AP50

~~lectures~~ group work ~~exams~~ projects

AP50

Welcome to Applied Physics 50 — Physics as a Foundation for Science & Engineering — a new, team- and project-based introductory physics course sequence. This packet contains some information to make the most of your class observation. Additional class handouts may be available on the day of your visit. Feel free to add these to this information packet.

We are very interested in disseminating the ideas for this course design and are happy to share a complete set of curricular materials for the two-semester sequence covering mechanics, waves, electricity and magnetism, circuits and optics. A small subset of these materials is included in this packet.

Logistics

Please note:

1. In accordance with University policy stipulates it is not permitted **to take pictures or film** the classroom. We have plenty of pictures and video of AP50 available. Contact us if you need any.
2. You are welcome to sit anywhere in the classroom and/or walk around, but note that the one empty seat at each table is for the use of the Teaching Staff.
3. You are welcome to interact with the students during most activities, but please ask instructor first.

Overview

The main goal in the design of AP50 is to provide an environment that promotes intrinsic motivation to learn. This is accomplished by using a combination of projects and team-based learning in a "flipped classroom" framework. The month-long projects are meant to engage the students and help them take ownership of their learning. The team-based approach provides a social responsibility for the learning: students need to keep up with the work to avoid letting their team down. Finally, flipping the classroom helps move information transfer out of the classroom, so that students can take part in cognitively more engaging tasks during class time.

The class meets twice a week for three hours (10–1). There are no other regularly scheduled class meeting times — no labs and no discussion sessions. The in-class activities vary day by day. See the Schedule (on the back side of the *AP50 Quick Reference Guide* included in this information packet) to see what activities are taking place today.

Pre-class component

Before coming to class the students are required to annotate an electronic version of the textbook using a social document annotation system called *Perusall* (perusall.com). In this packet is a Rubric explaining how we evaluate their pre-class preparation (see *Annotation Rubric*). Typically students provide each about a dozen annotations per chapter, engaging in an asynchronous conversation with their peers. The instructors use these annotations to adjust the activities in class. See *Reading Schedule* on the back of the *AP50 Quick Reference Guide*.

In-class activities

In class students work on a series of guided, scaffolded activities that help develop a solid understanding of the physics principles required to successfully complete the projects (see *AP50 Quick Reference Guide* and syllabus). Toward the end of each month-long project, an increasing amount of time in class is allocated for the students to work on their projects (as indicated by the white areas on the schedule). During that time students may be working in the classroom or in one of the Teaching Labs on the ground floor of the building, where a machine shop is available. A detailed description of the in-class activities is in the *Syllabus* (included) and the *AP50 Quick Reference*

Guide. Going from building to conceptual understanding to helping students evaluate their learning, these activities are:

1. Learning Catalytics: Peer Instruction on a modern platform
2. Tutorials: Online worksheets that probe and address common misconceptions
3. Estimation Activity: a team competition aimed at developing estimation and order-of-magnitude skills
4. Experimental Design Activity: an activity designed to help students develop experimental skills required by the projects
5. Problem set reflection: a new innovative approach to homework, aimed at developing both metacognition and problem solving skills (see the *Problem Set Rubric* for more information)
6. Readiness Assurance Activity: a form of collaborative exam, focused on formative assessment (the highest stake assessment in AP50)

Projects

There are three month-long projects per semester. At the beginning of each project students are assigned to teams (designed so as to diversify the team make-up) and the students receive a Project Brief (see the included brief for the *Symphosium* project). Each time a new project starts students are reassigned to a new team. Each team is assigned a Team Mentor from the Teaching Staff. A week after the start of the project, students must submit a Team Contract (a document that lays out the team's expectations on how they will work together and what to do to resolve problems and disagreements) and a Proposal describing their approach to the project. For projects that require building an apparatus, each team is allocated a fixed budget. Each project ends with a fair where the projects are evaluated by an external panel of judges. Some fairs include a competitive component between teams. Other fairs are poster competitions.

After the fair (as students begin working within a new team on a new project) each team must submit a project report (see the *Symphosium* project brief for details) and each team member must complete a Team, Peer, and Self Assessment. See the included *Team, Peer, and Self-Assessment* for an idea of what the students see; the actual assessment is carried out online. Note that the relative contribution matrix puts the students in the "prisoner's dilemma" as the average of all relative contributions on a team is fixed to "Fair share." There is no way for the students to game the system! Students obtain feedback on this assessment shortly after completing it. The last page on the *Team, Peer, and Self-Assessment* form gives an idea of the feedback that the students receive.

Further information

News article on AP50: http://bit.ly/AP50news
Short video documentary: http://bit.ly/AP50video
Extensive video overview from Harvard Graduate School of Education on AP50: http://bit.ly/HGSEAP50
Introductory class explaining approach and philosophy to students: http://bit.ly/AP50firstclass (Chrome only)
Peer Instruction: http://blog.peerinstruction.net
Perusall: http://perusall.com
Learning Catalytics: http://learningcatalytics.com
Team-based learning: http://teambasedlearning.org

Contents of this package

1. Quick Reference Guide and Schedule
2. Syllabus
3. Rubrics: Professionalism, Annotation, Problem Set ("Homework"; including example)
4. Sample in-class activities: Estimation, Experimental Design ("Electroscopes")
5. Project Brief (one of three given out in a semester)
6. Peer, Self, and Team Assessment (carried out online)

AP50 QUICK REFERENCE AND SCHEDULE

BEFORE CLASS

Perusall: Reading — see schedule

Read and annotate text BEFORE class

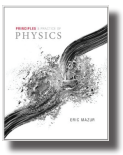
Respond to others' annotations

Annotations guide the class

need device

NEEDED FOR COURSE

Mazur: Principles and Practice of Physics



web-enabled device

IN CLASS

Tuesday/Thursday 9 – 11:45 am in Pierce 301

understand

LC: Learning Catalytics — 90 min

Instructor poses question

Answer alone

Discuss in team

Answer again

bring device

Tutorial — 60 min

Work on worksheet with team

Explore concepts

Discuss with staff

apply

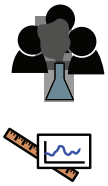
EA: Estimation Activity — 30 min

Estimate quantities

Develop individual strategy

Discuss and solve as team

EDA: Experimental Design Activity — 90 min



Conduct experiment with team

Take measurements

Analyze data

Carry out simulations

bring device

evaluate

Problem Set & Reflection — 90 min

Work problems alone BEFORE class

Discuss with team, mark up

Self-assess & turn in

RAA: Readiness Assurance Activity — 90 min

Part 1: solve problems alone

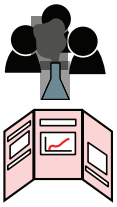
Open book, open internet

Part 2: solve with team

bring device

THROUGHOUT

Projects — one/month



Read and understand project brief

Prepare model, build project with team

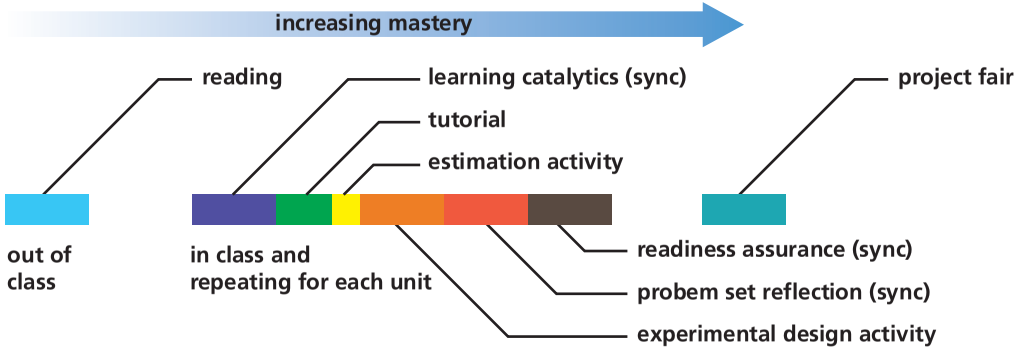
Present project at Project Fair

Hand in and revise report

Complete team, peer, and self-evaluation

AP50 Spring 2020

SCAFFOLDED ACTIVITIES



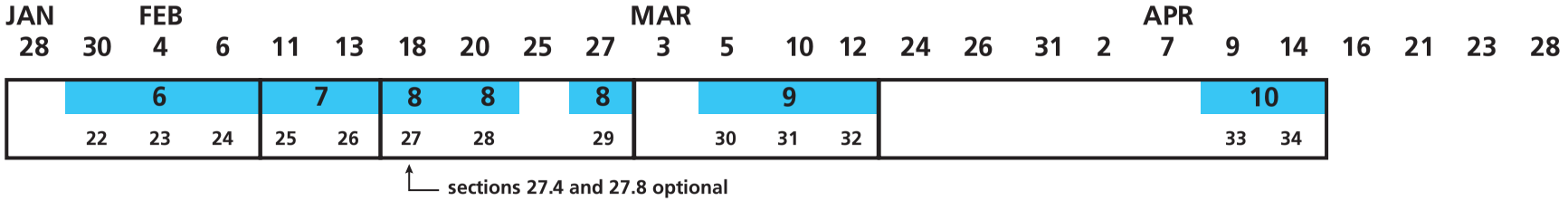
UNITS

Unit 6	Ch 22-24	electrostatics
Unit 7	Ch 25-26	potential and charge separation
Unit 8	Ch 27-29	magnetism
Unit 9	Ch 30-32	elecromagnetism and circuits
Unit 10	Ch 33-34	optics

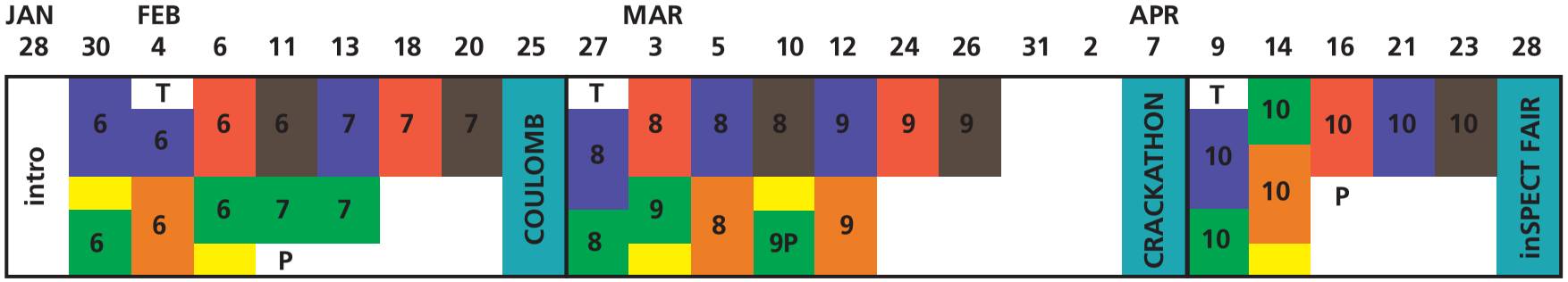
LEGEND

22–34	chapter to be read
6–10	unit
T, P	team assignment, project proposal review

READING SCHEDULE



CLASS SCHEDULE



Syllabus

Applied Physics 50b — Physics as a Foundation for Science & Engineering — is the second part of a project-based introductory physics course sequence for engineering students. Applied Physics is at the intersection of physics and engineering. Physicists build to understand; engineers understand to build. In AP50 you will be doing both. The goal in AP50 is to provide a one-year long introduction to physics and at the same time help you develop — in a friendly community of peers — skills that will be useful in your career regardless of your field: team work, design skills, discussion skills, evaluations skills. This course is for you if you are interested in:

- learning by doing rather than by listening
- exchanging ideas with others
- seeing how science applies to the real world, and enjoy
- working in teams to solve problems and build things

As the instructor for this course, I am ready to help you gain a better understanding of how science applies to the real world and develop skills that will be useful in your career. My goals are to promote self-directed study of basic physics, explore physics in the context of real-world applications, improve collaborative and communication skills in team-driven activities, and develop research skills by working on projects.

I look forward to getting to know you this coming semester. I take my teaching duties very seriously and will work very hard so as to attain the above goals and make AP50 an enjoyable, rewarding, and useful experience for you. I will make myself as accessible as possible — I do want to interact with you both in and out of class. I encourage you to stop by my office or call; my contact information appears below. Call or text me at the number below any time I can help.

This document is meant to help you make the most of this course. I always welcome feedback and hope you will let me know if I am meeting your expectations and needs.

I am excited to work with you this semester!

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Course Web Site: https://canvas.harvard.edu/courses/63764

What this course promises you

Most likely, the majority of the courses you have taken so far involved you listening to lectures and taking exams. As you are progressing in your studies here at Harvard, you might have a number of important questions. How does what you learn relate to the real world and to your future career? What are the skills that will make you successful in your career? How can the work you do now help you continue to grow after you graduate?

In this course, I will help you obtain answers to these questions. You will have an opportunity to explore physics by engaging in physics through projects. In the process, you will obtain insight into the thought processes that underlie most of science and engineering. You will also hone skills that will be beneficial to you, regardless of your career path. How do you design something? Take data and analyze them? Convince others of your thought processes? How do you learn on your own, for your own benefit? How do you work with others and convince them that what you are doing, or thinking, is relevant and important?

How will these promises be fulfilled?

There are no lectures and no examinations in AP50. Instead, to realize these promises, you must take responsibility for your own learning and actively participate in the learning process — what you get out of this course depends very much on what you put in! In general, the best way to learn something is by engaging in the material and by interacting with others. For this reason, the core of the course is a set of three, month-long projects on which you will work in teams. During the course of the semester, you will apply electrostatics to build a generator, design and build an electromagnetic safe, and design and build an imaging spectrometer. At the same time, the best way to develop important skills, such as collaborative skills, is by engaging in these skills. In other words, you will be learning by doing and I promise you that it will be both rewarding and fun!

COURSE GOALS

After successful completion of this course, you will be able to… (within the context of introductory physics)

1. Engage in **self-directed learning** by:
    - identifying and addressing your own educational needs in a changing world, including awareness of personal attributes, fluency in use of information sources, planning, and problem solving
    - using independent study and research to tackle problems, especially ill-defined or open-ended ones.
    - using a variety of techniques to get a handle on problems: represent the problem visually or graphically, perform order of magnitude estimates, use dimensional analysis and proportional reasoning, recognize symmetries, evaluate limits, and/or relate the problem to cases with known solutions
    - explaining and justify any assumptions made
    - “thinking critically,” both positively and negatively, about any situation or the solutions to any problem.
    - evaluating the correctness of a solution

2. Demonstrate **content mastery** by:
    - meeting the content learning goals specified in the project briefs
    - applying your knowledge of physics to solve problems
    - taking data, analyzing, and interpreting them

3. Engage in productive **team work** by:
    - contributing effectively in a variety of roles on diverse teams.
    - conveying information and ideas effectively, using written, oral, and visual and graphical communication.

4. Exhibit **professionalism** in your conduct by
   - acting in a manner that is respectful to your teammates and the teaching staff
   - being punctual and participating fully in all classroom activities
   - taking decisions and executing actions that are fair and honest, and that are consistent with accepted standards of conduct.

The activities in AP50 are designed to contribute to the development of the following general competencies:

- **Qualitative Analysis**: The ability to analyze and solve problems in science and engineering and other disciplines qualitatively, including estimation, analysis with uncertainty, and qualitative prediction and visual thinking.
- **Quantitative Analysis**: The ability to analyze and to solve problems in science and engineering and other disciplines quantitatively, including use of appropriate tools, quantitative modeling, numerical problem solving, and experimentation.
- **Diagnosis:** The ability to identify and resolve problems within complex systems through problem identification, formation and testing of a hypothesis, and recommending solutions.
- **Design:** The ability to develop creative, effective designs that solve real problems though concept creation, problem formulation, application of other competencies, balancing tradeoffs, and craftsmanship and which integrate knowledge, beliefs and modes of inquiry from multiple and diverse fields of study.
- **Teamwork**: The ability to contribute effectively in a variety of roles on teams, including diverse teams, while respecting everyone's contributions. You will develop collaborative skills that may include questioning, listening, and identifying multiple approaches and points of view.
- **Communication**: The ability to convey information and ideas effectively, using written, oral, and visual and graphical communication.
- **Lifelong Learning**: The ability to identify and address your own educational needs in a changing world, including awareness of personal attributes, fluency in use of information sources, planning, and self-directed learning. The ability to "think critically," both positively and negatively, about any situation or the solutions to any problem.
- **Ethics**: The ability to take decisions and execute actions that are fair and honest, and that are consistent with accepted standards of conduct.

COURSE LOGISTICS

Prerequisites

AP50a or equivalent. A solid knowledge of multivariable calculus at the level of Applied Math 21a or Math 21a is strongly recommended. Mathematics 21a can be taken concurrently.

Class meetings

The class meets twice a week and is scheduled from 9 am to 11:45 am on Tuesdays and Thursdays, in Pierce 301, a classroom designed for interactive, team-based learning. The schedule of activities during this class time is shown on the course schedule. When no activities are planned, you can use class time to work with your team mates on your projects.

We won't lecture you during the class meetings. Instead, you'll have an opportunity to work in teams on class activities that are designed to help you master the relevant physics and get you started on the projects. For details on these activities, see Course Activities below. See also *AP50 Quick Reference*.

In addition to these two class meetings, you need to sign up for a time slot during which you will be available to meet with your team members to work on your project. These meetings can take place at any place that works for your team or, when you need to construct things, in the Learning Labs on the ground floor in Pierce Hall. To prevent congestion in the Learning Labs, the teams will be distributed over the following four time slots:

Thursday 1:30–2:45 pm
Friday 9–10:15 am
Friday 12–1:15 pm
Friday 3–4:15 pm

For each month-long project you **must indicate your availability for at least two** of these four project time slots so we can assign time slots to teams. If you anticipate this to be a problem, please contact us as soon as possible.

Textbook

AP50b uses the same (electronic) textbook as AP50a, *Principles and Practice of Physics* by Eric Mazur (Pearson) via the *Perusall* platform (details below). If you took AP50a this fall, you should be all set. If you didn't take AP50a this fall, you can access Chapters 22–26 of the book without buying access. When you access Chapter 27 (we'll get there by the middle of February) or beyond, you will be prompted to purchase access to the book; you can choose either perpetual access (no time limit) or a 180-day rental. As I am the author of the book, I will be donating the royalties of this book collected by the publisher for this class.

Technology

You need a laptop or tablet in this course. First of all, you will need one to access the textbook. Secondly, a number of class activities are completed using a web-based electronic response system. Please bring your device and its charger to each and every class. You might be able to use a smartphone, but the small screen may be limiting. If you do not own a compatible device, we will work on finding a way to accommodate you.

The electronic response system is called *Learning Catalytics*. To subscribe to the system, point your browser at http://LearningCatalytics.com and create a student account with the access code **HSSLCS-BAZOO-VETCH-BLOBS-SARTO-ROSES** (at no cost). We will explain in class how to use the system.

Getting help

Because we are not lecturing you, we can make our time available to help you and provide personal assistance, both in and out of the class. Never hesitate to contact us — our contact information includes our numbers and you are free to call us anytime; you will never disturb us. We all hold office hours (see Teaching Staff list), but we are happy to schedule a meeting at any time that is convenient to you and to us. In addition to our office hours, your team will be assigned a Team Mentor for each project cycle. The Team Mentor will be your go-to person for help with any aspect of the course. You will check in with your Team Mentor twice weekly in class, and s/he will be offering you and your teammates feedback throughout all aspects of the course.

TEAMWORK

Teamwork creates synergy. Because the combined effect of an effective team is significantly greater than the sum of individual efforts, teams can tackle problems that are too big to solve for any individual. In the professional world, effective teamwork is paramount. For this reason, AP50 uses a team-based approach that will help you develop collaborative skills, that will help you work effectively in a team, and that will maximize your learning. As in the professional world, three important features affect your productivity and success in a team: your own effort, the effort of people you depend on, and the way you work together.

Throughout the term, you will work closely with three or four of your classmates, as part of a project team. The teams will change for each of the projects, so as to provide an opportunity for you to become better acquainted with your peers and also to develop the interpersonal skills you need in the professional workforce where you are likely to encounter a diverse ensemble of people.

The activities in AP50 are designed so that no one individual can successfully complete them alone. It is therefore very likely that on the parts you work on alone, your performance will be significantly worse than in a course that does not involve teamwork. Don't let that discourage you, as individual activities are always followed by a phase where you get to work as a team on that same activity, permitting you to improve your performance with others (and learn in the process).

To be successful in AP50, therefore, you need to first try your best on each of the activities on your own and then tackle those activities and the projects as a team. While it is expected that you will divide and conquer when working as a group, each individual is responsible for the whole product.

Research on teamwork suggests the following good team practices:

- **Come to class prepared**. Before working as a team, read any relevant material(s) and formulate your own approach to the task at hand.
- **Actively participate** and contribute to all activities when the team is together (both in and out of class). When even one team member checks out and starts working individually (or starts checking email, text messages, etc.) instead of engaging with the team, the overall performance of the team is adversely affected.
- In all team activities, be prepared to **share** three things with your teammates: (a) what approach you chose as an individual, (b) why you chose that approach, and (c) how confident you are about your approach.
- Be **respectful** and listen and evaluate other people's points of view.
- **Deliberate as long as time permits**. Regardless of the make-up of the team, teams that deliberate longer do better in team activities.

Failure — the unavoidable price of success

Throughout your education, you have probably been led to view mistakes and failure as something that is unfavorable and that negatively affects you — something to be ashamed of. However, success is not possible without taking calculated risks, which inevitably means failing sometimes. The road to creativity and innovation, in particular, is littered with failure. "If you haven't failed, you're not trying hard enough," goes a well-known saying. Failure is a problem only if it is your end point. On the way to finding a solution, failure can be very productive as it can teach you a lot (what doesn't work, what might work, and what you might want to explore in greater detail) and lead you to success.

In AP50 we want to create a culture that encourages creativity and calculated risk taking. Also, we design all of the activities in AP50 so that they leave ample room for errors for anyone (including the staff) and your intermediate scores may be lower than you are used to in other courses. Only then can we guarantee that everyone's learning will be maximized and that you will learn to feel comfortable with the (productive) failures that go hand-in-hand with creativity. See them as learning opportunities, not negatives, as stepping-stones to success, not the end point. So be bold and take risks, both as an individual and as a team — failure, even repeated failure, is a healthy and necessary part of becoming successful. Also, rest assured that the assessment in AP50 does not penalize you the failures you may encounter on the way to success!

Peer Assessment

It is important to provide positive feedback to people who truly worked hard for the good of the team and to also make suggestions to those you perceived not to be working as effectively on team tasks. Three times during the semester you will provide an online assessment of the contributions of the members of your team (including yourself) to all the activities in class and to the project. The feedback you provide should reflect your judgment of each team members':

preparation – were they prepared when they came to class?
contribution – did they contribute productively to the team discussion and work?
respect for others' ideas – did they encourage others to contribute their ideas?
flexibility – were they flexible when disagreements occurred?

Your teammates' assessment of your contributions and the accuracy of your self- and peer-assessments play an important role in your final grade for the course — see *Assessment* below.

COURSE ACTIVITIES

I. PRE-CLASS: reading assignments and annotations (*Perusall*)

Purpose:	Provide you with a first exposure to the material so we can spend the class time doing activities that help you better understand the concepts
What you need to do:	Access the reading assignments in *Perusall* (see *Technology* above) via Canvas (Assignments > Reading Assignments). Read and annotate the chapters according to the class schedule; enter your questions, comments, and/or responses to others' questions and comments. Reading assignments are typically due at 11:59 pm the day before class.
Evaluation:	Your annotations will be evaluated on quality (thoughtfulness), quantity, timeliness, and distribution. See the *Annotation Rubric* for details

Details: Because there are no lectures in this class, you are responsible for familiarizing yourself with the physics principles involved in the projects by reading the relevant sections of the textbook before coming to class. The course schedule includes required weekly readings — you are free to study ahead, but the schedule ensures that you are prepared for the activities in class and any assignments.

The goal of the pre-class reading is to gain sufficient knowledge to be able to participate in the class activities in a meaningful way. Annotate the text in the *Perusall* system to interact asynchronously with your classmates and to get help when other people are not nearby. From the data we have obtained over the past years we find that **people who do the following tend to do better** in AP50:

- read for **understanding**, not memorization
- interact with others online by contributing **thoughtful** annotations
- help others by **upvoting** good questions and helpful answers
- don't wait until the deadline, but **start reading early**
- don't read the entire assignment in one sitting but **come back often** for shorter readings.

The goal of the pre-class reading is not to master every little detail — the in-class activities are designed to reinforce your understanding of the important principles before you begin to apply them in the projects. And you certainly won't ever need to memorize any information because we will never deprive you of access to the text (or any other source of information, including the Internet). However, by reading with attention and with an inquiring

mind, you take ownership of your learning. Additionally, your annotations help us determine how to best tailor the in-class activities to improve your understanding of the material.

II. IN-CLASS ACTIVITIES

Instead of presenting the textbook content to you, we will use the time in class to expand on your initial reading of the text and address any difficulties you express in the annotations using six types of interrelated activities that build on each other: Learning Catalytics, Tutorials, Estimation Activities, Experimental Design Activities, Problem Set Reflections, and Readiness Assurance Activities (details below). In addition, time will be allocated for project work. The class schedule shows the scheduled timing of these activities (white = project work).

Learning Catalytics (LC)

Purpose:	Probe and deepen your understanding of the course content
What you need to do:	Bring your laptop or other compatible device so you can log on to LC
Evaluation:	Your performance on these questions is recorded and can be reviewed by you. While the correctness of your responses to these questions is never considered in the evaluation scheme, your participation contributes to your professionalism score.

Details: During this activity, which lasts 90 minutes, the instructor will pose questions, which you first answer individually using your device, then discuss with your team members (effectively teaching each other), and then answer again. If an issue remains, you can always review the work done in class later or ask someone from the staff for a clarification. The skills you develop in this activity will improve your performance on the Problem Sets and Readiness Assurance Activities.

Tutorials

Purpose:	Address common misconceptions in the course content
What you need to do:	All materials for this activity will be supplied.
Evaluation:	Your work is neither corrected nor scored, however your active participation in this activity is evaluated by both your teammates and the teaching staff and this evaluation will factor into your professionalism score.

Details: During this activity, which lasts 60 minutes, you will work with your team on a worksheet that will explore your thinking about the more difficult concepts in the material. The teaching staff will contribute to the team discussions. Check in with your Team Mentor before ending this activity to make sure that you and your team members have resolved any misunderstandings. The skills you develop in this activity will improve your performance on the Problem Sets and Readiness Assurance Activities.

Estimation Activity (EA)

Purpose:	Develop estimation skills that are essential for problem solving
What you need to do:	All materials for this activity will be supplied
Evaluation:	The activity is run like a competition among teams, and while it is not graded, your active participation in this activity is evaluated by both your teammates and the teaching staff and this evaluation will factor into your professionalism score.

Details: Your team will receive a list of two or three unknown quantities to be determined to the nearest order of magnitude (see Chapter 1 of the text). You should estimate (not guess or Google!) the quantities using the estimation procedures discussed in the text. Spend the first five minutes thinking *individually* about a strategy,

then go at it with your team. There are only 20 minutes, so think fast! One or two teams will be selected at the end of this 20-minute period to present their estimates to the class. The skills you develop in this activity will improve your performance on the Problem Sets and Readiness Assurance Activities.

Experimental Design Activity (EDA)

Purpose:	Develop experimental and/or analytical skills that are important for the current project
What you need to do:	Bring your laptop or other compatible device
Evaluation:	Your work is neither corrected nor scored, however your active participation in this activity is evaluated by both your teammates and the teaching staff and this evaluation will factor into your professionalism score.

Details: The projects require you to take measurements, analyze data, carry out simulations, etc. The Experimental Design Activities help you master the skills that are required for successful completion of the projects.

Problem Sets (pre-class) and Problem Set Reflection (in-class)

Purpose:	Develop problem-solving skills; self-assessment of your knowledge and skills
What you need to do:	Before class: solve all problems, giving them your best effort and following the instructions given on the Problem Set Rubric. In class: work with your team to correct your solutions, resolve conceptual difficulties, and identify areas that need to be reviewed.
Evaluation:	Your work is evaluated on the effort you put into the application of problem-solving steps and the accuracy of your self-evaluation. You will receive a Problem-Solving Rubric with the first Problem Set.

Details: Learning to develop problem-solving strategies is an important goal for this course. Good problem-solving practices include:

- articulating your expectations for the solution to a problem before diving into the details
- breaking down longer problems into smaller, more manageable pieces
- checking your solution by justifying the reasonableness of your solution, checking the symmetry of your solution, evaluating limiting or special cases, relating your solution to situations with known solutions, checking units, dimensional analysis, and/or checking the order of magnitude of the answer.

You can hone these skills on five problem sets, each of which involves two phases:

1. You work on the problem set **ALONE**, before coming to class when it is due, giving it your best effort.
2. You work in class with your team members on correcting your work, comparing it to the solutions we hand out to you, and completing a self-evaluation form. You hand in this form together with your marked-up work.

Treat the problem set as an open-book take-home exam, even though **you will not be evaluated on the correctness of your answers**. Instead, your work will be assessed on the individual effort you put in solving the problem set before coming to class and the correct evaluation of your own level of understanding.

You should see the problem sets as an opportunity to learn. For example, you might give the entire problem set your best effort without getting it all correct, but by accurately identifying your difficulties in understanding, you will earn full credit and we can put you on a productive path forward that will maximize your learning. Please note that completing the individual portion of the problem set in class (rather than before coming to class) will be considered academic dishonesty.

Readiness Assurance Activity (RAA)

Purpose:	Assessment of content-specific goals and problem-solving skills
What you need to do:	Bring your laptop or other compatible device so you can log on to LC
Evaluation:	Your RAA performance is determined by a combination of your individual score (50%) and your team's score (50%).

Details: To assure that everyone is on track in the learning of the basic concepts we will have five RAAs over the course of the semester. During the first half hour of each RAA you will work alone to solve a set of problems similar to the preceding problem set (individual round). You are free to consult the text or the Internet, but not other people. During the remaining hour of the RAA you get to discuss the problems with your team members (team round). The goal for your team is to use the combined knowledge of the team to maximize the entire team's RAA score. This team round provides an opportunity to learn in a collaborative environment, consolidate your knowledge, hone your team-building skills to achieve the best possible scores, and receive immediate feedback on your performance.

We design the RAAs in such a way that the average score in the individual round is around 50% and nobody can score 100%. Typically, teams figure out the correct answers to all questions in the team round. The team round thus provides an opportunity for everyone to improve their scores and — most importantly — to learn.

If you fully participate in all in-class activities, and if you are fully conscientious with the relevant problem sets and annotations, then you will be well prepared for the RAAs without having to "study" for them like you do for an exam.

If you wish to practice your knowledge in order to be better prepared, you can

1. review the Checkpoints in the text (solutions are in the back of the textbook) and do the Worked Examples in the text (before looking at the solution). Typically, there are around 60 Checkpoints and 30 Worked Examples for each RAA unit.
2. Use the Practice Volume (second part of the textbook). Review the worked and guided problems in the Practice Volume. Also, for the odd-numbered problems you can check your answers.
3. Review the Tutorials which contain most of the major concepts.

III. PROJECTS

Purpose:	Transfer your learning and understanding of concepts to a real-world context
What you need to do:	Work with your team to produce a project presentation and a project report
Evaluation:	Your team's project presentation and project reports will be evaluated separately. In addition, your team members will evaluate your relative contribution to the project. A rubric will be distributed with each project.

Details: There will be three approximately month-long projects over the course of the semester. At the beginning of each project, you will receive a project brief that describes the learning goals and guidelines for that project. Be sure to carefully read the entire project brief before embarking on your project. The project brief includes project requirements and evaluation rubrics for the project presentation and the project report. Project materials will be made available in class. In certain cases, you will receive a budget for your project and your task is to stay within that budget. At the end of each monthly project cycle we will have a project fair where teams present their results.

Approximately a week after each project fair your team must submit a project report, using guidelines detailed in the project brief. After the report is evaluated and returned to you, you will have a few days to improve your report and your evaluation of the report.

COURSE POLICIES

Assessment and final grade

Unlike most courses, there are no exams or essays at the end of the course to evaluate your overall performance in AP50. Instead, your grade is determined by the continuous assessment of the activities that are part of AP50. All of these activities — all your work in AP50 — are evaluated on the same 3-point scale:

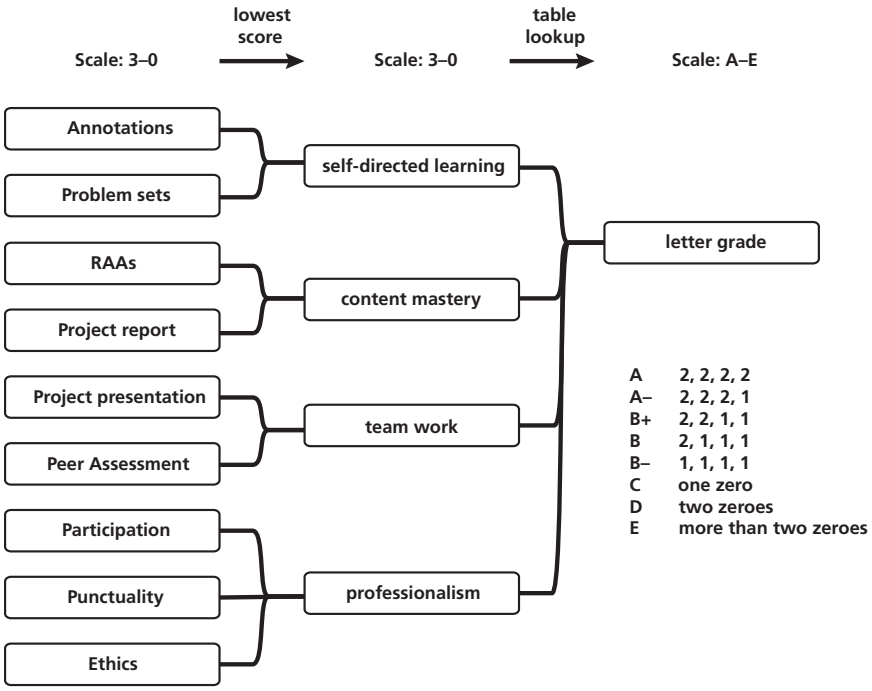
3 = significantly exceeds expectations (given only in the most exceptional cases)
2 = meets expectations
1 = improvement needed
0 = deficient

Your final grade is determined by how well you do in the following four domains *during the entire course of the semester*.

Domain	**Contributing activities**
Self-directed learning	1. **Textbook annotations:** We assess the extent to which your annotations reflect reading and thoughtful interpretation of the text. 2. **Problem Sets**: We assess your ability to solve problems using a four-step procedure, to evaluate your own work, and to determine what you need to review.
Content Mastery	1. **Readiness Assurance Activities**: At the end of each unit, we assess your ability to correctly solve 8–11 problems, first on your own, then in collaboration with others. 2. **Project Reports**: We assess the content and mechanics of the reports you submit at the end of each project.
Teamwork	1. **Project Presentation:** A panel of external judges assesses your team's presentation and discussion of each project 2. **Peer Assessment:** Your teammates assess your relative contribution to the project and your effectiveness as a team member. You are also assessed on how accurately you assess yourself and others.
Professionalism	1. **Participation:** Three variables factor into this assessment: your participation in the Learning Catalytics sessions, your team members' assessment of your participation in team activities, and your Team Mentor's evaluation of your engagement in the classroom activities that are not graded. 2. **Punctuality**: Your team members and your Team Mentor assess your punctuality. 3. **Ethics**: We assess your conduct in all activities relative to accepted ethical standards.

Scoring rubrics for the specific activities will be made available as we engage in each activity, so you will always know exactly what the expectations are.

Important: Because all activities are important, the score in each domain is determined by the activity for which you obtained the **lowest** score! The figure below shows how to convert your domain scores into a letter grade.



Midway through the semester you will receive *cumulative* feedback on your performance in each of the four domains, so you know where you stand and what you need to do to improve your learning.

Policy on collaboration

Because teamwork is emphasized in this class, working with others is not only permitted, but even encouraged. Please note the following restrictions, however.

1. During the individual parts of the problem sets and the RAAs you are not allowed to consult others directly or via any electronic means.
2. During the course of the semester, you will complete a number of surveys online. The purpose of these surveys is for us to better tailor the course to your needs and to evaluate how well the course works for you. Your answers will be used only to provide feedback on your learning and make adjustments to the course. They will not affect your grade in any way. You may not consult others during these surveys.

Consulting others includes any form of electronic communication. For this reason, having email or any chat or text messaging software open on your computer screen during the above activities constitutes academic dishonesty. This not only forces us to report to the Honor Council but automatically results in an Ethics score of zero, which causes your Professionalism score to be zero and which, in turn, automatically drops your grade to a C or lower.

Policy on use of materials and software

You are permitted to use information sources, including looking up information in (text)books, consult notes, and carrying out Internet searches. This policy holds true even during the RAAs. Please note the following restrictions, however.

1. During the online surveys mentioned above, we ask that you work without consulting any sources of information (nor other people).

2. When working on your problem sets, you may not copy solutions from the internet or from each other.
3. During the Estimation Activities you should not look up any information, as this would defeat the purpose of the exercise.
4. All your work, including the projects, should be original and not a copy of something that can be found on the internet or elsewhere.

Ethical conduct

We expect everyone to adhere to the highest standards of ethical conduct and respect. For every action/decision you take, subject yourself the "headline test": if your action were printed as the front-page headline in the newspaper and those you care about — your friends, family, your team members, peers, the teaching staff — would read it, how would you feel? If the answer is anything but "good", you are probably not adhering to the highest ethical standards and your Ethics score is likely to be affected. In the extreme, copying work of others, using material found online or in books as your own without proper attribution, interfering with the performance of others or other teams, plagiarizing ideas or work that are copyrighted or in the public domain, communicating in person or electronically during the individual parts of the RAAs, constitute academic dishonesty. Any such dishonesty will be reported in accordance with University policy. Any single such occurrence of academic dishonesty immediately drops your ethics score to 0, which according to the policy outlined in the figure on the previous page **automatically drops your final grade to a C or lower**. Also, bear in mind that for any team assignment plagiarism by one team member affects the score *for the entire team*, as every team member is responsible for the entire content of the assignment, even if the tasks for that assignment were divided among team members. Finally, note that disrespect for anyone in the class — fellow students or teaching staff — will negatively impact your Ethics score (see also *Diversity, inclusivity, and productive teamwork* below).

RAA Appeals

If your team feels strongly about the correctness of an item on an RAA, the team may submit a written appeal. This appeal process must occur immediately following an RAA and only teams, not individuals, may write appeals. Only teams that write successful appeals get credit for that appeal, even if another team missed the same question(s). Appeals are not simply an opportunity to dig for more points. Rather, they are an opportunity for teams to make scholarly arguments for their collective positions. All arguments must be supported by evidence from the text or other source. If the appeal is based on an ambiguously phrased question, the team must suggest wording that is less ambiguous. The decision to grant or refuse an appeal will be made by the instructors after class via e-mail. The following is an example of a successful appeal:

> Argument: "We feel that A, rather than B, should be the correct answer to question 8."
>
> Evidence: "According to Figure 12.42 in the text, friction affects the motion of the objects. The speed of cart 2 decreases over time. Because friction cannot be excluded in question 8, we would expect the same decrease in speed to occur for the cart in this question."

Policy on missed activities and assignments

Due to the collaborative nature of the activities, it is not possible to make up any team activities, such as project work, problem set discussions, RAAs or project fairs. (The same, incidentally, is true in the professional world.) We understand, however, that certain factors may occasionally interfere with your ability to participate. If — for whatever reason — you have to be absent from any team activity (graded or ungraded) your first duty is to **inform your team members** (if you are not there, you cannot help them out). Please ask your team members to inform the Head TF or one of the instructors in class of your absence.

Missed Classes. Teamwork requires working and learning together as a team. It is therefore important to be there for your team. If you need to miss class, please inform your team and discuss how to make up for your absence.

Note that if you repeatedly miss class, your team is likely to negatively rate your team contribution, which affects your grade.

Missed Problem Set Reflection. If you have to miss one of the Problem Set Reflections, but you are **able to do the work** before the Problem Set Reflection takes place, please:

1. Scan your solutions and email them to the Head TF before 9 am on the day of the Reflection, explaining why you will not be in class. The Head TF will email you an official solution and a Reflection Sheet.
2. Mark up your solutions and complete the Reflection sheet. You may only use a **red pen** to add anything to your solutions after you have scanned them.
3. Hand in the marked solutions and the completed Reflection sheet to the Head TF within two days of the original due date (or let the Head TF know of any extenuating circumstances).

We will review your work and your grade will be based on your individual work only.

If you are **not able to do the work** before the Problem Set Reflection takes place, please let us know as soon as possible and obtain an official note from the University explaining any extenuating circumstances. As far as your grade is concerned, provided you submit **proper documentation of the extenuating circumstances**, we will not give you any grade for that problem set and exclude this problem set in the computation of your final grade. Otherwise your grade for that problem set will be **zero**. We will discuss with you how to catch up with the class.

Missed RAA. If you have to miss one of the RAAs, obtain an official note from the University explaining any extenuating circumstances. Upon submitting proper documentation, we will ask you to come and take a make-up RAA by yourself (45 minutes; individual round only). You must do this before the following RAA in order to be able to participate in the following RAA. As you will not have a team score, we will average your individual score with the score obtained by your team (without you). If **no proper documentation of the extenuating circumstances** is provided, your grade for that RAA will be **zero**.

Missed Project Fair. If you have to miss one of the Project Fairs, obtain an official note from the University, explaining any extenuating circumstances. Upon submitting that note to the Head TF, we will give you your team's grade for the Project Fair presentation. If **no proper documentation of the extenuating circumstances** is provided, you will receive **zero** for the Project Fair presentation.

All other work must be done according to the posted schedule regardless of any extenuating circumstances, as all deadlines and all work are posted well in advance.

Accessibility

If you have a documented disability (physical or cognitive) that may impair your ability to complete assignments or otherwise participate in the course and satisfy course criteria, please meet with us at your earliest convenience to identify, discuss, and document any feasible instructional modifications or accommodations. You should also contact the Accessible Education Office (AEO) to request an official letter outlining authorized accommodations. All discussions will remain confidential, although AEO may be consulted to discuss appropriate implementation.

Diversity, inclusivity, and productive teamwork

Great teams tend to be diverse (so each team member can provide a unique perspective) and inclusive (so everyone can contribute equally). The best teams need to have a range of voices, experiences, viewpoints and skills in the room when decisions need to be made or projects need to be completed. For that reason, creating a team culture that supports a diversity of thoughts, perspectives and experiences, and honors your identities (including race, gender, class, sexuality, religion, ability, etc.) is likely to lead to the best possible learning outcome for all. The teaching staff will treat everyone in the class with equal respect so that students from all diverse backgrounds and perspectives benefit from this course. Respect is perhaps be the most fundamental principle in

all of ethics and I therefore expect everyone in the class display respect for others, as doing so will maximize the outcome of this course for all.

My goal is to provide an environment in which everyone's learning needs are addressed — in class and out of class. Please let me know ways to improve the effectiveness of the course for you personally or for other students or student groups.

GETTING STARTED

To get started in AP50, you need to:

1. Create a student account (if you do not already have one) at http://LearningCatalytics.com using access code: **HSSLCS-BAZOO-VETCH-BLOBS-SARTO-ROSES**.

2. Complete *General* and *E&M Background* surveys on Learning Catalytics (Access codes are **54871989 and 99103561**, respectively) by Wednesday Jan 29 at 5 pm.

3. Complete the reading assignment on Chapter 22 posted on Canvas by midnight Jan 29th and on Chapter 23 by midnight Feb 3rd (see Annotation Rubric for details)

NOTE: If the course is oversubscribed, admittance to AP50 will be based on your completion of these three items.

How Perusall Works

Perusall helps you understand the material better and get more out of your classes. To achieve this goal, you will be collaboratively annotating reading assignments with others in your class. The help you'll get and provide your classmates (even if you don't know them personally) will resolve any confusion and make the learning fun. While you read, you'll receive rapid answers to your questions, help others resolve their questions (which also helps you learn), and advise the instructor how to make class time most productive. You can start a new annotation thread in *Perusall* by highlighting text, asking a question, or posting a comment; you can also add a reply or comment to an existing thread. Each thread is like a chat with one or more members of your class, and it happens in real time. Finally, to help others you can upvote thoughtful questions or helpful answers. Your **goal** in each reading assignment is *to stimulate discussion by posting good questions or comments, to help others by answering their questions* and *to draw the attention of others to good questions or comments, by upvoting these*.

Research shows that by annotating thoughtfully, you'll learn more and get better grades, so here's what "annotating thoughtfully" means: Effective annotations *deeply engage points in the readings, reveal thought processes, stimulate discussion, and help others by addressing their questions or confusions*. To help you connect with classmates, you can "mention" a classmate in a comment or question to have them notified by email (or immediately if online), and you'll also be notified when your classmates respond to your questions.

For each assignment we will evaluate a number of **metrics of engagement** that have been found to correlate with course performance, as well as the **quantity** and **quality** of the annotations you submit **on time**.

Metrics of engagement

- starting the assignment early,
- breaking the reading up into chunks (instead of reading the entire assignment all at once)
- reading all the way to the end of the assignment
- interacting with your peers online by posing thoughtful questions that promote discussion
- answering questions, and
- upvoting thoughtful questions and helpful answers.

Annotation Quality

3 = demonstrates exceptionally thoughtful and thorough reading of the entire assignment
2 = demonstrates thoughtful and thorough reading of the entire assignment
1 = demonstrates superficial reading of the entire assignment OR thoughtful reading of only part of the assignment
0 = demonstrates superficial reading of only part of the assignment

See the annotation example on the back to better understand the quality metric.

Annotation Quantity

When we look at your annotations we want them to reflect the effort you put in your study of the text. It is unlikely that that effort will be reflected by just a few thoughtful annotations per assignment. On the other extreme, 30 per assignment is probably too many, unless a number of them are superficial or short comments or questions (which is fine, because it is OK to engage in chat with your peers). Somewhere in between these two extremes is about right and, thoughtful questions or comments that stimulate discussion or thoughtful and helpful answers to other students' questions will earn you a higher score for the assignment. Note, also, that to lay the foundation for understanding the in-class activities, you must familiarize yourself with each assignment *in its entirety*. Failing to annotate the entire assignment will result in a lower score.

In the preceding two chapters, we developed a mathematical framework for describing motion along a straight line. In this chapter, we continue our study of motion by investigating inertia, a property of objects that affects their motion. The experiments we carry out in studying inertia lead us to discover one of the most fundamental laws in physics—conservation of momentum.

4.1 Friction

Picture a block of wood sitting motionless on a smooth wooden surface. If you give the block a shove, it slides some distance but eventually comes to rest. Depending on the smoothness of the block and the smoothness of the wooden surface, this stopping may happen sooner or it may happen later. If the two surfaces in contact are very smooth and slippery, the block slides for a longer time interval than if the surfaces are rough or sticky. This you know from everyday experience: A hockey puck slides easily on ice but not on a rough road.

Figure 4.1 shows how the velocity of a wooden block decreases on three different surfaces. The slowing down is due to *friction*—the resistance to motion that one surface or object encounters when moving over another. Notice that, during the interval covered by the velocity-versus-time graph, the velocity decrease as the block slides over ice is hardly observable. The block slides easily over ice because there is very little friction between the two surfaces. The effect of friction is to bring two objects to rest with respect to each other—in this case the wooden block and the surface it is sliding on. The less friction there is, the longer it takes for the block to come to rest.

Figure 4.1 Velocity-versus-time graph for a wooden block sliding on three different surfaces. The rougher the surface, the more quickly the velocity decreases.

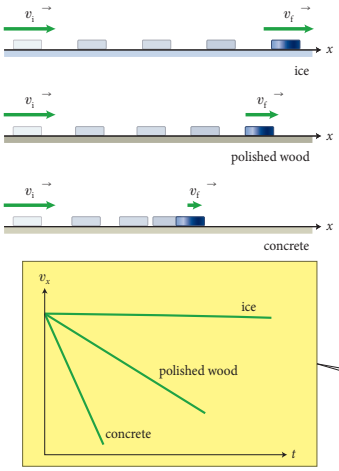


Figure 4.2 Low-friction track and carts used in the experiments described in this chapter.

You may wonder whether it is possible to make surfaces that have no friction at all, such that an object, once given a shove, continues to glide forever. There is no totally frictionless surface over which objects slide forever, but there are ways to minimize friction. You can, for instance, float an object on a cushion of air. This is most easily accomplished with a low-friction track—a track whose surface is dotted with little holes through which pressurized air blows. The air serves as a cushion on which a conveniently shaped object can float, with friction between the object and the track all but eliminated. Alternatively, one can use wheeled carts with low-friction bearings on an ordinary track. Figure 4.2 shows low-friction carts you may have encountered in your lab or class. Although there is still some friction both for low-friction tracks and for the track shown in Figure 4.2, this friction is so small that it can be ignored during an experiment. For example, if the track in Figure 4.2 is horizontal, carts move along its length without slowing down appreciably. In other words:

In the absence of friction, objects moving along a horizontal track keep moving without slowing down.

Another advantage of using such carts is that the track constrains the motion to being along a straight line. We can then use a high-speed camera to record the cart's position at various instants, and from that information determine its speed and acceleration.

CONCEPTS

4.1 (*a*) Are the accelerations of the motions shown in Figure 4.1 constant? (*b*) For which surface is the acceleration largest in magnitude?

4.2 Inertia

We can discover one of the most fundamental principles of physics by studying how the velocities of two low-friction carts change when the carts collide. Let's first see what happens with two identical carts. We call these *standard carts* because we'll use them as a standard against which to compare the motion of other carts. First we put one standard cart on the low-friction track and make sure it doesn't move. Next we place the second cart on the track some distance from the first one and give the second cart a shove toward the first. The two carts collide, and the collision alters the velocities of both.

Alan: I remember, in high school, being amazed at how quickly carts could travel on these tracks - air would blow up through these tiny holes evenly distributed along the length of the track and the cart would essentially float on the air and consequently - the cart would move very quickly with the slightest push.

Bob: Although there is no way to create frictionless surfaces, I find it interesting that we consider experiments "in the absence of friction." In a way, this relates back to Chapter 1.5 where we talked about the importance of having too little or too much information in our representations. In some cases, the friction is so insignificant that we ignore it (simplifying our representation).

Claire: Does this only apply to solid surfaces? I feel as if a substance that floats on water either has negligible or very little friction.

Alan: Why is this? I don't get it.

Bob: I believe this applies to almost every surface, although I'm not sure if water would count more as resistance than friction. Anyways, the best example I could think of would be a surf board. If people who were paddling in the same direction as the waves experienced no resistance, they would continually speed up, and eventually reach very high speeds. However, in reality if they were two stop paddling they'd slow down and only the waves would slowly push them to shore.

Claire: Is it possible to have a surface, in real life, that inflicts NO friction at all?

Claire: Doesn't air resistance factor into this at all?

Bob: The key word is "appreciably". In the absense of friction, the cart does not slow down appreciably but still would a little due to air resistance

Alan: a) yes b) concrete has the acceleration of greatest magnitude

Claire: I would think that they are not constant because if we think of the formula F=ma, the force of friction is different in every case.

Bob: As a theoretical question about inertia, if an object in motion will stay in motion, but is being affected by friction, will it slow down perpetually but remain in motion, or will it eventually stop completely due to the friction? Just curious.

Claire: With friction everything slows down to a half at one point or another. It is only if an outside force acts on the object if that object will maintain motion after the effects of inertia.

Alan: Standard carts: identical carts in mass, shape, etc. I like this notion of standard carts, it provides a good baseline to compare other motion and to understand the concepts before building on it.

Alan: Great visual representation of friction! It is interesting how this compares the velocity of things on different surfaces

Bob: The rougher the surface, the more friction between the surface and the wooden block, and thus acceleration will be greater.

Assuming these annotations are representative of these students' annotations for this assignment (and also that their annotations are distributed throughout the entire assignment and submitted on time), they would obtain the following evaluations for their body of annotations:

Meets expectations: Bob's annotations reveal interpretation of the text and demonstrate his understanding of concepts through analogy and synthesis of multiple concepts. His responses are thoughtful explanations with substantiated claims and/or concrete examples. He also poses a profound question that goes beyond the material covered in the text. Finally, he applies understanding of graphical representation to explain the relationship between concepts.

Improvement needed: While Claire asks possibly insightful questions, she does not elaborate on thought process. She demonstrates superficial reading, but no thoughtful reading or interpretation of the text. When responding to other students' questions, she demonstrates some thought but does not really address the question posed.

Deficient: Alan's annotations have no real substance and do not demonstrate any thoughtful reading or interpretation of the text. His questions do not explicitly identify points of confusion. Moreover, his annotations are not backed up by any reasoning or assumptions.

Professionalism Rubric

Your professionalism in the class is evaluated in the following categories: participation, punctuality, and ethics. Each will be rated on a scale from 0 to 3.

Important: Because all three aspects are equally essential for the success of your team, your "Professionalism score" will be equal to your **lowest** of the scores for these three categories.

Participation This class requires teamwork, which can't happen unless you're present and engaged. This means you need to fully participate in all scheduled class activities (graded or not). For example, you are not: completing work in class that you should have done at home; doing non-class related work; engaged in non-class related activities on your computer (such as chatting, texting, surfing the internet, emailing, etc.). Not being fully engaged is unfair to your team.

3 = fully engaged in all scheduled activities & helping team members stay engaged
2 = missed (or not engaged in) less than 10% of time allocated for scheduled class activities
1 = missed (or not engaged in) no more than 20% of time allocated for scheduled class activities
0 = missed (or not engaged in) more than 20% of time allocated for scheduled class activities

Punctuality We know you're busy, but please respect the members of your team and of the teaching staff by being punctual. This means arriving on time to class, not leaving before class is over, and handing in all assignments (including surveys) by their deadlines.

3 = always on time to class & all assignments/surveys on time
2 = mostly on time to class & all assignments/surveys on time
1 = mostly on time to class & no more than two assignments/surveys late
0 = repeatedly late to class OR more than two assignments/surveys late

Ethics Respect, honesty, fairness, and equality are essential to learning and teamwork. Everyone in this class — you, your team members, your peers, and the teaching staff — should therefore adhere to the highest ethical standards and be respectful of all others. For every action/decision you take, subject yourself the "headline test": if your action were printed as the front-page headline in the newspaper and all those you care about — your friends, family, your team members, peers, the teaching staff — would read it, how would you feel? If the answer is anything but "good", you are probably not adhering to the highest ethical standards.

3 = displays ethical leadership — gets others to improve their actions
2 = all behavior perfectly ethical and respectful
1 = one ethically questionable action during course
0 = more than one ethically questionable action during course OR any academic dishonesty

Note on dishonesty: Please be aware that academic dishonesty zeroes out your Ethics score, which makes your Professionalism Score zero. As explained in the Syllabus, that zero, in turn, limits your grade to a C at best.

Introductory Estimation Activity — Solution

1. People lose about 100 hair strands in a day. If 99 of these get replenished, how long would it take for an average human to become bald?

   Getting started

   With that rate of hair loss and replenishment, one would lose 1 hair/day. If I estimate the number of hair on a human head, I can calculate the number of days it would take to lose all hair.

   Devise plan

   1. Estimate area of scalp covered by hair, A_{scalp}
   2. Estimate the spacing between hairs and calculate the average area A_{hair} containing one hair
   3. Number of hair: $N = A_{scalp}/A_{hair}$
   4. Number of days needed to lose all hair = N

   Execute plan

   If I hold a sheet of paper (8.5 x 11") over my head, I estimate that the skin area covered by hair is about one square foot, or A_{scalp} = 12 x 12" = 300 x 300 mm = 10^5 mm^2 (I'm rounding off). Having seen hair close up, I estimate the average distance between adjacent hairs to be about 1 mm. This means that for each mm^2 of scalp there is one hair: A_{hair} = 1 mm^2. The number of hairs on a human head is thus approximately

   $$N = A_{scalp}/A_{hair} = (10^5 \text{ mm}^2)/(1 \text{ mm}^2) = 10^5.$$

   At a hair loss rate of 1 hair a day, it would take 10^5 days to lose all this hair.

   Evaluate answer

   10^5 days corresponds to (10^5 days)/365 days/year) = 27 years, which is quite a long time, but at a moderate hair loss, people do indeed take a long time to get bald, so my answer does not seem unreasonable.

2. How many breaths do you need to take to inhale one molecule of gas that would have come from Ramses the Great's last exhalation?

   Getting started

   For simplicity, I'll assume that the molecules that Ramses the Great exhaled in his last breath have diffused evenly throughout the whole atmosphere, and these molecules were not absorbed by the ocean or plants for thousands of years. Although these are not valid assumptions, we can at least get some feeling and then we can always revisit our assumption.

   Devise a plan

   1. Estimate the volume exhaled in a single breath
   2. Estimate the volume of the whole atmosphere
   3. The ratio of these to volumes, V_{breath}/V_{atm} , gives the factor by which Ramses' last breath was "diluted"
   4. Estimate the number of molecules in a single breath

5. Multiply this number by the dilution factor in 3 to calculate the number of molecules inhaled in a single breath

Execute

I know I can blow up a balloon roughly the size of a gallon milk container (about 3.8 liters), but that requires me to blow really hard so the volume of a regular breath should be around 1 liter, or

$$V_{\text{breath}} = 1 \text{ liter} = (0.1 \text{ m})^3 = 10^{-3} \text{ m}^3$$

The volume of the atmosphere is given by the Earth surface area multiplied by the height of the atmosphere. I know planes fly at 10 km altitude where there is still plenty of air, so I take a value of about 30 km for the height of the atmosphere. I also know that the Earth radius is about 6,400 km, so

$$V_{\text{atm}} = 4\pi R^2 = 4\pi(6400 \text{ km})^2 \text{ x } 30 \text{ km} \approx 10^{19} \text{ m}^3$$

Therefore, the molecules in one breath eventually get diluted by a factor

$$V_{\text{breath}}/V_{\text{atm}} = (10^{-3} \text{ m}^3)/(10^{19} \text{ m}^3) = 10^{-22}$$

The number of molecules in a volume of gas is given by Avogadro's number. More specifically one mole (or about 22 liters) contain N_A = 6.0221413 x 10^{23} molecules. One breath therefore contains

$$1/22 \text{ x } (6 \text{ x } 10^{23}) \approx 10^{22} \text{ molecules}$$

Diluting these molecules by a factor 10^{-22} yields about 1 molecule.

Evaluate answer

That is a pretty amazing conclusion, especially considering the fact that this implies that for every person that died long enough for his/her breath to spread out over the atmosphere, one molecule from that person's last breath is contained in every breath you take. Currently the population on Earth is about 7 billion, so it is not unreasonable to assume that the number of people who ever lived is about an order of magnitude larger, or about 100 billion = 10^{11}. That means that just a tiny fraction of each breath — $10^{11}/10^{22} = 10^{-11}$ — are molecules exhaled by other people during their last breath. Suppose we take not just the last breath, but ALL breaths ever exhaled: average human lifetime over the ages = 50 yrs = 10^{10} s, or with roughly one breath per second 10^{10} breaths. So for each breath you take, the fraction of molecules ever exhaled by the people that ever lived would be 10^{10} x 10^{-11} or about 10% of the air you inhale. It's just that Avogradro's number is so incredibly large!

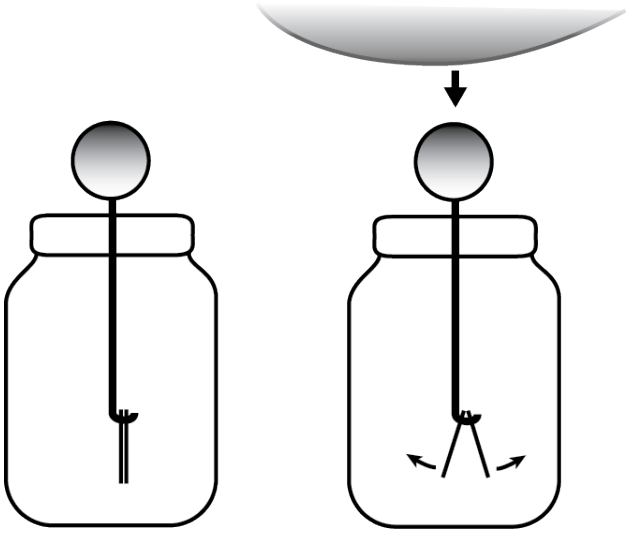
Experimental Design Activity 1 — Electroscopes!

By the end of this activity you will be able to:

1. Construct and use an electroscope
2. Measure potential difference between a charged object and the electroscope.
3. Determine sensitivity of equipment useful for Project 1.

I: Introduction

You will be constructing your own electroscope using basic supplies. An electroscope is an instrument used to detect the presence of electric charge and external electric fields. This electroscope will be useful for Project 1 as a way to troubleshoot your electrostatic generator, and estimate the charge that it generates.



The electroscope consists of two foil leaves, connected to a conductive sphere. The leaves are suspended within a glass jar to isolate them from air currents. When the conductor is charged or polarized, the leaves move apart due to electrostatic repulsion.

II: Building an Electroscope.

You have been provided:

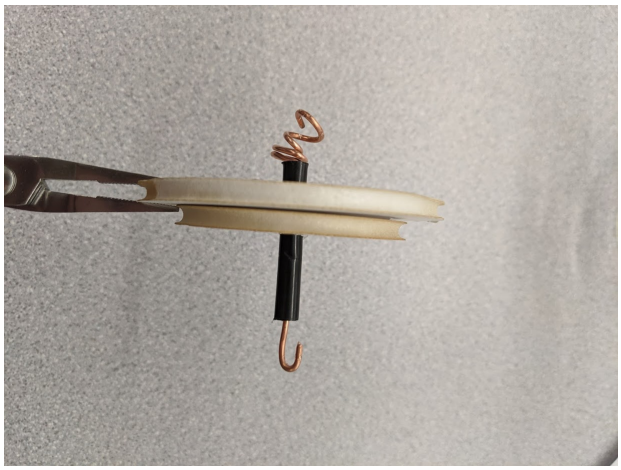
- Mason jar
- Foamcore jar lid
- 14 gauge copper wire
- Plastic straw
- Wire cutters
- Scissors
- Pliers

- 2 sheets of aluminum foil
- Balloon

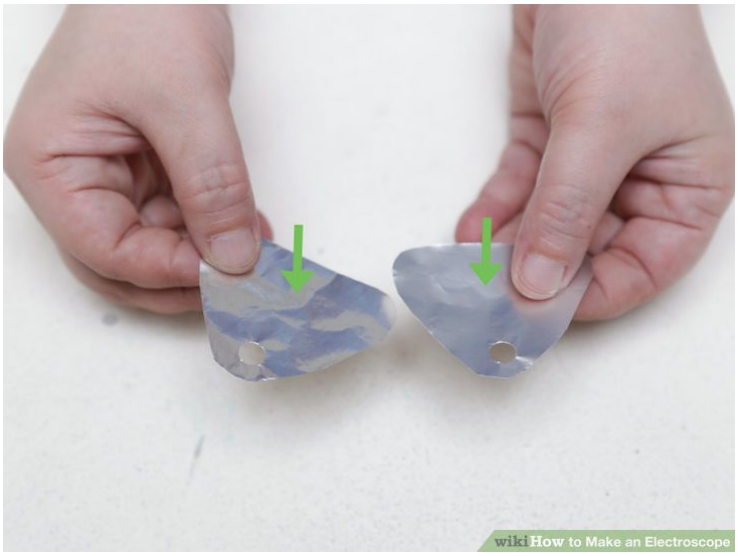
To construct the electroscope, start by inserting part of the straw into the hole in the jar lid with about half of the straw on either side of the lid.

Use the pliers to twist the top 4 inches of the copper wire into a corkscrew. Then crumple the aluminum foil sheet around the corkscrew to form a conductive sphere about 2 inches in diameter.

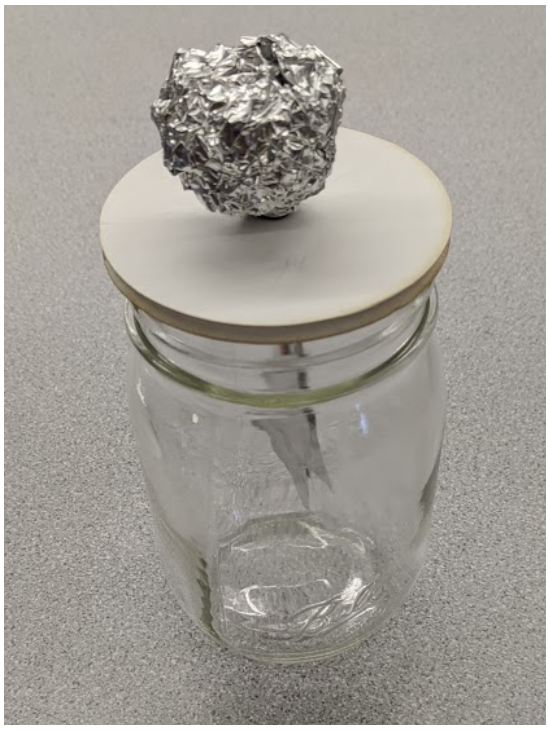
Insert the other end of the copper wire into the straw/lid, and make a hook with the last inch of the wire. The hook end of the wire should be on the inside of the lid, and the ball should be outside. This hook will hold the foil leaves in place.



Cut two thin strips out of aluminum foil, measuring 1 cm × 4 cm. Carefully punch a small hole into the top of each strip, large enough to fit the copper wire. Avoid crumpling the foil during this process. Try to leave them as smooth as possible.



Hang the strips on the copper hook and place the lid onto the jar. The strips should hang freely, and in contact with each other.



III. Polarization and Charging

This section will familiarize you with the functions of the electroscope and the types of measurements it can make. Rub the inflated balloon against your hair for at least a few seconds. Notice that your hair will stick to the balloon. This is because the balloon has become negatively charged.

a) **Holding the charged balloon above the electroscope, gradually lower it until the foil strips begin to move. What is causing the leaves move apart?**

b) **What happens to the leaves when the balloon is raised up again, away from the electroscope? Does this match your expectations?**

Ground the electroscope by touching the conductor and the jar for a few seconds. This will remove any charged particles that may have been accumulated. Your body acts as the ground.

c) **Repeat the experiment with the charged balloon. This time, touch the balloon to the conductive sphere. What is happening to the electroscope in this scenario?**

d) **What happen to the leaves this time when the balloon is removed from the electroscope? Can you explain your observations?**

Once again, ground the electroscope by touching the conductor and the jar for a few seconds to remove the accumulated charge.

e) **Experimenting with the distance between the electroscope and the balloon, can you transfer charge to the electroscope (like part d) without ever making contact between the two (like part a)? Do you hear any noises when charging occurs?**

f) As mentioned earlier, the balloon becomes negatively charged when rubbed against your hair. Using your knowledge from the previous class, how can you charge the electroscope positively? Please demonstrate.

g) How can you verify that you have charged the electroscope positively? Please demonstrate.

IV. Measuring Sensitivity

The electroscope can detect static charge and electric fields, making it very useful for troubleshooting in Project 1. For example, you can use it to determine if your electrostatic generator is able to build up a charge. In this section you will determine the sensitivity of your electroscope — the smallest measurable electric field.

You can detect the dielectric breakdown of air by charging the balloon (by rubbing it on your sweater) and bringing it close to the knob on the electroscope, until you hear a click. This click represents the transfer of charge from the balloon to the electroscope. The physical mechanism of this transfer is the dielectric breakdown of air. This breakdown occurs at a known electric field strength ($\mathbf{E} = 3\times10^6$ V/m).

Record the distance between the balloon and the electroscope where you hear the spark.

Now ground the electroscope and ground the balloon and recharge the balloon. To recharge the balloon, rub it on your sweater the same way you did in the previous experiment so the balloon has approximately the same amount of charge as when you charged it before. Now bring the charged balloon towards the electroscope and measure the maximum distance over which you can detect even the smallest deflection of the needle.

Record this second distance.

Now you have 2 distances. From these two distances, figure out a way to estimate the smallest electric field that your electroscope can detect (*i.e.*, the sensitivity of your electroscope).

Problem Set 1

Due Th Feb 6 in class

Instructions

Before you begin on this problem set, carefully read the rubric below. If you are new to AP50, please read **Section 1.8 of the book** to understand **the 4-step problem-solving procedure you must apply to every problem**. The first problem provides some guidance on the four steps to help you get started with this procedure. Furthermore, as we will scan all work so we can grade it efficiently, please hand in your work **on the template distributed in class**.

Evaluation Rubric

The goal of the problem sets is to develop problem-solving skills, not just to test your ability to obtain the right answer. You will receive the problem sets a week before they are due. Each problem set involves both individual work (at home) and teamwork (in class).

Individual phase (at home, evaluated on **effort not correctness**): From the time you receive a problem set to the time it is due in class at 9 am, you are to work on the problem set **alone**. As you work on the problem set, remember that the work you complete during this phase will be evaluated on **effort only**. You may only use **blue or black ink** and you must attempt to solve each problem using the 4-step procedure explained in Section 1.8 of the textbook:

Getting Started	State the important information and summarize the problem. If possible, include a diagram. Note any assumptions you're making.
Devise Plan	Devise a plan of attack before diving into the solution. Break down the problem into smaller, manageable segments. Identify which physical relationships you can apply.
Execute Plan	Carry out your plan, explaining each step. The argument should be easy to follow. Articulate your thought process at each step (including roadblocks). Any variables should be clearly defined, and your diagrams should be labeled.
Evaluate Result	Check each solution for reasonableness. There are many ways to justify your reasoning: check the symmetry of the solution, evaluate limiting or special cases, relate the solution to situations with known solutions, check units, use dimensional analysis, and/or check the order of magnitude of an answer. **Note:** If you get stuck in the Execute Plan stage and there is no solution to evaluate, you should still attempt to use estimation skills to get a feeling for what would constitute a reasonable answer to the problem. So **never leave this section blank**!

You may consult the textbook and online resources, and you may consult the teaching staff. However, you should not consult other people; you will have an opportunity to collaborate with your peers in class and **only your effort will be evaluated**. It's ok to try hard and not succeed at first, but you must attempt every problem and convincingly show that you've done your best to solve the problem (in which case you will receive **full credit** for this part!). If you reach the Evaluate stage and find that your answer does not seem reasonable, but you can't fix it, try to describe your thought process, so you are prepared for a discussion with your team in class.

Team/Reflect phase (in class, evaluated on **accuracy of your markup and self-evaluation**): On the due date of the problem set, you will work with your team in class to mark up your solutions, reflect on your work, and determine what you need to review. During this stage, you may only use **red ink** to write on your problem sets (pens will be provided in class). This part will be evaluated on accuracy of your markup and self-evaluation, so your goal is to

identify your errors (**not to complete your work!**). After the first 45 minutes, your team will be provided with a solution set which you may use to confirm your solutions. After an additional 45 minutes, you must submit the marked-up problem set together with a completed reflection sheet.

It is the team's responsibility to ensure that *all* team members hand-in complete and completely marked up solutions with a completed reflection sheet, because your team's submitted work will result in a shared team score. This means that if you do not put in adequate effort before the Team/Reflect phase, you will lower not only your own score, but also that of your team members. Likewise, it is important to ensure that everyone on your team marks his/her work up correctly during the Team/Reflect phase.

Important: Writing on the problem set in class in any other color but red will be considered academic dishonesty.

Scoring

Your problem set will be evaluated in two domains, using the standard 0–3 scale.

Effort For each problem, all steps of the 4-step problem-solving procedure are written **in blue or black ink** and convincingly demonstrate effort.

0 = incomplete 4-step procedure implementation OR solution appears copied from another source
1 = 4-step procedure implemented, but effort difficult to judge
2 = 4-step procedure implemented AND solution convincingly demonstrates effort
3 = 4-step procedure implemented AND effort demonstrated AND approach novel and creative

Reflection For each problem you clearly identify and explain (**in red ink**) any conceptual errors you made when you worked on the problem alone, as well as any mechanical errors you made.

0 = no or cursory markup
1 = errors mostly correctly identified OR comments attempt to analyze error but lack depth
2 = accurate identification of errors AND comments reveal insightful learning

AND your reflection sheet demonstrates an accurate self-assessment and a productive plan to improve your learning.

0 = Incomplete or inaccurate submission
1 = Self-assessment lacking accuracy OR poor plan for improvement
2 = Self-assessment AND plan to improve mostly accurate/relevant
3 = Accurate self-assessment AND productive plan to improve
4 = Level 3 PLUS demonstrates ability to grow and question assumptions
5 = Level 4 PLUS demonstrates ability to define new modes of thinking as a result of reflection

The above maximum of 30 points per problem set are divided by 10 and rounded to obtain an **individual score** on the standard 0–3 scale for AP50. Your individual score will be combined with a **team score** that is obtained by averaging the individual scores of all team members and rounding the result to the nearest integer. Your **problem set score** will be the average of these two scores. For example, if your team scored 3, 2, 1, 2, and 1, the team score is (3 + 2 + 1 + 2 + 1)/5 = 9/5, which rounds to 2. The team member with an individual score of 1, obtains a problem set score of 1.5; the team member with an individual score of 3, obtains a problem set score of 2.5.

Please see the syllabus for what to do if you need to miss the reflection phase in class.

Problem Set 1

Due Th Feb 6 in class

1. **Floating Peanut (Guided Problem: repeat the four-step procedure for each part of the problem).** A friend tells you he saw a spherical Styrofoam peanut float in the air after unpacking a box. You know that near the Earth's surface there is a downward pointing electric field of 100 N/C. Do you believe that the peanut could float? You also know that Styrofoam peanuts can be charged to stick to your hand, and they can even "jump" to your hand from a short distance. This is because Styrofoam picks up electrons easily, and the charges on the peanut induce an opposite charge on your hand that makes an electric field. How much charge needs to be on the surface of the peanut for it to stick to your hand? Does this seem realistic?

❶ Getting started

1. What needs to be true about the forces on the Styrofoam peanut in order for it to float in the air or jump to your hand?

2. What are the relevant forces on the peanut?

❷ Devise plan

3. Think about the magnitudes and directions of the forces of the peanut. (Draw a free body diagram if necessary.) How do you calculate each of these forces? List the assumptions that you make, including the approximate weight and surface area of the peanut.

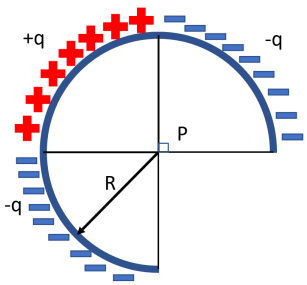
❸ Execute plan

4. Solve for the desired condition required for the Styrofoam peanut to float in the air or jump to your hand. How much charge needs to be on the surface of the peanut to float? To jump to your hand?

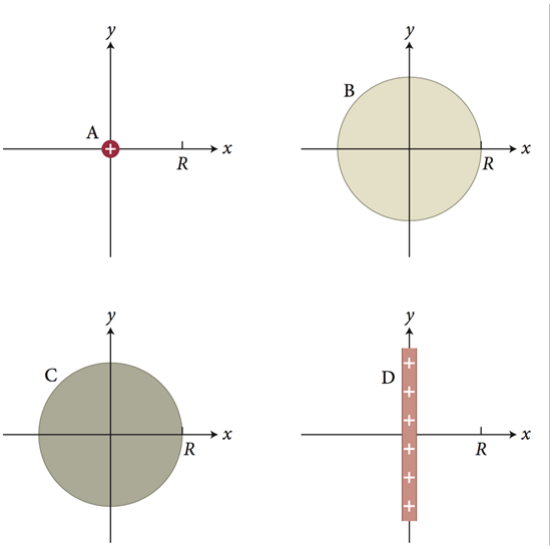
❹ Evaluate result

5. Given your results, is it realistic to imagine either situation happening? Does this align with your personal experience with packing peanuts?

2. **Three-quarter Ring.** In the uniform charge distribution shown in the figure below, each of the three arcs forms one-fourth of the circumference of a ring. The upper right and lower left arcs each carry a negative charge $-q$ while the upper left arc carries a charge $+q$. Determine the electric field at P, the ring center, in terms of q and R.



3. **Different Charge Distributions.** Consider the charged objects shown below: a particle A, a charged conducting solid ball B, a nonconducting solid ball C, and a nonconducting infinite sheet D aligned with the *y* and *z* axes. Let C and D be uniformly charged. For all four objects the electric field is the same at $x = R$. Rank the magnitudes of the electric fields in increasing order at (a) $x = 2R$ and (b) $x = R/2$.

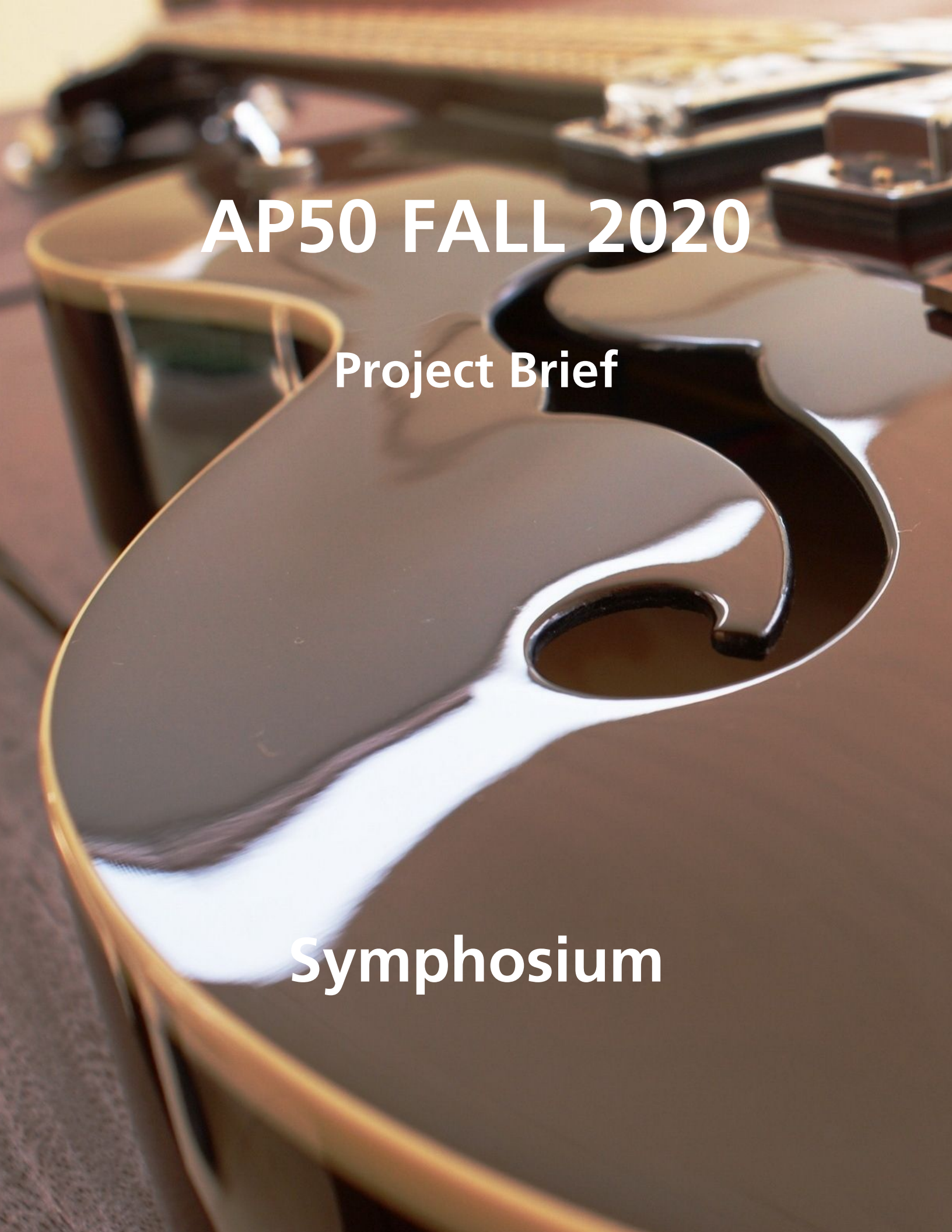


4. **Parallel Planes.** There are three infinite planes that intersect the *x* axis and are parallel to the y and z axes. Each sheet carries a charge that is uniformly distributed on the surface of the planes. The surface charge density and *x*-axis position of the planes is shown below. At 15 mm along the *x* axis, there is no electric field. Given this information, what is the electric field at –20 mm, 30 mm, and 60 mm along the *x* axis?

Plane	x intercept	Surface charge density
A	10 mm	–σ
B	20 cm	Unknown
C	40 mm	–3σ

5. **Ion Positions** Calculate the location of a chlorine ion when placed near a silicon dioxide ion. Silicon dioxide is composed of two oxygen atoms and one silicon atom. The ions are arranged so that the silicon is midway between the two oxygens, and all three lie on a straight line. The total ion length is 300 picometers. You position the chlorine on a line with the silicon that is perpendicular to the line of the silicon dioxide. You may assume that the chlorine does not affect the positions of any atoms in the silicon dioxide. You find that as you move the chlorine towards and away from the silicon there is only **one** distance where the chlorine feels no effect from the silicon dioxide. What is this distance?

Atom	Effective Charge
Cl	$-e$
Si	$+3e$
O	$-2e$



AP50 FALL 2020

Project Brief

Symphosium

Cover photo from My Wallpapers, http://www.my-walls.net/musical-instrument-violin-strings

Contents

Important dates

11/17 Project proposals due by 10 am
12/3 Video presentation to be uploaded to Canvas by 10am
12/3 Symphosium (Maxwell Dworkin Lobby)
12/8 Project reports due by 11:59 pm
12/11 Peer and self-assessments due by 11:59 pm

Symphosium

Music is pure magic consisting of sound and silence. Music affects the brain and touches the soul. What is it about music that stirs up emotions and at the same time soothes them? This is a recurrent question that scientists, psychologists, and musicians have been wondering about for a long time. Because of your background in the physics of waves and sound, you have been asked to participate in *Symphosium 2020* — an international conference on Music and Society, which will take place on December 3, 2020, in Cambridge, MA. The theme of this year's conference, *Fighting Poverty with Music*, is inspired by *El Sistema*, the radical approach to music education that is used in Venezuela to fight poverty with music.

José Abreu, who obtained an Honorary Doctorate from Harvard University in 2013, founded El Sistema in Venezuela in 1975. Abreu's dream was to help the poor children he saw in the streets break out of the cycle of poverty through classical music. In his view the classical orchestra represents an ideal society and a perfect environment in which to nurture a child. He started with eleven children and the project grew rapidly.

El Sistema survived different political systems in Venezuela and currently includes 125 youth orchestras and countless instrumental training programs, reaching close to 400,000 children. The program has yielded many success stories and is being copied in a growing number of developing and developed nations, including the US. Because of a lack of resources, however, programs for younger children in third-world countries are often constrained to use make-believe instruments made from cardboard rather than real instruments.

The goal of the Symphosium conference organizers is to tap into the combined expertise of the conference participants to come up with novel designs for simple musical instruments that can be made cheaply and that can replace make-believe instruments. Through this effort the conference organizers hope to spread the idea of using music to fight societal problems and unite the world with musical harmony.

Conference participants are to work in teams to develop functioning musical instruments from recycled materials and readily available, inexpensive parts. Teams are encouraged to look for innovative new approaches that produce unusual timbres and/or involve novel sound-producing mechanisms. The instruments must be able to play at least two full musical scales, with good sound quality, and remain in tune for the duration of the Symphosium (3 hr).

At the Symphosium, your team will exhibit and demonstrate its musical instrument, and display a short (2–4 minutes) pre-recorded video of a team presentation of the musical instrument. Together with a panel of outside experts appointed by the conference organizers, the teams will examine each others' instruments and determine which instruments are ready to be rolled out in El Sistema-like programs around the world.

Your team must also submit an article for the conference proceedings. The article is to describe the instrument and provide a description of the physical characteristics of its sound. Publication guidelines are provided below in the section entitled "Project Report."

Background

Musical instruments fall into three broad categories: percussion instruments (sound produced by some kind of impact), wind instruments (sound produced by blowing air), and string instruments (sound produced by striking, plucking, or bowing strings).

The sound produced by a musical instrument is affected by many factors, including the material from which the instrument is made, its size and shape, and the way that it is played. For example, a stringed instrument may be struck, plucked, or bowed, each method producing a distinctive sound. A wooden instrument struck by a beater sounds markedly different from a metal instrument, even if the two instruments are otherwise identical. The characteristic timbre of wind instruments depends on factors such as the material, the length, and the shape of the tube. The length of the tube not only determines the pitch but also affects the timbre: the piccolo, being half the size of the flute, has a shriller sound. The shape of the tube determines the presence or absence of harmonics, which determine the perceived sound of a single note.

References

El Sistema:

- NY Times: Fighting Poverty, Armed with Violins (http://www.nytimes.com/2012/02/16/arts/music/el-sistema-venezuelas-plan-to-help-children-through-music.html?_r=0)
- http://harvardmagazine.com/2013/05/honorary-degree-recipients
- http://www.sistemasomerville.org/what-we-do

Land Philharmonic, Paraguay:

- http://www.youtube.com/watch?v=yDQ6c_bLr2o

Musical instruments:

- http://ocw.usu.edu/Electrical_and_Computer_Engineering/Science_of_Sound/Module_1_-_Physical_Acoustics_1.htm
- http://books.google.com/books/about/Fundamentals_of_Musical_Acoustics.html?id=cCW5Ng0UfYYC
- http://www.mrfizzix.com/instruments/
- http://books.google.com/books/about/The_Physics_of_Musical_Instruments.html?id=9CRSRYQlRLkC
- http://www.phys.unsw.edu.au/music/
- http://www.zahniser.net/~russell/physics05/index.php?title=Physics%20of%20Musical%20Instruments
- http://windworld.com/features/back-issues/volumes-1-2-1985-1987/
- http://www.trombamarina.com/about/

AIP Style Manual:

- http://www.aip.org/pubservs/style/4thed/AIP_Style_4thed.pdf

DELIVERABLES

1. Team contract (due Thursday, November 17, 2020, 10 am)
2. Project proposal (due Tuesday, November 17, 2020, 10 am)
3. Functional instrument (to be displayed and played at the Symphosium on December 3)
4. Video presentation (to be uploaded on Canvas by Thursday Dec 3, 10am)
5. Team Report (due Tuesday December 8 at 11:59 pm)
6. Self and peer assessment of your team members (due Friday December 11 at 11:59 pm)

1. Team contract

As you meet your new team members, the first order of action is to get to know each other and agree on how you will work together. Please exchange email and phone numbers. Chances are that you will need to reach each other on various occasions; so having that information at hand will come in handy later in the project. The next order of business is to write a short "Team contract" — a document that lays out the expectations for how you will work together and what to do to resolve problems and disagreements. What are some of the difficulties that you have encountered in previous teams and how are you going to resolve those?

Arrange to meet with your team to produce a Team Contract that contains

1. A name for your team
2. A few paragraph describing how you will work together and resolve problems
3. A mission statement for the team

Bring the contract, signed by all members of the team, to class on Tuesday November 17th.

2. Project proposal

Your team must submit a proposal providing a rough description of the instrument you propose to build, including a list of materials. If any of these materials need to be ordered, please check that they are available from the web sites listed on bit.ly/ap50order and be as specific as possible. The maximum budget for your team is $20. We will discuss your proposal during class on November 17. During the discussion your team must be ready to explain the rationale for your design parameters and the need for purchasing any parts. An example of a project proposal is in Appendix B. Once your proposal is approved, you may order any supplies online at bit.ly/ap50order.

3. Musical Instrument Requirements

Your team's goal is to develop a pleasant sounding and reliable musical instrument that can be produced cheaply from readily available materials. Electronic instruments are not permitted. You will demonstrate your instrument at the Symphosium and the instrument must satisfy the following five requirements.

It must…

1. be **reliable**. That is, it must be readily playable without requiring extensive adjustments (and remain so for the entire duration of the fair),
2. have a **musical range** of at least two octaves,
3. be **tunable**,
4. **hold tune** long enough to be useful in a concert setting (for the purpose of the fair this will be the duration of the fair), and
5. be **loud enough** to be clearly audible in a concert setting (for the purpose of the fair, this means clearly audible above the ambient noise of the fair).

Extra Challenge

Combine forces with at least one other team and play, in concert, a piece of music of your choosing at the fair. Teams that chose to opt for the extra challenge will be required to perform their piece of music in front of all the participants at the fair.

4. Video Presentation

Your team should record a short, creative team presentation of your instrument. The video should not be longer than 4 minutes and not be shorter than 2 minutes and may not include any copyrighted material. In your video:

- Include all members of your team
- Demonstrate the instrument by playing it
- Explain how, using your knowledge of physics, you improved the sound and/or performance of the instrument

In the credits be sure to describe who contributed what to the video. Your video must be uploaded to Canvas before the start of the Symphosium. During the Symphosium, your video will be peer evaluated.

5. Project report

By 11:59 pm on December 8 your team must upload a comprehensive report describing your musical instrument to the course Web site. The report should be in the form of an engineering publication that details the operation of your musical instrument. You should carefully weigh what you write down because there are strict limits on length — reports that are too long will be returned to you without evaluation until you satisfy the length requirement. You must therefore judiciously use bibliographic citations. You should familiarize yourself with the style guide for writing scientific papers, such as the one published by the American Institute of Physics before beginning to write (search the Web for "AIP Style Manual" or see the reference at the end of this document).

You must understand the basic physics of Units 1-5, but you need not explain basic principles in your report (in a journal article one does not describe basic techniques or previous work; instead an appropriate bibliographic citation is incorporated). You can simply refer to the textbook (*The Principles and Practice of Physics,* Eric Mazur, Pearson, 2020) and explain how the basic principles of mechanics you learned in this course so far apply to your solution.

The report must include results and a discussion of the following measurements: 1) musical range of the instrument, 2) sound intensity level at 1 m, 3) sound energy produced, 4) instrument's energy efficiency (ratio of sound energy produced to amount of energy transferred to the instrument), 5) harmonic spectrum, 6) quality factor, and 7) stability. You should refer to your YouTube video in your report.

Your report may not exceed 7000 words. For each displayed equation (that is, it is not typeset inline), subtract 40 words from the maximum word count. For each figure or table, subtract 200 words from the maximum word count. So, a paper containing 20 equations and 6 figures cannot contain more than 7000 – (20 x 40) – (6 x 200) = 5000 words, etc. There is no limit on the number of figures or tables in your report (other than the word limit). Bibliographic citations are not included in the word count and there is no limit on the number of citations.

Your paper should have a title, a list of authors with their affiliation, an abstract, the body of the paper (including figures, tables, equations), and a list of bibliographic citations. Papers may have section headings, but only one "level" (no subheadings). If you wish, you can provide a separate document containing "Supplemental Material", along with your paper to present material that might be useful to a reader. The content of this supplemental material will not be evaluated.

Your report must be original and may not contain text from online or other sources. Incorporation of text similar to already existing text will be considered plagiarism, result in a grade of zero for the entire project, and cause the Ethics score for all team members to be zero (immediately dropping the final grade to a C at best).

Project report review

A member of the teaching staff will review your report. Approximately a week after you submit the report, it will be returned to you with the report from the teaching staff member (including scored rubric). You will have 3 days to resubmit a revised report and improve your scores.

6. Peer Assessment

Each member of the team must also submit Peer Assessments (including a self assessment) by 11:59 pm on December 11. This assessment is submitted online and provides an opportunity to recognize those team members that have worked particularly hard and provide constructive feedback to those who could improve their team skills.

You will receive two scores from the Peer Assessment, each on a scale of 0–3. The first score is your team members' assessments of your relative contributions to the project. The second score is based on the accuracy of your self-evaluation and peer-evaluations. Basically, we'll compare your self-evaluation to your team members' evaluation and your evaluation of your team members to the remaining team members' evaluation of their contribution. It is of utmost importance that you give your best effort to accurately assess each team member's relative contribution to the project, including your own.

PROJECT RESOURCES

Each team is allocated a supply budget of $20 for the musical instrument. If you are proposing to build a string instrument, we propose that you buy real musical instrument strings (ordinary nylon and or metal wire do not work well). These purchases must be specified in the project proposal by the proposal due date. Only in exceptional circumstances will it be possible to place additional orders after the project proposal has been submitted.

Ordering materials

Once your proposal has been approved, you can order any materials that are needed for your project. The order form is at bit.ly/ap50order. Order time is generally about 3–4 days, and orders are fulfilled more quickly with approved vendors than with other vendors. Please do not order anything on your own and try to get reimbursed. Your order will be delivered to the Teaching Labs and you will be notified in class when it arrives.

Building your musical instrument

All building of the projects involving power tools must be done in Pierce G11 and G12a. Power tools may not be taken out of these two rooms unless they are used in Pierce G13 or G9. Additionally you can work on your projects in Pierce 301 during class time and whenever the room is free.

Storage of projects between classes

Each team will receive a large bin to store project parts. These bins should be stored in either Pierce G11 or G9. Materials that are too large to fit in the bins must be clearly marked with a team name and placed with the bin. Tampering with the materials belonging to another team irrevocably results in an Ethics score of 0 for the course.

SYMPHOSIUM

During the Symphosium you will be asked to briefly demonstrate your instrument to a team of external evaluators and answer questions about the physics of the operation of your instrument. Each team member must participate and the judges will select who gets to explain various aspects of your musical instrument. The panel will also ask questions to probe your understanding of the physics behind your instrument (as it pertains to Units 1–5). See the Rubrics below for the evaluation criteria.

In preparation for the Symphosium, your team must be prepared to answer the following questions and explain *how you used your knowledge of physics to improve the sound and/or performance of the instrument*:

- **Musical range:** What range of musical tones can your instrument produce? Can it play both major and minor scales? What determines/limits the range of tones that is accessible? What did you do to maximize this range?

- **Volume:** What is the maximum sound intensity level produced by your instrument at 1 meter distance? What is the useful range of intensity levels over which your instrument can be played? Is the intensity level the same in different directions? What affects the intensity level produced? Given the measured sound intensity level, how much sound energy is produced by your instrument? Estimate your instrument's energy efficiency by determining how much energy you need to transfer to the instrument to produce a given maximum sound intensity level. What did you do to maximize the sound intensity level of your instrument?

- **Timbre:** Determine the harmonic spectrum of your instrument. Does the spectrum vary with the pitch of the tone played? Can you qualitatively explain the presence or absence of harmonics produced by your instrument? What factors affect the harmonic spectrum — or, put differently, can you change the timbre as you play the instrument? What design alterations did you make to affect the timbre of your instrument?

- **Quality factor:** Determine the quality factor for your instrument. Is the quality factor frequency-dependent? Intensity-dependent? What determines the quality factor of your instrument? What did you do to increase (or decrease) the quality factor?

- **Stability:** What factors affect the tuning of your instrument? How far can you tune the pitch? How stable is the tuning — that is, how long can your instrument hold its frequency under stable external conditions? What did you do to maximize stability?

At the end of the Symphosium everyone will be required to help clean up. Instruments need to be disassembled and their parts stored for use in future projects in bins that will be provided.

Note: Keep in mind that "Breakdown" is one of the evaluation criteria.

Appendix A: Rubrics

Symphosium Rubric

A team of TFs will evaluate your instruments on the requirements. Two panels of judges will evaluate you on the overall function of your instrument (demonstration) as well as your ability to explain the underlying physics and answer questions (presentation and discussion).

Requirements

The instrument must be 1) reliable and 2) functional and 3) be produced cheaply from readily available materials. The instrument must 4) have a range of at least two octaves. It 5) must be tunable, 6) hold tune long enough to be useful in a concert setting (for the purpose of the fair this will be the duration of the fair), and 7) be loud enough to be clearly audible in a concert setting (for the purpose of the fair, this means clearly audible above the ambient noise of the fair).

2 = All six requirements met.
1 = Five requirements met.
0 = Fewer than five requirements met.

Demonstration

A panel of judges will ask your team to demonstrate your instrument by playing a song. For the instrument to be acceptable for a musical performance, it must be loud enough, in tune, and harmonious.

2 = Instrument produces music acceptable for a musical performance.
1 = Instrument produces music, but quality inadequate for musical performance.
0 = Sound produced by instrument not suitable for musical performance.

Presentation

The judges will ask your team to explain your instrument's operation, including the tuning mechanism, factors affecting tuning stability, and any measurements you have carried out.

3 = All team members present clearly and confidently, demonstrating a mastery of the material that is beyond the scope of the material in Units 1–5.
2 = All team members present clearly and confidently, demonstrating a mastery of the material in Units 1–5.
1 = All team members present clearly and confidently, but not every team member demonstrate mastery of the material in Units 1–5.
0 = Not all team members present clearly and confidently OR demonstrate mastery of the material in Units 1–5.

Discussion

During and after your team's demonstration and explanation of your instrument, the panel of judges will ask questions to probe your knowledge of the material in Units 1–5 as it pertains to your machine. The panel will indicate which team member should answer the panel's question.

3 = All team members confidently answer any questions, demonstrating a mastery of the material that is beyond the scope of the material in Units 1–5.
2 = All team members confidently answer any questions, demonstrating a mastery of the material in Units 1–5.
1 = All team members confidently answer any questions, but not every team member demonstrates mastery of the material in Units 1–5.
0 = Not all team members answer confidently OR demonstrate mastery of the material in Units 1–5.

Video Rubric

Requirements

The video includes all members of the team, demonstrates the instrument by playing it, and explains how, with their knowledge of physics, the team improved the sound and/or performance of the instrument

2 = All requirements are met
1 = One requirement is not met
0 = More than one requirements are not met

Explanation

The video should clearly explain how the team used their knowledge of physics to improve the sound and/or performance of the instrument.

3 = Video provides an outstanding explanation of the physics that was used to improve the instrument as well as the steps taken to implement the improvements.
2 = Video provides an adequate/good explanation of the physics that was used to improve the instrument as well as the steps taken to implement the improvements.
1 = Video provides an inadequate explanation of the physics that was used to improve the instrument OR the steps taken to implement the improvements.
0 = Video provides an inadequate explanation of the physics that was used to improve the instrument AND the steps taken to implement the improvements.

Creativity

3 = Video is outstandingly creative
2 = Video is creative
1 = Video is not that creative
0 = Video is incredibly boring and completely uncreative

Report Rubric

1. Content

Abstract

Professional publications in science and engineering journals start with an abstract. This is a brief description of the major points covered in the paper, including context, solution, and practicality. The abstract has a strict limit on length.

2 = Abstract is concise and complete. All essential points covered in less than 150 words.
1 = One or two major points are omitted, or between 150–200 words.
0 = No abstract is provided, or it exceeds 200 words.

Requirements

The following measurements are required: 1) musical range of instrument, 2) sound intensity level at 1 m, 3) sound energy produced, 4) instrument's energy efficiency (ratio of sound energy produced to amount of energy transferred to the instrument), 5) harmonic spectrum, 6) quality factor, and 7) stability.

3 = Report includes measurements that go beyond those required. All data plausible.
2 = All required data reported and values are plausible.
1 = One ore two measurements missing OR data not plausible
0 = More than two measurements missing OR data not plausible.

Correctness Content and data analysis are correct, both qualitatively and quantitatively.

2 = No mistakes and no misconceptions
1 = A few (1–3) incorrect or inaccurate statements AND/OR misconceptions evident
0 = Many (more than 3) incorrect or inaccurate statements AND misconceptions evident

Contributions Contains descriptions of contributions of each member.

2 = Complete descriptions both building of machine and writing of report.
1 = Partial descriptions of either building of machine or writing of report
0 = Partial descriptions of both building of machine and writing of report OR one aspect missing

2. Mechanics

Flow/Organization Report has clear structure and flows well from one section to another. The reader does not have to flip back and forth from one section to another to understand the content.

3 = Meets expectations (see 2); would require no editing for publication
2 = Well organized and structured, good flow from one section to another
1 = Attempt at organization but poorly structured overall, little/no thought to flow
0 = Totally disorganized (no sections identified and poor flow throughout)

Use of Graphics Graphics are used effectively to clarify and lend support to content. They should be clear, well labeled, and relevant. Extraneous figures can impede the flow of the paper. However, some figures are necessary to adequately explain your reasoning. (For example, you should include a diagram of your instrument.)

3 = Meets expectations (see 2) and figures used in novel and unexpected ways
2 = All figures are clear and well labeled. No figures are omitted or extraneous.
1 = One or two figures unclear or poorly labeled. Some figures omitted or extraneous.
0 = More than two figures unclear or poorly labeled. Some figures omitted or extraneous

Citations Your report must be well documented and referenced. The goal is to provide evidence for any non-obvious claim from another source (*e.g.*, "There are only 200 white tigers on earth [1]"). These citations should follow the convention outlined in the syllabus.

2 = Complete and thorough
1 = A few (1–3) statements are unreferenced, undocumented, or poorly cited.
0 = Several (4 or more) of statements are unreferenced, undocumented, or poorly cited.

Notation All calculations, figures, and tables should adhere to notation and unit standards. For example, values are accompanied by appropriate units, and variables are clearly identified.

2 = No mistakes or missing units
1 = Several (1–3) notational mistakes or missing units
0 = Many (more than 3) mistakes or missing units

Timeliness Your report must be submitted by the deadline: December 8, 11:59 pm.

2 = By the deadline
1 = No more than one day late
0 = More than one day late

Length Your report may not exceed 7000 words, minus allowances for equations and figures (consult the project brief for details).

2 = < 7000
1 = < 8000
0 = > 8000

Appendix B: Learning objectives

This project concludes all Units in AP50a. The learning objectives for the last Unit are listed below. You will need to have mastered the content of the all five Units to complete this project.

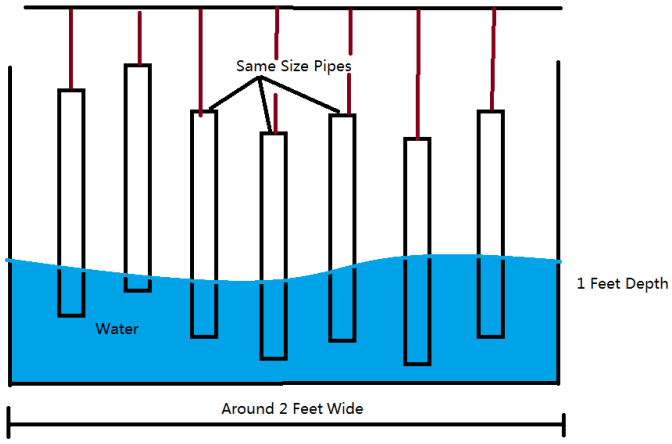
Unit 5

- Define periodic motion
- Identify and describe simple harmonic motion
- Explain Fourier's Theorem
- Describe restoring forces in simple harmonic motion
- Determine the energy of a simple harmonic oscillator
- Explain simple harmonic motion and springs
- Explain restoring torques
- Identify and describe damped oscillations
- Represent waves graphically
- Describe wave propagation
- Explain superposition of waves
- Define boundary effects
- Compute wave functions
- Describe standing waves
- Explain wave speed
- Describe energy transport in waves
- Define the wave equation
- Describe wavefronts
- Understand sound
- Explain interference
- Describe diffraction
- Calculate intensity
- Identify beats
- Identify Doppler effects
- Explain shock waves

Appendix C: Proposal Example

Description

The musical instrument will consist of seven metal tubes of equal length which are submerged in water in the trough. The metal tubes will be submerged within the water at different distances (measured from the bottom of the metal tube to the surface of the water). The length can be changed by pulling the metal tubes up from the water using a string. One of the metal tubes is fixed, while the positioning of the others will vary. Three musicians will pull the strings to vary the distances from the bottom of the trough to vary the amount of water in each of the tubes. Each musician will be controlling two metal tubes. The other two musicians will be using metal rods to strike the metal tubes to create a vibration in the metal tube, and consequently, a musical note. In order to make sure that the musicians varying the lengths of the tubes are getting to the right distance to produce the correct note, there will be a board against which the string will be pulled. This board will have markings detailing the specific notes, such that pulling to different markings will lead to different distances (again, distance being the difference in the position of the bottom of the metal tube to the surface of the water).



Materials

- 7 metal tubes of equal length (2 inches in diameter, 18 inches in length)
- 4 rods/drumsticks/mallets to hit the tubes with (we can use whatever is available)
- jug or pitcher
- trough for water that all the tubes can fit in (Max has one, so no need to purchase)
- string to hang the metal tubes
- poster board/cardboard

Peer, Self, and Team Assessment

Team work is central in your projects and it is important to provide positive feedback to people who truly worked hard for the good of the team and to also make suggestions to those you perceived not to be working as effectively on team tasks. You may want to review the sections entitled on Teamwork and Peer Assessment in the syllabus to refresh your memory on why we stress teamwork and how to maximize the benefit from work together. Please complete the form below to assess your own contributions and those of your team members, and the effectiveness of your team.

How we will use your assessment

We use your data and that of your team members to compute two scores reflecting:

1. How well you did your fair share of the work (the average of your team members assessment of your relative contribution)
2. The accuracy of your assessment (that is, how well it matches that of your team members' assessment of you and your peers).

Each of these scores will be reported on a scale of 0–3:

3 = significantly exceeds expectations (given only in the most exceptional cases)
2 = meets expectations
1 = improvement needed
0 = deficient

Peer Assessment

	Assessment of <first name> <last name>	Never	Rarely	Sometimes	About half the time	Most of the time	All of the time
1.	**Participates fully** in team activities						
2.	Comes to class **well-prepared** for all team activities						
3.	**Communicates effectively and respectfully** with team members: • Expresses opinions respectfully and with clarity • Listens respectfully to the perspectives and contributions of others • Collaborates effectively with team members to make decisions and resolve conflicts						
4.	**Attendance**: • Is present for team activities • On time/punctual						
5.	**Takes responsibility** for his/her own part of team work and decision-making						
6.	Is **open to change** and willing to re-evaluate his/her own position in light of new information from others						

7.	Tell <first name> one thing she/he does well, which helps to make your team more effective. Please address him/her directly using the second person ("you"). The text you enter below will be transmitted verbatim (but anonymously) to <first name>.
8.	Give <first name> one constructive suggestion to help him/her become a more effective part of the team. Please address him/her directly using the second person ("you"). The text you enter below will anonymously be transmitted to <first name>.

Self Assessment

	Self Assessment (you!)	Never	Rarely	Sometimes	About half the time	Most of the time	All of the time
1.	I **participate fully** in team activities						
2.	I come to class **well-prepared** for all team activities						
3.	I **communicate effectively and respectfully** with team members: • I express my opinions respectfully and with clarity • I listen respectfully to the perspectives and contributions of others • I collaborate effectively with team members to make decisions and resolve conflicts						
4.	**Attendance**: • I am present for team activities • I am on time/punctual						
5.	I t**ake responsibility** for my own part of team work and decision-making						
6.	I am **open to change** and willing to re-evaluate my own position in light of new information from others						

7.	Please describe one thing that you think you do well, that helps to make your team more effective
8.	Please explain what you think you should do to become a more effective part of the team

Team assessment

1. Please rate the team overall

My team:

1. rocked!
2. worked well together
3. was ok
4. was problematic
5. was absolutely horrendous

2. Describe what worked well in the team:

3. Describe what didn't work in the team:

4. Relative contributions

How much did each team member contribute to the overall goals? Please note that the **sum of all relative contributions must be zero** — if one person did more than his/her fair share, then others must have done less.

	RELATIVE CONTRIBUTION						
	Less than fair share				More than fair share		
	Almost nothing	Much less	Somewhat less	Fair share	Somewhat more	Much more	Almost everything
Self							
Member 1							
Member 2							
Member 3							
Member 4							

Assessment Report

Columns for each student (one student per row)

	You…	Average Peer Assessment	Self Assessment
1.	**Participate fully** in team activities		
2.	Come to class **well-prepared** for all team activities		
3.	**Communicate effectively and respectfully** with team members: • Express your opinions respectfully and with clarity • Listen respectfully to the perspectives and contributions of others • Collaborate effectively with team members to make decisions and resolve conflicts		
4.	**Attendance**: • You are present for team activities • On time/punctual		
5.	**Take responsibility** for your own part of team work and decision-making		
6.	Are **open to change** and willing to re-evaluate your own position in light of new information from others		

Scale: 0 = Never, 1 = Rarely, 2 = Sometimes, 3 = About half the time, 4 = Most of the time, 5 = All of the time

Your team members **praise you** for helping make your team more effective in the following ways (the quotes are in random order):

“quote 1”
“quote 2”
“quote 3”
“quote 4”

What you said you did to help make your team more effective:

“self quote”

Your team members have the following **suggestions** to help you become a more effective team member (the quotes are in random order):

“quote 1”
“quote 2”
“quote 3”
“quote 4”

What you said you could do to become a more effective team member:

“self quote”

Assessment of team and relative contributions

	Average Peer Assessment	Self Assessment
Overall team rating		

Scale: 1 = Rocked!, 2 = worked well together, 3 = was ok, 4 = was problematic, 5 = was absolutely horrendous

Your team members said the following **worked well** in the team (the quotes are in random order):

"quote 1"
"quote 2"
"quote 3"
"quote 4"

You said the following worked well in the team:

"self quote"

Your team members said the following **didn't work** in the team (the quotes are in random order):

"quote 1"
"quote 2"
"quote 3"
"quote 4"

You said the following didn't work in the team:

"self quote"

Relative contributions to team work	Average Peer Assessment	Self Assessment
You		
Team member 1		
Team member 2		
Team member 3		
Team member 4		

Scale: –3 = did almost nothing, –2 = did much less than fair share, –1 = somewhat less than fair share, 0 = fair share; +1 = somewhat more than fair share, +2 = much more than fair share, +3 = did almost everything

Scores

Your **team work score**: 0–3 (based on peers' assessment of **your** relative contributions)
Your self and peer **assessment accuracy score**: 0–3

Scale: 3 = exceptional (very rarely given); 2 = meets expectations; 1 = needs improvement; 0 = deficient

Reflection

Your response to your peers' assessment of you:

Describe what, if anything, you plan to do differently in your next team assignment: