta V_c}{d}$

MAGNETOSTATICS

$B_{\text{loop}} = \frac{\mu_0 IR^2}{2(z^2+R^2)^{3/2}}$ $\quad \vec{F}_{\text{on } q} = q\vec{v}\times\vec{B}$ $\quad |\vec{A}\times\vec{B}| = AB\sin\phi$

$\vec{B}_{\text{point}} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}$ $\quad B_{\text{solenoid}} = \frac{\mu_0 NI}{l} = \mu_0 nI$ $\quad \vec{F}_{\text{wire}} = I\vec{l}\times\vec{B}$ $\quad \mathcal{E}_{\text{motional}} = vLB$

$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{s}\times\hat{r}}{r^2}$ $\quad \vec{B}_{\text{dipole}} = \frac{\mu_0 2\vec{\mu}}{4\pi z^3}$ $\quad \vec{\tau} = \vec{\mu}\times\vec{B}$ $\quad \Phi_m = \vec{A}\cdot\vec{B} = AB\cos\phi$

$B_{\text{wire}} = \frac{\mu_0 I}{2\pi d}$ $\quad \vec{\mu} = (IA,\ \text{Ⓢ to Ⓝ})$ $\quad \mathcal{E} = \left|\frac{d\Phi_m}{dt}\right| = \left|\vec{B}\cdot\frac{d\vec{A}}{dt} + \vec{A}\cdot\frac{d\vec{B}}{dt}\right|$

KINEMATICS

$s = \frac{1}{2}a_s\Delta t^2 + v_{0s}\Delta t + s_0$

$v_s = v_{0s} + a_s\Delta t$ $\quad v_s = \frac{ds}{dt}$

$v_s^2 = v_{0s}^2 + 2a_s\Delta s$ $\quad a_s = \frac{dv_s}{dt}$

DYNAMICS

$\Sigma\vec{F} = m\vec{a}$

$\vec{F}_{\text{A on B}} = -\vec{F}_{\text{B on A}}$ $\quad f_s \le \mu_s n$

$\vec{F}_{\text{spring}} = -k\vec{x}$ $\quad f_k = \mu_k n$

CIRCULAR MOTION

$s = \theta r$ $\quad \omega = \frac{d\theta}{dt}$ $\quad \alpha = \frac{d\omega}{dt}$

$v_t = \omega r$ $\quad a_t = \alpha r$

$a_r = a_{\text{centrip}} = \frac{v^2}{r} = r\omega^2$

CONSERVATION LAWS

$W_{\text{ext}} = \Delta K + \Delta U + \Delta E_{\text{th}}$ $\quad K_{\text{trans}} = \frac{1}{2}mv^2$ $\quad K_{\text{rot}} = \frac{1}{2}I\omega^2$ $\quad \vec{p} = m\vec{v}$ $\quad \vec{p}_i = \vec{p}_f$ $\quad \vec{J} = \Delta\vec{p}$

$\Delta E_{\text{th}} = f_k d$ $\quad U_g(y) = mgy$ $\quad U_s(x) = \frac{1}{2}kx^2$ $\quad W = \int_{x_1}^{x_2} F_x(x)dx$ $\quad \vec{J} = \int_{t_1}^{t_2}\vec{F}(t)dt = F_{\text{avg}}\Delta t$

ROTATION OF A RIGID BODY

$\vec{\ell} = \vec{r}\times\vec{p} = m(\vec{r}\times\vec{v})$ $\quad \ell = I\omega$ $\quad \vec{\ell}_i = \vec{\ell}_f$

$\tau = rF\sin\phi = rF_\perp = r_\perp F$ $\quad \vec{\tau}_{\text{net}} = I\vec{\alpha}$ $\quad I_{\|} = I_{\text{com}} + Md^2$ $\quad I_{\text{point}} = \sum m_i r_i^2$

$I_{\text{baton}} = \frac{1}{12}ML^2$ $\quad I_{\text{sphere}} = \frac{2}{5}MR^2$ $\quad I_{\text{pipe}} = \frac{1}{2}MR_1^2 + R_2^2$ $\quad I_{\text{log or disk}} = \frac{1}{2}MR^2$ $\quad I_{\text{hoop}} = MR^2$

CONSTANTS

$K = 8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$

$\varepsilon_0 = 8.85\times10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2$

$e = 1.60\times10^{-19}\text{C}$

$m_p = 1.67\times10^{-27}\ \text{kg}$

$m_e = 9.11\times10^{-31}\ \text{kg}$

$g = 9.81\ \text{m/s}^2$

$N_A = 6.02\times10^{23}$ particles/mole

$\mu_0 = 1.257\times10^{-6}\ \text{T}\cdot\text{m/A}$

INTEGRALS

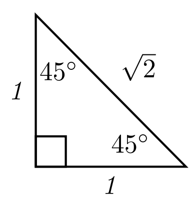
$$\int\frac{xdx}{(x^2\pm a^2)^{3/2}} = -\frac{1}{\sqrt{x^2\pm a^2}}$$

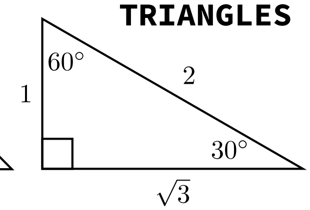
$$\int\frac{dx}{(x^2\pm a^2)^{3/2}} = \frac{\pm x}{a^2\sqrt{x^2\pm a^2}}$$

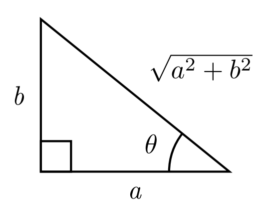
$$\int\frac{dx}{\sqrt{x^2\pm a^2}} = \ln\left(x+\sqrt{x^2\pm a^2}\right)$$

$$\int\frac{dx}{x^2+a^2} = \frac{1}{a}\tan^{-1}\left(\frac{x}{a}\right)$$

TRIANGLES







$\tan\theta = \frac{b}{a}$

Table 4: Physics 132 Supplemental Lecture and Tutorial Videos

Topic	Duration	URL
Introduction to Buoyancy	15:24	youtube.com/watch?v=r4wm-F673tw
Buoyancy example	5:49	youtube.com/watch?v=3Oc-9AnCW1g
Hydraulic example	5:56	youtube.com/watch?v=p3TyVLGXk8s
Hydraulic Lift	9:36	youtube.com/watch?v=-Enbr7zvbes
Introduction to Power and Intensity	12:12	youtube.com/watch?v=Nt2MtQp5Jgo
Doppler Effect Example Problem	5:16	youtube.com/watch?v=G6sfu9PV9nk
Sound Intensity Level (dB)	13:34	youtube.com/watch?v=PndztQ6Olkw
Damped Oscillation Example Problem	6:34	youtube.com/watch?v=8gDO2680-Ys
Doppler Effect Lecture Notes	6:39	youtube.com/watch?v=X5hyjpHLlzY
Interference in One Dimension	9:24	youtube.com/watch?v=bHlJx-rNZlc
Interference in Two Dimensions	10:01	youtube.com/watch?v=2SSj5hxVwrU
Interference in Two Dimensions	10:01	youtube.com/watch?v=2SSj5hxVwrU
Introduction to Exponential Decay	14:58	youtube.com/watch?v=qgTQO2LqxaM
Isobaric Processes	6:37	youtube.com/watch?v=ef4mzQLuMJw

Lecture Slides

I utilize slides as a multimedia accompaniment to my lecture presentation. As a focus of my slides in Physics 133, I've implemented realtime class feedback through analog "clicker" questions. Clicker questions start each lecture and are used when switching topics. I've received overwhelmingly positive student feedback about these multiple choice discussion questions.

I also have produced animations and 3D visualizations of EM fields (Figure 7) using mathematica that are incorporated into my lecture and included in the lecture slide deck.

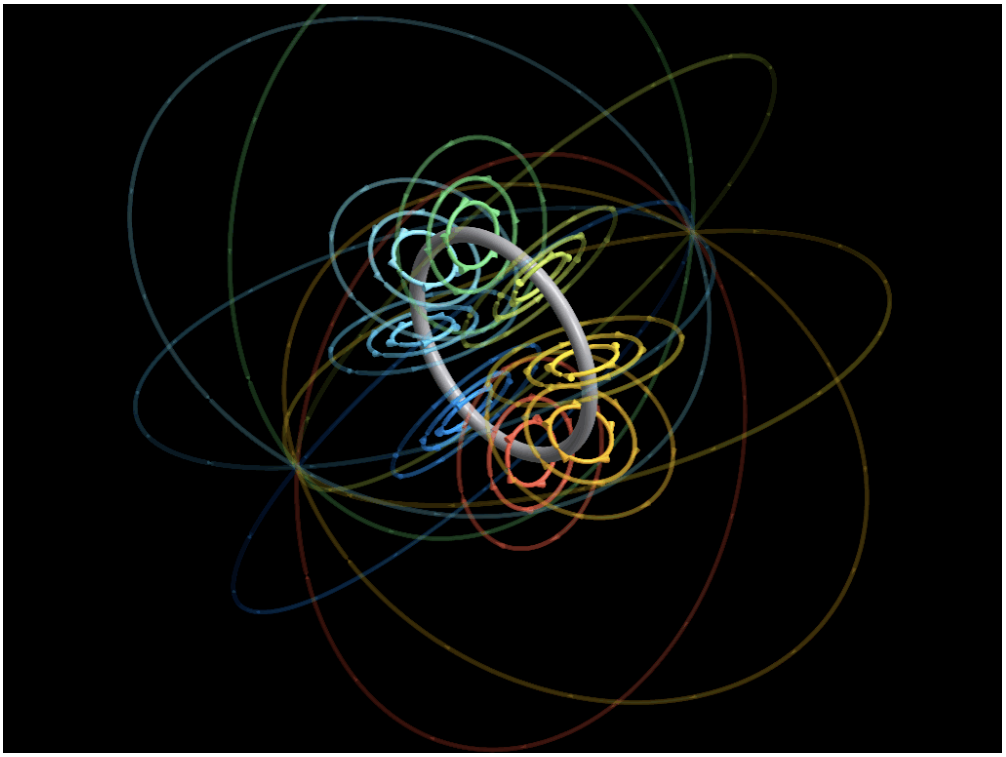


Figure 7: The 3D nature of EM fields make computer animations an excellent tool for illustrating their properties. Here's my attempt at the magnetic field produced by a solenoid.

The a live copy of the complete slide deck is available through a link on my website, and students have cited is an important study resource.

Course Website

The PHYSICS 133 COURSE WEBSITE (`http://physicscloud.net/133`), shown above in figure 8 is the central communication hub for the class. The website provides student access to the course

- Syllabus
- Course Due Dates and Reminders
- Objectives
- Schedule
- Homework assignments
- Instructor-prepared homework solutions
- Equation sheets
- Midterm solutions
- Lab Manual
- Supplemental lecture videos
- Homework solution videos (select problems)

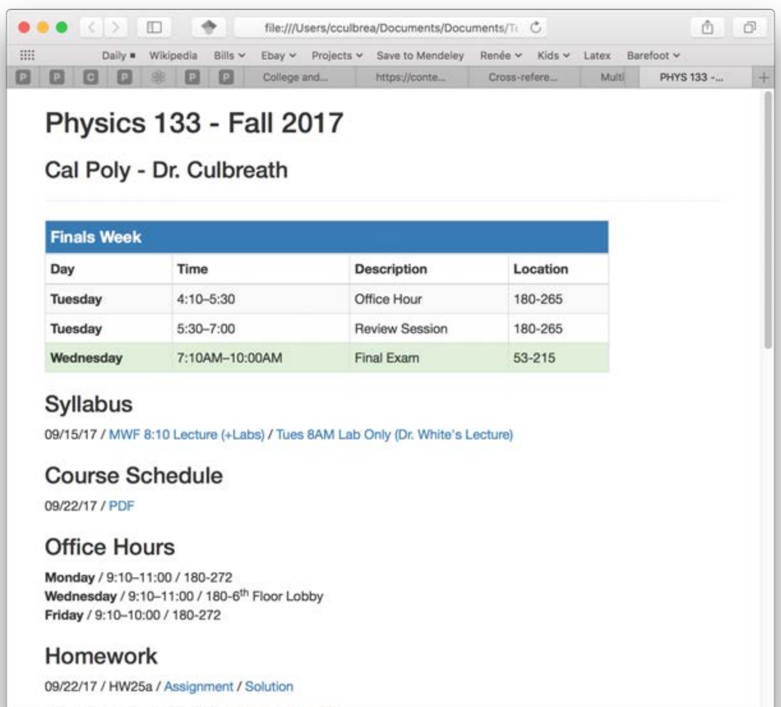
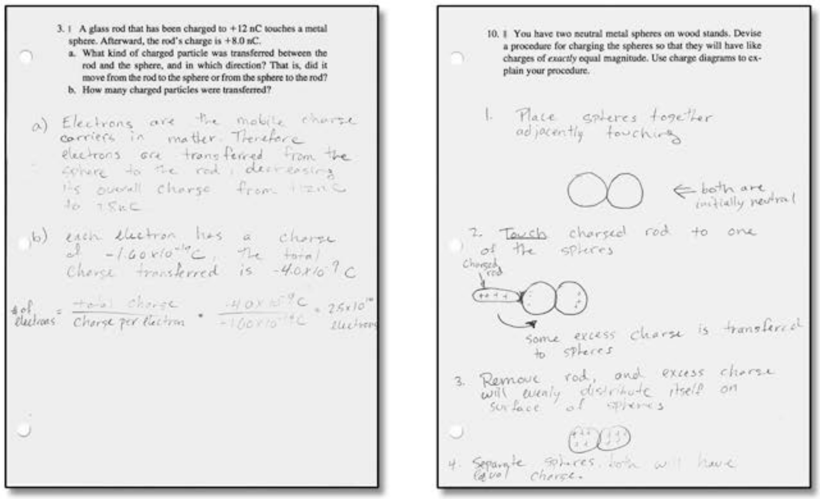


Figure 8: The course website is the central communication hub for the class and is updated several times per week. Visit the site at `http://physicscloud.net/133`

Homework Assignments are posted at least one week before their due date. Homework assignments often include links to one or two homework solution videos (see *Online Videos* on page 213). Changes to the course schedule are relayed by email and updated on the site.

Homework and Exam solutions



3. | A glass rod that has been charged to +12 nC touches a metal sphere. Afterward, the rod's charge is +8.0 nC.
   a. What kind of charged particle was transferred between the rod and the sphere, and in which direction? That is, did it move from the rod to the sphere or from the sphere to the rod?
   b. How many charged particles were transferred?

a) Electrons are the mobile charge carriers in matter. Therefore electrons are transferred from the sphere to the rod, decreasing its overall charge from +12nC to +8nC

b) each electron has a charge of -1.60×10^{-19} C, the total charge transferred is -4.0×10^{-9} C

$$\#\text{ of electrons} = \frac{\text{total charge}}{\text{charge per electron}} = \frac{-4.0\times10^{-9}\,C}{-1.60\times10^{-19}\,C} = 2.5\times10^{10}\text{ electrons}$$

10. | You have two neutral metal spheres on wood stands. Devise a procedure for charging the spheres so that they will have like charges of *exactly* equal magnitude. Use charge diagrams to explain your procedure.

1. Place spheres together adjacently touching

⇐ both are initially neutral

2. Touch charged rod to one of the spheres

Charged rod

some excess charge is transferred to spheres

3. Remove rod, and excess charge will evenly distribute itself on surface of spheres

4. Separate spheres. both will have equal charge.

Figure 9: Instructor prepared homework solutions including explanatory notes and commentary.

Instructor prepared homework solutions including explanatory notes and commentary are posted to the course website the same day that homework is collected, as time allows. The homework solutions detail the step-by-step approach to solving the problem as shown in figure 9. I have completed 30% of the homework solutions for Physics 133, and supplement with the book publisher's solutions as needed. In addition, detailed exam solutions are posted after students receive their graded exams. For exams, I require students to submit corrections which reference the posted solutions and remedy mistakes in their original work.

Online Videos

Overview

The PHYSICS 133 COURSE WEBSITE provides links to my YouTube Channel and content-specific links to videos related to assignments. I produce two types of video content for Physics 133: *Solution Videos* and *Supplemental Lecture Videos.*

Solution Videos

Table 5: Physics 133 Homework Solution Videos

Topic	Duration	URL
Ch 25 #47	7:50	youtube.com/watch?v=dlR7lSEWa3Y
Ch 26 #12	17:48	www.youtube.com/watch?v=Q0haGFlKT8k

PHYSICS 122

Course Syllabus

Spring 2019

INSTRUCTOR: Dr. Christopher Culbreath **MAILBOX**: Physics Department Office (180-204)

OFFICE HOURS: T 12:40–1:30 PM • W 9:10–10 AM • W/R/F 11:10–12 PM in (180-274 or 276)

EMAIL: cculbrea@calpoly.edu **WEB:** http://physicscloud.net/122

LECTURE: T/R 11:10-12:00 in Science North (53-202)

LAB: W 12:10-3:00 in 180-276 (with Dr. S. Echols) • F 8:10-11:00 in 180-276 (with Dr. Kuriabova)

COURSE OBJECTIVES: Physics 122 is the second course in the series of introductory physics classes presented without the use of calculus. Unlike the other courses in the introductory physics series, Physics 132 covers three broad topics: Waves, Optics and Thermodynamics. A full outline of the course objectives is posted on the course website.

TEXT: *College Physics: A Strategic Approach*, 3rd Edition, by Knight, Jones, Field. Lab handouts are distributed digitally by the lab instructor.

COURSE WEBSITE: The course website is **http://physicscloud.net/122/** ***The website is a source of essential information for this course.*** Assignments, solutions, the syllabus, course objectives, course schedule, equation sheets and exam solutions will all be posted to the site. Please check it regularly. I do not use the campus Poly Learn system.

PREREQUISITES: Prior completion of PHYS 121 or 141 (or equivalent) is a required prerequisite.

GRADING: Three exams 20-25% each • Lab 15% • Quizzes 0-15% • Homework 10%. No individual assignments will be curved, and no letter grades will be assigned until the end of the term. At the end of the quarter, every student's weighted point total will be ranked and the distribution curved such that the median score is a C+. B- and C grades indicate performance not far from the average. *A*s are typically awarded to 15%-or-less of the class. The mean GPA of final grades assigned in a given lecture section will be 2.3±0.3.

QUICK-CHECK QUESTIONS: During lecture, real-time feedback, and attendance will be provided by multiple-choice conceptual and discussion questions. Answers are registered through multi-colored answer cards passed out on the first day of class, and are expected at each class meeting.

HOMEWORK: Homework will be collected regularly. Homework is due at the beginning of class. Late homework will receive a 33% deduction, and be graded on a credit/no-credit basis.

HOMEWORK PRESENTATION: Homework problems should be worked on blank, unruled, paper or quad-ruled, engineering-type graph paper. ***Do not use regular lined notebook paper.*** Blank printer paper is everywhere; use that instead. Clearly indicate the problem number on each page. Bind all pages of the homework set with a single staple in the upper-left corner. Number the pages in the upper right corner. Whenever possible, the solution should ***include a figure or sketch*** that illustrates the key parameters of the problem. Answers must be reported using a reasonable number of significant figures. Try to make your calculation as clear and tidy as possible; little effort will be made to decipher sloppy work. ***Work problems symbolically until the last step***, at which point you can plug-in actual numbers and recover a numeric answer. ***All numeric values must include units:*** if you write down a number, it must include appropriate units, even in intermediate calculation steps. If you don't want to include units, work symbolically until the last step.

HOMEWORK GRADING: As decided by class vote, homework will either be graded using a 1-2-3 or lottery grading scheme. Under the 1-2-3 scheme, each problem is worth three points. 1 point is awarded for submitting a reasonable solution *on time*, and the remaining 2 points are awarded with crude precision: 2 points for a correct, complete solution that fully adheres to the presentation guidelines above, 0 points for a solution obviously less than 50% complete/correct, and 1 point for any solution in between. With a lottery-type grading scheme, 0-3 problems per assignment are chosen at random to be graded rigorously with 10 points possible per problem.

PHYSICSCLOUD.NET At the beginning of the quarter you will receive email to signup for my course-management system at physicscloud.net. In addition to viewing your course grade and assignment statistics, physicscloud.net is used for scheduling review sessions, and for voting on important ***course options*** such as the inclusion of graded quizzes and the homework grading scheme.

LAB: The three-hour lab meets weekly. Prepare for lab each week by reading the lab handout before coming to class. The lab schedule is attached to this syllabus. ***Attendance and participation for every lab exercise is required.*** If you miss a lab, your course performance will be considered Incomplete—and you must make up all missing lab assignments in a future quarter to receive a passing grade. If you must miss lab, you can make it up the same week in another section, but you must make arrangements with the appropriate lab instructor to participate in an alternate lab session. Exceptions to the lab attendance policy will only be made on a one-time basis, and only for a compelling reason. Specific lab requirements, assessment, and attendance are at the discretion of the individual lab instructor. Exceptional performance in lab can give an advantage to students whose performance is near the borderline of two grades. Lab report requirements are determined by the lab instructor and will be explained during the lab period. You may not leave before your lab group is done, you must be present for your work to be accepted.

EXAMS: Two midterm exams and a final exam will be given during the quarter as tentatively scheduled below. An equation sheet will be provided. The equation sheets for each midterm are available on the course website, and I encourage you to use them as a resource when working homework problems. Be aware that the equation sheet doesn't necessarily include the full form of every conceivable equation. Only the equations on the equation sheet should be considered as given, and any other relationships should be derived or justified from the relationships on the sheet. Solutions that arrive at an answer or equation without justification are not acceptable. **Calculators are not allowed on any exams in this course.** Exam solutions should always show *all* steps of the calculation and be worked *symbolically* until the last step, which should be a calculator-ready expression for the desired quantity. On an exam, it is the symbolic answer that counts, and you should avoid using exam time to perform tedious arithmetic. **Any time a number is used, anywhere on the exam, appropriate units are required.** Symbolic quantities do not require units.

EXAM CORRECTIONS: Exam corrections are collected one week (or so) after exams are returned in class. Submit corrected solutions for all problems for which you did not receive full-credit. Small errors may be corrected in-place using an alternate pen color. Submit a new rewritten solution for problems with significant errors (scores below 70%). Missed multiple choice problems require a written or mathematical explanation that justifies the correct answer or remedies your misconception. Exam corrections should be stapled to the front of your midterm exam and resubmitted by the due date. The original midterm may be omitted if the corrected solution includes every problem on the exam. Corrections do not earn points back towards the original exam score, but are scored as a separate assignment and are count towards the 5% "other" grading category.

LATE WORK: Late work is accepted as specifically described in this syllabus and on a case-by-case basis. All work in this course that is not submitted during the main submission period must be turned in to my *mailbox in the physics department office (180-206)*. **I do not regularly use my official office in Jesperson Hall. Please do not leave late work or other correspondence for me there.**

SECOND CHANCE FINAL: The first portion of the final exam period will be used to complete Exam 3 which will exclusively cover the untested material from the last weeks of the course. After that, two *optional* single-calculation exams will be offered covering Exam 1 or Exam 2 material. Students must specify their intention to take a second-chance exam before the last day of regular class. The recorded Exam 1/Exam 2 score will be a weighted average of the original exam score plus the second-chance score with the second-chance score worth 25%–45% of the total points.

COURSE SUCCESS: Here are some tips for success in this class, especially if you are anxious or struggling. ***1) Find a physics buddy.*** Get their phone number. Those who work homework problems in pairs or small groups are much more likely to be successful through peer instruction, and the social aspect makes doing physics homework more enjoyable. ***2) Read the book.*** I like our textbook a lot; it's cogent, well-written and clear. In my lecture, I generally apply the notation, methods, reasoning, and ordering presented in the textbook. While the book can be a good way to start studying, the best approach is to read the relevant book sections *before coming to class*. You'll find lecture more understandable, and be more inclined to ask questions with lecture serving to illuminate misconceptions. ***3) Utilize the Learning Center.*** Located in 180-272 the learning center offers free physics tutoring. The learning center is open more than 20 hours per week and is available on a drop-in basis. ***4) Attend office hours.*** I am here to help. Email me, come to my office hours, ask as many questions as you need—your questions are not an interruption; answering them is what I'm here to do. I love teaching physics.

ACADEMIC HONESTY: Keep all electronic devices stored and completely out of sight on exam days. I interpret any sighting of a phone during an exam period as evidence of cheating.

PHYSICS 122

Tentative Course Schedule

Spring 2019

WK	TUESDAY	THURSDAY	
1 Mar 31 Apr 6	**2** 11.1-11.4	**4** 11.5-11.7	**Lab:** Simple Pendulum
2 Apr 7 Apr 13	**9** 11.7-11.8/12.1	**11** 12.2-12.3	**Lab:** Temperature and Thermometers
3 Apr 14 Apr 20	**16** 12.4-12.6	**18** 12.7-12.8/13.1-13.3	**Lab:** Specific Heat, Heat of Transformation
4 Apr 21 Apr 27	**23** 13.4-13.5	**25** 14.1-14.3	**Lab:** Pressure and Archimedes' Principle
5 Apr 28 May 4	**30** **Exam 1** Chapters 11-13	**2** 14.4-14.5	**Lab:** Simple Harmonic Motion
6 May 5 May 11	**7** 14.6-14.7 / 15.1-15.2	**9** 15.3-15.5	**Lab:** Vibrating Strings
7 May 12 May 18	**14** 15.6-15.7 / 16.1-3	**16** 16.4-16.7 / Ch 17 Briefly	**Lab:** Sound Resonance In Air Columns
8 May 19 May 25	**21** **Exam 2** Chapters 14-16	**23** 18.1-18.4 / 19.6	**Lab:** Diffraction and Interference of Light
9 May 26 Jun 1	**28** **MONDAY** **SCHEDULE**	**30** 18.5-18.6	**Lab:** Reflection & Refraction of Light
10 Jun 2 Jun 8	**4** 18.7 19.1	**6** 19.2	**Lab:** Simple Lenses
FINAL Jun 9 Jun 16	**11**	**13** 1:10-4:00 (53-202) **Exam 3** Chapters 17-19	

Last Updated 4/2/19

NAME: ______________________________

PHYSICS 122 EXAM 1 • CAL POLY • SPRING 2019 • DR. CULBREATH

No calculators. No notes. Use only the provided paper and equation sheet. 80 minutes ·

SECTION 1 • MULTIPLE CHOICE & RANKING *(2 points each)*

1. A Carnot heat engine operating between 727˚C and 127˚C takes in 2,000 J from the hot reservoir and exhausts 800 J to the cold reservoir. **For each modification described below, specify how the *efficiency* of this Carnot heat engine will change.** (All of the following modifications are individual changes applied to the initial situation)

a) The temperature of the hot reservoir (727˚C) is increased. The efficiency will

❒ increase ❒ decrease ❒ remain the same

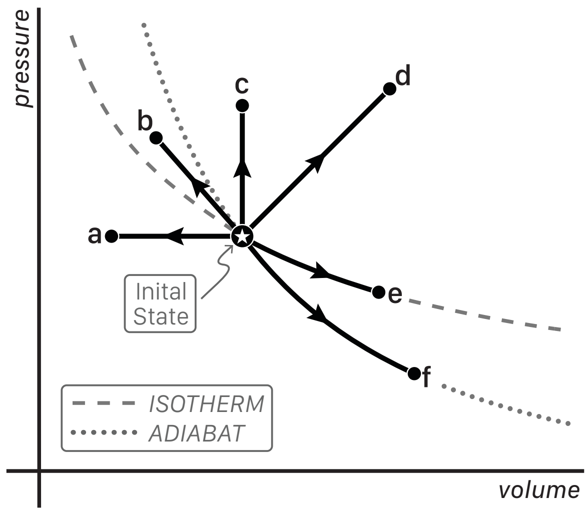
b) The temperatures of the hot reservoir and cool reservoir are increased by the same amount. The efficiency will

❒ increase ❒ decrease ❒ remain the same

c) Energy taken into the engine (2000 J) is increased to 3000J. The efficiency will

❒ increase ❒ decrease ❒ remain the same

2. A cylinder contains a sample of an ideal gas, initial at a pressure and volume corresponding to the initial state point ✪ in the PV diagram to the right. The points *a-f* each depict six distinct processes that originate from the initial state. The final state for each scenario is indicated by the labeled point (*a* through *f*). In the table below determine whether each term in the first law of thermodynamics (***W, ΔE**th*) is ***positive*** (greater than 0J) ***negative*** (less than 0J) or ***zero***



	W (work *on* gas)			**ΔE**th		
	positive $W>0$	*negative* $W<0$	*zero* $W=0$	*positive* $\Delta E_{th}>0$	*negative* $\Delta E_{th}<0$	*zero* $\Delta E_{th}=0$
a						
b						
c						
d						
e						
f						
	Check two boxes in each row					

2b. Which final state *a-f* has the highest temperature?

❒ a ❒ b ❒ c ❒ d ❒ e ❒ f

2c. For which process *a-f* is the work done *by the gas* the greatest?

❒ a ❒ b ❒ c ❒ d ❒ e ❒ f

2d. Is there any heat exchange in process *f*?

❒ Yes, energy is added to the gas through heating (Q>0)

❒ Yes, energy is removed from the gas through heating (Q<0)

❒ No, process *f* does not involve heat (Q=0)

2e. Is there any heat exchange in process *e*?

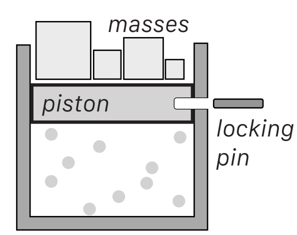
❒ Yes, energy is added to the gas through heating (Q>0)

❒ Yes, energy is removed from the gas through heating (Q<0)

❒ No, process *e* does not involve heat (Q=0)

SECTION 2 • SHORT ANSWER

Answer in the space provided (12 points each or as marked)



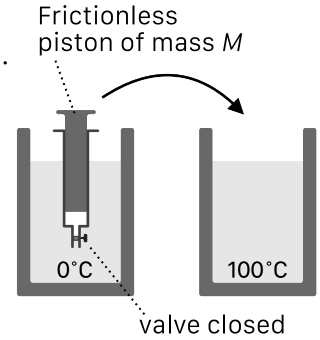
3. The cylinder of gas shown to the right has a piston that can float up and down. You can:
   i) Lock or unlock the piston in place with a pin
   ii) Add or remove masses from the piston
   iii) Place the entire cylinder in a hot or cold liquid

Explain how you would execute process *a* in the figure above with the apparatus to the right

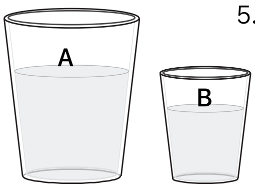
Continued on back ☞

4. A vertical syringe with a frictionless piston of mass *M* is initially at thermal equilibrium in ice water and then transferred to boiling water, and allowed to come to thermal equilibrium.

e) **Does the volume of the gas increase, decrease or stay the same? Explain.**



f) **Does the pressure of the gas increase, decrease or stay the same? Explain.**

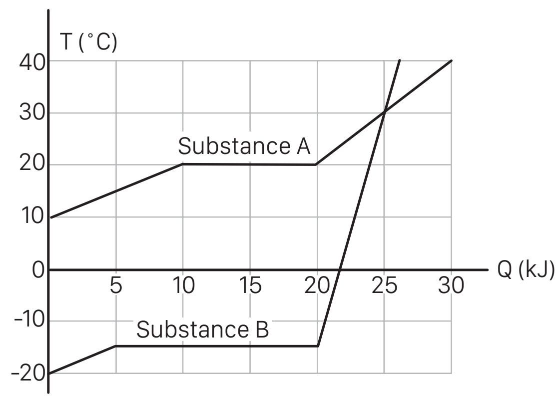


5. Two different glasses contain different samples of water. Glass A contains 750 grams of water, and Glass B contains 500 grams of water. The water in Glass A has twice the thermal (internal) energy as the water in Glass B. **Is the temperature of Glass A greater than, less than, or the same as the temperature of Glass B? Explain your reasoning.** *(10 points)*

SECTION 3 • CALCULATIONS

Answer on a separate sheet of paper. (20 points each)

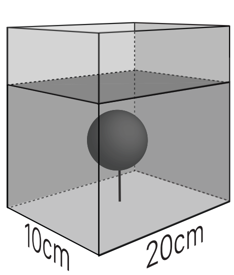
6. Samples of two pure substances are heated at a constant rate, and their temperature as a function of applied heat are plotted to the left. Both substances started as solids and melted. Each sample has an identical mass of 2kg.



a) **Is the specific heat of substance A in its solid state greater than, less than, or equal to the specific heat of substance B in its solid state?**

b) **Is the latent heat of fusion of substance A greater than, less than, or equal to the latent heat of fusion of substance B?**

c) **For substance B, determine a numeric value for the melting temperature, latent heat of fusion (L_f), and the specific heat of the liquid state.**



7. Pictured to the left is a rectangular tank of water. Completely empty, the tank has a mass of 500g. The bottom of the tank is a 10cm x 20cm rectangle. A plastic ball with a volume of 600cm^3 and a density of 0.2 g/cm^3 is submerged in the tank. A thin string attached to the bottom of the tank prevents the ball from floating to the surface. Prior to submerging the ball the tank was filled with water to a depth of 15cm.
a) What is the tension in the string attached to the submerged ball?
b) What is the net force exerted on the bottom of the tank?
(Approximate the acceleration due to gravity g≈10 m/s^2)

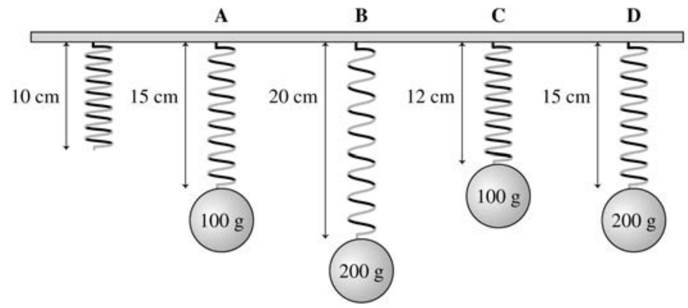
NAME: ______________________________

PHYSICS 122 MIDTERM 2 • CAL POLY • SPRING 2019 • DR. CULBREATH

No calculators. No notes. Use only the provided paper and equation sheet. 110 minutes

SECTION 1 • MULTIPLE CHOICE & RANKING

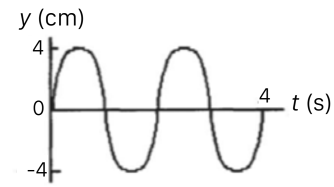
3 points or as marked



1. A set of springs all have initial length 10 cm. Each spring has a mass suspended from its end, and the different springs stretch as shown to the right. Now, each mass is pulled down by an additional 1 cm and released, so that it oscillates up and down.

   Rank the resulting frequency of oscillation *(8 points)*

☐	☐	☐	☐	OR	☐
1 Greatest	2	3	4 Least		All the same



2. What is the wavelength of the wave shown in the figure to the right?

   ❒ 8 m ❒ 4 m ❒ 2 m ❒ 1 m ❒ It cannot be determined

3. Neglecting friction, the total mechanical energy of a cart oscillating in simple harmonic motion is

   ❒ Zero as it passes the equilibrium point ❒ zero when it reaches maximum displacement
   ❒ A maximum as it passes the equilibrium point ❒ A non-zero constant

4. If the intensity level at distance *d* of one trombone is 70 dB, what is the intensity level of 76 identical trombones, all at distance *d*? (Even without a calculator, only one answer makes sense).

   ❒ 146 dB ❒ 76 dB ❒ 5320 dB ❒ 89 dB ❒ 81 dB

5. You and a friend a playing a game of catch with a buzzer that produces a 500Hz tone. As you throw the buzzer to your friend

   ❒ You both hear a 500Hz tone ❒ You both hear a tone with a frequency higher than 500Hz
   ❒ You hear a frequency lower than 500Hz and your friend hears a frequency higher than 500Hz
   ❒ You hear a frequency higher than 500Hz and your friend hears a frequency lower than 500Hz

SECTION 2 • SHORT ANSWER

Answer the question in the space provided.

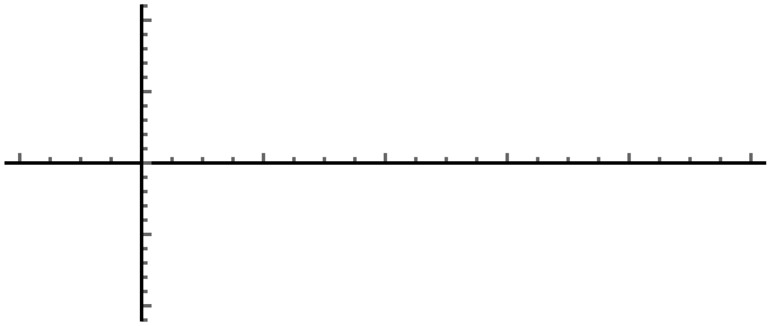
6. Four waves are described by the following equations (distances are measured in meters, and times are measured in seconds)

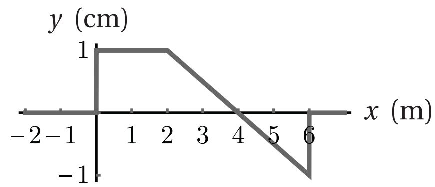
   I. $y(x, t) = 0.12\cos(3x - 21t)$
   II. $y(x, t) = 0.15\cos(6x + 42t)$
   III. $y(x, t) = 0.13\cos(6x + 21t)$
   IV. $y(x, t) = 0.23\cos(3x - 42t)$

   Which of these waves have the same speed? Explain your reasoning. *(10 points)*

Continued on back

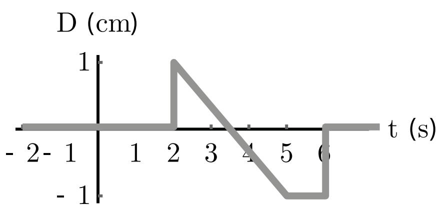
7. On the axes below, draw the history graph for (x = 4m) for the wave shown in the plot on the right, below. Include axes labels and scale. *(10 points)*



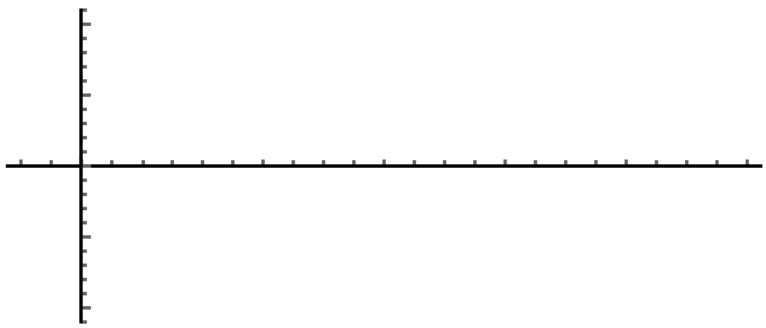


Snapshot graph of a wave at (t = 5s)
Wave moving to the **left** at 1 m/s

8. On the axes below, draw the snapshot graph at (t = 3s) for the wave shown in the plot on the left, below. Include axes labels and scale. *(10 points)*



History graph of a wave at (x = 7 m)
Wave moving to the **right** at 1 m/s



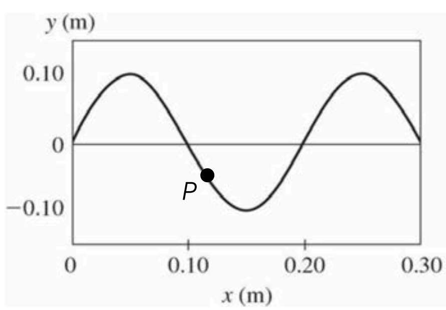
SECTION 3 • CALCULATIONS

Answer each on a separate sheet of paper

9. The intensity level of a lawn mower at a distance of 1.0 m is 104 dB. You wake up one morning to find that four of your neighbors are all mowing their lawns using identical mowers. When they are each 20 m from your open bedroom window, what is the intensity level of the sound that reaches your bedroom? *(15 points)*

10. The free-fall acceleration on the moon is only one-sixth of that on earth. What is the length of a pendulum whose period on the moon matches the period of a 1.50m long pendulum on earth? *(10 points)*

11. The figure shows a snapshot of a wave propagating on a string held under constant tension, at a particular instant in time. The frequency of the wave is 120 Hz.
    a) Determine the **amplitude**, **wavelength**, and **speed** of this wave
    b) At the moment of this snapshot point ***P*** on the string is moving downward. What direction is the wave propagating?
    c) Using the parameters from parts a and b, determine the displacement function for the wave $y(x,t)$.
    d) The string is replaced with another one, held at the same tension, but having 4 times the mass of the original. The wave's source is unchanged. Determine the the wave's **amplitude**, **wavelength** and **speed** with the new string.
    (25 points)



NAME: ______________________________

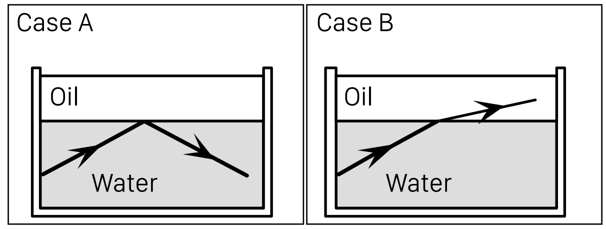
PHYSICS 122 EXAM 3 • CAL POLY • SPRING 2019 • DR. CULBREATH

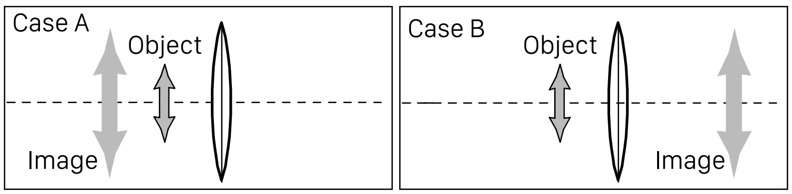
No calculators. No notes. Use only the provided paper and equation sheet. 110 minutes

SECTION 1 • MULTIPLE CHOICE & RANKING

(3 points or as marked | 14 points total)

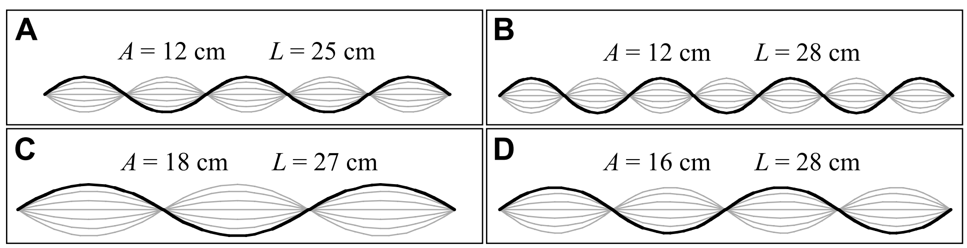
1. Show to the right, an aquarium is partially filled with water, and a layer of oil is floating on top of the water. The two cases are identical except for the type of oil used. Based on the behavior of the illustrated ray, the index of refraction of the oil is
   ❒ greater in Case A. ❒ greater in Case B.
   ❒ the same for both cases





2. In both cases to the left, an object is placed 20 cm from a converging lens. Is which case is the focal distance of the lens greater ?
   ❒ greater in Case A. ❒ greater in Case B.
   ❒ cannot be determined

3. A string is stretched so that it is under tension and is tied at both ends so that the endpoints don't move. A mechanical oscillator then vibrates the string so that a standing wave is created. All of the strings are identical except for their lengths, and all strings have the same tension. The lengths of the strings *L* and the amplitudes at the antinodes *A* are given in each figure.



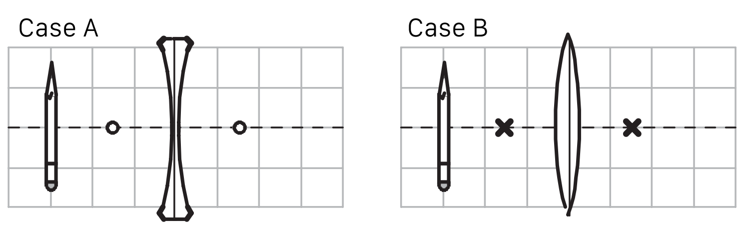
Rank the frequencies of the waves. (8 points)

				OR	
1 Greatest	2	3	4 Least		All the same

SECTION 2 • SHORT ANSWER

Answer the question in the space provided.

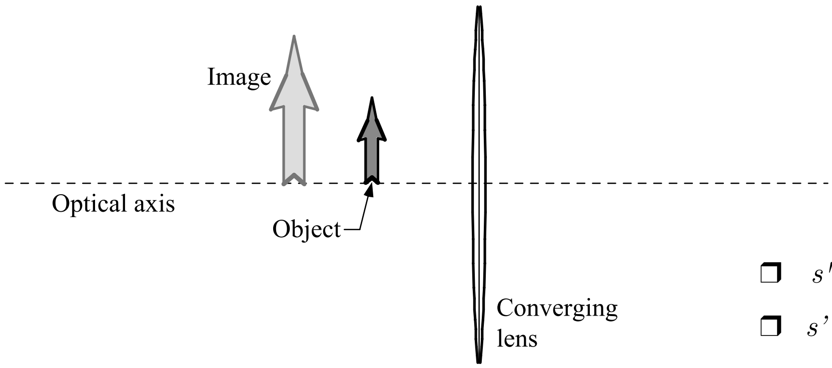
(15 points or as marked | 46 points total)



4. In both cases to the right, a lens is shown with its focal points marked over a grid. The type lens focal length can be inferred from the figure. A pencil is placed to the left of each lens.
   Is the distance from the pencil to the image of the pencil (i) greater in Case A, (ii) greater in Case B, or (iii) the same in both cases? **Justify your answer by drawing three rays directly on the figure for both Case and Case B and explain your conclusion in the space below.** (16 points)

Continued on back

5. A laser pointer is incident on a crystal with n=2 as shown to the right. On the figure to the right, draw the path the laser takes in the crystal (and leaves the crystal). Exact angles are not important, just make the relative direction of the ray at each interface clear.

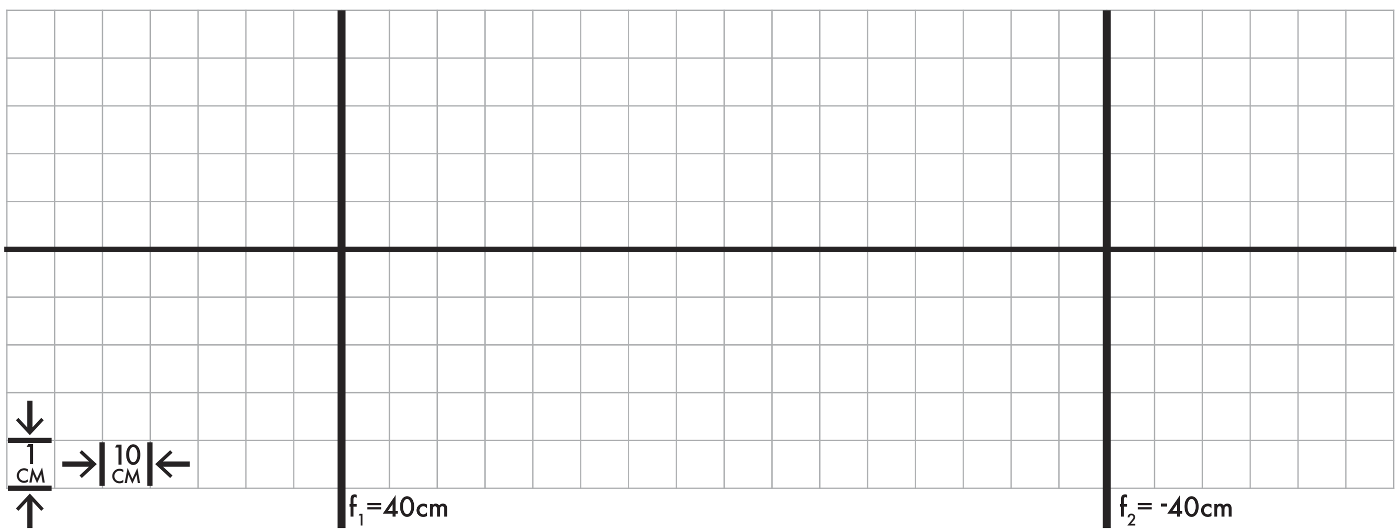


6. Based on the image and object locations shown in the figure to the left
   a) construct the three primary rays.
   b) Identify and label the location for two focal points for this lens.
   c) Complete the image properties checkboxes below

❒ $s' < 0$	❒ $f < 0$	❒ $m < 0$	❒ $\|m\| < 1$
❒ $s' > 0$	❒ $f > 0$	❒ $m > 0$	❒ $\|m\| > 1$

SECTION 3 • CALCULATIONS

Complete calculations on a separate sheet of paper, and ray-trace directly on grid below. (20 points each | 40 points total)



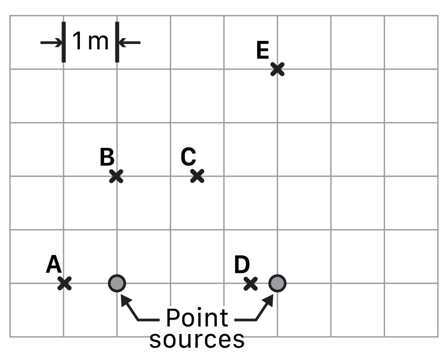
7. A converging lens with a focal length of 40 cm and a diverging lens with a focal length of -30 cm are 160 cm apart. A 2.0-cm-tall object is 60 cm in front of the converging lens.
   a) Use ray tracing and the grid above to determine the location and properties of the final image.

   The final image is: (Choose one response for each column)

❒ real	❒ upright	❒ magnified
❒ virtual	❒ inverted	❒ reduced

   b) On a separate sheet, use the thin lens equation to calculate the final image location and magnification.

8. Two identical point sources speakers are oscillating and generating waves with the same amplitude A and a frequency of 343 Hz in 20˚C air.Rank the maximum amplitude of the wave observed at each of the labeled points. **Write your answer in the box below and on a separate sheet of paper, show your work (for each point) and explain your reasoning.**

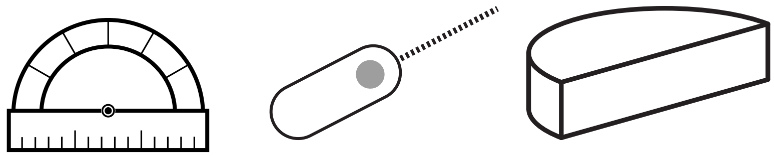


					OR	
1 Greatest	2	3	4	5 Least		All the same

NAME: ________________________________

PHYSICS 132 MIDTERM 2 • SECOND CHANCE QUESTION • SPRING 2019

No calculators. No notes. Use only the provided paper and equation sheet. 50 minutes ·



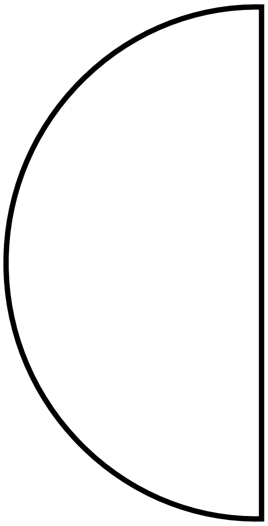
1. You are trapped on a desert island with three tools: a laser pointer, a protractor and a semi-circular transparent slab of plastic (and a calculator). Inexplicably, you decide to measure the index of refraction of the plastic. On a separate sheet, explain the experiment you use to measure the index of refraction. Your answer should include these elements
    - A sketch that illustrates the path of the laser-beam
    - Illustration and explanation of the significance of laser placement in your proposed experiment
    - Illustration and explanation which specific angles are to be measured with the protractor and how they will be used in your calculation of the refractive index

Continued on back

Your desert island situation improved once you discovered that, despite forgetting your glasses, you can use the hemispherical piece of plastic to improve your vision.

b) In this were true, would you this fix work for *nearsightedness* or *farsightedness*? Explain.

c) On the figure below draw at least two rays that show how this shape can be used as lens. Your rays should show the path *inside the lens* and include the refraction and the entry and exit surfaces. Specific angles are not important, you're just looking to show how the hemisphere correctly bends the incoming rays



Extra Extra Credit (makes a full-credit answer worth 30/20 points):
If the plastic has an index of refraction of 1.5, what is the radius of the hemisphere you'd needs to make a lens with a focal length such that $|f|$ = 150cm

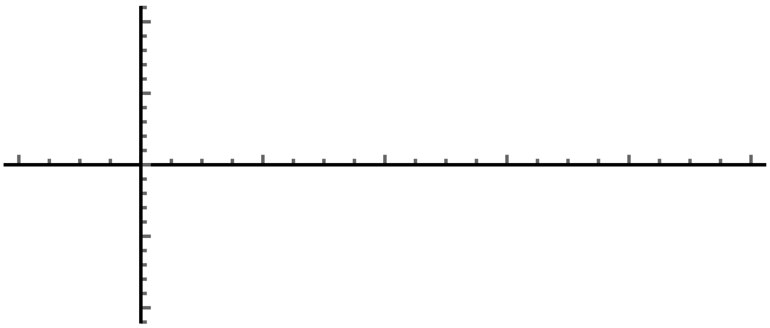
NAME: Student Name

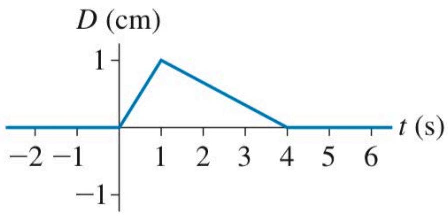
PHYSICS 122 • SECOND CHANCE EXAM 2 • SPRING 2019 • DR. CULBREATH

No calculators. No notes. Provide a calculator-ready expression if appropriate.

QUESTION 1

For the wave depicted to the right, draw a **snapshot graph for t = 1 s.**
Include appropriate scale, units and labels on your axes.





History graph for x=1m
Wave traveling to the right
at 1m/s

QUESTION 2

You have tickets for an outdoor rock concert, forth row from the stage. However, at that distance the intensity level is 100dB, too loud to be enjoyable. You decide to move to a row where the intensity level is a more moderate 80dB. In what row should you look for a new seat (assuming the distance between each row of seats is constant)?

QUESTION 2

You have cold hands on a winter day and take two different (successful) approaches to comfort:

a. You rapidly rub your palms together, and
b. You breathe into to your cupped hands

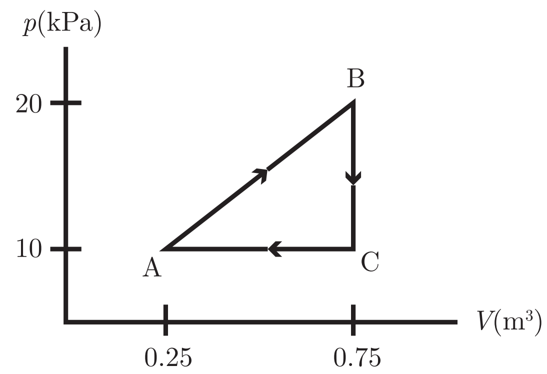
Which processes, if any, involve heat? Which processes, if any, involve a change in the thermal energy of your hands? *Explain your reasoning*.

NAME: Student Name

PHYSICS 122 • SECOND CHANCE EXAM 1 • SPRING 2019 • DR. CULBREATH

No calculators. No notes. Provide a calculator-ready expression if appropriate.

QUESTION 1



An ideal gas undergoes the the process A→ B→ C→A as shown on the pV diagram above.

a) At which labeled point does the gas have the highest temperature?

b) How much work is done on the gas during each process (A→B, B→C and C→A) ?
Show your work below and record your answers in the table to the right.
Remember to include the appropriate sign and units.

Process	W
A→B	
B→C	
C→A	

c) What is the change in the thermal energy of the gas after the entire cycle (A→ B→ C→A)?

Continued on back

Physics 122 ★ Midterm 1

EQUATION SHEET

Thermodynamics

$$e = \frac{\text{what you get}}{\text{what you pay}} = \frac{W_{\text{out}}}{Q_H} = \frac{Q_H - Q_C}{Q_H}$$

$$e_{\max} = 1 - \frac{T_C}{T_H}$$

$$e_{\text{human}} = 25\%$$

$\Delta E_{\text{th}} = Q + W$

$W_{\text{on gas}} = -p\Delta V$ (constant pressure)

$PV = nRT = Nk_BT$ ideal gas

$W_{\text{on gas}} = -$(area under $p - V$ curve)

$E_{\text{th}} = NK_{\text{avg}} = \frac{3}{2}Nk_BT = \frac{3}{2}nRT$

$W_{\text{on gas, cycle}} = -$(area inside p-V curve)

$K_{\text{avg}} = \frac{3}{2}k_BT = \frac{1}{2}mv_{\text{rms}}^2$ (all gasses)

$\Delta E_{\text{th}} = nC_V\Delta T$ (all processes)

$C_{P,\,\text{monatomic}} = \frac{5}{2}R$ $C_{V,\,\text{monatomic}} = \frac{3}{2}R$

$C_{P,\,\text{diatomic}} = \frac{7}{2}R$ $C_{V,\,\text{diatomic}} = \frac{5}{2}R$

$Q_P = nC_P\Delta T$ $Q_V = nC_V\Delta T$

$$\left.\begin{aligned} Q &= nC\Delta T \\ Q &= mc\Delta T \\ Q &= \pm mL \end{aligned}\right\}\ \text{open-container calorimetry}$$

Fluids

$p = \frac{F}{A}$ pressure

$Av = \text{const.}$ (incompressible)

$p_{\text{gauge}} = p - p_{\text{atm}}$

$$F_B = \left(m_{\substack{\text{fluid}\\ \text{disp}}}\right)g = \left(\rho_{\text{fluid}}\right)\left(V_{\substack{\text{fluid}\\ \text{disp}}}\right) \quad \text{buoyancy}$$

$p = p_0 + \rho g d$ (d depth)

$\rho = \frac{m}{V}$ density

Constants

$R = 8.314\,\frac{\text{J}}{\text{mol K}}$	$N_A = 6.02\ \text{mol}^{-1}$	1000 calories = 1 Calorie (food)
$k_B = 1.37 \times 10^{-23}\,\text{J/K}$	$0\ \text{K} = -273\ ^\circ\text{C}$	1 calorie = 4.184 J
$p_{\text{atm}} = 1.013 \times 10^5\ \text{Pa}$	$\rho_{\text{water}} = 1000\,\frac{\text{kg}}{\text{m}^3}$	$c = 3 \times 10^8\ \text{m/s}$ speed of light
$T_{\text{room}} = 20\,^\circ\text{C} = 293\ \text{K}$	$c_{\text{water}} = 4186\,\frac{\text{J}}{\text{kg}\,^\circ\text{C}}$	
$\sigma = 5.67 \times 10^{-8}\,\frac{\text{W}}{\text{m}^2\text{K}^4}$	$g = 9.8\,\frac{m}{s^2}$	

Physics 122 ★ Midterm 2

EQUATION SHEET

Oscillations

$x(t) = A\cos\left(2\pi f t\right)$ $\quad v_x(t) = -(2\pi f)A\sin\left(2\pi f t\right)$ $\quad a_x(t) = -(2\pi f)^2 A\cos\left(2\pi f t\right)$ $\quad (F_{\text{net}})_x = -kx$

$E_{\text{total}} = K + U = \frac{1}{2}mv_x^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2 = \frac{1}{2}mv_{\text{max}}^2$ $\quad v_{\text{max}} = 2\pi f A$

$T = \dfrac{1}{f} = \dfrac{2\pi}{\omega}$ $\quad T_{\text{pendulum}} = 2\pi\sqrt{\dfrac{L}{g}}$ $\quad T_{\text{spring}} = 2\pi\sqrt{\dfrac{m}{k}}$ $\quad v_{\text{spring}} = \pm\sqrt{\dfrac{k}{m}(A^2 - x^2)}$

Waves

$y(x,t) = A\cos\left(2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right)$ $\quad v = \lambda f = \dfrac{\lambda}{T}$ $\quad \beta = (10\text{dB})\log\left(\frac{I}{I_0}\right)$ $\quad I = \dfrac{P}{\text{Area}} = \dfrac{P_{\text{source}}}{4\pi r^2}$

$v_{\text{string}} = \sqrt{\dfrac{T_s}{\mu}}$ $\quad f_{\mp} = \dfrac{f_0}{1 \pm {}^{v_s}/_{v}}$ $\quad f_{\text{beat}} = |f_2 - f_1|$

constructive: $\Delta r = m\lambda$ $\quad m = 1, 2, 3\ldots$

destructive: $\Delta r = (m + {}^{1}/_{2})\lambda$ $\quad m = 1, 2, 3\ldots$

$v_{\text{sound}} = \sqrt{\dfrac{\gamma RT}{M}}$ $\quad f_{\pm} = \left(1 \pm \dfrac{v_o}{v}\right)f_0$ $\quad$ open-closed tube: $\quad f_m = m\dfrac{v}{4L}, \quad m = 1, 3, 5\ldots$

$v_{\text{sound}} = (331 + 0.6T_c)$ m/s $\quad$ string/open-open/closed-closed tube: $\lambda_m = \dfrac{2L}{m}, \quad f_m = m\dfrac{v}{2L}, \quad m = 1, 2, 3\ldots$

Thermodynamics

$e = \dfrac{\text{what you get}}{\text{what you pay}} = \dfrac{W_{\text{out}}}{Q_H} = \dfrac{Q_H - Q_C}{Q_H}$ $\quad e_{\text{max}} = 1 - \dfrac{T_C}{T_H}$ $\quad e_{\text{human}} = 25\%$ $\quad C_{V,\,\text{monatomic}} = \frac{3}{2}R$

$\Delta E_{\text{th}} = Q + W$ $\quad W_{\text{on gas}} = -p\Delta V$ (constant pressure) $\quad C_{V,\,\text{diatomic}} = \frac{5}{2}R$

$PV = nRT = Nk_BT$ ideal gas $\quad W_{\text{on gas}} = -$(area under $p - V$ curve) $\quad C_{P,\,\text{monatomic}} = \frac{5}{2}R$

$E_{\text{th}} = NK_{\text{avg}} = \frac{3}{2}Nk_BT = \frac{3}{2}nRT$ $\quad W_{\text{on gas, cycle}} = -$(area inside p-V curve) $\quad C_{P,\,\text{diatomic}} = \frac{7}{2}R$

$K_{\text{avg}} = \frac{3}{2}k_BT = \frac{1}{2}mv_{\text{rms}}^2$ (all gasses)

$\Delta E_{\text{th}} = nC_V\Delta T$ (all processes)

$$\left.\begin{aligned} Q &= nC\Delta T \\ Q &= mc\Delta T \\ Q &= \pm mL \end{aligned}\right\}\ \text{open-container calorimetry}$$

$Q_V = nC_V\Delta T$

$Q_P = nC_P\Delta T$

Fluids

$p = \dfrac{F}{A}$ pressure $\quad p = p_0 + \rho g d$ (d depth) $\quad Av = \text{const.}$ (incompressible)

$p_{\text{gauge}} = p - p_{\text{atm}}$ $\quad \rho = \dfrac{m}{V}$ density $\quad F_B = \left(m_{\substack{\text{fluid}\\\text{disp}}}\right)g = \left(\rho_{\text{fluid}}\right)\left(V_{\substack{\text{fluid}\\\text{disp}}}\right)g$ buoyancy

Constants

$R = 8.314\frac{\text{J}}{\text{mol K}}$ $\quad N_A = 6.02\ \text{mol}^{-1}$ $\quad g = 9.8\frac{m}{s^2}$ $\quad I_0 = 10^{-12}\ \text{W/m}^2$ $\quad$ 1 calorie = 4.184 J

$k_B = 1.37 \times 10^{-23}$J/K $\quad \rho_{\text{water}} = 1000\frac{\text{kg}}{\text{m}^3}$ $\quad 0\ \text{K} = -273\ ^\circ\text{C}$ $\quad$ 1000 calories = 1 Calorie (food)

$p_{\text{atm}} = 1.013 \times 10^5$ Pa $\quad c_{\text{water}} = 4186\frac{\text{J}}{\text{kg}\,^\circ\text{C}}$ $\quad T_{\text{room}} = 20^\circ\text{C} = 293$ K $\quad c = 3 \times 10^8$ m/s speed of light

Physics 122 ★ Midterm 3

EQUATION SHEET

Optics

$n = \frac{c}{v}$ $\theta_i = \theta_R$ $n_a \sin\theta_a = n_b \sin\theta_b$ $\sin\theta_{\text{crit}} = \frac{n_{\text{out}}}{n_{\text{in}}}$ $m = \frac{h'}{h} = -\frac{s'}{s}$ Thin lens equation: $\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$

$\lambda = \frac{\lambda_0}{n}$ Lens maker's equation : $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ Image inside a spherical surface: $\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R}$

Waves

$y(x,t) = A\cos\left(2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right)$ $v = \lambda f = \frac{\lambda}{T}$ $I = \frac{P}{\text{Area}} = \frac{P_{\text{source}}}{4\pi r^2}$ $f_{\text{beat}} = |f_2 - f_1|$ constructive: $\Delta r = m\lambda$ $m = 0, 1, 2\ldots$

destructive: $\Delta r = (m + {}^1\!/_2)\lambda$ $m = 0, 1, 2\ldots$

$v_{\text{sound}} = \sqrt{\frac{\gamma R T}{M}}$ $v_{\text{sound}} = (331 + 0.6T_c)$ m/s $\beta = (10\text{dB})\log\left(\frac{I}{I_0}\right)$

open-closed tube: $f_m = m\frac{v}{4L}$, $m = 1, 3, 5\ldots$

$v_{\text{string}} = \sqrt{\frac{T_s}{\mu}}$ $f_{\mp} = \frac{f_0}{1 \pm {}^{v_s}\!/_{v}}$ $f_{\pm} = \left(1 \pm \frac{v_o}{v}\right)f_0$ string/open-open/closed-closed tube: $\lambda_m = \frac{2L}{m}$, $f_m = m\frac{v}{2L}$, $m = 1, 2, 3\ldots$

Oscillations

$x(t) = A\cos(2\pi f t)$ $v_x(t) = -(2\pi f)A\sin(2\pi f t)$ $v_{\text{max}} = 2\pi f A$ $v_{\text{spring}} = \pm\sqrt{\frac{k}{m}(A^2 - x^2)}$ $a_x(t) = -(2\pi f)^2 A\cos(2\pi f t)$

$T = \frac{1}{f} = \frac{2\pi}{\omega}$ $T_{\text{pendulum}} = 2\pi\sqrt{\frac{L}{g}}$ $T_{\text{spring}} = 2\pi\sqrt{\frac{m}{k}}$ $E_{\text{total}} = K + U = \frac{1}{2}mv_x^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2 = \frac{1}{2}mv_{\text{max}}^2$ $(F_{\text{net}})_x = -kx$

Fluids

$p = \frac{F}{A}$ pressure

$p_{\text{gauge}} = p - p_{\text{atm}}$

$p = p_0 + \rho g d$ (d depth)

$\rho = \frac{m}{V}$ density

$F_B = \left(m_{\substack{\text{fluid}\\\text{disp}}}\right)g = (\rho_{\text{fluid}})\left(V_{\substack{\text{fluid}\\\text{disp}}}\right)g$ buoyancy

Thermodynamics

$PV = nRT = Nk_BT$ ideal gas $\Delta E_{\text{th}} = Q + W$ $W_{\text{on gas}} = -p\Delta V$ (constant pressure) $Q_V = nC_V\Delta T$

$e = \frac{\text{what you get}}{\text{what you pay}} = \frac{W_{\text{out}}}{Q_H} = \frac{Q_H - Q_C}{Q_H}$ $\Delta E_{\text{th}} = nC_V\Delta T$ (all processes) $W_{\text{on gas}} = -$(area under $p - V$ curve) $Q_P = nC_P\Delta T$

$e_{\text{max}} = 1 - \frac{T_C}{T_H}$ $e_{\text{human}} = 25\%$ $W_{\text{on gas, cycle}} = -$(area inside p-V curve)

$E_{\text{th}} = NK_{\text{avg}} = \frac{3}{2}Nk_BT = \frac{3}{2}nRT$

$K_{\text{avg}} = \frac{3}{2}k_BT = \frac{1}{2}mv_{\text{rms}}^2$ (all gasses)

$\left.\begin{aligned} Q &= nC\Delta T \\ Q &= mc\Delta T \\ Q &= \pm mL \end{aligned}\right\}$ open-container calorimetry

$C_{V,\text{ monatomic}} = \frac{3}{2}R$ $C_{P,\text{ monatomic}} = \frac{5}{2}R$

$C_{V,\text{ diatomic}} = \frac{5}{2}R$ $C_{P,\text{ diatomic}} = \frac{7}{2}R$

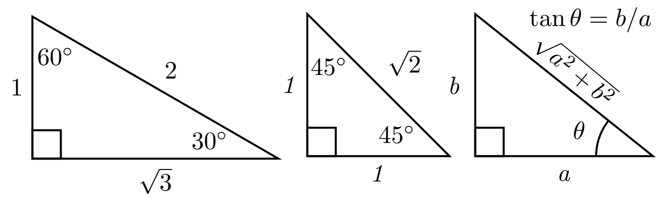
Constants

$R = 8.314\ {}^{\text{J}}\!/_{\text{mol K}}$ $N_A = 6.02\ \text{mol}^{-1}$ $g = 9.8\ {}^{\text{m}}\!/_{\text{s}^2}$ $I_0 = 10^{-12}\ {}^{\text{W}}\!/_{\text{m}^2}$ $v_{\text{sound}} = 343\ {}^{\text{m}}\!/_{\text{s}}$ 1 calorie = 4.184 J $n_{\text{water}} = 1.33$

$k_B = 1.37 \times 10^{-23}\ {}^{\text{J}}\!/_{\text{K}}$ $\rho_{\text{water}} = 1000\ {}^{\text{kg}}\!/_{\text{m}^3}$ $0\ \text{K} = -273\ °\text{C}$ 1000 calories = 1 Calorie (food) $n_{\text{air}} = 1$

$p_{\text{atm}} = 1.013 \times 10^5$ Pa $c_{\text{water}} = 4186\ {}^{\text{J}}\!/_{\text{kg °C}}$ $T_{\text{room}} = 20\,°\text{C} = 293$ K $c = 3 \times 10^8\ {}^{\text{m}}\!/_{\text{s}}$ speed of light $n_{\text{glass}} = 1.5$

$\tan\theta = b/a$



NAME: ______________________________

PHYSICS 122 • QUIZ 1 • SPRING 2019 • DR. CULBREATH

No calculators. No notes. Provide a calculator-ready expression if appropriate.

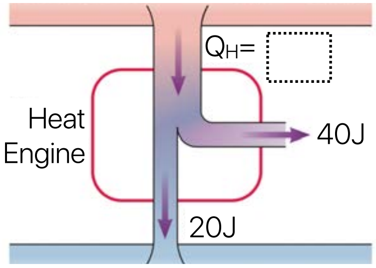
QUESTION 1 • CONCEPTUAL SHORT ANSWER

You have cold hands on a winter day and take two different (successful) approaches to comfort:

a. You rapidly rub your palms together, and

b. You breathe into to your cupped hands

Which processes, if any, involve heat? Which processes, if any, involve a change in the thermal energy of your hands? Explain your reasoning.



QUESTION 2 • CALCULATION

For the heat engine shown, supply the missing value and determine the efficiency. If the hot reservoir is at a temperature of 600K, what is the temperature of the cold reservoir?

$$e = \frac{W_{\text{out}}}{Q_H} = \frac{Q_H - Q_C}{Q_H} \qquad \Delta E_{\text{th}} = Q + W \qquad 0\ \text{K} = -273\ ^\circ\text{C} \qquad e_{\max} = 1 - \frac{T_C}{T_H}$$

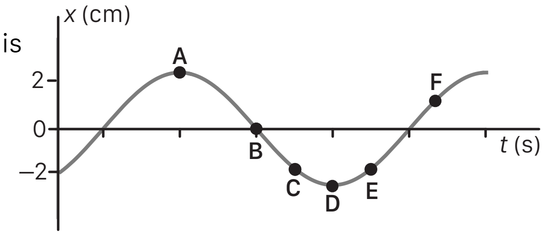
$$E_{\text{th}} = N K_{\text{avg}} = \tfrac{3}{2} N k_B T = \tfrac{3}{2} n R T \qquad P V = n R T = N k_B T \quad \text{ideal gas}$$

NAME: ______________________________

PHYSICS 122 • QUIZ 2 • SPRING 2019 • DR. CULBREATH

No calculators. No notes. Provide a calculator-ready expression if appropriate.

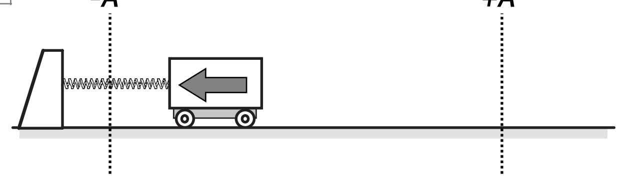
1. A cart attached to a spring is displaced from equilibrium and then released. A graph of displacement as a function of time for the cart is shown. There is no friction. Points are labeled A–F in the graph. The arrows and signs above the cart indicate the positive and negative directions for the displacement of the cart.



Point	Acceleration	Velocity	Displacement	Net Force
A				
B				
C				
F				

For each labeled point above, identify if the vector quantity listed in the table is in the positive (+) direction, negative (–) direction, or is zero (0) for no direction.

2. Using the graph from problem 1, determine which of the points [A-F] is best represented by the cartoon-cart figure pictured to the right. (The gray arrow represents the instantaneous direction of motion for the car)

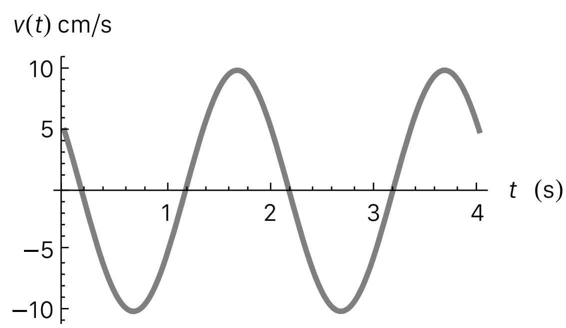


❒ A ❒ B ❒ C ❒ D ❒ E ❒ F

3. In the space below, draw a carton cart, similar to the figure in problem № 2, that best represents the oscillators motion at point F. Be sure to label +A and -A. Indicate the direction of motion using an arrow on the cart

PART 2 • CALCULATION

4. The graph in Figure to the right, was generated by observing the motion of a a cart in Simple Harmonic Motion. Using the graph, determine the frequency *f* and the oscillation amplitude *A* for this cart's motion.



Mini Equation Sheet: Oscillations

$T=\frac{1}{f}$ $\quad x(t)=A\cos(2\pi f t)$ $\quad v_x(t)=-(2\pi f)A\sin(2\pi f t)$ $\quad a_x(t)=-(2\pi f)^2 A\cos(2\pi f t)$ $\quad v_{max}=2\pi f A$ $\quad (F_{net})_x=-kx$

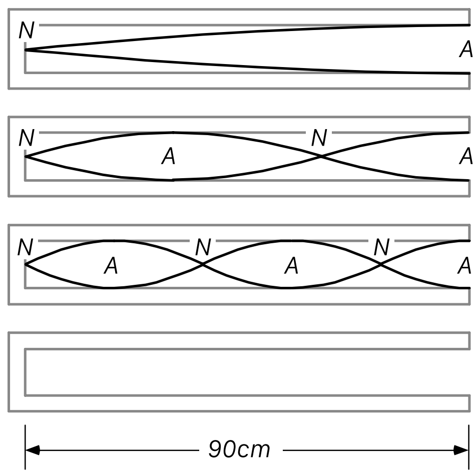
$E_{total}=K+U=\frac{1}{2}mv_x^2+\frac{1}{2}kx^2=\frac{1}{2}kA^2=\frac{1}{2}mv_{max}^2$ $\quad T_{pendulum}=2\pi\sqrt{\frac{L}{g}}$ $\quad T_{spring}=2\pi\sqrt{\frac{m}{k}}$ $\quad v_{spring}=\pm\sqrt{\frac{k}{m}(A^2-x^2)}$

NAME: ______________________________

PHYSICS 122 • QUIZ 3 • SPRING 2019 • DR. CULBREATH

No calculators. No notes. Provide a calculator-ready expression if appropriate.

8. A pipe of length 90 cm is closed at one end and open at the other. Sound is created in the pipe at four different frequencies. The diagram shows the location of nodes (N) and antinodes (A) in the pipe for three different modes. The table to the right has an entry for wave speed of the third harmonic.



	Frequency	Wavelength	Wave Speed
Funamental			
2nd Harmonic			
3rd Harmonic			360 m/s
5th Harmonic			

Complete the table of frequencies, wavelengths, and wave speeds for the four modes, and sketch the displacement standing wave pattern for the 5th harmonic mode in the pipe depicted above. Partial credit may be awarded for any supporting work, explanations or calculations included below

Waves

$y(x,t) = A\cos\left(2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right)$ $\quad v = \lambda f = \frac{\lambda}{T}$ $\quad I = \frac{P}{\text{Area}} = \frac{P_{\text{source}}}{4\pi r^2}$ $\quad f_{\text{beat}} = |f_2 - f_1|$

constructive: $\Delta r = m\lambda \quad m = 0,1,2\ldots$

destructive: $\Delta r = (m + {}^1\!/_2)\lambda \quad m = 0,1,2\ldots$

$v_{\text{sound}} = \sqrt{\frac{\gamma R T}{M}}$ $\quad v_{\text{sound}} = (331 + 0.6T_c)\ \text{m/s}$ $\quad \beta = (10\text{dB})\log\left(\frac{I}{I_0}\right)$

open-closed tube: $f_m = m\frac{v}{4L}, \quad m = 1,3,5\ldots$

$v_{\text{string}} = \sqrt{\frac{T_s}{\mu}}$ $\quad f_{\mp} = \frac{f_0}{1 \pm {}^{v_s}\!/_{v}}$ $\quad f_{\pm} = \left(1 \pm \frac{v_o}{v}\right) f_0$

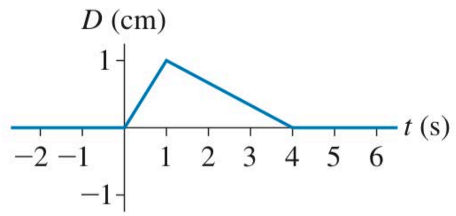
string/open-open/closed-closed tube: $\lambda_m = \frac{2L}{m}, \quad f_m = m\frac{v}{2L}, \quad m = 1,2,3\ldots$

NAME: ______________________________

PHYSICS 122 • QUIZ 3 • SPRING 2019 • DR. CULBREATH

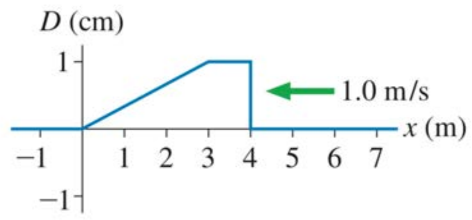
No calculators. No notes. Provide a calculator-ready expression if appropriate.

1. For the wave depicted to the right, draw a **snapshot graph for t = 3 s.** Include appropriate scale, units and labels on your axes.



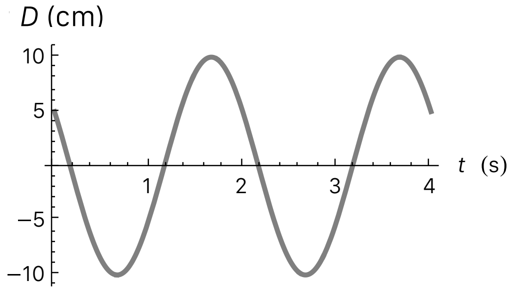
History graph of a wave at $x = 2$ m
Wave moving to the right at 1.0 m/s

2. For the wave depicted to the right, draw a **history graph at x = 2 m**. Include appropriate scale, units and labels on your axes.



Snapshot graph at t=0s

2. For the wave depicted to the right, determine the wavelength λ.



History graph for x = 0 m
Wave moving to the right at 4 m/s

Mini Equation Sheet: Traveling Waves

$y(x,t) = A\cos\left(2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right)$ $\qquad v = \lambda f = \frac{\lambda}{T}$

Course Website

The Physics 122 Course Website (`http://physicscloud.net/122`), shown above in figure 10 is the central communication hub for the class. The website provides student access to the course

- Syllabus
- Objectives
- Schedule
- Homework assignments
- Instructor-prepared homework solutions
- Equation sheets
- Midterm solutions
- Lab Manual
- Supplemental lecture videos
- Homework solution videos (select problems)

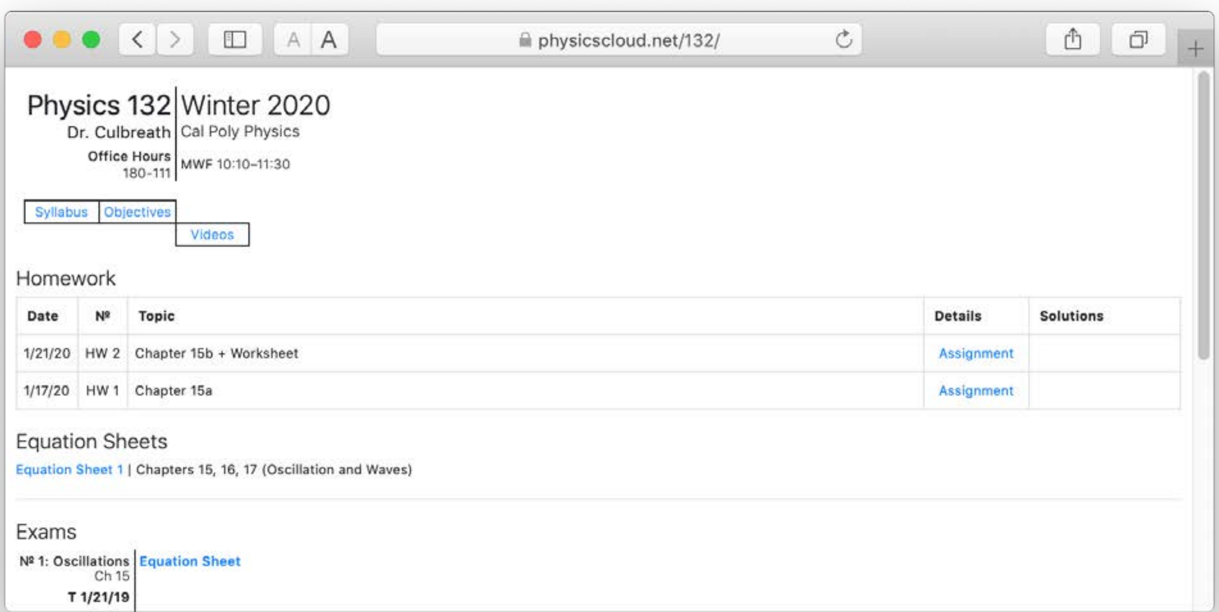


Figure 10: The course website is the central communication hub for the class and is updated several times per week. Visit the site at `http://physicscloud.net/122`

Homework Assignments are posted at least one week before their due date. Homework assignments (figure 5) often include links to one or two homework solution videos (see *Online Videos* on page 189). Changes to the course schedule are relayed by email and updated on the site.

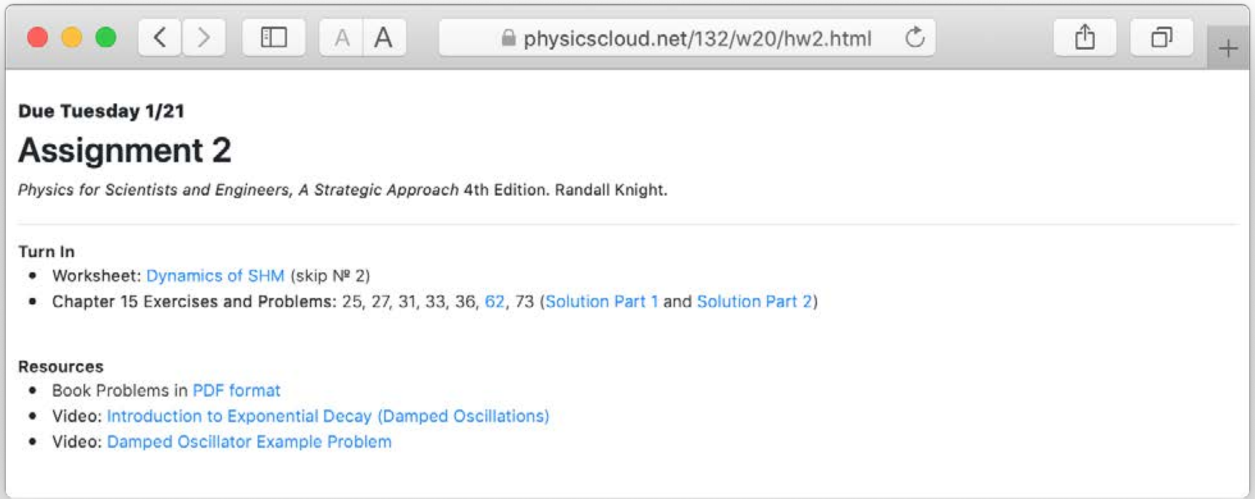


Figure 11: Homework assignments are posted to the course website at least one week before their due date and often include links to 1–3 instructor-prepared solution videos.

Enhanced Homework and Exam solutions

For Physics 122, I decided to take a different approach to preparing the homework and exam solutions that are posted to the course website. Using color presentation, improved figures and lengthy explanations, the prepared solutions not only detail the step-by-step approach to solving the problem, they serve as a supplement to the course lecture notes. A full page sample can be found on page 238. In addition, detailed exam solutions are posted after students receive their graded exams. For both exams and homework, I require students to submit corrections which reference the posted solutions and remedy mistakes in their original work[‡].

[‡]The corrections policy is detailed in the course syllabus (page 214)

16. | | A violin string has a standard length of 32.8 cm. It sounds the musical note A (440 Hz) when played without fingering. How far from the end of the string should you place your finger to play the note C (523 Hz)?

The fundamental (lowest) frequency standing wave is the tone-producing vibration in a musical instrument

From this information we can calculate the wave speed*

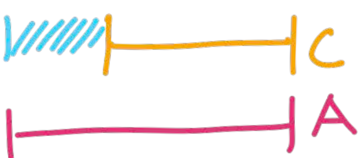
$$V = \lambda f = 2(0.328\,m)(440\,Hz)$$

$$V_{string} = 288.64\ m/s$$

Now, we calculate the length of string required for a 523Hz fundamental frequency

$$V = \lambda' f' = 2L' f$$

$$L' = \frac{V}{2f'} = \frac{(288.6\ m/s)}{2(523\,Hz)} = 27.6\,cm$$



32.8cm
− 27.6cm

A finger placed $\boxed{5.2\,cm}$ from the end of the A string produces a C

*If this is a musical instrument, Why isn't the wave speed 343 m/s (the speed of sound)?

Because the tone is produced by a standing wave on the string

That tone is then carried to our ears, through the air, at the speed of

Course Videos

A full general description of my online video content can be found on page 241. Listed below is the content I produced and is available on my course website specifically for Physics 122.

Table 6: Physics 122 Step-by-step Solution Videos

Topic	Duration	URL
Ch 16 №13	3:17	youtube.com/watch?v=uolyiPPu6l8
Ch 16 №63	9:16	youtube.com/watch?v=PUTnXCVOPtg
Ch 16 №9	2:19	youtube.com/watch?v=DteQUktHmok
Ch 16 №20	3:50	youtube.com/watch?v=ExJwIijxdCs
Ch 16 №37	3:58	youtube.com/watch?v=-wg3q48hy1fw
Ch 16 №40	4:07	youtube.com/watch?v=Ikc93TUGRRA

Table 7: Physics 122 Supplemental Lecture and Tutorial Videos

Topic	Duration	URL
Two source interference	6:58	youtube.com/watch?v=_oi_CkzwVqQ
Buoyancy example	5:49	youtube.com/watch?v=3Oc-9AnCW1g
Introduction to Power and Intensity	12:12	youtube.com/watch?v=Nt2MtQp5Jgo
Doppler Effect Example Problem	5:16	youtube.com/watch?v=G6sfu9PV9nk
Sound Intensity Level (dB)	13:34	youtube.com/watch?v=PndztQ6Olkw

PHYSICS 123 Lab

Course Syllabus/Winter 2020

INSTRUCTOR: Dr. Christopher Culbreath **MAILBOX**: Physics Department Office (180-204)

OFFICE HOURS: MWF 10:10 AM—11:30 AM • 180-111

EMAIL: cculbrea@calpoly.edu **WEB:** http://physicscloud.net/123

LOCATION: 180-270 (Baker Science ground floor)

LAB HANDOUTS: Lab handouts are available from my course website http://physicscloud.net/123 You are expected to read the handout ahead of time, but may print one copy per group in class.

LAB WRITE-UPS: One lab report will be collected for each lab group. You may not leave before your lab group is done: you must be present for your work to be accepted. If a group is not done with the write up at the end of the period, the writeup may be turned during the next lab meeting. For worksheet-type labs, you may complete your work on the worksheet. Show all steps for all calculations, and answer all questions. For labs that don't provide a worksheet, 1) clearly state your results and 2) include complete, full-sentence answers to all questions. Your lab write up must stand on its own. Don't reference question numbers or equation numbers from the handout, but reproduce them in your answer. If possible, try and address the motivation or misconception that must have prompted the inclusion of the question when the author designed the experiment. In other words, try and answer *why* is the question being asked, in addition to answering it (your primary goal)

RECITATION: Most lab periods will start with group-work problems (provided to me by your lecture instructor) in an instructor-assisted recitation. Participation in recitation is mandatory. Problem sets may require individually submitted solutions or a group submission depending on the week. Students habitually or significantly tardy will receive a zero for graded recitation weeks.

ATTENDANCE: ***Attendance and participation for every lab exercise is required.*** If you miss a lab, your course performance will be considered Incomplete—and you must make up all missing lab assignments in a future quarter to receive a passing grade. If you must miss lab, you can make it up the same week in another section, but you must make arrangements with the appropriate lab instructor to participate in an alternate lab session. Exceptions to the lab attendance policy will only be made on a one-time basis, and only for a compelling reason.

GRADING: In general, lab reports will be graded out of 10 points, with points awarded for completeness, correctness and sound experimental technique. The grading is essentially a lottery scheme, with the recitation graded some weeks, entire lab reports other weeks or occasionally a single calculation or question set from the writeup being graded in detail. From time to time, no report will be collected and the lab may be assessed by a short quiz the following week.

SAFETY: 1) ***No food or drink allowed in the lab, including water bottles.*** This is not my rule, but the department's and it is strictly enforced. Tables are provided outside of the lab for storing food and drinks. 2) Make sure you understand and follow directions for each experiment. When in doubt, ask! 3) Do not perform unauthorized experiments 4) Do not use any equipment not required for the experiment, or in a different way than requested. 5) If any equipment is broken or not functioning correctly stop using it and inform your instructor immediately. 6) If you are injured (including small cuts and burns) tell your instructor at once.

Christopher Culbreath

Beyond the Classroom

Online Videos

Overview

I use the Course Website to provide links to my YouTube Channel and content-specific links, to videos related to assignments. I produce two types of video content for my courses: *Step-by-step Solution Videos* and *Supplemental Lecture Videos*.

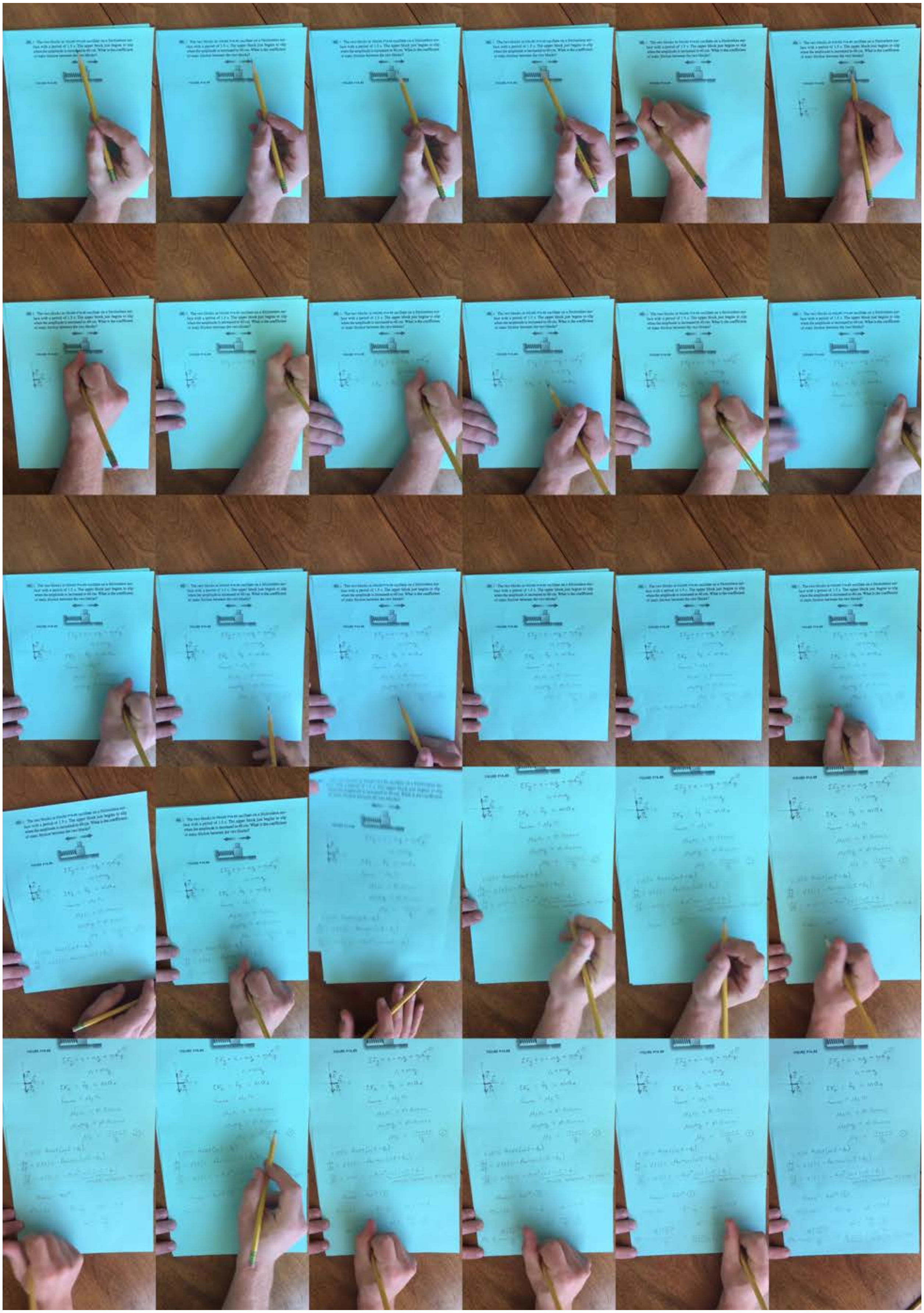
Step-by-step Solution Videos

A typical 15-20 problem assignment page includes direct links to one to three YouTube solution videos. The solution videos are produced with a document-camera setup, and provide a detailed, step-by-step solution to the problem along with problem-solving tips and commentary. Since the publisher's printed solutions are widely available to students, I make solution videos available when homework is assigned and encourage students to utilize them with a attempt-and-check strategy and to avoid wrote copying. Students love solution videos, and I have received overwhelmingly positive feedback citing their effectiveness. An example solution video is depicted by the frame sequence and transcript that begin on page 251.

Suplemental Lecture Videos

I do everything I can to maximize the impact of my class time with students. My efforts have focused on incorporating demonstrations, clicker-style questions and flipped-classroom problem solving into my lectures without skimping on course content. In order to balance these goals, and to accomodate a wide-range of learning styles, I produce *Supplemental Lecture Videos* that are posted to YouTube and the course website. These videos feature either a document-camera setup with a traditional-style lecture, or a narrated and animated slideshow that detail and explain course content not explicitly reviewed in class. Physics 132 has several small topics which are ideal for the format, leaving lecture time available for innovative and high-impact material.

Sample Homework Solution Video: Chapter 20, Problem 49 ·
`youtube.com/watch?v=IGVrH1UBNRY`



Sample Solution Video Transcript

Chapter 14, problem 49

`https://www.youtube.com/watch?v=IGVrH1UBNRY`

All right guys, Dr. Culbreath here with Chapter 14 number 49. It says, "The two blocks in the figure oscillate on a frictionless surface with a period of 1.5 seconds"—This bottom surface down here is frictionless and these two blocks oscillate back and forth—"The upper block just begins to slip when the amplitude is increased to 40cm. What is the coefficient of static friction between the two blocks?" There's friction between this upper block and the lower block. As the blocks oscillate, it's this friction that moves the upper block to the right and moves the upper block to the left. At some point, the acceleration of the oscillation becomes too great and the static friction cannot provide the required force to move the upper block with the lower block so it slips. Since we're dealing with static friction here, this is a clue that we need to use dynamics and Newton's laws to analyze these forces so we can apply our static friction force model.

Let's start with a free body diagram of the upper block. What forces do we have acting on that upper block? We have the force of gravity, which points down. The normal force, which points up. I'm going to consider when the two block assembly is moving to the right, in which case it is the static friction force on this upper block that moves it to the right. That is all of our forces acting on the block. We've completed our free body diagram, the next step is to sum the forces.

I'm going to start in the y direction. The sum of the forces in the y direction is plus the normal force and minus the force of gravity, which I'm going to write as mg, is equal to the mass times the acceleration in the y direction. We're considering oscillations in the x direction, but there's no motion in the y direction so our acceleration in the y direction is equal to zero. That gives us that the normal force is equal to mg. We can repeat this process in the x direction. The sum of the forces in the x direction: We have just our static friction force F_s and that's what gives us our acceleration in the x direction. On the right hand side, we have that equal to m times a.

All right. Now we want to consider the situation just when the block begins to slip. The static friction force as you may recall can have a range of values from zero up unto a maximum value. Above the maximum value, the static friction force gives way and it slips. At this slipping point, our static friction force is equal to that maximum value and $F_{s,\text{max}}$ is given by the coefficient of static friction, μ_s times the normal force n and we can substitute that into this upper equation here and we get μ_s times n is equal to the mass times the maximum allowed acceleration in the x direction and into this expression we can substitute mg for n because we solved for that up here doing the sum of the forces in the y direction.

We're going to get μ_s times mg is equal to the mass times the maximum acceleration in the x direction. Our masses cancel. We get that μ_s is equal to $a_{x,\text{max}}$ divided by g. I'm going to call that equation one.

All right so we come to the end of the line with Newton's laws here and we found that for our maximum allowable acceleration $a_{x,\text{max}}$. Once we've calculated that, we can get a value for the coefficient of static friction but how are we going to figure out what the maximum acceleration is when we have an oscillation of amplitude 40cm? We're going to need to use our oscillation kinematics for that. We're going to have to push the kinematic equation further than we did in class.

Let's go ahead and start with the position equation. We got the position at time t is equal to the amplitude times the cosine of ωt plus the initial phase, ϕ_0. We need to move down the kinematic ladder to the acceleration so starting with the position, if we want the velocity, we take the derivative of the position with respect to time which gives us the velocity. The derivative of cosine is minus sine and we get an ω which multiplies our independent variable t. We're going to get $-A$ times ω times the sine of $\omega t + \phi_0$.

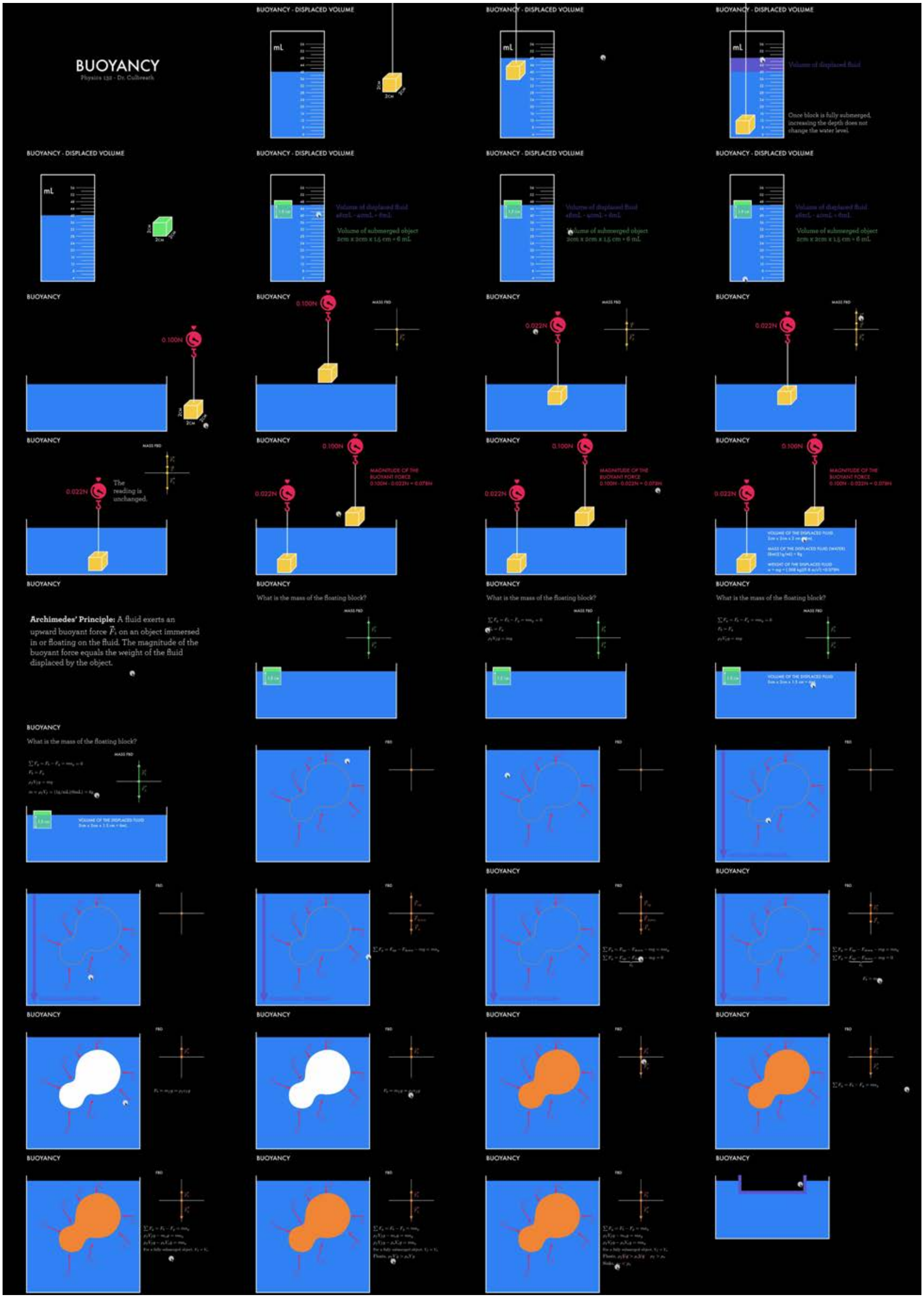
Now if we want the acceleration, we need to carry the kinematic ladder one step further so we want to take the derivative of the velocity with respect to time. That gives us the acceleration. The derivative of sine is cosine. We get another ω out in front so we get $-A$ times ω^2 times the cosine of ωt plus our initial phase ϕ_0. Now, we are looking for the maximum acceleration. We have an expression for our acceleration at any time t, but when is this going to be a maximum?

Cosine here can have any value between plus one and minus one. We can take this to be one and we recover our maximum acceleration and we get that the maximum acceleration is going to be equal to $A\omega^2$. All right. We don't know what ω is so we need to look back at our given information and see if we can get at this ω and it says here that the period of the oscillation is 1.5 seconds so we need to go from period to angular frequency and so we have T is given. T equals 1.5 seconds and we know that the frequency is equal to $1/T$ and we know that ω is equal to 2π times the frequency. So, we get that ω is equal to $2\pi/T$ or...I guess that's all we need. We have T and that gives us an ω.

Now we just need to combine these three equations, one, two, and three. We have 1 which depends on $a_{x,\ \mathrm{max}}$, we have 2 which depends on ω and here we have ω which depends on T so let's go ahead and combine those. We're going to get the amplitude A times ω^2 which is 2π over the period squared. Divided by g and that is going to give us μ_s. This is returning us to equation one here. Last step, we just need to put in some values. This is equal to 0.4 meters—that's our amplitude—divided by 9.8 meters per second squared—that's g—times 2π divided by the period, which is 1.5 seconds.

All this guy gets squared which gives us a value for the coefficient of static friction which is 0.716.

Sample Supplemental Lecture Video: Introduction to Buoyancy



Sample Supplemental Lecture Video Transcript

Introduction to Buoyancy

`https://www.youtube.com/watch?v=r4wm-F673tw`
Hi guys. Dr. Culbreath here with some bonus lecture content on buoyancy. To begin our discussion of buoyancy, we just need to work through some simple experiments. For this first one, we have a graduated cylinder, and we have a mass that is 2cm by 2cm by 2cm that is suspended from a string. We want to consider this situation where we put this mass into the graduated cylinder.

When we put the mass into the graduated cylinder, we see that the water level in the graduated cylinder rises. It was originally at 40mL, and now it is at 48mL. Once the block is submerged, we can also see what happens if we lower the block further down into the graduated cylinder. When we lower the block further down, it doesn't change the depth of the water.

Once the block is fully submerged, increasing the depth has not changed the water level, and this purple volume here is the volume of the displaced fluid. It was originally at 40 mL, and now it's at 48 mL, so we can assume or we can deduce that the volume of this cube itself is 8mL which is consistent with the original dimensions we had. 2cm by 2cm by 2cm adds up to 8 cubic centimeters which is the same as 8 mL. For a fully submerged object, the volume of the displaced fluid is equal to the volume of the object.

Now, let's consider this green cube here which has a somewhat different behavior when we put it in the graduated cylinder. When we put the green cube in the graduated cylinder, it did not sink. It floats, and approximately 1.5cm is submerged relative to its two-centimeter height, and we can see that the behavior of the graduated cylinder was a little bit different as well. Before, when we fully submerged our cube, the water level rose from 40 mL to 48 mL.

In this case, with the floating cube, we see that the water level changed from 40 mL to 46 mL, so the volume of the displaced fluid in this case is that 46 mL minus 40 mL, for a total of 6 mL, and we'll see that this is the same as the volume of the submerged object. We have a cube, so it's 2 cm by 2 cm, and then our depth is 1.5 cm, so that also gives us 6 mL for the submerged volume.

That is an important topic because in the topic of buoyancy, we often talk about the volume of the fluid displaced by the object, so if the object is fully submerged, the volume of fluid displaced is the same as the volume of the entire object. In the case of a floating object like this where we have it partially submerged, the volume of the displaced fluid is just equal to the volume of the object which is actually submerged in the water.

Now, we're going to talk about what we mean by buoyancy, so we're going to take our same yellow cube here, 2cm by 2cm by 2cm, and we've suspended it from a spring scale. Out here in air, this cube has a weight of 0.1 newtons. The gravitational force being pulled down by the cube is balanced by the tension force, and the tension force is measured by the spring scale to be 0.1 newtons.

We can see that on a free-body diagram, we've got the gravity which points down and the tension which points up. Now, let's make a prediction. How does the scale reading change when the mass is lowered into the fluid? Does it change at all? Does the scale reading increase, decrease, or stay the same? We find that when we lower the scale or excuse me, we lower the mass into the water while it's attached to the scale that the scale value decreases. We were at .1 newtons before. Now, we're at 0.022 newtons.

Before, the tension force and the gravitational force balanced each other. We know that the force of gravity is not changing for this cube, but we do also know from our measurement that the tension force has been reduced, so there must be another force at work. In fact, the fluid is exerting an upward force on the mass, and we call that the buoyant force. We give it the symbol F_b.

The next question is, how does the scale reading change if we lower the box further into the water? We're going to have more water on top. We're going to lower it further down. Does the scale reading increase, decrease, or stay the same? If we were to lower the box down further, the reading is, in fact, unchanged.

We've done some experiments or at least *virtually* done some experiments here to get a sense of how buoyancy works, and we can just review those numbers.

When the scale was in air, the block was in air, the tension was 0.1 newtons. When it is submerged in the water, it is equal to 0.22 newtons, so that means that whatever force has changed between being in the air and being in the water, meaning the force, the upward force that the fluid is exerting on the mass, which we are calling the "buoyant force," the magnitude of that force must be that additional upward force between the first situation and this situation—which we calculate to be 0.078 newtons.

Just to relate these ideas in a direct way, I guess I can't explain it as anything other than a lucky guess at this point, but it's worthwhile. If we also consider the volume of the displaced fluid here, which we calculated to be 8mL for this cube, we can calculate the mass of the displaced fluid, which is 8 grams, and the *weight* of the displaced fluid is in fact 0.078 newtons. What we read as the difference in these tensions is actually equal to the weight of the fluid displaced by the mass when we lower it into the container.

This brings us to the summary here, Archimedes' principle, and Archimedes' principle says that, "a fluid exerts an upward buoyant force F_b on an object immersed in or floating on the fluid. The magnitude of the buoyant force equals the weight of the fluid displaced by the object." I've shown that through a series of example experiments, but we can do this somewhat more rigorously. But first, let's look at a quick example here, and that is, what is the mass of this floating block?

We are told that the block is submerged 1.5 centimeters, so let's go ahead and complete our free-body diagram. We've got the force of gravity which points down. We've got the buoyant force which points up. If we do the sum of the forces in the y direction, we have plus F_b minus F_g. That's going to be the mass times the acceleration in the y direction. Assuming that this thing is not accelerating up or down, we can set this equal to zero, and we recover that the buoyant force must be equal to the force of gravity, and the buoyant force we said has got a magnitude which is equal to the weight of the fluid displaced by the block.

We can take the density of the fluid times the volume of the fluid. That's going to give us the mass of the fluid times g, so this is going to be the weight of the fluid, and that must be equal to the weight of the block. The volume of the displaced fluid in this case is our 2cm by 2cm by 1.5cm which gives us 6 mL , so we can put 6 mL in for the volume of the fluid. This is water in this case, so we know the density. We know g. In fact, the gs cancel. We are left with the mass of the block is equal to the density of the fluid times the volume of the fluid which is equal to six grams. Six grams.

All right. Now, to put some more rigorous underpinning into Archimedes' principle, we're going to consider a container of fluid. Inside of that container of fluid, we're going to consider an arbitrary volume within the fluid, so this is a three-dimensional volume within the fluid. Since the pressure exists in the fluid, there is going to be forces due to the pressure being exerted along the surface of the fluid everywhere, so the fluid is exerting forces on this volume of fluid that we're interested in.

Since the pressure is omnidirectional, we have forces to the right, and we have forces to the left, and we have forces from the top, and we have forces from the bottom. In a liquid like this, the pressure increases as we go towards the bottom, so along the layer, the pressure is the same, and the pressure is least at the top and greatest at the bottom. That means, since the pressure is the same along the horizontal line, that all of our horizontal forces are going to cancel out. We have forces from the right. We have forces from the left. Those are going to be equal and opposite, but up and down, our forces are not going to cancel out because the forces at the top due to the pressure are going to be smaller than the forces at the bottom due to the pressure because the pressure increases as the depth increases within the fluid.

The net result of all of these pressure forces is we're going to have an up-force and a down-force, and we expect that the force that is exerted...being exerted on the bottom of the volume—or the up-force—should be greater than the down-force because it is at a higher depth, so the pressure is higher.

To summarize that on the free-body diagram, we have an up-force and a down-force. We expect the up-force to be bigger than the down-force, and we also have the force of gravity due to the actual volume of fluid here, so it has mass, and it's going to have a force of gravity, which also points down.

If we do a sum of the forces in the y direction, we get plus F_{up} minus F_{down} minus mg, and that's going to be equal to the mass times the acceleration in the y direction. Since this fluid is in hydrostatic equilibrium, the volume of fluid is not moving up or down, so we can set this equal to zero. On the right-hand side, and we're going to define this quantity of the difference in the pressure forces—the up-force minus the down-force—which is due to our increasing pressure here (we have a gradient). We're going to define this as the buoyant force. This is the force that the fluid, the upward force that the fluid exerts on the volume, and that is exactly what we define the buoyant force as in Archimedes' principle, so we get that the buoyant force is equal to the mass of the fluid times g.

Now, I want to do a thought experiment here where we consider suddenly removing this entire volume of liquid from the container, and the only thing that changes about our free-body diagram is that the gravitational force which points down disappears. The buoyant force which is the up-force minus the down-force still exists. Nothing has changed about the fluid on the outside. Nothing has changed about the forces exerted by the fluid on this volume.

By removing the water inside or the fluid inside of this volume. Nothing has changed about these forces which we're acting on this volume in the first place. It's the geometry, right? That defined it, and nothing has changed about the geometry, so we still have that the buoyant force is equal to the mass of the fluid times g which we can also write instead of the mass of the fluid, as the density of the fluid times the volume of the fluid times g.

Now, if we put an object in the place of the void, then our free-body diagram changes a little bit in that we have the mass of the object or the gravitational force of the object which is now pulling down. We have the buoyant force which is unchanged whose magnitude is just equal to the weight of the fluid that was contained within this shape, and we have the gravitational force which points down. For this free-body diagram that I've shown here, this object sinks, right, because the gravitational force is greater than the buoyancy force, or in other words, this object which has this volume weighs more than water of this same volume—or of the *fluid*—of a volume of fluid the same size.

Let's go ahead and do the sum of the forces. We get that the buoyant force points up, minus the force of gravity which points down, and we can rewrite this in terms of the density of the fluid times the volume of the fluid times g minus, the mass of the object times g. This is just F_g rom our orange object here, and so we can rewrite that as the density of the object times the volume of the object times g.

For a fully submerged object, we have that the volume of the fluid is equal to the volume of the object, so the volume of the displaced fluid is equal to the volume of the object for a fully submerged object. If we compare these two terms, we're going to get a positive acceleration if this term is bigger than this term and a positive acceleration corresponds to our object floating. Meaning, the upward forces exceed the downward forces, and so in that case, that's going to be that the density of the fluid times the volume times gravity must be greater than the density of the object times the volume times gravity.

We can do some cancellation here and say that this is going to—the object is going to float if the density of the object is less than the density of the fluid. It's going to sink if the density of the object is greater than the density of the fluid, and it has what's called "neutral buoyancy." Meaning, it does not have a net force up or down if the density of the fluid is equal to the density of the object.

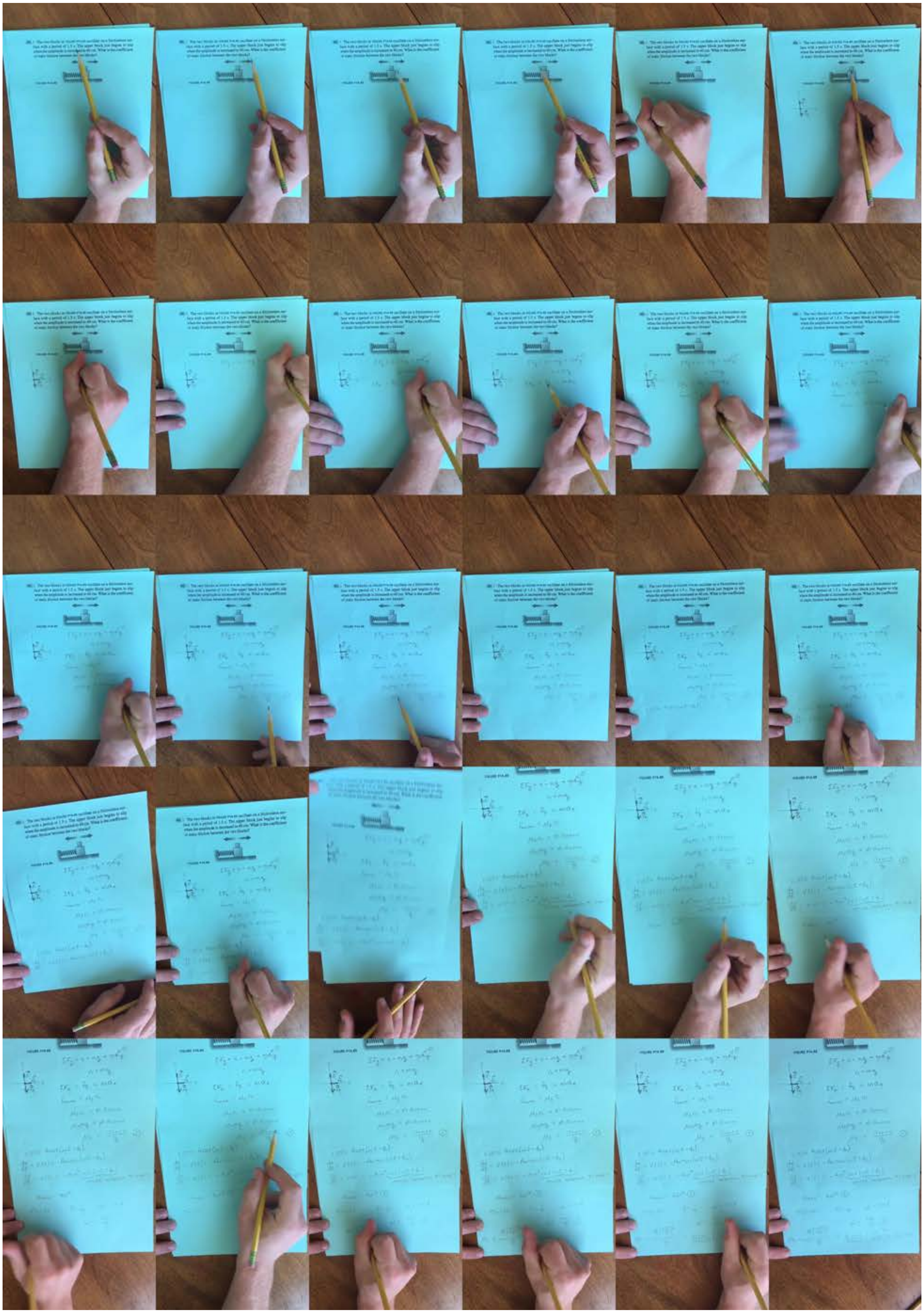
All right. One last topic, and that's the topic of boats. Instead of considering just a rectangular object here, let's consider a rectangular object that is hollowed out. By hollowing it out, we remove a lot of the mass of this object, but we don't actually change the footprint here for the amount of fluid that's displaced—So the shape of the boat causes it to displace far more water than the volume of the boat's materials alone.

If this was a steel boat, and these were steel plates here, and we just stack the steel plates up, the volume displaced would be much less than this shape here which allows this big empty region inside, allows the boat to displace more water than the materials alone, and a boat will float if its geometry allows it to displace enough water equal to the weight of the boat. If the boat's shape allows it to displace enough water such that the volume of water displaced is equal—excuse me—the weight of the volume of water displaced is equal to the weight of the boat, then the boat will in fact float. Those are my comments on buoyancy. I do have some example problems in some other videos. Thanks a lot. Bye-bye.

Suplemental Lecture Videos

I do everything I can to maximize the impact of my class time with students. My efforts have focused on incorporating demonstrations, clicker-style questions and flipped-classroom problem solving into my lectures without skimping on course content. In order to balance these goals, and to accomodate a wide-range of learning styles, I produce *Supplemental Lecture Videos* that are posted to YouTube and the course website. These videos feature either a document-camera setup with a traditional-style lecture, or a narrated and animated slideshow that detail and explain course content not explicitly reviewed in class. Physics 132 has several small topics which are ideal for the format, leaving lecture time available for innovative and high-impact material.

Sample Homework Solution Video: Chapter 20, Problem 49 ·
`youtube.com/watch?v=IGVrH1UBNRY`



Sample Solution Video Transcript

Chapter 14, problem 49

`https://www.youtube.com/watch?v=IGVrH1UBNRY`

All right guys, Dr. Culbreath here with Chapter 14 number 49. It says, "The two blocks in the figure oscillate on a frictionless surface with a period of 1.5 seconds"—This bottom surface down here is frictionless and these two blocks oscillate back and forth—"The upper block just begins to slip when the amplitude is increased to 40cm. What is the coefficient of static friction between the two blocks?" There's friction between this upper block and the lower block. As the blocks oscillate, it's this friction that moves the upper block to the right and moves the upper block to the left. At some point, the acceleration of the oscillation becomes too great and the static friction cannot provide the required force to move the upper block with the lower block so it slips. Since we're dealing with static friction here, this is a clue that we need to use dynamics and Newton's laws to analyze these forces so we can apply our static friction force model.

Let's start with a free body diagram of the upper block. What forces do we have acting on that upper block? We have the force of gravity, which points down. The normal force, which points up. I'm going to consider when the two block assembly is moving to the right, in which case it is the static friction force on this upper block that moves it to the right. That is all of our forces acting on the block. We've completed our free body diagram, the next step is to sum the forces.

I'm going to start in the y direction. The sum of the forces in the y direction is plus the normal force and minus the force of gravity, which I'm going to write as mg, is equal to the mass times the acceleration in the y direction. We're considering oscillations in the x direction, but there's no motion in the y direction so our acceleration in the y direction is equal to zero. That gives us that the normal force is equal to mg. We can repeat this process in the x direction. The sum of the forces in the x direction: We have just our static friction force F_s and that's what gives us our acceleration in the x direction. On the right hand side, we have that equal to m times a.

All right. Now we want to consider the situation just when the block begins to slip. The static friction force as you may recall can have a range of values from zero up unto a maximum value. Above the maximum value, the static friction force gives way and it slips. At this slipping point, our static friction force is equal to that maximum value and $F_{s,\mathsf{max}}$ is given by the coefficient of static friction, μ_s times the normal force n and we can substitute that into this upper equation here and we get μ_s times n is equal to the mass times the maximum allowed acceleration in the x direction and into this expression we can substitute mg for n because we solved for that up here doing the sum of the forces in the y direction.

We're going to get μ_s times mg is equal to the mass times the maximum acceleration in the x direction. Our masses cancel. We get that μ_s is equal to $a_{x,\mathsf{max}}$ divided by g. I'm going to call that equation one.

All right so we come to the end of the line with Newton's laws here and we found that for our maximum allowable acceleration $a_{x,\mathsf{max}}$. Once we've calculated that, we can get a value for the coefficient of static friction but how are we going to figure out what the maximum acceleration is when we have an oscillation of amplitude 40cm? We're going to need to use our oscillation kinematics for that. We're going to have to push the kinematic equation further than we did in class.

Let's go ahead and start with the position equation. We got the position at time t is equal to the amplitude times the cosine of ωt plus the initial phase, ϕ_0. We need to move down the kinematic ladder to the acceleration so starting with the position, if we want the velocity, we take the derivative of the position with respect to time which gives us the velocity. The derivative of cosine is minus sine and we get an ω which multiplies our independent variable t. We're going to get $-A$ times ω times the sine of $\omega t + \phi_0$.

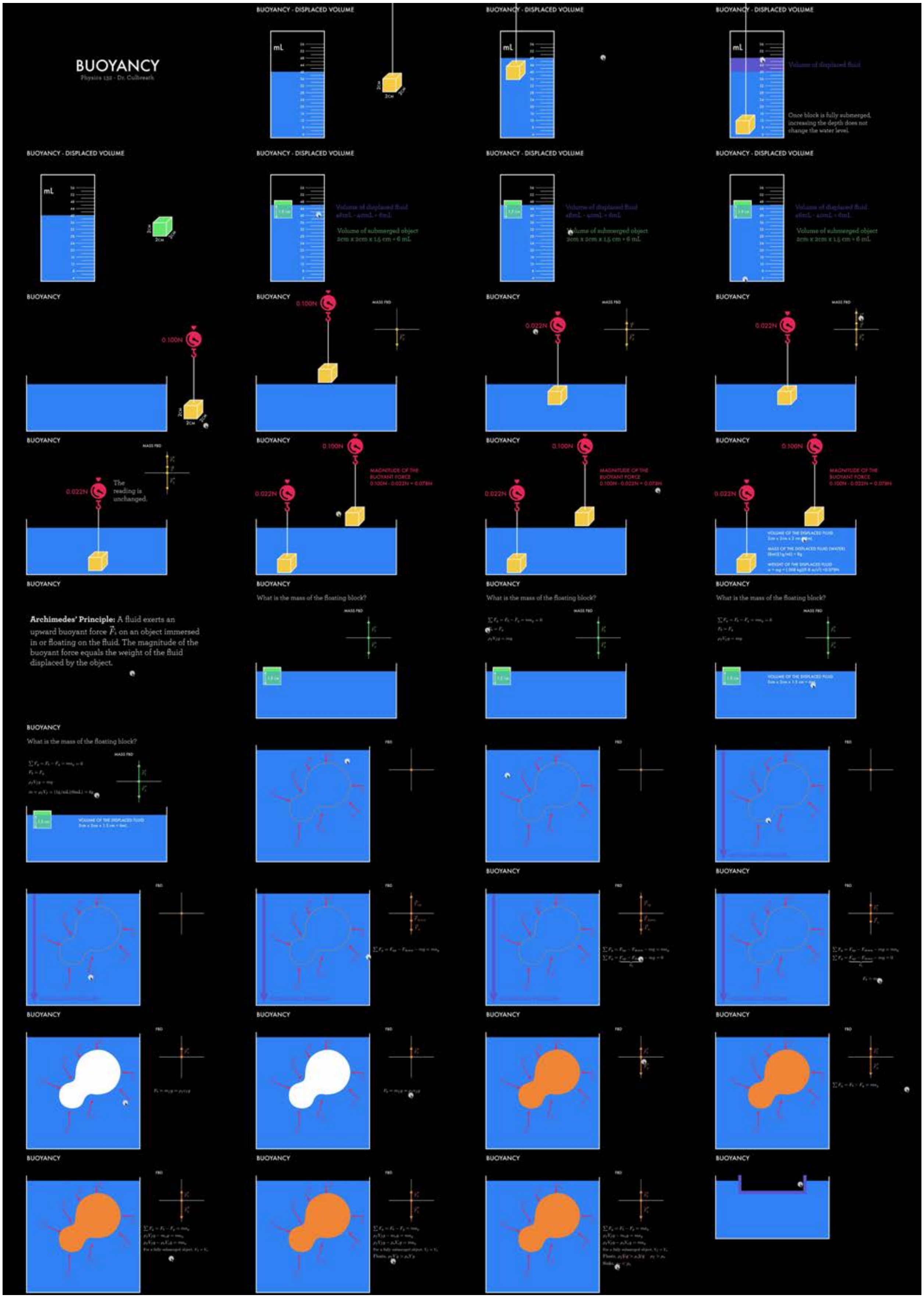
Now if we want the acceleration, we need to carry the kinematic ladder one step further so we want to take the derivative of the velocity with respect to time. That gives us the acceleration. The derivative of sine is cosine. We get another ω out in front so we get $-A$ times ω^2 times the cosine of ωt plus our initial phase ϕ_0. Now, we are looking for the maximum acceleration. We have an expression for our acceleration at any time t, but when is this going to be a maximum?

Cosine here can have any value between plus one and minus one. We can take this to be one and we recover our maximum acceleration and we get that the maximum acceleration is going to be equal to $A\omega^2$. All right. We don't know what ω is so we need to look back at our given information and see if we can get at this ω and it says here that the period of the oscillation is 1.5 seconds so we need to go from period to angular frequency and so we have T is given. T equals 1.5 seconds and we know that the frequency is equal to $1/T$ and we know that ω is equal to 2π times the frequency. So, we get that ω is equal to $2\pi/T$ or...I guess that's all we need. We have T and that gives us an ω.

Now we just need to combine these three equations, one, two, and three. We have 1 which depends on $a_{x,\,\mathrm{max}}$, we have 2 which depends on ω and here we have ω which depends on T so let's go ahead and combine those. We're going to get the amplitude A times ω^2 which is 2π over the period squared. Divided by g and that is going to give us μ_s. This is returning us to equation one here. Last step, we just need to put in some values. This is equal to 0.4 meters—that's our amplitude—divided by 9.8 meters per second squared—that's g—times 2π divided by the period, which is 1.5 seconds.

All this guy gets squared which gives us a value for the coefficient of static friction which is 0.716.

Sample Supplemental Lecture Video: Introduction to Buoyancy



Sample Supplemental Lecture Video Transcript

Introduction to Buoyancy

`https://www.youtube.com/watch?v=r4wm-F673tw`

Hi guys. Dr. Culbreath here with some bonus lecture content on buoyancy. To begin our discussion of buoyancy, we just need to work through some simple experiments. For this first one, we have a graduated cylinder, and we have a mass that is 2cm by 2cm by 2cm that is suspended from a string. We want to consider this situation where we put this mass into the graduated cylinder.

When we put the mass into the graduated cylinder, we see that the water level in the graduated cylinder rises. It was originally at 40mL, and now it is at 48mL. Once the block is submerged, we can also see what happens if we lower the block further down into the graduated cylinder. When we lower the block further down, it doesn't change the depth of the water.

Once the block is fully submerged, increasing the depth has not changed the water level, and this purple volume here is the volume of the displaced fluid. It was originally at 40 mL, and now it's at 48 mL, so we can assume or we can deduce that the volume of this cube itself is 8mL which is consistent with the original dimensions we had. 2cm by 2cm by 2cm adds up to 8 cubic centimeters which is the same as 8 mL. For a fully submerged object, the volume of the displaced fluid is equal to the volume of the object.

Now, let's consider this green cube here which has a somewhat different behavior when we put it in the graduated cylinder. When we put the green cube in the graduated cylinder, it did not sink. It floats, and approximately 1.5cm is submerged relative to its two-centimeter height, and we can see that the behavior of the graduated cylinder was a little bit different as well. Before, when we fully submerged our cube, the water level rose from 40 mL to 48 mL.

In this case, with the floating cube, we see that the water level changed from 40 mL to 46 mL, so the volume of the displaced fluid in this case is that 46 mL minus 40 mL, for a total of 6 mL, and we'll see that this is the same as the volume of the submerged object. We have a cube, so it's 2 cm by 2 cm, and then our depth is 1.5 cm, so that also gives us 6 mL for the submerged volume.

That is an important topic because in the topic of buoyancy, we often talk about the volume of the fluid displaced by the object, so if the object is fully submerged, the volume of fluid displaced is the same as the volume of the entire object. In the case of a floating object like this where we have it partially submerged, the volume of the displaced fluid is just equal to the volume of the object which is actually submerged in the water.

Now, we're going to talk about what we mean by buoyancy, so we're going to take our same yellow cube here, 2cm by 2cm by 2cm, and we've suspended it from a spring scale. Out here in air, this cube has a weight of 0.1 newtons. The gravitational force being pulled down by the cube is balanced by the tension force, and the tension force is measured by the spring scale to be 0.1 newtons.

We can see that on a free-body diagram, we've got the gravity which points down and the tension which points up. Now, let's make a prediction. How does the scale reading change when the mass is lowered into the fluid? Does it change at all? Does the scale reading increase, decrease, or stay the same? We find that when we lower the scale or excuse me, we lower the mass into the water while it's attached to the scale that the scale value decreases. We were at .1 newtons before. Now, we're at 0.022 newtons.

Before, the tension force and the gravitational force balanced each other. We know that the force of gravity is not changing for this cube, but we do also know from our measurement that the tension force has been reduced, so there must be another force at work. In fact, the fluid is exerting an upward force on the mass, and we call that the buoyant force. We give it the symbol F_b.

The next question is, how does the scale reading change if we lower the box further into the water? We're going to have more water on top. We're going to lower it further down. Does the scale reading increase, decrease, or stay the same? If we were to lower the box down further, the reading is, in fact, unchanged.

We've done some experiments or at least *virtually* done some experiments here to get a sense of how buoyancy works, and we can just review those numbers.

When the scale was in air, the block was in air, the tension was 0.1 newtons. When it is submerged in the water, it is equal to 0.22 newtons, so that means that whatever force has changed between being in the air and being in the water, meaning the force, the upward force that the fluid is exerting on the mass, which we are calling the "buoyant force," the magnitude of that force must be that additional upward force between the first situation and this situation—which we calculate to be 0.078 newtons.

Just to relate these ideas in a direct way, I guess I can't explain it as anything other than a lucky guess at this point, but it's worthwhile. If we also consider the volume of the displaced fluid here, which we calculated to be 8mL for this cube, we can calculate the mass of the displaced fluid, which is 8 grams, and the *weight* of the displaced fluid is in fact 0.078 newtons. What we read as the difference in these tensions is actually equal to the weight of the fluid displaced by the mass when we lower it into the container.

This brings us to the summary here, Archimedes' principle, and Archimedes' principle says that, "a fluid exerts an upward buoyant force F_b on an object immersed in or floating on the fluid. The magnitude of the buoyant force equals the weight of the fluid displaced by the object." I've shown that through a series of example experiments, but we can do this somewhat more rigorously. But first, let's look at a quick example here, and that is, what is the mass of this floating block?

We are told that the block is submerged 1.5 centimeters, so let's go ahead and complete our free-body diagram. We've got the force of gravity which points down. We've got the buoyant force which points up. If we do the sum of the forces in the y direction, we have plus F_b minus F_g. That's going to be the mass times the acceleration in the y direction. Assuming that this thing is not accelerating up or down, we can set this equal to zero, and we recover that the buoyant force must be equal to the force of gravity, and the buoyant force we said has got a magnitude which is equal to the weight of the fluid displaced by the block.

We can take the density of the fluid times the volume of the fluid. That's going to give us the mass of the fluid times g, so this is going to be the weight of the fluid, and that must be equal to the weight of the block. The volume of the displaced fluid in this case is our 2cm by 2cm by 1.5cm which gives us 6 mL , so we can put 6 mL in for the volume of the fluid. This is water in this case, so we know the density. We know g. In fact, the gs cancel. We are left with the mass of the block is equal to the density of the fluid times the volume of the fluid which is equal to six grams. Six grams.

All right. Now, to put some more rigorous underpinning into Archimedes' principle, we're going to consider a container of fluid. Inside of that container of fluid, we're going to consider an arbitrary volume within the fluid, so this is a three-dimensional volume within the fluid. Since the pressure exists in the fluid, there is going to be forces due to the pressure being exerted along the surface of the fluid everywhere, so the fluid is exerting forces on this volume of fluid that we're interested in.

Since the pressure is omnidirectional, we have forces to the right, and we have forces to the left, and we have forces from the top, and we have forces from the bottom. In a liquid like this, the pressure increases as we go towards the bottom, so along the layer, the pressure is the same, and the pressure is least at the top and greatest at the bottom. That means, since the pressure is the same along the horizontal line, that all of our horizontal forces are going to cancel out. We have forces from the right. We have forces from the left. Those are going to be equal and opposite, but up and down, our forces are not going to cancel out because the forces at the top due to the pressure are going to be smaller than the forces at the bottom due to the pressure because the pressure increases as the depth increases within the fluid.

The net result of all of these pressure forces is we're going to have an up-force and a down-force, and we expect that the force that is exerted...being exerted on the bottom of the volume—or the up-force—should be greater than the down-force because it is at a higher depth, so the pressure is higher.

To summarize that on the free-body diagram, we have an up-force and a down-force. We expect the up-force to be bigger than the down-force, and we also have the force of gravity due to the actual volume of fluid here, so it has mass, and it's going to have a force of gravity, which also points down.

If we do a sum of the forces in the y direction, we get plus F_{up} minus F_{down} minus mg, and that's going to be equal to the mass times the acceleration in the y direction. Since this fluid is in hydrostatic equilibrium, the volume of fluid is not moving up or down, so we can set this equal to zero. On the right-hand side, and we're going to define this quantity of the difference in the pressure forces—the up-force minus the down-force—which is due to our increasing pressure here (we have a gradient). We're going to define this as the buoyant force. This is the force that the fluid, the upward force that the fluid exerts on the volume, and that is exactly what we define the buoyant force as in Archimedes' principle, so we get that the buoyant force is equal to the mass of the fluid times g.

Now, I want to do a thought experiment here where we consider suddenly removing this entire volume of liquid from the container, and the only thing that changes about our free-body diagram is that the gravitational force which points down disappears. The buoyant force which is the up-force minus the down-force still exists. Nothing has changed about the fluid on the outside. Nothing has changed about the forces exerted by the fluid on this volume.

By removing the water inside or the fluid inside of this volume. Nothing has changed about these forces which we're acting on this volume in the first place. It's the geometry, right? That defined it, and nothing has changed about the geometry, so we still have that the buoyant force is equal to the mass of the fluid times g which we can also write instead of the mass of the fluid, as the density of the fluid times the volume of the fluid times g.

Now, if we put an object in the place of the void, then our free-body diagram changes a little bit in that we have the mass of the object or the gravitational force of the object which is now pulling down. We have the buoyant force which is unchanged whose magnitude is just equal to the weight of the fluid that was contained within this shape, and we have the gravitational force which points down. For this free-body diagram that I've shown here, this object sinks, right, because the gravitational force is greater than the buoyancy force, or in other words, this object which has this volume weighs more than water of this same volume—or of the *fluid*—of a volume of fluid the same size.

Let's go ahead and do the sum of the forces. We get that the buoyant force points up, minus the force of gravity which points down, and we can rewrite this in terms of the density of the fluid times the volume of the fluid times g minus, the mass of the object times g. This is just F_g rom our orange object here, and so we can rewrite that as the density of the object times the volume of the object times g.

For a fully submerged object, we have that the volume of the fluid is equal to the volume of the object, so the volume of the displaced fluid is equal to the volume of the object for a fully submerged object. If we compare these two terms, we're going to get a positive acceleration if this term is bigger than this term and a positive acceleration corresponds to our object floating. Meaning, the upward forces exceed the downward forces, and so in that case, that's going to be that the density of the fluid times the volume times gravity must be greater than the density of the object times the volume times gravity.

We can do some cancellation here and say that this is going to—the object is going to float if the density of the object is less than the density of the fluid. It's going to sink if the density of the object is greater than the density of the fluid, and it has what's called "neutral buoyancy." Meaning, it does not have a net force up or down if the density of the fluid is equal to the density of the object.

All right. One last topic, and that's the topic of boats. Instead of considering just a rectangular object here, let's consider a rectangular object that is hollowed out. By hollowing it out, we remove a lot of the mass of this object, but we don't actually change the footprint here for the amount of fluid that's displaced—So the shape of the boat causes it to displace far more water than the volume of the boat's materials alone.

If this was a steel boat, and these were steel plates here, and we just stack the steel plates up, the volume displaced would be much less than this shape here which allows this big empty region inside, allows the boat to displace more water than the materials alone, and a boat will float if its geometry allows it to displace enough water equal to the weight of the boat. If the boat's shape allows it to displace enough water such that the volume of water displaced is equal—excuse me—the weight of the volume of water displaced is equal to the weight of the boat, then the boat will in fact float. Those are my comments on buoyancy. I do have some example problems in some other videos. Thanks a lot. Bye-bye.

Self-paced slideshow presentations

I have also incorporated self-paced keynote slide presentations on a few topics to supplement the lecture presentation. Generally, I was inspired to produce these slideshows in response to a student's question during class or office hours. I've found ray optics to be a topic that is well-demonstrated by illustrative figures that build with an increasing level of explanation. The computer constructed drawings can show a lot more detail that what I can feasibly produce on the board, and I can target the content of the presentations to areas of frequent misconception or uncertainty.

physicscloud.net

Overview

Feeling frustrated by the limitations and mobile-unfriendliness of standard university web systems like Blackboard and PolyLearn, I began writing `physicscloud.net` is the Fall of 2014. Physics Cloud is an online gradebook and course management system, custom built to serve the needs of my courses. Physics cloud is a mobile-friendly PHP/MySQL/JavaScript Web 2.0 application built on the high-performance Yii Application Framework[§]. I designed Physics Cloud to be a versatile platform for both the existing and future online course elements. As a first application, I wrote a gradebook application which provides rich student views detailing their scores and grade calculation, as shown on pages 261 and 260 below. I have also implemented class polling, student preferences, and access-limited grader functionality. Physics cloud is under active development. I plan to use physics cloud as the platform to provide many other online course features including online assignment submission, interactive simulations and student collaboration.

Screenshots

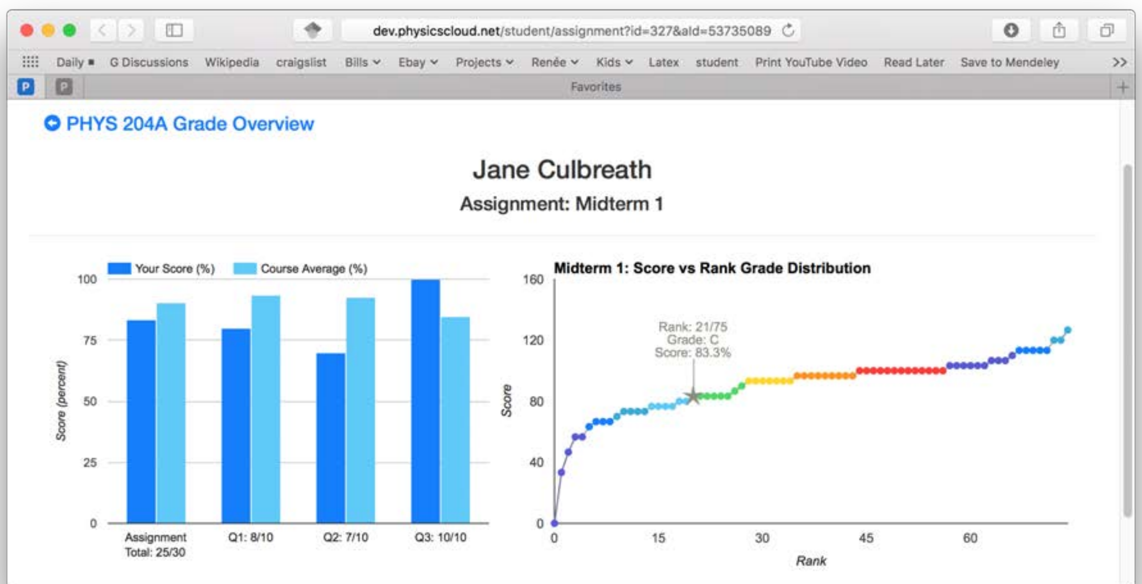
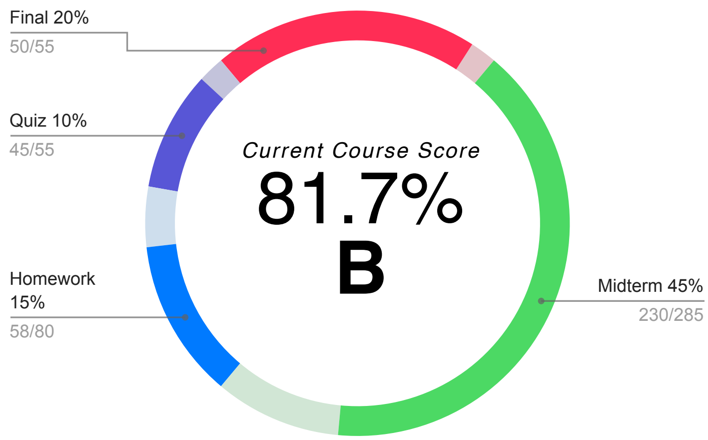


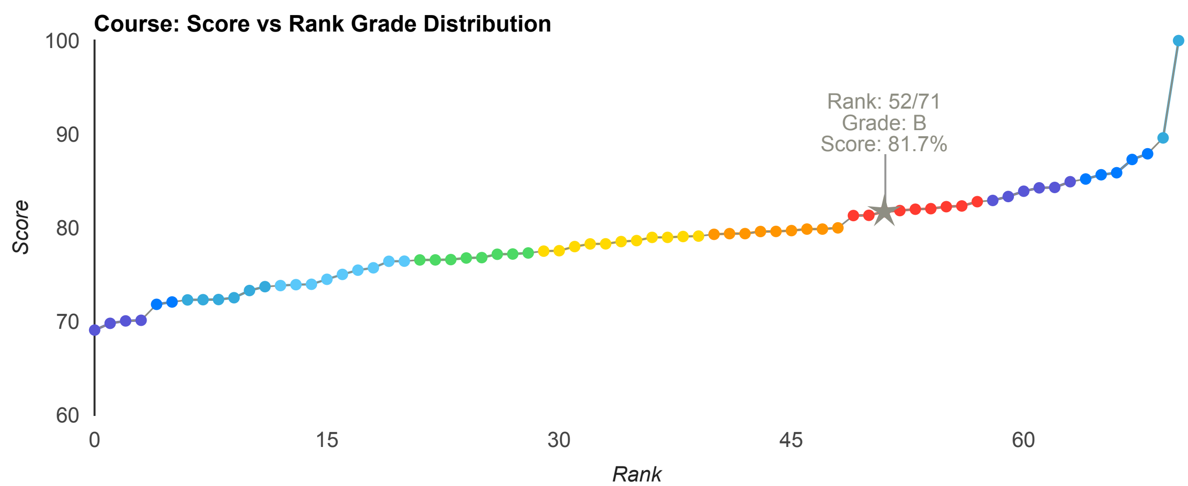
Figure 12: The *Student Assignment View* shows student scores per-question for exams, along with course averages for each problem, the overall course average, and the grade distribution as a function of rank, and a letter grade assignment (if enabled).

[§]`http://yiiframework.com`

Jane Culbreath

PHYS 204A Grade Overview





Midterm

Assignment Name	Question Scores	Score	Possible	Percent
Midterm 1	Q1: 8/10 , Q2: 7/10 , Q3: 10/10	25	30	83.3%
Midterm 3	Q1: 25/25 , Q2: 25/25	50	50	100.0%
Test 4	Q1: 10/10 , Q2: NS/10 ,	10	---	---
(Score dropped)	Q3: NS/10 , Q4: NS/10			

Exam 3	Q1: 40/10 , Q2: 0/30	40	40	100.0%
Test 6 Problems	Q1: 0/10 , Q2: 0/15 , Q3: 0/20 , Q4: 25/25 , Q5: 30/30 , Q6: 30/35	85	135	63.0%
Midterm 1Q		30	30	100.0%
	Midterm Total:	230	285	80.7%

Quiz

Assignment Name	Question Scores	Score	Possible	Percent
Quiz 1	Q1: 10/20 , Q2: 20/20	30	40	75.0%
Quiz 2	Q1: 5/5 , Q2: 5/5 , Q3: 5/5	15	15	100.0%
	Quiz Total:	45	55	81.8%

Homework

Assignment Name	Question Scores	Score	Possible	Percent
Homework 1		25	30	83.3%
Homework 3		33	50	66.0%
	Homework Total:	58	80	72.5%

Final

Assignment Name	Question Scores	Score	Possible	Percent
Finally	Q1: 0/5 , Q2: 5/5 , Q3: 22/22 , Q4: 23/23	50	55	90.9%
	Final Total:	50	55	90.9%

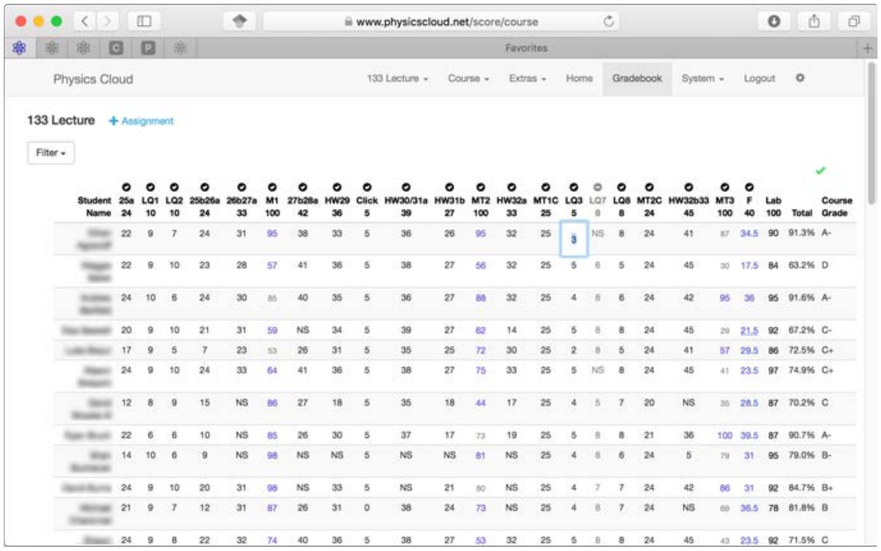


Figure 13: *Instructor Gradebook View*

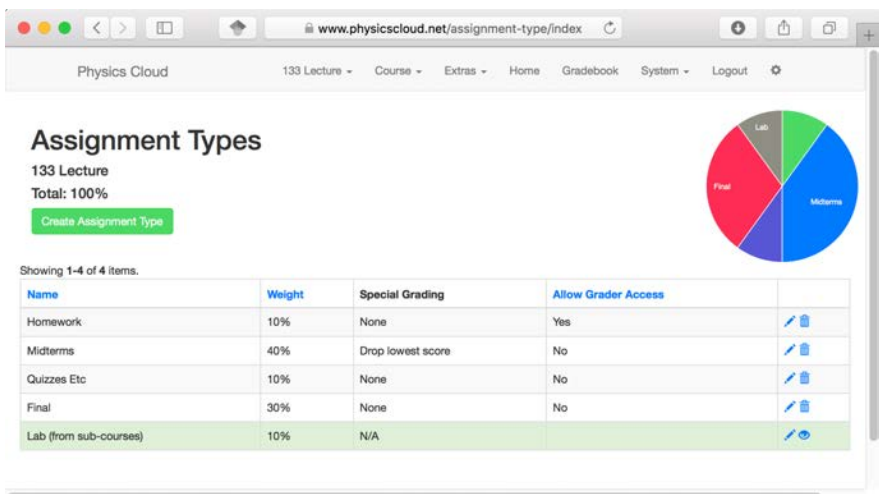


Figure 14: *Assignment Weight Configuration*

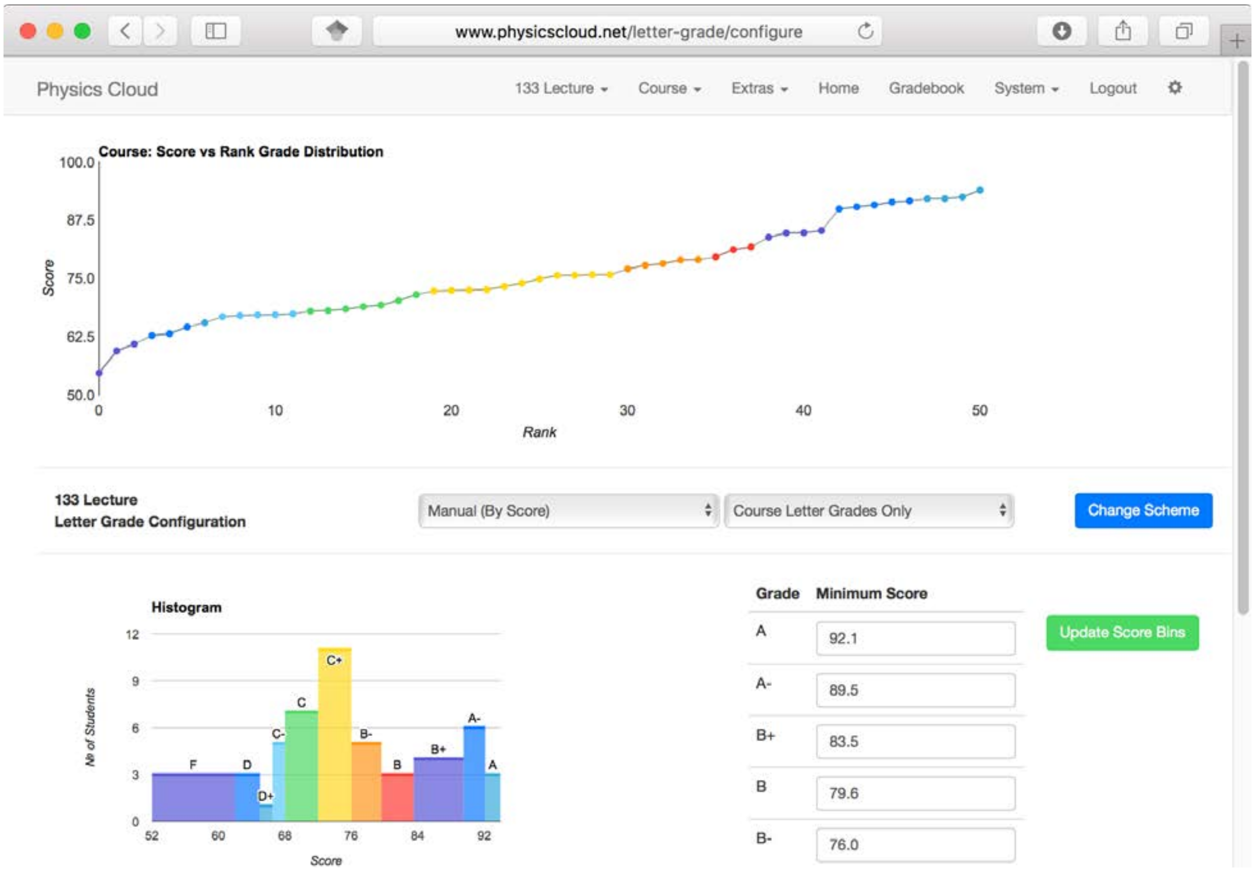


Figure 15: *Instructor Letter Grade Configuration:* Physics Cloud supports several curve schemes, and a responsive interface for observing changes to the letter grade distribution

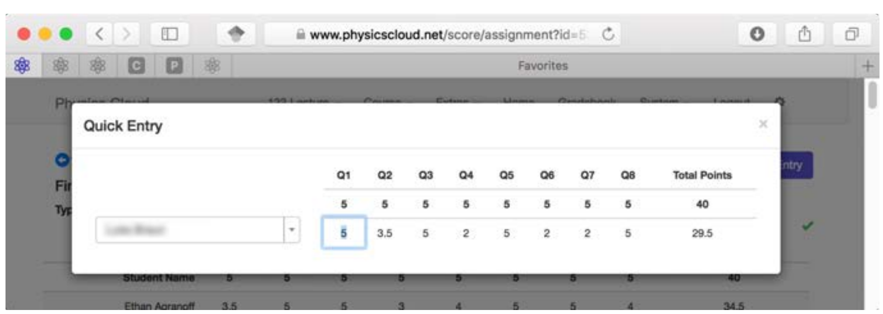


Figure 16: *Grader Quick Entry View:* A smart auto-complete search interface streamlines grade input

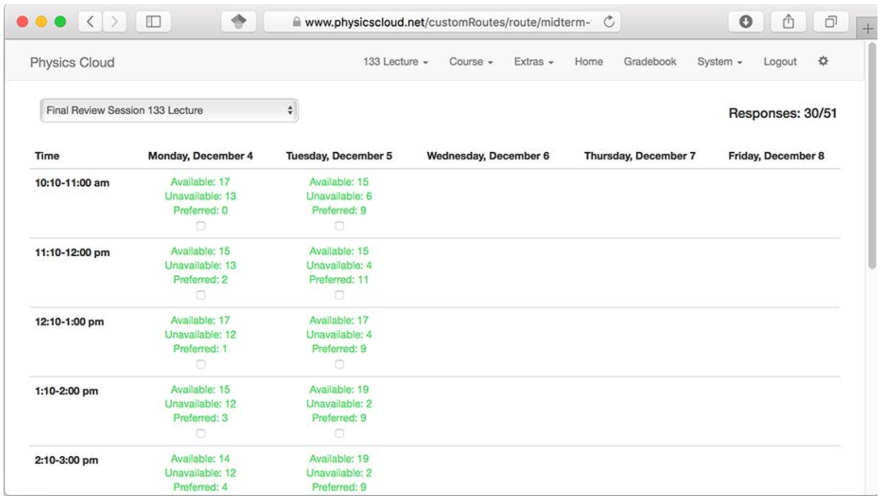


Figure 17: *Event scheduling and availability - Instructor View*

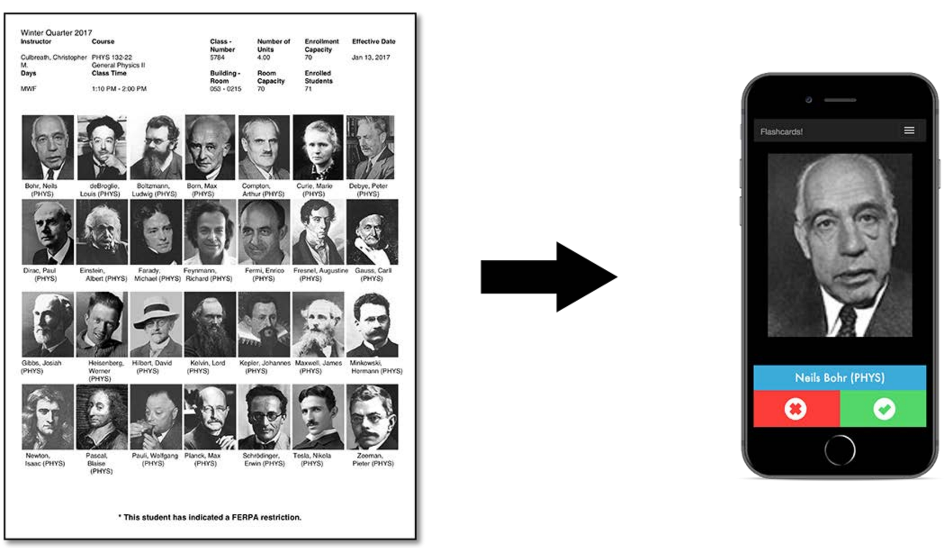


Figure 18: Physics Cloud can turn Cal Poly course rosters into an interactive flashcard game

Christopher Culbreath

Virtual Instruction Addendum

Philosophy and Approach

As the tone of the letter[¶] which I sent to students just before the start of the Spring 2020 quarter makes clear, I had considerable apprehension as we switched to virtual instruction for all of our courses. I had taken an online course or two in the early era of such offerings, and not only did I hate them, my performance was among the lowest of any class that I've taken. After a few class meetings, however, I soon found my concerns to be excessive. Towards the beginning of the term, I found myself with sufficient bandwidth to expand my toolset and try to make the most of this new format. My approach is guided by the same principles that I've identified in my teaching philosophy (page 14). In trying to build a course that I would enjoy taking myself, I emphasized flexibility and have found the online format to complemented my own interests in a way that has allowed me to enhance the class while having fun. As a life-long technologist, and gaining enthusiasm for the task, I decided to emphasize and experiment on a quest to find out the ways technology can enhance digitally delivered class. Over the past three quarters, I've used face tracking motorized cameras, incorporated live drone footage, document cameras, and three-camera board setup. I've tried a slew of different iPad apps for livecasting and an assortment for digital grading. After some disappointment with some 3rd party solutions, I've expanded the capabilities of my website to include online assessment, digital curation of submitted files and zoom group selections (see figure 268 below). I wrote tools using the Zoom API that automatically posted my lecture recordings when they were done processing and was testing an application that would allow students to control LEDs in my digital classroom— a mechanism for digital hand raising without the need for me to focus on zoom notifications during my lecture[‖] Hopefully the tone of these last few sentences convey how much I really do love this stuff. I am usually a maker and a coder on my own time, and one thing that I've really appreciated about virtual instruction is that I've had reasons to flex and challenge these skills in a way that (hopefully) makes my classes better. I know that for a significant contingency of my students, my enthusiasm for these interests is a positive force in the class. Others see it as a distraction or a frustration— this is a sentiment that I can understand. As I move forward, with (at least) one more quarter of virtual instruction, I will be honing in on the technology that works best. It takes experimentation and the early adopters to learn these very lessons, and learned I have. My expectation is that moving forward, an equilibrium will be reached in a way that satisfies the vast majority of students.

[¶] Included in this document beginning on page 271

[‖] Unfortunately, some time near the beginning of the Fall quarter, ITS disabled the installation of all plugins with faculty zoom accounts except for a short approved list. I emailed them with a request to allow me to continue using my self-developed plugins, but they said no.

The Digital Classroom

Two summers ago, I started consulting for a local firm, Nuance Designs, providing my service as a materials scientist and automation programmer. Until recently, Nuance occupied a facility in downtown San Luis Obispo. When Nuance vacated their facility due to the COVID-19 lockdown, they allowed me to use an office from which to broadcast my digital classes[**]. The digital classroom that I assembled over the past two quarters in shown in the photos below. The setup as pictured included three whiteboard cameras, wider-angle lecture camera that provided good framing for gesturing while offering explanations. Also included are a retractable green screen, two condenser microphones, one for the desk area and another over the whiteboards. The iPad is used primarily to livestream during office hours and occasionally during lecture. On the iMac, I run my video mixing application and Keynote slides and the video output is captured by a Windows 10 laptop from which I connect to zoom and maintain the broadcast. Last month a reorganized branch of Nuance Designs called NRD established a facility in San Luis Obispo off of Orcutt Road. They started moving in to their new location January 1, and the former Nuance Designs location was closed. In exchange for being one half of the two-man moving crew that relocated their entire office/shop/lab[††] I have an office in the new facility that will be my new classroom. The good news is the internet connection is better at the new place. The bad news is that I only managed to hang a single whiteboard on the wall the Sunday night before class began, so there's a lot of work yet to be done.

[**]This was a particularly great arrangement for me, because I share my 900ft^2 house with my wife, our two teenaged kids, our 5th grade daughter—all of whom are taking virtual classes or homeschooling— a dog, a cat and two rats. It's already a tight squeeze, to say the least, without adding my courses to the mix

[††]it was a big, big job

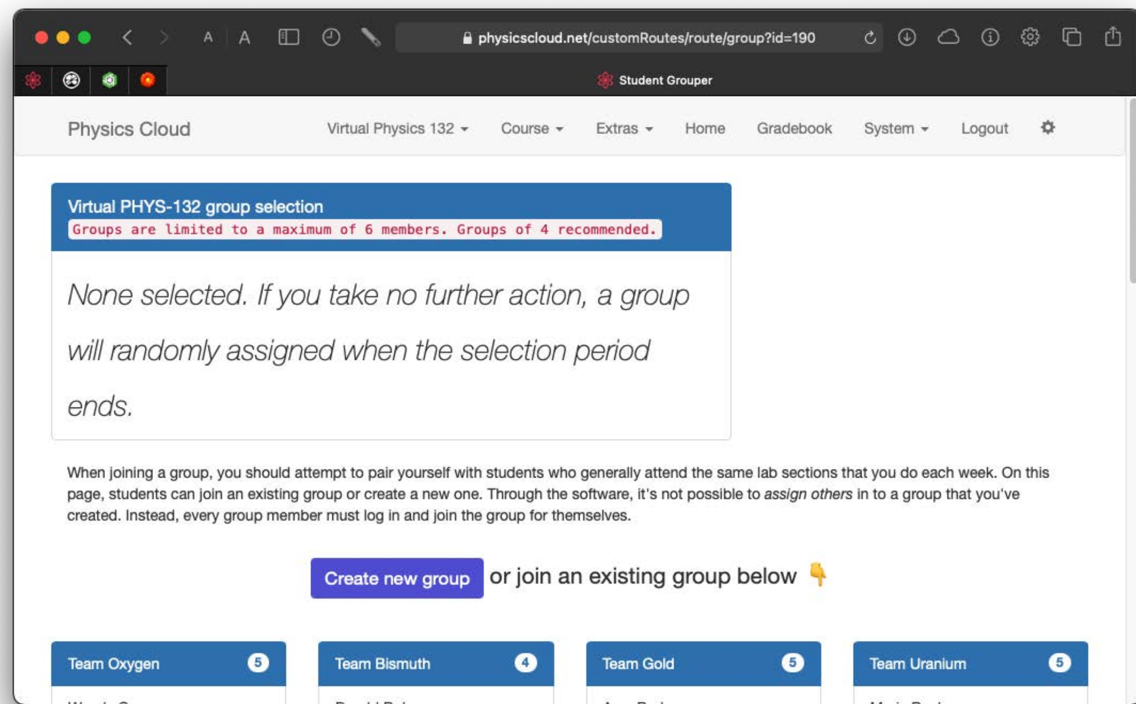


Figure 19: This Physics Cloud tool allows students to choose their breakout room groups, and randomly assigns a group to those who don't. After students make their group elections, a TSV file is generated that can be imported into the breakout room tool on Zoom's website.

Figure 20: My digital classroom for the Spring and Fall quarters. The photo above left shows the three cameras mounted above the whiteboard. I can dynamically switch between the cameras during lecture. Optionally, when switching cameras the video feed from the previous board in shown as an inset in the corner of the frame so that students still copying down their notes can see it without interruption. Above right shows the green screen that I mounted to a motorized projector screen. I've experimented using the green screen in conjunction with my lecture slides so that I can point and emphasize various features of the animated content (and yes, I feel like a weatherman). The photo at the bottom shows my three-display computer setup. The vertically oriented display shows my scanned lecture notes, the iMac is used for keynote slides and as the video mixing terminal, and the Windows 10 laptop is connected to the display at right and is used to run the zoom meeting.

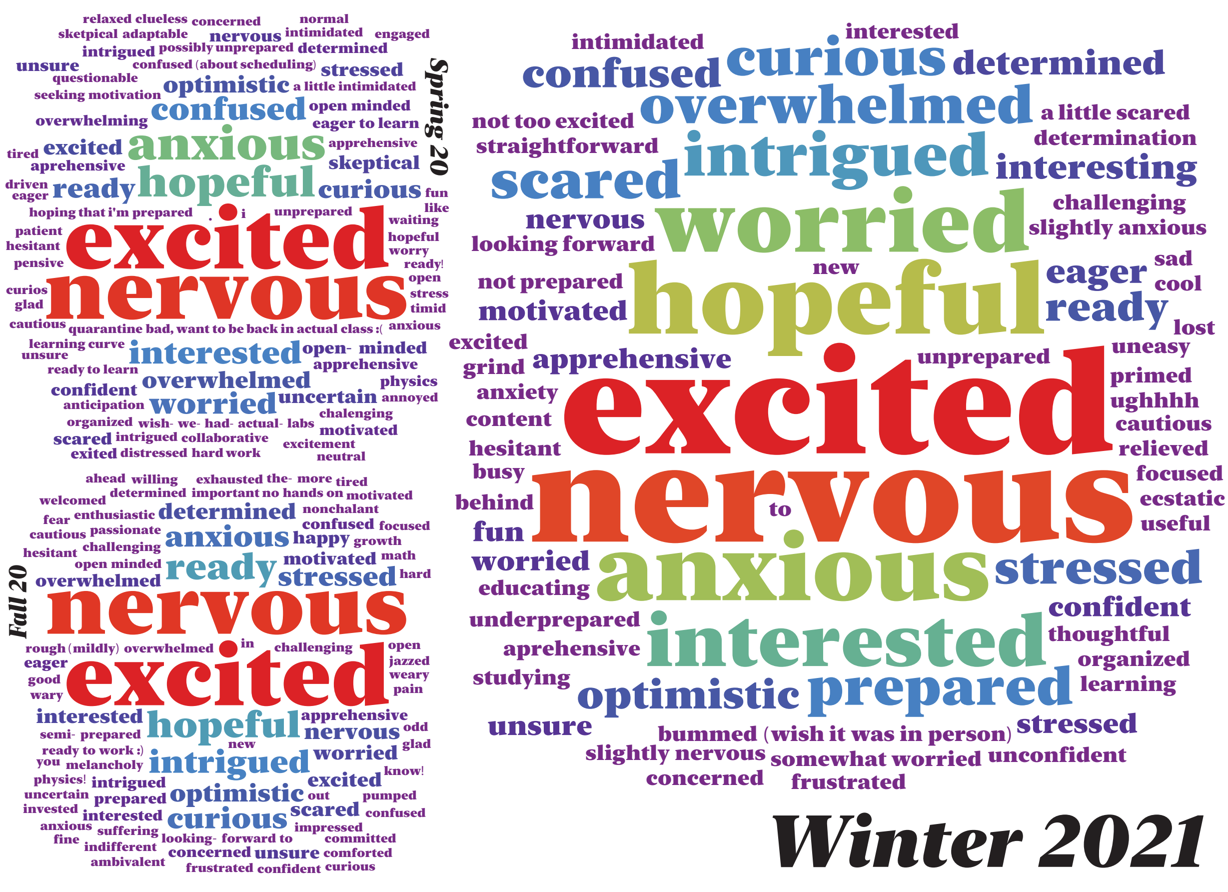


Figure 21: As part of a start-of-quarter survey, I ask students to write three words that describe their feelings about the new quarter. In the figure above, the word-cloud representation generated from student responses is shown for the Spring 2020, Fall 2020 and Winter 2021 quarters of virtual instruction.

Virtual ~~Studio~~

Physics 132 Welcome Letter Spring 2020

Instructor: Dr. Christopher Culbreath (he/him/his)
Web: physicscloud.net/132 **Zoom Meeting ID:** drculbreath **Zoom Passcode:** newtonwins

We've got this!

We're set to embark on our journey through Physics 132. It goes without saying that this is a remarkably unusual academic quarter. If your experience over the past few weeks has been anything like mine, the prospects and impending reality of virtual instruction has been accompanied by a significant amount of stress and uncertainty. Frankly, it's been hard. None of us signed up for this, we don't know to what extent we'll struggle nor how long it will last. I've found great comfort in the realization that much of my own difficulty has been compounded by the temporal uncertainty of the situation—that notion that whatever difficulties and discomforts lie ahead will persist indefinitely. I have found the antidote to this thinking to be embracing immediacy. No one moment is overwhelming or even particularly difficult on its own. It's the notion of all the unknown-and-potentially miserable moments stretched out into the indefinite future that is paralyzing. When stress levels rise, I try to be in the moment. I take a breath and make an effort see, hear and smell my surroundings. What can I do now? What do I need to do next, just one step further, for the specific task in front of me? What does this very moment—this instant—demand? When broken down into small enough pieces, anything and is bite-sized and manageable.

My intention in sharing my experience is not only to help those who may be struggling in preparation for the quarter, but also to lay a foundation for what I hope to be a shared attitude of empathy, openness and understanding that persists throughout the duration of this course. Even though we aren't in the same physical space, have an opportunity to virtually cultivate a class culture and community that strengthens us all. I hope for an environment in which no one feels shame in asking for help, especially those who are aspiring to catch up after falling behind

I want to specifically address those of you who are not having difficulty in adjusting to virtual instruction: Your attitude and level of participation are paramount to our shared success. Peer instruction, community and social connections are neither automatic nor particularly easy with to come by though the barrier of social distancing. Ultimately, the success of our virtual tools will be determined by the extent to which people actively reach out to others. At our best, we reject cynicism and instead we consciously put effort into this mode of instruction and seek opportunities to take a step in and help one another. On its own, a willing attitude isn't enough. To those who have the bandwidth, I encourage you to be on the lookout for the actions that you can take to virtually close our social distance— spend some extra time virtually collaborating, extend an offer to be a physics texting buddy, or by take inclusive action during stalled group work instead of retreating to work on your own. Strive, as each of you are able, to be an active participant in shaping our shared success this quarter.

I look forward to another great quarter of physics with each of you.

Warm Regards,

Christopher Culbreath

Dr. Culbreath

Course Structure

Iterate and Evolve

Below I lay out my initial vision for the structure of Virtual Physics 132 . I will do my best to explain my concerns and choices. I haven't taught this way before, so this is very much a work in progress. I intend to solicit regular feedback and make iterative changes as appropriate (unsolicited feedback is also encouraged).

Zoom

The primary method of interaction this quarter will be through Zoom video conferencing (`zoom.calpoly.edu`). Class, recitation, office hours and exams will all utilize Zoom, and will be accessible through my zoom url `https://calpoly.zoom.us/my/drculbreath` using the password `newtonwins`

Your Voice

Whenever practical, I have tried to leave decisions regarding how the class will be structured to class vote. Voting will be done through Physics Cloud. After receiving your emailed invitation, register and log in. You will find VIRTUAL INSTRUCTION SURVEY AND BALLOT under the COURSE ACTIONS menu.

Assessment

We have three options for exams in PHYS-132 this quarter. The option receiving the most votes will apply to the entire course. For every option, 60% of your overall class grade will be determined by your midterm/chapter exam scores and 15% of your overall class grade will be determined by your final exam score. The trend in evidence-backed Physics Education Research is towards more frequent assessments. Although more frequent tests put less pressure on any one exam, the reality of having an exam every week can be relentless. The choice is yours. The specific options are enumerated below:

Option 1

- One 90–110 minute midterm exam around Week 4
- One 90–110 minute midterm exam around Week 8
- A 170 minute final exam during the finals week
- All scores included in overall grade calculation

Option 2

- One 90–110 minute midterm exam around Week 4
- One 90–110 minute midterm exam around Week 8
- One 90–110 minute midterm exam on the last day of class (Thurs/Fri Week 10)
- A 170 minute final exam during finals week
- Lowest scoring midterm score (MT1, MT2 or MT3) will be dropped from overall grade calculation

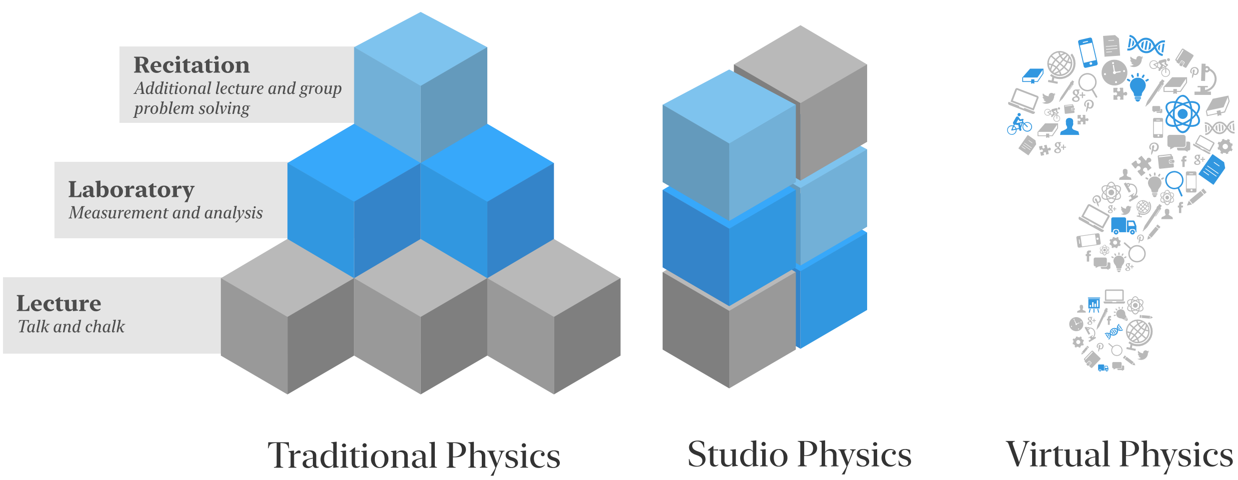
Option 3

- Seven 35-50 minute chapter tests (nearly every week during the middle of the quarter)
- A final exam (March 8 at 7:10 am) in three parts:
    1. Last regular chapter test (exam 7 of 7) covering week 10 content, counts the same as every other exam grade (towards 60% overall grade category)
    2. Final Exam Part 1 will be limited to content/topics from your lowest scoring of the Ch 15, 16 and 17 exams (50% of final exam grade)

3. Final Exam Part 2 will be limited to content/topics from your lowest scoring of Ch 34, 35, 18/19 exams (50% of final exam grade)

- Lowest scoring chapter exam score will be dropped from overall grade calculation
- If either score from Final Part 1 or Final Part 2 reflect improvement from the original exam score for that content, your final exam score will replace the old score
    1. lowest scoring exam will determined and dropped after improvement points have been applied
- Students who are content with their lowest exam score from either Part 1 or Part 2 may elect to substitute their previous exam score in lieu of taking the final exam for that section

Instructional Mode



Traditionally, PHYS-132 is structured as three 50-minute lectures and one 2 hour and 50 meeting with the first hour dedicated to recitation with the balance dedicated to a laboratory exercise. Clearly, the biggest difference in structuring this class virtually is the lack of a true lab component. This is an area where I feel that it would be inappropriate to force compliance with the ordinary structure. With some exceptions, I don't think that there's much to be gained by requiring you all to reproduce our hands-on labs using dinky interactive web animation. There are some exercises that we will perform as a simulation, but inevitably these simulations will be shorter than there hands-on analogs. I'm budgeting an hour a week on average for these exercises, with the remaining time split between additional problem solving, tutorials and lecture.

Synchronous vs Asynchronous

Considerations

I have identified several factors worthy of consideration when assessing the merit of synchronous instruction (with real-time student attendance expected) and asynchronous instruction (recorded sessions available for later viewing)

- I graduated as an undergraduate in 2008, at a time when distance learning and online classes were new but available. The one online course that I took (Engineering Statics at Cuesta College) was completely asynchronous except for in-person exams, and I found it nearly impossible to actually consume all of the course content I was expected to. It was a procrastinator's nightmare and I got a D. With that experience, I feel inclined to prioritize synchronous to maintain regular consumption of new material and to foster community among the group.

- Students aren't in SLO, and are spread across multiple timezones and may live outside of the country. Off-campus living situations may require that students share their space and computer equipment with family, also working from home or learning virtually. Students may not have access to high speed internet, and may be compelled to keep unusual hours based on the unusual times we find ourselves in. All of the these complexities favor a model of asynchronous instruction. In short, asynchronous instruction is more accessible.
- We have learning assistants—upper division students trained to help you guys tackle in-class problems and tutorials—hired to assist with our class this quarter. I need to accommodate their schedule and expected role in the class in whatever final form the schedule of the class takes
- Studio Physics is scheduled in either 2 hour or 3 hour blocks. This strikes me as an intolerably long stretch to sustain a single video conference meeting.

Synchronous Schedule 1.0 (starts Tuesday 4/7)

This is my proposed schedule for the course under the weekly assessment scheme. Specific times and the overall format are subject to change based on your feedback provided through the course survey.

	Mon	Tue	Wed	Thu	Fri
8:10					
9:10	Recitation 1A		Recitation 2A		
10:10	Lecture		Lecture		
11:10	Recitation 1B	Lecture	Recitation 2B	Lecture	*Exam A*
12:10	Office Hour	Office Hour	Office Hour	Office Hour	Office Hour
1:10		Recitation 1C		Recitation 2C	*Exam B*

- **Lecture** ***(attendance strongly encouraged)*** I propose we split a typical 2 hour studio lecture in to single-topic 50-minute-or-less blocks. Each will be live-streamed on zoom during the scheduled time and then made available on the website immediately thereafter. Because of asynchronous availability, I hope subject to your feedback, to hold a single lecture that covers all three sections. Students who are unable to attend a lecture must complete a brief conceptual quiz that will be posted to the course website at the same time as the video content. The quizzes will be graded on a credit/no-credit basis and will count towards the 5% of your overall grade assigned to attendance and participation. Attendance quizzes are due at 11:59PM on Tuesday (covering Monday and Tuesday's videos) and 11:59PM Thursday (covering Wednesday and Thursday's videos). I will take synchronous lecture attendance, and those present will be excused from that day's attendance quiz.
- **Recitation 1** ***(attendance encouraged)*** Required course content will be distributed during recitation 1. You may attend at any one of the three times Recitation 1 is offered each week. I will be accompanied by upper division student learning assistants. Given the group-work oriented nature of the recitation period, I cannot guarantee that videos will be made available in every case, but any worksheets or handouts will be published on the course website
- **Recitation 2** ***(attendance optional)*** Recitation 2 is intended as something in between an office hour and a formal class meeting. There is no requirement to attend, and no required course content will be distributed during Recitation 2. If the class elects to have weekly assessments (see below) a typical Recitation 2 will be focused on preparing for the next day's exam and I may go over example problem's from previous exams. Problems introduced during Recitation 2 will be posted to the

course website, but without the solution and discussion that will accompany the Recitation 2 presentation. You may attend Recitation 2 at any of the three times it is offered.

- **Exam (attendance (or specific alternate arrangement) mandatory)** If the class elects for weekly exams, exams will be on Friday. During weeks with no exams, there will be no class meeting on Friday. Exam period scheduling is more rigid than with recitation. Once you elect to take your exam during a particular exam period, you must contact me in order to change to an alternate time. Under a conventional midterm assessment scheme, Recitation 2 will no longer be deemed optional content, and the two or three exams will be given during the recitation 2 period instead.

Homework Grading

Homework will be assigned and virtually collected weekly. Homework is graded by an upper-division Instructional Student Assistant. Given the number of problems and number of students in the class, it isn't practical to rigorously grade every problem assigned. By majority vote through Physics Cloud, the grader will either rigorously grade a small number of problems, or the he will grade each problem with limited, cursory assessment as described below:

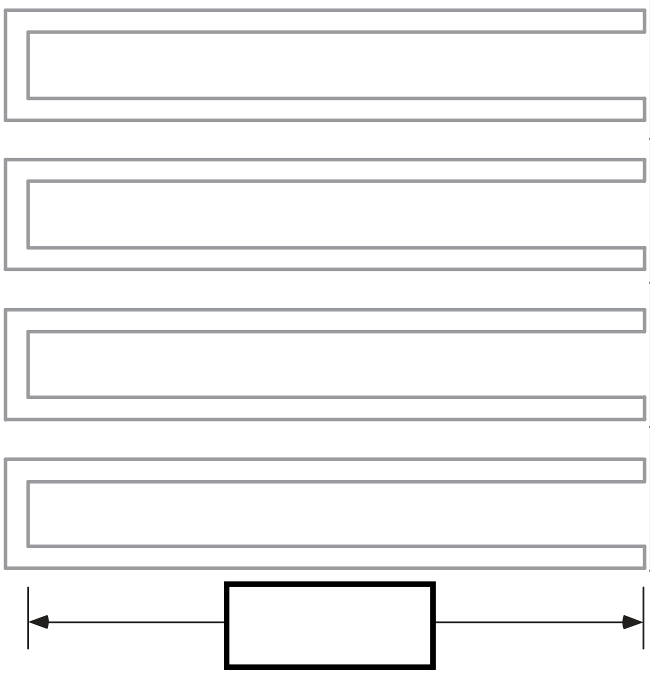
- **Option I: Lottery Grading**
  Approximately one in ten problems is selected at random to be rigorously graded. The scores on the graded problems are recorded as the score for the entire assignment, regardless of the completeness or correctness of the ungraded portion.

- **Option II: 1-2-3 Grading**
  Every problem submitted is quickly graded using these rules:
  - Perfect solutions (submitted on time) that include all of required elements—--figures, units, symbolic problem solving, etc.---and arrive at the right answer are awarded three points.
  - Any (on-time) meaningful problem attempt that is not perfectreceives two points, regardless of the severity or quantity of the errors.
  - One point is deducted for any solution submitted late. (In either scheme, late work is accepted until the last day of the quarter for 2/3 credit.)

Question 1

Updated: Tuesday 10/27/2020 at 4:26pm

A pipe of unknown length is closed at one end and open at the other. In the same experimental setup, sound is created in the pipe at four different frequencies.



	Frequency	Wavelength	Wave Speed
Funamental			
2nd Harmonic	300 Hz		360 m/s
3rd Harmonic			
5th Harmonic			

The table above is reproduced, row by row, in the five parts below.

Pipe length

Based on the information provided in the table, determine the length of the pipe.

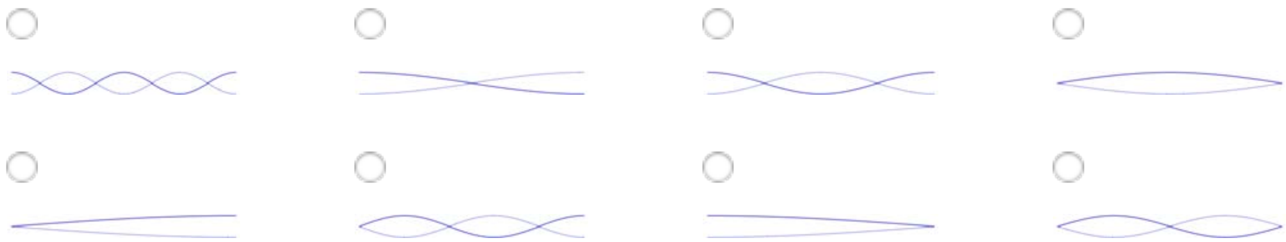
L = ________ *Include units in your answer.*

Each of the four sections below correspond sequentially to the four rows in the table above. For each requested mode, use the information given to determine the frequency, wavelength, and wave speed. For each part, choose the best sketch among the provided answer choices that illustrates the key feautres of the wave's displacmentment amplitude function produced in the pipe for the specified mode.

Fundamental

Frequency	Wavelength	Speed
______	______	______

Choose the best representation of the displacement for this standing wave (the fundamental mode):

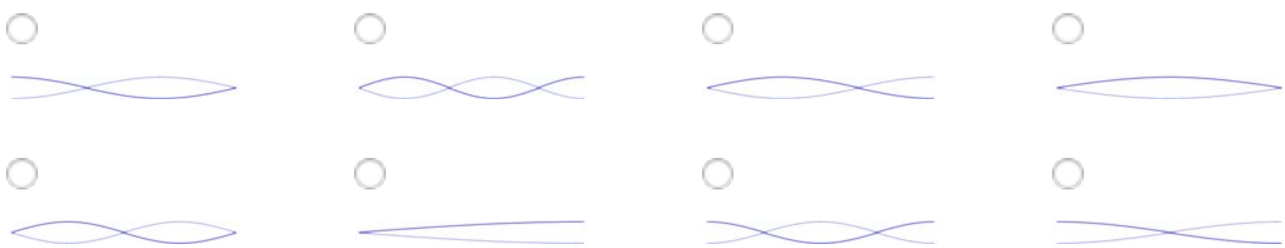


Score: 0/2

2nd Harmonic

Frequency	Wavelength	Speed
300 Hz	______	360 m/s

Choose the best representation of the displacement for this standing wave (the 2nd harmonic mode):



Score: 0/1

3rd Harmonic

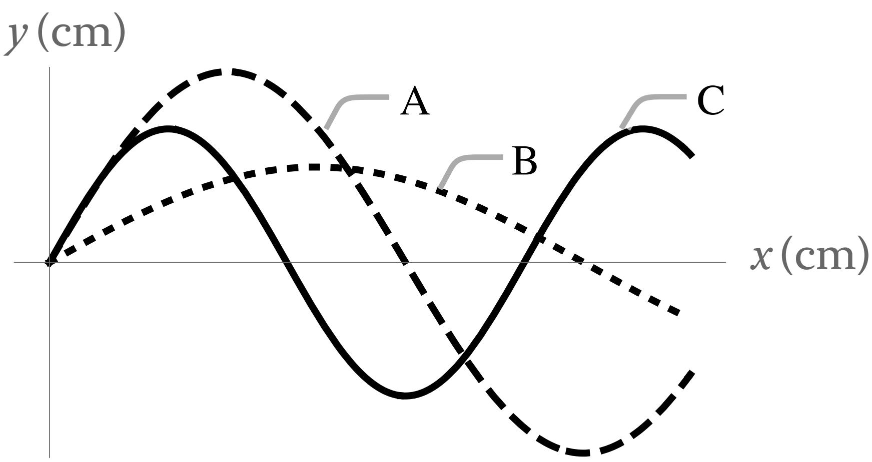
Frequency	Wavelength	Speed
______	______	______

Choose the best representation of the displacement for this standing wave (the 3rd harmonic mode):

Question 1

Open book. Open notes. Closed to discussion, collaboration and calculators.

1



The figure above eshows three waves that are *separately* sent along a string that is stretched under a certain tension along the *x*-axis. Rank the waves by their

(i) wavelengths

Score: 0/9

Greatest Least

______ ______ ______

Indicate the relative mangitude of each wave's wavelength by typing either A, B, or C in each box above. **If all the waves have the same wavelength, type "abc" in every box.**

(ii) speed

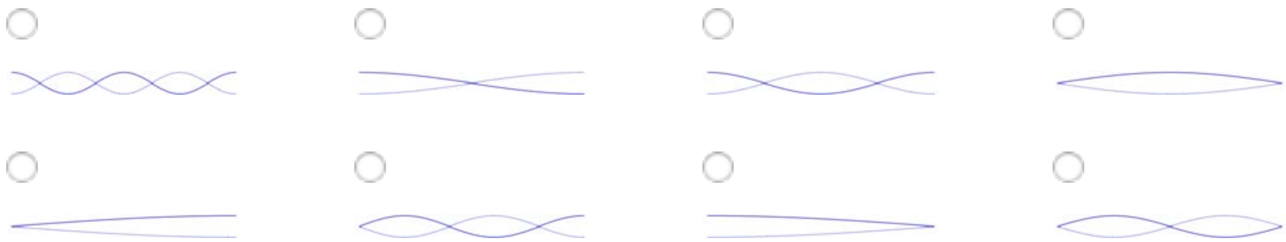
Greatest Least

______ ______ ______

Fundamental

Frequency	Wavelength	Speed
______	______	______

Choose the best representation of the displacement for this standing wave (the fundamental mode):

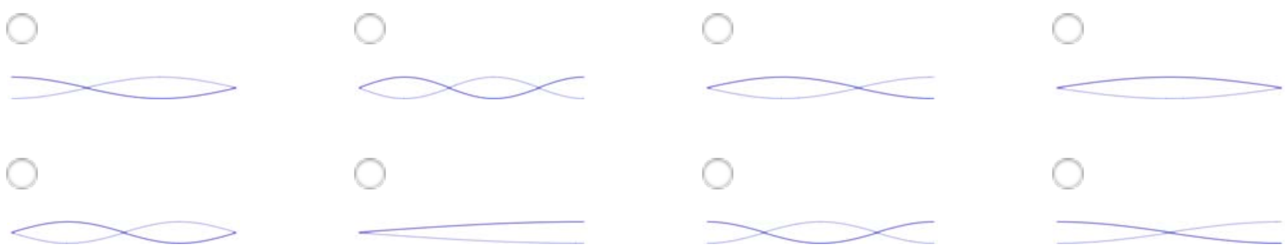


Score: 0/2

2nd Harmonic

Frequency	Wavelength	Speed
300 Hz	______	360 m/s

Choose the best representation of the displacement for this standing wave (the 2nd harmonic mode):



Score: 0/1

3rd Harmonic

Frequency	Wavelength	Speed
______	______	______

Choose the best representation of the displacement for this standing wave (the 3rd harmonic mode):

Christopher Culbreath

Other Materials

Scholarship

Submitted Grant Applications

NSF STTR Proposal: Single-crystal shape-memory thermal actuator for rugged fire-suppression sprinkler

Status	*Declined*	**Revised/Resubmitted**	5/31/2018
Type	Sub-Award	**Lead Organization**	TiNi Alloy Company Emeryville, CA
Funding Organization	National Science Foundation	**Program**	Small-business Technology Transfer (STTR)
Award Period	Jan 2019-Dec 2019	**Amount**	$93,981

Status	*Declined*	**Submitted**	12/15/2016
Type	Sub-Award	**Lead Organization**	TiNi Alloy Company San Leandro, CA
Funding Organization	National Science Foundation	**Program**	Small-business Technology Transfer (STTR)
Award Period	July 2017-June 2017	**Amount**	$134,967

Project Description

The National Science Foundation's Small Business Technology Transfer (NSF-STTR) program provides funds for small businesses to research and develop technological innovations with promising commercial and societal impact. The STTR program is designed for collaborative research efforts between small business and non-profit research institutions. This work is to be funded through a sub-award on a proposal submitted by TiNi Alloy Company of San Leandro, California. TiNi Alloy was founded in 1987 by physicist Dr. A. David Johnson, and is a pioneer and leader in the technology and use of thin film shape memory alloys, with fundamental publications and patents. For the last ten years, TiNi Alloy's efforts have been directed to methods of manufacture, physical characterization, and commercial applications of superelastic single-crystal shape-memory copper-aluminum-nickel alloys (Hereafter referred to as *single-crystal shape-memory alloy(s)*, and abbreviated *SCSMA(s)*.)

While the existence of single-crystal shape-memory alloys has long been established, TiNi Alloy's recent effort in developing and refining the manufacturing of these materials has produced single-crystal copper-aluminum-nickel suitable for commercial applications. The goal of this project is the research and development of a rugged fire-suppression sprinkler based on a patented, novel, thermally-actuated valve constructed from TiNi Alloy's innovative shape-memory material. As an STTR Phase I project, this 12-month effort will be focused on establishing the technical feasibility of a SCSMA heat-actuated valve.

Dr. Johnson has sought the collaboration of my research group for characterizing and understanding the actuation behavior of their SCSMAs and testing and refinement of prototype sprinkler designs.

Materials Characterization

Shape memory alloys are a class of active materials that exhibit a shape-changing solid-state phase transformation that is influenced by alloy composition and changes in temperature and stress. Due to the complexity of this phase-transformation behavior and its dependence on both the mechanical and thermal environment, the development of shape-memory devices requires a detailed understanding and numerical modeling of the material's behavior within the constraints of the device application. The proposed fire sprinkler valve actuator utilizes a specific SCSMA, single-crystal Cu-Al-Ni. Single-crystal Cu-Al-Ni exhibits several unique properties that address the shortcomings of conventional Ni-Ti shape-memory actuators such as a large shape recovery, a pseudo-elastic strain response at constant stress, and a wide range of phase-transition temperatures.

In this work, we will conduct a systematic study to characterize the proposed single-crystal Cu-Al-Ni materials in order to determine the ideal alloy composition and loading conditions for the sprinkler actuator. We will measure the thermoelastic properties of the low- and high-temperature phases, the critical stress and temperature states associated with the phase diagram, and the evolution of strain during loading. These initial measurements will calibrate an empirical model we will develop to optimize the application-specific material parameters, range of ambient conditions, and mechanical specifications of the final device. Beyond this specific device application, we will publish the results of our characterization study in a peer-reviewed journal.

Prototype Refinement

In addition to materials characterization, this project has a significant applied physics/engineering component. Using on-campus machining facilities and working with contracted machinists, we will fabricate, refine and test device prototypes, and investigate the feasibility of alternate designs for demanding applications. We will utilize a 3D solid-modeling CAD package in the mechanical design of prototype devices, and fabricate many of the components in-house. At each design evolution, the prototype will be tested for temperature accuracy, reliability, actuation time and stability. For successful designs, the 3D CAD model will be used to perform finite-element stress analysis as an assessment of the mechanical strength and limiting operating conditions of the prototype device.

Student Involvement

As a Cal Poly graduate and researcher focused on instrumentation and device technologies, I celebrate the value of *Learn by doing.* This project is ideally suited for undergraduate research. Since the project's goal is the development of feasible product, it is enhanced by hands-on, tangible milestones in the form physical prototypes. Further, the project involves several distinct components that are appropriately scaled to the skills and time constraints of undergraduate research efforts. The characterization of SCSMA materials can be cleanly divided into three smaller experiments: mechanical and colorimetric measurements of the phase transition temperatures, the measurement of strain as a function of applied stress, and numerical optimization. Prototyping refinement can be split into separate CAD/design/fabrication and device-testing roles. While each of these roles involve a significant amount of collaboration, the individual components stand on their own as significant undergraduate research efforts. Beyond departmental support for summer research students, the sub-award budget includes 800 hours of student researcher compensation —open to applicants in physics, mechanical engineering and materials engineering—to be divided over the 12-month Phase I award period.

Consulting Activities

- *Automation Engineer* (Summer 2016 & Summer 2017) Elastium Technologies. Emeryville, California.
- *Automation and Materials Engineer* (May 2019–August 2021) NRD/Nuance Technologies. San Luis Obispo, California.

Elastium Technologies – Emeryville, California

Materials Physicist and Automation Engineer March 2018-September 2018 Over the past year, I have worked as a consultant for Elastium Technologies assisting in the development of their Ohno continuous casting furnace, built for the production of single-crystal shape-memory wires. My primary duties were to guide the process of nucleating wires and the development of a multi-system LabVIEW based control system for temperature monitoring, motion control and thermal stability. My work continues in an informal capacity as we establish a research collaboration, with my Cal Poly research group taking a lead role in materials characterization and prototype development as the group at Elastium Technologies continues to refine production of single-crystal shape memory materials.

Nuance Designs – San Luis Obispo, California

R&D Consultant May 2019–January 2020 Nuance Designs is a medical devices company with a recent R&D portfolio focused on autoinjectors. I have consulted a number of scientific, organizational and engineering aspects of the project.

NRD – San Luis Obispo, California

Automation and Materials Engineer April 2020–August 2021 In early 2020 Nuance Designs reorganized to become NRD. With my contribution, NRD has expanded their portfolio to include the research and development of single-crystal shape memory alloys. Through a collaboration with Elastium Technologies, NRD has assumed the main development responsibility of a novel single-crystal copper aluminum nickel continuous casting furnace, which aims to bring production-scale quantities of Cu-Al-Ni shape-memory and super-elastic materials to market. Single crystal materials exhibit the same properties as polycrystalline materials, but with an allowable deformation and recovery ten times greater than standard materials. As the project continues, my hope (and expectation) is that NRD will partner with the university to give our students in physics and engineering hands-on research experience through internships and collaboration with on-campus research groups.