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: 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 *Rube-A-Thon* 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 *Rube-A-Thon* 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
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

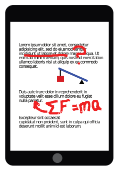
Contents of this package

1. Quick Reference Guide and Schedule
2. Syllabus
3. Rubrics: Professionalism, Annotation, Problem Set ("Homework")
4. Sample in-class activities: Estimation, Experimental Design ("Need for Speed"), Problem Set
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

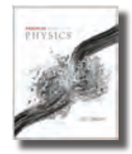


- Read and annotate text BEFORE class
- Respond to others' annotations
- Annotations guide the class

need device

NEEDED FOR COURSE

Mazur: Principles and Practice of Physics



web-enabled device

IN CLASS
Tuesday/Thursday 10am – 1 pm 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

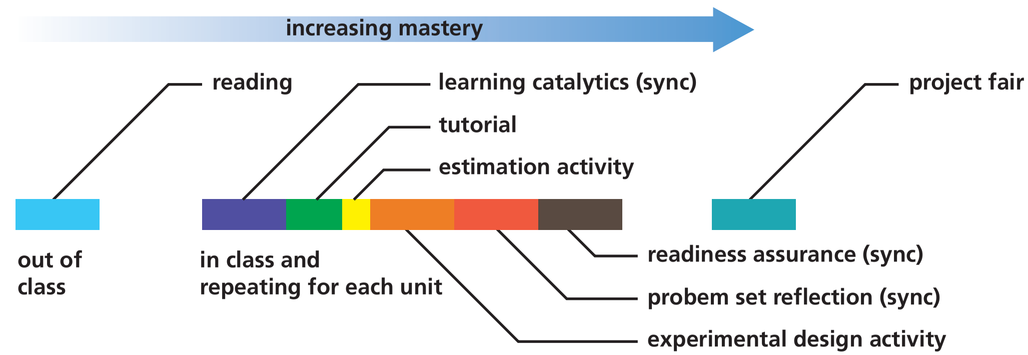
THROUGHOUT

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 2016

SCAFFOLDED ACTIVITIES



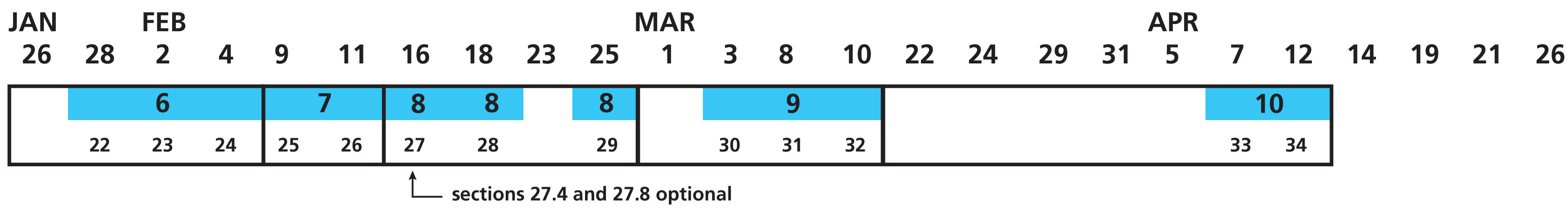
UNITS

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

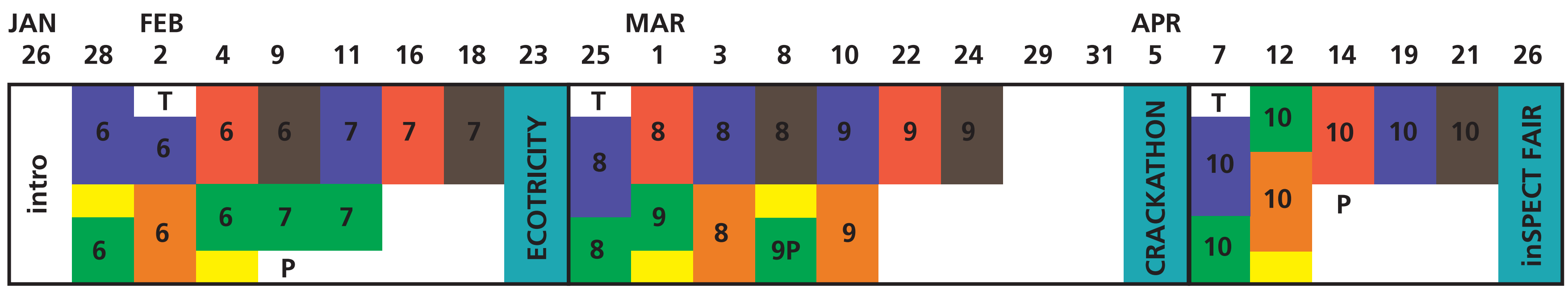
LEGEND

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

READING SCHEDULE



CLASS SCHEDULE



Syllabus

Welcome to Applied Physics 50b — Physics as a Foundation for Science & Engineering — the second part of a new, project-based introductory physics course sequence. Applied Physics is at the intersection of physics and engineering. Physicists build to understand; engineers understand to build. In this course you will be doing both. If you like to learn by doing rather than by listening, thrive on the exchange of ideas, love to see how science applies to the real world, and enjoy working in teams to build things, this course is for you!

The subject area covered by AP50b includes electrostatics, conservation principles, electromagnetic forces, circuit analysis, magnetostatics, and optics. Because it is equivalent to the standard introductory physics course (Physics 15, Physical Sciences 12), this course meets the premedical requirements as well as the physics requirements for many concentrations (engineering, chemistry, biology, etc.). This course also satisfies the Science of the Physical Universe, General Education requirement.

There are no lectures and no examinations in AP50. At the core of the course are three, month-long projects on which you will work in teams. During the course of a semester, you will apply electrostatics to clean up the environment, design and build an electromagnetic safe, and design and build an imaging spectrometer.

As the instructors for this course, we are 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. Our goals for this course 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.

We look forward to getting to know you this coming semester. We take our 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. We will make ourselves as accessible as possible — we do want to interact with you both in and out of class. We encourage you to stop by our offices or call; our contact information appears below.

This document is meant to help you understand the course goals and logistics and to make the most of this course. Throughout the semester we will ask for your feedback to see if we are moving toward achieving the course goals and satisfying your needs.

We are excited to work with you this semester!

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Course Web Site http://www.ap50.net

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

Mathematics preparation at least at the level of Mathematics 1a concurrently is required. However, some elementary ideas from multivariable calculus are used. Prior exposure to physics is helpful, but not required. AP50 is specially designed for freshmen and sophomores with an interest in science and engineering.

Class meetings

The class meets twice a week, from 10 am to 1 pm on Tuesdays and Thursdays, in Pierce 301, a new classroom designed for interactive team-based learning. There are no additional sections or laboratories.

We won't lecture you during the class meetings. Instead, you'll have an opportunity to work in teams on three successive, month-long projects. The class activities 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*.

Textbook

The textbook for AP50 is *Principles and Practice of Physics* by Eric Mazur. The book comes in several different versions, so be sure to purchase the correct one. The ISBN number for the comprehensive book that contains the material for both semesters of this course (AP50a and AP50b) is ISBN 0321961595 (hardback). The Coop has also ordered an unbound, 3-hole punched version of the book that is more economical (ISBN 0321965086). Both of these packages consist of two physical books — a white "Principles" book and a black "Practice" book.

There is no need to purchase a version that includes Mastering Physics and eText, as we will not use Mastering Physics and you will get electronic access to the Principles book via a social document annotation system at no additional cost. You will use the annotation system to add notes to the book, discuss sections of the book with your classmates and the staff, ask questions, etc. (more on the annotating below).

Note: The electronic version of the book on Perusall does not include the Practice book (which you need to practice problem solving) nor any solutions to the checkpoints (which are essential to help your understanding), so you cannot just rely on the provided electronic text.

Technology

You need a laptop or tablet in this course. First of all, you will need to annotate the textbook in the social document annotation system. 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 social document annotation system is called *Perusall*. To subscribe to the system:
1. Point your browser at http://app.perusall.com.
2. Log in using Facebook or Twitter, or create an account.
3. Once logged in, click 'Enter an access code' and then enter the access code UM895JGDPN.

The electronic response system is called *Learning Catalytics*. To subscribe to the system, point your browser at http://LCatalytics.com and create a student account with the signup code USLCSX-CHURR-HAIRY-ATMAN-STATO-FFLSE (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 will 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.

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 — 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.

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:	Read the chapters according to the class schedule and enter your questions, comments, and/or responses to others' questions and comments in *Perusall* (see *Technology* above)
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.

One word of advice: when we say "reading" we do not mean skimming the text. Study it. Understand it. Learn it. Take control of your knowledge. At the other extreme, we don't mean study until you 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). 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.

We also want to encourage you to help each other learn the material. Consult your team members and Team Mentor. Annotate the text in the *Perusall* system to interact asynchronously with your classmates and to get help when other people are not nearby. Annotating the text helps you and us. First, you get practice reading a technical textbook. Second, by reading with attention and with an inquiring mind, you take ownership of your learning. Third, your annotations help us determine how to best tailor the in-class activities to help you learn.

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 five or six 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 30 minutes, so think fast! 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 a traditional exam. If you do wish to practice your knowledge, be sure to review the Checkpoints in the text (solutions are in the back of the textbook), try the Worked Examples in the text, and above all use the Practice Volume. Typically there are around 60 Checkpoints and 30 Worked Examples for each unit. The RAAs also draw from the Tutorials and involve at least one estimation problem, so you may want to review those as well. The Practice Volume contains many examples.

III. PROJECTS

Purpose:	Transfer your learning and understanding of concepts to the 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 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:

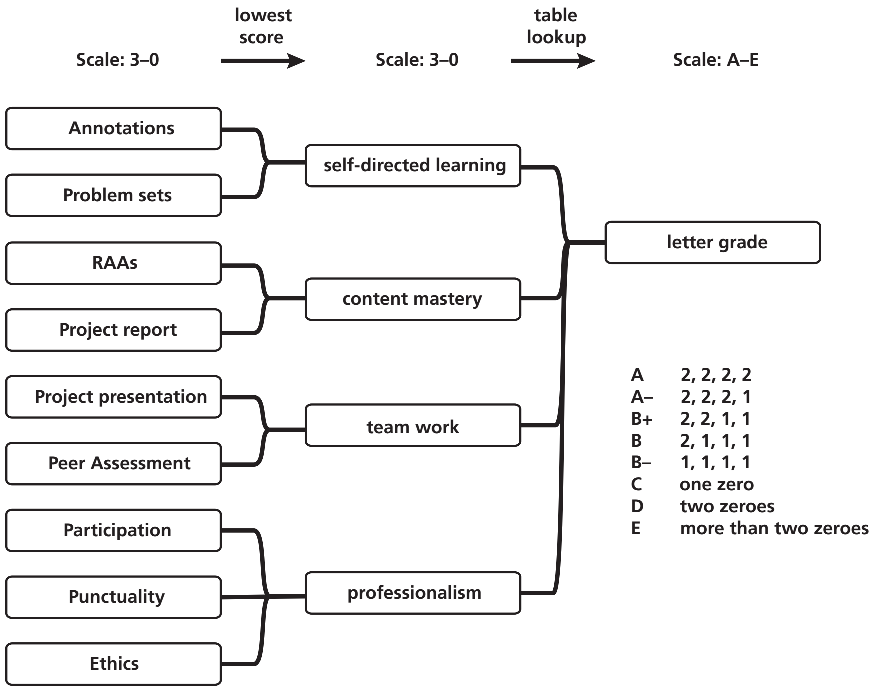
3 = significantly exceeds expectations (given only in the most exceptional cases)
2 = meets expectations
1 = improvement needed
0 = deficient

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 stressed in this class, working with others is permitted. 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.
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 automatically results in an Ethics score of zero, which in turn 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, as mentioned above).
2. During the Estimation Activities you should not look up any information, as this would defeat the purpose of the exercise.

3. When working on your problem sets, you may not copy solutions from the internet or from each other.

Ethical conduct

We expect everyone to adhere to the highest standards of ethical conduct. 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 the work of others, 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. It also immediately drops your 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.

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 let the Head TF or one of the instructors know in class that you will not be there.

Missed Project Work. If you miss class during which project work occurs, you will have to make arrangements with your team members. Remember that they will evaluate your contributions to the project, so you'll probably want to find a way to make up for your absence.

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 10 am on the day of the Reflection.
2. Shortly after you email your solutions, you will receive an official solution and a Reflection sheet.
3. Mark up your solutions and complete the Reflection sheet (which you affix to the front of your solutions). You may only use a **red pen** to add anything to your solutions after you have scanned them.

4. 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 solutions and your grade will be based on your individual work only (not your team grade).

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 not include 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 (30 minutes; individual round only). You must do this before the following RAA in order to be able to participate in that 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.

GETTING STARTED

To get started in AP50, you need to:

1. Create a student account (if you do not already have one) at http://LCatalytics.com using signup code: USLCSX-CHURR-HAIRY-ATMAN-STATO-FFLSE.
2. Complete *Physics Background* and *General Background* questionnaires on Learning Catalytics. If you participated in the demo RAA during the first lecture, these will show up automatically. If you didn't, ask someone on the teaching staff to give you the session ID numbers.
3. Log in to *Perusall* at https://app.perusall.com and enter access code UM895JGDPN.
4. In *Perusall*, annotate Chapter 22 by Jan 28th and Chapter 23 by Feb 2nd (see Annotation Rubric for details)

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

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. 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
1 = one ethically questionable action during course
0 = more than one ethically questionable action during course OR any academic dishonesty

Annotating in Perusall

Annotating helps you master the course readings so you are better prepared for class. To achieve this goal, you will be collaboratively annotating the textbook with others in the class. Doing so offers you an opportunity to obtain answers to your questions, to help others resolve their questions, and to help us determine how to best structure class time to help you learn.

Your **goals** in annotating each reading assignment are *to stimulate discussion by posting good questions or comments* and *to help others by answering their questions*. Your annotations of the readings on *Perusall* are evaluated on the basis of **quality, timeliness**, **quantity,** and **distribution**.

Evaluation rubric

Quality The reading replaces the lectures so that we can do more useful things in class. Therefore it is important you read the text thoughtfully and attempt to lay the foundation for the work in class.

Each of your annotations is assigned one of the following scores, based on its quality:

2 = Demonstrates thorough and thoughtful reading AND insightful interpretation of the reading
1 = Demonstrates reading, but no (or only superficial) interpretation of the reading
0 = Does not demonstrate any thoughtful reading of the reading

See the examples on the next page to see the quality criterion applied to sample annotations.

Quantity We compute your overall score using your 7 highest-quality annotations for each assignment, so be sure to write at least this number to ensure the best score. Because we want you to engage in a natural conversation with your classmates through your annotations, your overall score depends only on these 7 highest-quality annotations. So, as long as you have 7 high-quality annotations, a brief response to another student (*e.g.*, answering "Yes" to what is just a yes or no question) won't hurt your overall score, even though by itself that response is nominally a "0."

Timeliness The work done in class depends on you having done the reading in advance, so completing the reading and posting your annotations before the posted deadline is required to receive credit.

To encourage discourse, there is always a three-day "reply window" after each posted deadline during which you can continue to reply, for full credit, to questions posted by others. However, the number of additional points you can earn during the post-deadline reply window is capped at the credit you receive for annotations made on that assignment before the deadline (so no credit before the deadline means no credit after).

Distribution To lay the foundation for understanding the in-class activities, you must familiarize yourself with each assignment *in its entirety*. Annotating only part of the text and/or failing to distribute your annotations throughout the document lowers your overall score.

Overall Evaluation

You will receive an overall evaluation for each reading assignment based on the criteria above as follows:

3 = exceptional (rarely given)
2 = meets expectations
1 = needs improvement
0 = insufficient

CONCEPTS

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.

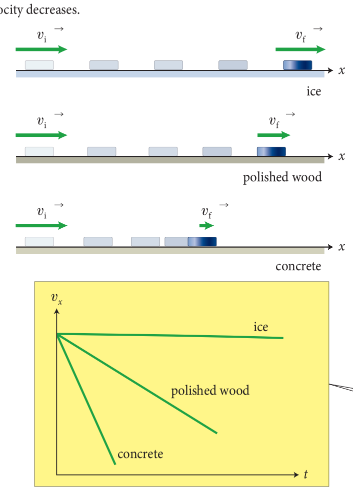


Figure 4.2 Low-friction track and carts used in the experiments described in this chapter.

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.

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.

ANNOTATION	EVALUATION	
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.	No substance. Does not demonstrate any thoughtful interpretation of the text.	0
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).	Annotation interprets the text and demonstrates understanding of concepts through analogy and synthesis of multiple concepts.	2
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.	Possibly insightful question but does not elaborate on thought process, nor demonstrate thoughtful reading of the text.	1
Alan: Why is this? I don't get it.	Question does not explicitly identify point of confusion nor demonstrates thoughtful reading or interpretation of the text.	0
David: 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.	Response demonstrates a thoughtful explanation with a claim substantiated with a concrete example	2
Alan: Is it possible to have a surface, in real life, that inflicts NO friction at all?	Question exhibits superficial reading, but does not exhibit any interpretation of the textbook.	1
Erica: Doesn't air resistance factor into this at all? It seems that it is not enough for there to be only an absense of friction for something to keep moving without slowing down. What about some other opposing force - like air resistance? Or is air resistance just another example of friction?	Demonstrates thoughtful interpretation of the text by refuting a statement through a counter example.	2
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	Responds to the question by thoughtfully interpreting the text	2
Alan: a) yes b) concrete has the acceleration of greatest magnitude	Annotation not backed up by any reasoning or theoretical assumptions. No evidence of thoughtful reading of text.	0
Erica: 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 so that would change the acceleration value (where mass would stay the same since it's assumed that th object is the same in each situation).	Response backed up with reasoning that demonstrates an interpretation of the text and applies understanding of concepts	2
Claire: 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.	Profound question that goes beyond the material covered in the textbook.	2
Alan: 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.	Demonstrates some thought but does not really address Claire's question	1
Claire: 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.	No substance. Does not demonstrate any thoughtful reading.	0
Alan: Great visual representation of friction! It is interesting how this compares the velocity of things on different surfaces	No substance. Does not demonstrate any thoughtful reading.	0
Bob: The rougher the surface, the more friction between the surface and the wooden block, and thus acceleration will be greater.	Interprets the graph and applies understanding of both the concept of friction, how a v-t graph correponds to acceleration and the relationship between the force of friction and acceleration	2

Problem Set 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 sets involves both individual and team work.

Individual phase (at home): From the time you receive a problem set to the time it is due in class at 10 am, you are to work on the problem set **alone**. The work you complete during this phase will be evaluated on effort, not correctness. You may only use **blue or black ink** and you must attempt to solve each problem using the following 4-step procedure (see Section 1.8 in the textbook for additional details)

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 Solution — 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 got 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 don't just leave this section blank!

You can consult the textbook and online resources, and you may consult the teaching staff by posting questions to the Problem Set Discussion on the course Web site. However, you may not consult other people, nor collaborate with your peers. It's ok to try hard and not succeed at first (only your effort is evaluated), but you must attempt every problem. If you reach the Evaluate stage and find that your answer does not seem reasonable, try to describe your thought process so you are prepared for a discussion with your team in class.

Team/Reflect phase (in class): On the due date of the problem set, you will work with your team in class to improve and/or correct 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). 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, your team must submit the marked-up problem sets together with completed reflection sheets for the entire team and a team scoring sheet.

It is the team's responsibility to ensure that *all* team members hand-in complete and completely marked up solutions together 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	All steps of the 4-step problem-solving procedure written **in blue or black ink** show convincing effort on 3 = all problems 2 = more than 75% of the problems 1 = more than 50% of the problems 0 = 50% or fewer of the problems
Reflection	You clearly identify and explain (**in red ink**) any conceptual errors you made (or encountered) when you worked on the problem alone, as well as any mechanical errors you made on 3 = all problems and you submit a complete reflection sheet 2 = more than 75% and you submit a complete reflection sheet 1 = more than 50% and you submit a complete reflection sheet 0 = 50% or fewer of the problems OR you do not submit a complete reflection sheet

These two scores are combined into an **individual score** as follows:

3	3 in Effort and Reflection
2	2 in both domains or one 2 and one 3
1	1 in either domain
0	0 in either domain

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. 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.

If you miss the team phase, but hand in your individual work before the due date, we will evaluate that work on Effort only. Your individual score will not be taken into account in the team score and the team score will not factor into your problem set score. Instead, your individual score will be divided by two. Any work submitted after the deadline will not be accepted. If extenuating circumstances exist, we will ask you to provide documentation directly issued by the University, and we will try to work out an agreeable solution with you.

See the attached sample forms, which you will receive at the beginning of each Problem Set Reflection.

Problem Set N

Name: _________________________ Score: _____________

Instructions

1. Fill out your name
2. Affix this form to the front of your problem set using a paperclip
3. After review in class, gather all the problem sets (including these "Reflection forms") and affix a Team Scoring Sheet

Do not complete anything on this form until class starts and use only the red pen given to you.

Problem Set Reflection

Describe what you **learned** from working on this problem set before coming to class and reviewing it in class. (Do you think you would be able to take the concepts you explored in this problem set and transfer those concepts in a whole new context?) For example, would you be able to solve a problem involving the same physics concepts, but of a form you have never seen before?).

Based on your overall experience with this problem set, describe what you need to **review**.

Estimation Activity 1

Th Jan 29

Instructions: Estimate (don't guess or Google!) the quantities below to the nearest order of magnitude. You may use any resources available to look up basic values. Report all your answers as an order of magnitude (using the indicated units).

When your team has completed all problems, raise your hand to check with a Teaching Staff Member. The first team to correctly estimate all values wins!

1. We know that within the limits of measurement, the magnitudes of the negative charge on the electron and the positive charge on the proton are equal. Suppose, however, that these magnitudes differed from each other by as little as 0.0001%. Estimate the repulsion force between two copper pennies, placed 1.0 m apart. Units : [N]

2. In the comic strip, Garfield the cat always has a negative attitude. Estimate the number of (negative) electrons in a common house cat. Units : [none]

3. Estimate the magnitude of the electric force between a proton and an electron in an atom. Units: [N]

4. The number of protons in a 1-liter bottle of cola. Units: [none]

5. We think of planetary orbits as influenced solely by gravity, but surely other interactions are possible. Given that we *can* safely ignore the influence of electrostatic attraction on Earth's orbit around the sun, estimate an upper bound for the possible **net** charge on the planet. Units : [C]

The Need for Speed: Fun with Motion Videos — Tue Sep 9, 2014

Background: For today's Experiment Design Activity, we will learn how to use two pieces of software to visualize and analyze motion. **SAM** (Stop Action Movie) allows you to capture individual frames and convert them to video format. **Tracker** identifies objects of interest in a video file (e.g. a billiard ball) and follows their motion throughout the video, generating plots of position vs. time, velocity vs. time, etc. You will find these tools helpful in analyzing the results of **your first project**.

Materials for each group:
- One meter stick
- Several post it notes (maybe 5 or 6)
- Computer with both SAM and Tracker installed
- Computer with a web cam, or a separate digital camera with ability to transfer photos to a computer
- Whiteboard or large blank of piece of paper

Part 1 — Tutorial (15 min)

- SAM: taking still frames, adjusting frame rate, exporting to MOV format
- Tracker: loading video, tracking an object, analyzing motion

Part 2 — Team Competition! (60 min)

There will be **three rounds** to the competition. For each round, every team will get the same plot of velocity vs. time and/or acceleration vs. time. The team must use **SAM** to make a video of an object undergoing that motion, and analyze the video with **Tracker** to show that the object does indeed follow the desired velocity vs. time and acceleration vs. time profiles.

Each time a team is finished one round, they will ask one of the TF's to **confirm** that their video does reproduce the desired motion. Then they will be given permission to go on to the next round. The motions in each round get progressively more complicated. **The first team to complete all three rounds wins!**

Hints:
- Use your meter stick to draw an axis with tick marks at regular intervals on the whiteboard or a large, blank piece of paper. You will find that if you draw a higher density of tick marks, you will be able to move an object along the axis with more precision
- Draw a high-contrast target on a post-it note and move it along the 1-m long axis one frame at a time. Capture each frame with SAM, then move the target forward one step in its motion. You will need to figure out how the desired motion will look, one frame at a time
- The demo version of SAM limits you to 50 frames total
- You should include two or three buffer frames at the start and finish of your video (e.g. keep your target motionless there) because Tracker can unpredictably cut out the ends of your video
- Try to keep the overall scene unchanged from frame-to-frame, except for the moving target. Tracker will discard frames that are more than 20% different from the rest. Also, if your camera angle is shaking, then the resulting motion will not be accurate
- Once you have acquired all the desired frames of your video in SAM, you can export it by going to File → Export. Select "Movie to QuickTime Movie" to save a MOV file
- Load the MOV file in Tracker, and analyze the motion in the video. You can either ask the program to automatically find the target (be careful that this does not always work!) or go frame-by-frame through the video and select the target location by holding down shift and clicking
- Your acceleration vs. time plots will not look very smooth (why?) but you should be able to nicely produce the desired velocity vs. time plots

Problem Set 1

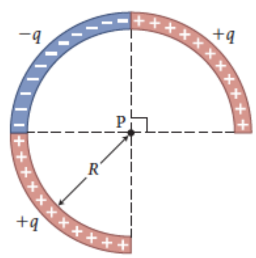
due Th Feb 4 in class

Instructions: Before you begin on this problem set carefully read the Problem Set Rubric. Furthermore, as we need to quickly scan your work so we can return it to you before the end of class, please:

- use 8.5 x 11" paper, no-dog ears or torn out of ring-bound notebook
- no staples — use a paperclip (we'll have some on hand)
- blue or black ink (no light pencils); **write in one color only**
- name on each page
- single-sided (no writing on back); leave margins blank

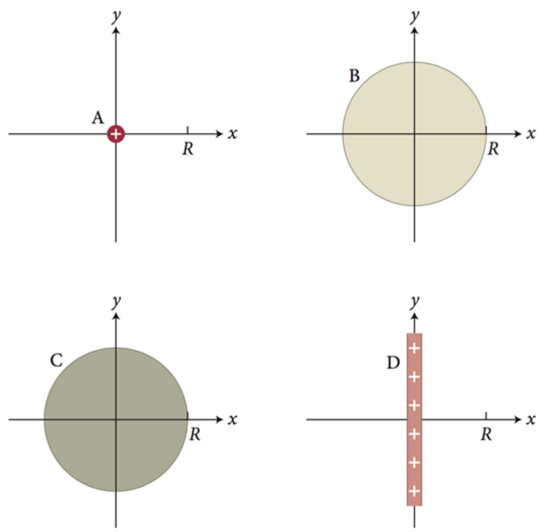
1. **Floating Peanut.** Part 1: A friend tells you he saw a spherical Styrofoam peanut float in the air after unpacking a box. You know that near the Earth's surface there is a downward pointing electric field of 100 N/C. Do you believe that the peanut could float? Part 2: You also know that Styrofoam 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 many charges need to be on the surface of the peanut for it to stick to your hand? Does this seem realistic?

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 positive 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.** The figure below shows four charge distributions in an *xyz* coordinate system. A is a charged particle at the origin, B is a charged conducting solid sphere of radius R centered at the origin, C is a uniformly charged nonconducting solid sphere of radius R centered at the origin, and D is a nonconducting infinite sheet of uniformly distributed charge in the *yz* plane, shown in cross section. In each case the electric

field at $x = R$ is the same. Rank the magnitudes of the electric fields for the four cases, largest first, at (*a*) $x = 2R$ and (*b*) $x = R/2$. Explain your reasoning.

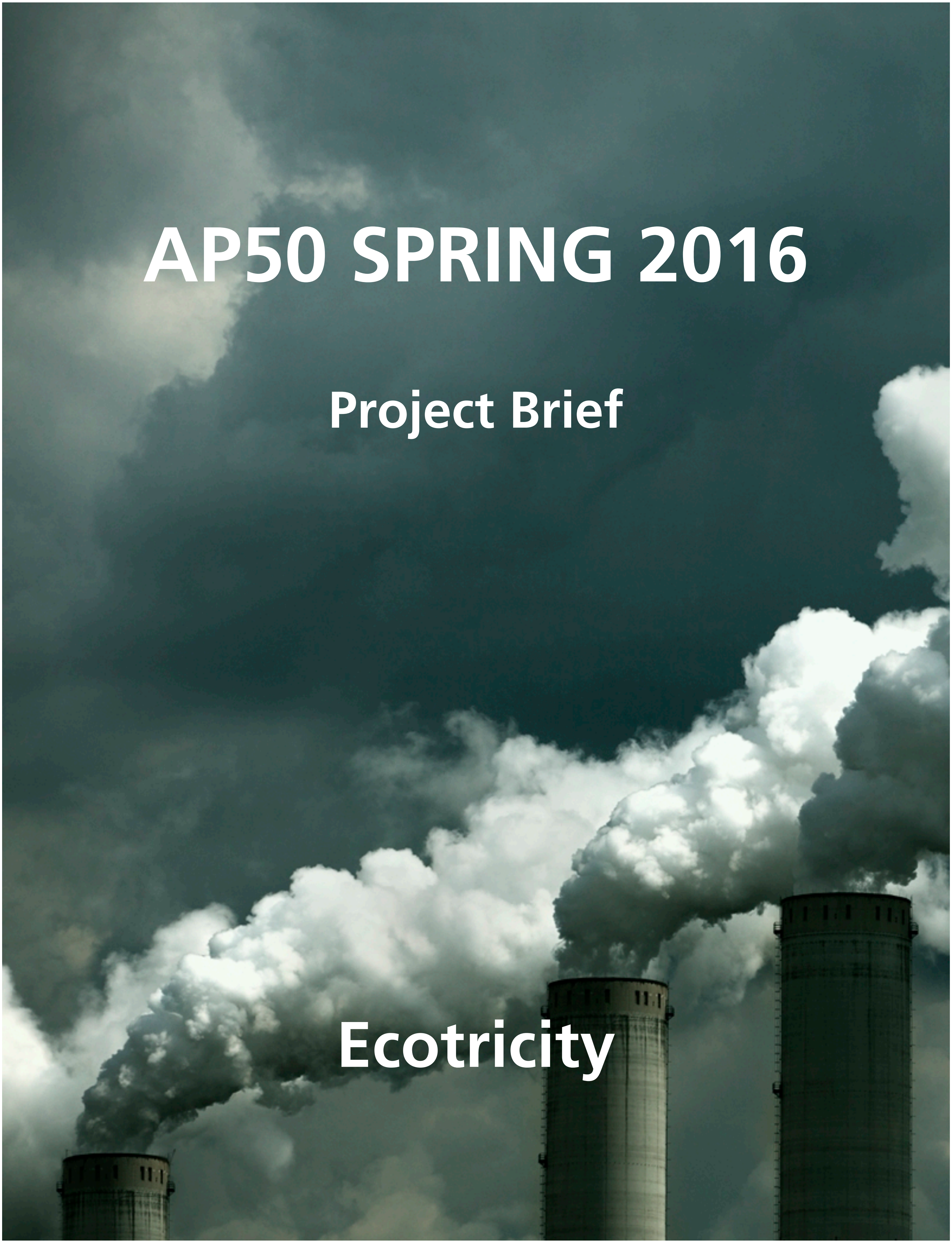


4. **Parallel Sheets.** Three nonconducting infinite sheets are parallel to the *yz* plane and an *xyz* coordinate system. Each sheet has a uniform surface charge density. Sheet 1, negatively charged with surface charge density $-\sigma$, passes through the *x* axis at $x = 1.0$ m. Sheet 2 has an unknown surface charge density and passes through the x axis at $x = 2.0$ m. Sheet 3, negatively charged with surface charge density -3σ, and passes through the *x* axis at $x = 4.0$ m. The electric field due to the sheets is zero at $x = 1.5$ m. (*a*) What is the surface charge density of sheet 2? If the electric field at $x = 0$ is $\vec{E}_0$, what is the electric field at (*b*) $x = -2.0$ m, (*c*) $x = 3.0$ m, and (*d*) $x = 6.0$ m?

5. **Du Point.** As recent alum of Harvard University's AP50, you have been hired to work for DuPont. Your boss, Dew Pont, has asked you to determine where a chlorine ion of effective charge $-e$ would situate itself near a carbon dioxide ion. The carbon dioxide ion is composed of 2 oxygen ions each with an effective charge $-2e$ and a carbon ion with an effective charge $+3e$. These ions are arranged in a line with the carbon ion sandwiched midway between the two oxygen ions. The distance between each oxygen ion and the carbon ion is 3.0×10^{-11} m. Assuming that the chlorine ion is on a line that is perpendicular to the axis of the carbon dioxide ion and that the line goes through the carbon ion, what is the equilibrium distance for the chlorine ion relative to the carbon ion on this line? For simplicity, you assume that the carbon dioxide ion does not deform in the presence of the chlorine ion.

AP50 SPRING 2016

Project Brief



Ecotricity

Cover photo from Columbia Center for Children's Environmental Health, http://ccceh.org

Contents

Important dates

2/9	Team contract and project proposals due by 10 am
2/23	Ecotricity Fair (Pierce 301)
3/1	Project reports & Engineering Design Notebooks due by 11:59 pm
3/4	Peer and self-assessments due by 11:59 pm

Background

Over the past 50 years, rapid population growth and economic expansion have increased the demands for energy around the world. Concern about the environment and the consumption of fossil fuels has forced society to look for renewable energy alternatives. One large problem with renewables is energy storage. Storing energy remains the missing link for many clean energy technologies, but Department of Energy researchers and startup companies are racing to fill the gap. Without a way to save electricity and heat for later use, intermittent renewable energy will never be a viable alternative to fossil fuels.

Ecotricity

You are working for a start-up company specializing in energy storage. The leadership of the company has decided to run an internal competition to promote innovative new ideas for a lightweight capacitor that stores a lot of charge.

As part of the internal competition, code-named *Ecotricity*, you have been assigned to a team that is to **design and build an inexpensive capacitor with the largest capacitance-to-mass ratio.**

Your team must first submit a proposal for the device. Once the competition managers approve your team's proposal for your design, your team should work building and measuring your capacitor. You should also prepare a poster that explains the design and operation of your proposed capacitor as well as its specific application. All posters and capacitors from teams participating in the internal competition will be presented during the Ecotricity Fair on February 23, 2016 in Pierce 301.

A week after the Ecotricity Fair, by March 1, 2016 at 11:59 pm, your team must submit a full report of the proposed device to the agency management. Guidelines for the proposal, the poster, the fair, and the report are below.

Reference

AIP Style Manual:

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

DELIVERABLES

1. Project proposal & Team contract (due Tuesday, February 9, 2016, 10 am)
2. Poster & Capacitor, to be displayed and presented at the Ecotricity Fair on February 23, 10 am
3. Project Report (due Tuesday March 1, at 11:59 pm)
4. Self and peer assessment of your team members (due Friday March 4 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 mission statement for the team
3. A few paragraphs describing how you will work together and resolve problems

Bring the contract, signed by all members of the team, to class on Tuesday February 9.

2. Project proposal

Your team must submit a short proposal (roughly one page) providing a rough description of the capacitor that you will build, including the basic design and geometry, the materials you will use and the application for your capacitor. We will evaluate your proposal during class on February 9, according to its design, appropriateness, and feasibility.

During the evaluation of the proposal, your team must be ready to explain the rationale for the design and the electrostatics principles that are involved.

3. Capacitor

Your task is to design and build an inexpensive capacitor that maximizes the capacitance-to-mass ratio and that can be charged up to a potential difference of 20 V. You can use any materials you choose but your capacitor cannot be larger than 50 cm^3. Each team will have a budget of $40 for ordering materials. You must be able to justify all design choices, including how you chose the materials. You must model/predict the capacitance, energy storage, charge storage and discharge rate of your capacitor based on your design. You must also have an idea of the time scale that your capacitor will hold a charge (*i.e.*, the leakage rate). Your team will be provided with a multi-meter so that you can take relevant measurements of your iterations.

Safety Warning: When you test your capacitor, never exceed 20 V and always do the testing under supervision from a member of the Teaching Staff.

4. Engineering Design Notebook

Your team must record the entire design process from the project proposal stage to the final prototype, in an "Engineering Design Notebook" (one per team). This notebook should include all brainstorming sessions, sketches, measurements and data collected, and should be a physical notebook (electronic versions are not acceptable). The notebook should include an entry for each time your team meets and each time there is work done on the project.

Content-wise, your engineering design notebook must include (at a minimum):

1. **Problem identification**: an introduction to the problem with an overview of all design considerations and constraints
2. **Preliminary ideas or concepts:** copies of rough sketches should be included
3. **Record of all iterations:** collect data and use it to define your design. Record each of the various iterations and prototypes as you work towards your final design
4. **Data:** Experimentally collect data on capacitance and resistance for all iterations of your design.

It is important that:

- **each and every day that your team works on the project is represented in the notebook** with dates clearly labeled at the top of each entry.
- your notebook follows the Engineering Design Process outlined in Appendix D.
- your notebook observes the Engineering Design Notebook Standards outlined in Appendix E

Notebooks are to be handed in with the final project report as well as used to explain to judges the iterative design process that your team went through to produce the final design.

6. Poster

Your posters should be 36" wide and 48" tall. Your poster should be a graphically appealing, organized description of your proposed device, something that an interested outsider could read in a few minutes. It cannot possibly include all the details (these will go in the report), so an important task is to determine what content is necessary to include and how to organize that content.

Instructions for printing your poster at MCB Graphics (mcbgraphics@fas.harvard.edu) are provided in Appendix C. When you place your poster order, please type "AP50 class" instead of a 33-digit billing code. Also, please select the inexpensive poster tube ($3.60). Display boards and materials to mount your poster will be provided at the Ecotricity Fair. The poster and tube become your team's property after the fair.

Important: Please do not wait until the last minute to reserve a time slot to print your posters. If you wait too long you may not be able to print your poster in time for the Ecotricity Fair.

7. Project report

By 11:59 pm on March 1 your team must upload a comprehensive report describing your capacitor to the course Web site. The report should be in the form of an engineering publication that describes the details of your capacitor as well as the physics behind how it works. 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 1–7, 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, 2014) and explain how the basic principles of electrostatics you learned in this course so far apply to your device.

The report must include results and a discussion of the following:

1) Description of Design: Describe the design; what is the geometry? What materials did you use? How did you decide on the design and materials (justify your choices with your understanding of electrostatics)? Describe your design process, iterations, measurements, predictions.

2) Explanation of capacitor functionality: How does it work? Isolate the underlying electrostatics principles and explain them in the context of the function of your capacitor (focus on the unit 6 & 7 learning objectives listed at the end of this brief). Must model/predict the capacitance, energy storage, charge storage of your capacitor.

3) Evaluate the performance and draw a conclusion with respect to the application of your capacitor: quantify the performance of your final iteration — include data on capacitance, resistance, mass, discharge rate. How long will it run for? What kind of application would your capacitor be appropriate for (*i.e.* small ones may be for distributed sensors. Large ones could be used in cars.

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).

8. 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.

9. Peer Assessment

Each member of the team must also submit Peer Assessments (including a self assessment) by 11:59 pm on March 4th. 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.

ECOTRICITY FAIR

During the fair on February 23 you must be present with your team to present your poster and to demonstrate the performance of your capacitor. We are appointing an outside panel to evaluate your poster presentation using the Poster Presentation Rubric on page 9. The panelists will spend about 15 minutes at each poster. During that time the panel will evaluate your poster's content and your team's verbal presentation of the poster. The panelists will ask you and your team members questions to probe your understanding of the subject. Part of your team's evaluation will depend on how well your team handles panelists' questions, in terms of knowledge and understanding, and in your team's ability to communicate that knowledge through question-and-answer.

When the panel is evaluating your poster and capacitor, your entire team must be present at the poster.

In addition to two judging rounds, during which your team presents the capacitor and poster to two panels of judges, your team must also participate in a "testing round." During this round the capacitance and mass of your capacitor will be measured to determine your capacitor's capacitance-to-mass ratio. During the testing, your capacitor will be charged to a potential difference of 20 V, so be sure you have designed to operate up to that potential difference.

During the remainder of the fair, you may wander around and look at other posters, but you should always leave two team members at your poster to answer questions from other fair participants.

PROJECT RESOURCES

Each team is allocated a supply budget of $40 for parts for the capacitor. These purchases must be specified in the project proposal by the proposal due date.

Ordering materials

Once your proposal has been approved, you can order the rest of the materials 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 and assembling your project

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 students can work on their projects in Pierce 301.

Storage of projects between classes

Each group will receive a large bin to store any of their project parts in. 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.

Training and safety

In order to gain access to the Teaching Labs (where you will be able to use a variety of equipment to build your machine), you must complete a safety training. If you completed this training in AP50a or in another engineering course, you do not need to complete the training again; you will continue to have access to the Teaching Labs.

The safety training consists of two parts

1. Complete a 20-minute long safety training online (click "Enter TMS" at http://ehs.harvard.edu/training)
2. Complete a 45-minute long laser-cutter and machine shop training in the Teaching labs

Once you have completed these two parts, you will have access to the Teaching Labs. Please complete these trainings as soon as possible. You will be able to sign up for this training on the course Web site.

Appendix A: Rubrics

Your contribution to the Fair will be evaluated on the content and presentation of your poster and on the performance and practicality of your capacitor in the following six domains, each rated on a scale from 0 to 3.

Capacitor Rubric

Performance

3 = Capacitance-to-mass ratio more than 1 standard deviation larger than average of all teams.
2 = Capacitance-to-mass ratio within 1 standard deviation of the average of all teams.
1 = Capacitance-to-mass ratio more than 1 standard deviation less than average of all teams.
0 = Capacitance-to-mass ratio more than 1 standard deviation less than average of all teams.

Relevance

The focus of this project is to use your understanding of the concepts of electrostatics to come up with an innovative and practical design for a lightweight capacitor. Given this, it is important that the physics behind your capacitor is relevant, both in depth and in breadth, to the course material so far.

3 = Capacitor incorporates course material in unexpected ways. The exposition of electrostatics goes well beyond the course material as presented in the text.
2 = Capacitor incorporates course material thoroughly and clearly. Considerable thought has gone into integrating various (more than 3) concepts from units 6 & 7.
1 = Capacitor incorporates course material, but fewer than 3 concepts from units 6 & 7 are essential.
0 = Device incorporates course material but the concepts are not essential to the device.

Poster Presentation Rubric

Poster Design

Your poster should enhance your presentation by providing visuals and data. The poster should include just enough text to convey your main points—too many words will make the poster "busy" and less effective. The narrative should be easy to follow, with clear organization, and be mostly self-explanatory.

3 = Poster is exceptionally well streamlined, flowing effortlessly. It's ready to be displayed publicly.
2 = Poster is well organized, easy to follow, and features clear visuals.
1 = Poster is awkward in some places. It may be wordy or includes unnecessary content.
0 = Poster is haphazardly arranged or difficult to follow. It adds little to the presentation.

Presentation

You'll have 10 minutes to explain your project to an expert panel of judges. Practice this presentation beforehand, as it will be strictly timed. Within the allotted time, your team should cover everything you want others to know about your device, including (but not limited to) the background, a discussion of the physics, and an evaluation of the performance. As always, a good presentation involves clear projection, eye contact, and participation by the entire team.

3 = Presentation is clear and confident, and demonstrates a mastery of the material that is beyond the scope of the material presented in the textbook. All team members participate equally.

2 = A clear, practiced presentation that covers every aspect of the device. All team members participate equally.
1 = Presentation has rough edges, some aspects of the device are neglected, and/or not every team member participates.
0 = Presentation is improvised, many aspects of the device are neglected, and/or several team members fail to participate.

Discussion After the presentation, you'll have a chance to answer questions posed by the panel. This is an opportunity to address possible concerns, or to explain additional aspects of your device. The team should attempt to answer each question fully, putting it into the context of your device. All team members should participate in the discussion.

3 = Discussion phase is used to explore additional aspects of the device, with full team participation.
2 = Panel members' questions are fully addressed and put into context. All team members participate equally.
1 = Some questions are not completely addressed, and/or not every team member participates.
0 = Most questions are not completely addressed and/or most team members fail to participate.

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, device, 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 content is required: 1) description of design: Describe the design; what is the geometry? What materials did you use? How did you decide on the design and materials? Describe your design process, iterations, measurements, predictions. 2) Explanation of capacitor functionality: How does it work? Isolate the underlying electrostatics principles and explain them in the context of the function of your capacitor. Must model/predict the capacitance, energy storage, charge storage of your capacitor. 3) Evaluate the performance and draw a conclusion with respect to the application of your capacitor: quantify the performance of your final iteration — include data on capacitance, resistance, mass, discharge rate, leakage rate. How long will it run for? What kind of application would your capacitor be appropriate for.

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 design, analysis, and writing of report.
1 = Partial descriptions of either design, analysis, or writing of report
0 = Partial descriptions of both design, analysis, 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-labelled, 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 device.)

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

Engineering Design Notebook Rubric

Design Process

The notebook should reflect the design process (outlined in Appendix D). The following content components are required: a) Problem identification b) Preliminary ideas or concepts c) Refinement of the design d) Record of all design iterations e) Data on distance and speed versus time for all iterations of your design.

3 = Notebook includes content that goes beyond that required, design.
2 = All required content reported and data is plausible.
1 = One or two components missing OR data not plausible.
0 = More than two components missing OR data not plausible.

Completeness

Notebook includes all brainstorming sessions, sketches, measurements and data collected and entries for each time your team met and every time work was done on the project. At the very least, you should have one entry for every day in the AP50 schedule when there is designated project time, plus at least 3-4 out of class sessions.

3 = Notebook includes entries that go beyond what is expected.
2 = Notebook includes all expected entries.
1 = One or two entries missing.
0 = More than two entries missing.

Format

Notebook follows the correct Engineering Design Notebook conventions (pages numbered and dated, diagrams and calculations clearly labelled, etc. (see guidelines outlined in Appendix E).

2 = Notebook format follows all the outlined conventions.
1 = One or two conventions overlooked.
0 = More than two conventions overlooked.

Appendix B: Learning objectives

This project concludes Units 6 and 7 in AP50. The learning objectives for these two Units are listed below. You will need to have mastered the content of the first seven Units to complete this project.

Unit 6

- Conduct fundamental experiments in electrostatics and explain the resulting existence of the electrostatic interaction and the two types of charge.
- Explain quantization and conservation of charge.
- Describe the observations supporting the quantization and conservation of electric charge.
- Define and give examples of insulators and conductors.
- Describe how the charge carriers behave in insulators and conductors.
- Explain polarization and how it gives rise to an electric force on a neutral object.
- Describe what happens on the atomic level when a conductor (insulator) is polarized.
- Describe and explain the process of charging by induction.
- Use Coulomb's law to calculate or estimate the electric force that a given charged particle, or charge distribution, exerts on a charged particle.
- Explain the conditions in which Coulomb's law is valid.
- Explain what a field is and give examples of scalar and vector fields.
- Draw vector field diagrams for a simple distribution of charged particles.
- Describe a vector field by means of vector diagrams and vector function expressions.
- Define and explain the electric field.
- Explain the difference between the electric field concept and the instantaneous "action-at-a-distance" formulation.
- Explain the superposition principle and apply it to determine the electric field created by a given charge distribution.
- Compute the force exerted on a charged or uncharged object in an electric field and describe the resulting motion of the object.
- Calculate the electric field produced by a given charge distribution.
- Describe the difference between permanent and induced dipoles and their motion in an electric field.
- Compute the electric dipole moment for a charge configuration.
- Describe the force and torque exerted on a dipole by an electric field
- Draw electric-field-line diagrams for a given charge distribution.
- Obtain information about the electric field and charge distribution from the field lines.
- Define and explain the concept of field line density and relate it to the magnitude of the field.
- Quantify the field line flux through a given surface to the charge distribution, or the field line diagram.
- Relate the field line flux through a closed surface with the charge within that surface.
- Obtain information about the direction and magnitude of an electric field from the symmetry of the charge distribution creating the field.
- Calculate the electric flux through open and closed surfaces in simple situations.
- Explain what electrostatic equilibrium is and how it is attained in a conductor.
- Describe the charge distribution in conductors in electrostatic equilibrium.
- Explain how to obtain the charge distribution in a conductor in electrostatic equilibrium.

- Use Gauss's law to calculate the electric field produced by charge distributions with spherical, cylindrical, or planar symmetry.
- Select an appropriate Gaussian surface for calculating the electric field based on the symmetry of the electric field (or the underlying charge distribution).
- Derive Gauss's law from Coulomb's law and the superposition principle.
- Comment on the validity of Gauss's Law.
- Explain why Gauss's Law does not simplify the calculation of electric fields with low symmetry.

Unit 7

- Describe experimental evidence that shows the association between potential energy and charge distributions.
- Evaluate the change in energy of (and work done on) a charged object as it moves through an electric field.
- Explain why the electrostatic work done on a charged object depends only on the start and ending points and is independent of the path taken between these points.
- Define the potential difference between two points and the potential at a point.
- Identify the International System unit used to measure potential difference and relate it to the unit for energy.
- Explain why the potential difference does not depend on the charge used to probe it.
- Relate the potential difference between two points to the electrostatic work done on a charged particle between these points.
- Compare the potential at different points, given the electric field or the charge distribution creating the field.
- Sketch equipotential lines and equipotential surfaces for various charge configurations or electric fields (and vice versa).
- Determine the electric potential in a conductor in electrostatic equilibrium and relate it to the charge distribution.
- Calculate the electrostatic work done on a charged particle in an electric field.
- Calculate the electric potential energy related to a given charge distribution.
- Use the concept of electric potential energy to solve mechanics problems.
- Calculate the electric potential from the electric field.
- Calculate the electric potential produced by discrete and continuous charge distributions.
- Calculate the electric field from the potential.
- Measure the electric potential of various charge distributions over an extended area and create a map of the electric potential and electric field lines in space.
- Relate the work done in producing charge separation in a system to the change in the system's potential energy.
- Describe a capacitor and explain the process of charging and discharging.
- Qualitatively and quantitatively relate the magnitude of the charge distribution in a capacitor, the electric field between its conducting elements, and the potential difference across the capacitor.
- Explain how a capacitor's capacity to store charge depends on its geometry.
- Explain how a conducting or insulating element placed inside a capacitor affects its capacity to store charge, and modifies the electric field and the potential difference between its conducting elements.

- Explain the working principles of a voltaic cell and the energy transformations that occur in its operation.
- Explain the meaning of the "electromotive force" of a charge-separating device.
- Relate the electromotive force of a charge-separating device to the potential difference between its terminals.
- Define capacitance and explain on which parameters it depends.
- Calculate the capacitance of a capacitor from its geometry and the properties of the material between its conductors.
- Calculate the energy stored in a charged capacitor.
- Calculate the energy stored in an electric field.
- Explain the meaning of dielectric constant and the breakdown field of a material.
- Calculate the changes produced by the insertion of a dielectric in a capacitor in the electric field between its conductors, its capacitance, the charge on its conductor, the stored energy, and the potential difference across its terminals.
- Calculate the charge induced on a dielectric when it is inserted in a charged capacitor.
- Use Gauss's law to calculate the electric field inside matter.
- Comment on the validity of Gauss's law inside matter.

Appendix C: Poster printing instructions

PRINTING A POSTER @ mcb graphics

We use hp Designjets 5000, 5500 and Z6200 printers

- Please sign up in advance and reserve a time slot on the poster printer schedule; Harvard PIN required.
  http://www.mcb.harvard.edu/Resources/Facilities/ImagingCenter/index.html
- If you do not have a Harvard PIN or have a problem with reserving a time slot, please e-mail us immediately, mcbgraphics@fas.harvard.edu
- If you need to print a batch of posters --more than three –please let us know in advance and we'll make special arrangements with you.
- **Programs to use**
  We support Microsoft Powerpoint (.ppt and .pptx) and Adobe Creative Suite (Illustrator, Photoshop, InDesign; up to version CS5).
  If you have any question, please provide the original file as well as the pdf version.
  We will use Adobe Acrobat to print your .pdf file.
  We print from MACs and PCs. Let us know if you use a PC.
- **Poster dimensions**
  The most common poster size is 36" x 48". (The largest we can print is 3' x 100'.)
- **Paper**
  We print posters on high quality photo gloss paper.
  We also stock other types of paper and different material. Please inquire about types and pricing.
  After printing your poster we can also laminate it on mylar or foam core/board. Please inquire about pricing and turnaround time.
- **Poster-carrying tubes**
  White cardboard $3.60
  Fluorescent or clear PVC with carrying strap $15.00
- **Cost**
  $15/foot in length e.g. 36" x 48" = $60; 36"x60" = $75
- **Payment**
  We accept Harvard 33-digit billing codes.
  We also accept checks made out to "Harvard University".
  We can also make arrangements for you to pay in cash.
  Receipts are provided on request.
- **File transfer**
  Your file has to be with us at the beginning of your reserved time slot. We will send you an email confirming that it has been received.
  Send your file:
  Via e-mail
  Please send your file to mcbgraphics@fas.harvard.edu (up to 15 MB)
  Via the web
  e.g. YouSendIt; http://www.yousendit.com/ (up to 100 MB for free)
  Via secure FAS server
  https://fta.fas.harvard.edu/courier/1000@/mail_user_login.html
  (If you do not have an FAS e-mail address, please let us know and we will send you an invitation)
  Drop off your file:
  Bring it on a USB flash key to us; 16 Divinity Ave., BioLabs, room 2058
- **Pickup**
  Once your file is printed, you can stop by to pick up your poster.
  You will receive an email when your poster is ready. Typically it will be in a poster rack by the door, inside mcbgraphics.
  To help you identify your poster, there will be a small version of the same attached to the outside of your rolled up poster.

  The doors are unlocked, Monday through Friday, from 9 am until 7 pm.
  You can pick it up at your convenience.
- **Cancellations**
  If you can't make it to your appointment, please let us know because we don't mind re-scheduling but we do mind waiting in vain. Without keeping us posted, you will loose your slot on the poster printer ten minutes post-scheduled appointment; no kidding and no mercy. . .*and... we will remember you.*

  Please remove yourself from the online schedule as soon as you know that you need to cancel. Many times there is a later appointment available if you need to work longer on your file and reschedule. Obviously if you cancel, that will open a spot for another person to print.
- **Questions**
  Please don't hesitate to ask questions because we would rather prevent any potential problems than have to solve them down the road.
  Email **mcbgraphics@fas.harvard.edu** . Everyone who works here will receive it. You can also call 617-496-9159 but we are frequently not close to the phone.

HARVARD mcb graphics

mcbgraphics@fas.harvard.edu
617 496 9159

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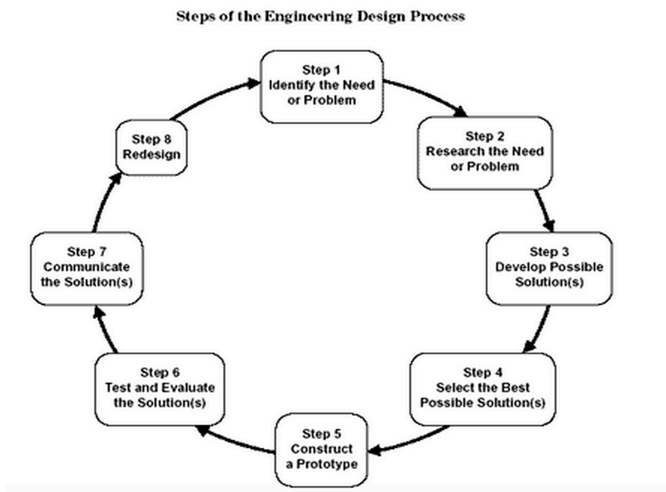
16 Divinity Avenue
Cambridge, MA 02138

rh 8-4-2011

Appendix D: Engineering Design Process

We will be using the Engineering Design Process, as specified by the *Accreditation Board for Engineering and Technology* (ABET) for the completion of engineering projects.

The fundamental elements of the design process are: establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation. The actual process is flexible but must have the **following 8 components**:



1. **Identify the need or problem**

2. **Research the need or problem**
    - Examine current state of the issue and current solutions
    - Explore other options via the Internet, library, interviews, etc.

3. **Develop possible solution(s)**
    - Brainstorm possible solutions
    - Draw on mathematics and science
    - Articulate the possible solutions in two and three dimensions
    - Refine the possible solutions

4. **Select the best possible solution(s)**
    - Determine which solution(s) best meet(s) the original requirements

5. **Construct a prototype**
    - Model the selected solution(s)

6. **Test and evaluate the solution(s)**
    - Does it work?
    - Does it meet the original design constraints?

7. **Communicate the solution(s)**
    - Discuss with the engineering team how the solution(s) best meet(s) the needs of the initial problem, opportunity, or need
    - Discuss any tradeoffs of the solution(s)

8. **Redesign**
    - Overhaul the solution(s) based on information gathered during the tests and discussion

Appendix E: Engineering Design Notebook

What is a design notebook?

A design notebook is a way for an engineering team (or an individual designer or engineer) to maintain a history the project from start to finish. It is a place to record research, observations, ideas, drawings, comments, and questions during the design process. At the end of the project, someone reviewing the design notebook should be able to understand fully how the team got to its solution.

*An **engineer's notebook** is a book in which an engineer will formally document, in chronological order, all of his or her work that is associated with a specific design project.*

What goes in a design notebook?

Your design notebook starts when you begin thinking about possible problems to solve. Write down everything you know about these problems and why you want to solve them. Then write down, draw, sketch, glue, or tape in every step of your process between this first step and your final solution.
Here are examples of what you might find in a design notebook:

- Notes on background research
- Interviews with users or experts
- Photos of competing products
- Lists of design requirements
- Questions/issues you face
- Written ideas
- Sketches (preferably annotated)
- Work session summaries
- Research findings
- Collected data
- Rationale for design modifications

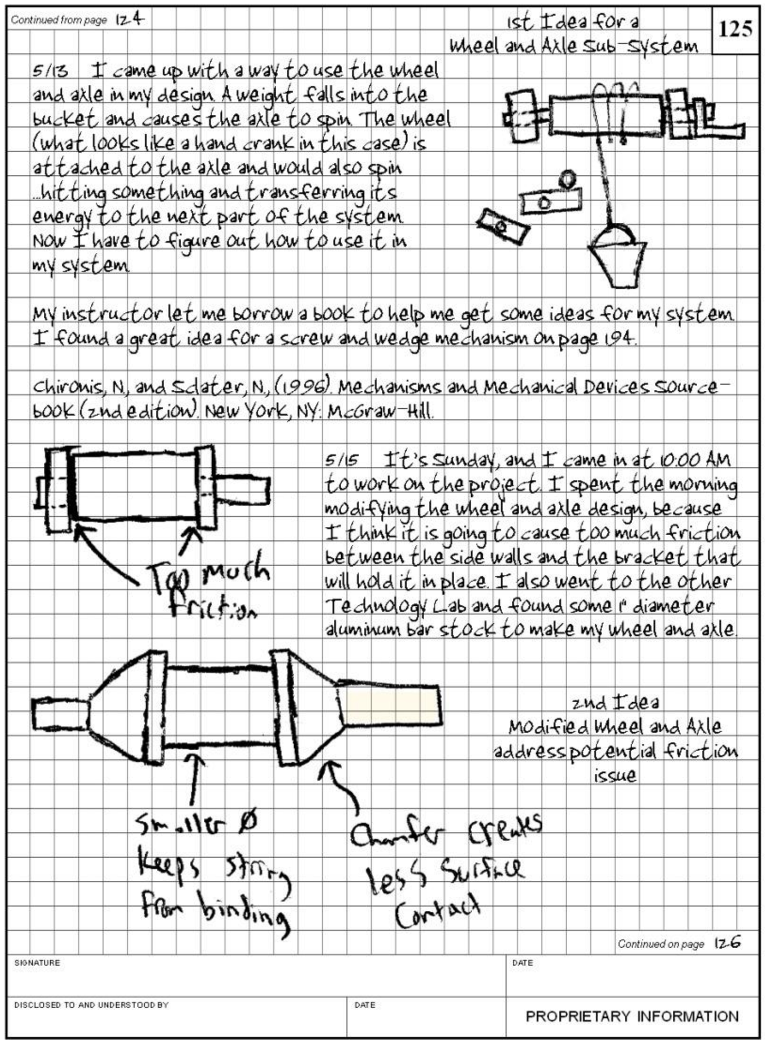
We will provide each team with an Engineering Design Notebook at the beginning of the project.

Standard Page Layout

- Bound quadrille-lined (grid) pages
- Individually labeled page #s
- The date that each entry was made is clearly indicated.
- Mistakes are crossed off, initialed, with correction placed nearby. Never erase or remove anything
- All figures and calculations are clearly labeled.
- Inserted items are permanently attached (glue is preferred). Loose leaf items do not belong in the notebook.
- Location for designer's signature and date

- Locations for identifying contents as continued from and to another page
- Statement of the proprietary nature of the notebook

See example below:



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: