Problem Set 1

due W Feb 6 in class

Instructions: as we need to quickly scan your work so we can return it before the end of class, please:

- use 8.5 x 11” paper
- no-dog ears or torn out of ring-bound notebook
- dark ink (no light pencils)
- no staples
- name on each page
- single-sided (no writing on back)
- leave margins blank

1. **Ink-Jet Printing.** In an inkjet printer, letters are built up by squirting drops of ink at a piece of paper from a rapidly moving nozzle. The ink drops leave a nozzle and travel toward the paper, passing through a charging unit that gives each drop a positive charge by removing some electrons from it. The drops then pass between parallel deflecting plates where there is a uniform vertical electric field (to be discussed in Chapter 23). Estimate the number of atoms present in a droplet of ink.

2. **Levitation.** One possible way of levitivating an object might be to use the forces associated with charged objects. For example, you have two charged particles that are fixed on a vertical pole 0.5 m apart. The lower one has a fixed charge of -3.0 \( \mu \)C. The upper one has a charge \( q_b \) that can be adjusted. A 30-mg particle with a charge of +8.0 \( \mu \)C can move freely on the pole below the other two. You wish to levitate (i.e., float) this particle at a distance of 1.0 m below the lower fixed charge. What should the adjustable charge \( q_b \) be to achieve this feat?

3. **Charge Square.** Four charged particles are arranged in a square as shown in the figure to the right, with \( q = 3.9 \times 10^{-4} \) C and \( a = 6.9 \) mm. What is the net force on the particle at the upper right corner due to the other three?

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1 design

2 approach
Problem Set 1
due W Feb 6 in class

Instructions: If we need to quickly scan your work so we can return it before the end of class, please:

- Use a bound notebook
- No dog ears or holes
- No staples
- Dark ink (no light pencils)
- Name on each page
- Leave margins if printing on back

1. **Ink-Jet Printing.** In an inkjet printer, ink is delivered by squirting drops of ink at a piece of paper, passing through a charging unit that gives each drop a positive charge by removing electrons or adding them. The drops then pass between parallel deflecting plates where there is a uniform vertical electric field (Chapter 23).

Estimate the number of atoms present in a droplet of ink.

2. **Levitation.** One possible way of levitating an object might be to use the forces associated with charged objects. For example, you have two charged particles that are fixed on a vertical pole 0.5 m apart. The upper one has a charge $q_1$ that can be adjusted. A 30 mg particle with a charge of $+8.0 \times 10^{-6}$ C can move freely on the pole below the other two. You wish to levitate (i.e., float) this particle at a distance of 1.0 m below the lower fixed charge. What should the adjustable charge $q_1$ be to achieve this feat?

3. **Charge Square.** Four charged particles are arranged in a square as shown in the figure to the right, with $q = 3.9 \times 10^{-4}$ C and $a = 6.9$ mm. What is the net force on the particle at the upper right corner due to the other three?

Now suppose that both charges $q_1$ and $q_2$ are spherically symmetric. Let $\rho$ denote the mass density of the spherical dust grains, 50 µm in diameter, with mass density $\rho = 4.5 \times 10^4$ kg/m$^3$. The charge $q_1$ is electricaly neutral, free of other external forces except electrostatic. Now suppose that both dust grains are prevented from moving by the electrical force $F$ that would prevent them from moving. Then, from $\nabla \cdot \mathbf{E} = \\rho$...
One possible way of levitating an object might be to use the forces associated with charged dark ink (no light pencils) name on each in four charged particles are arranged to no staples levitation charge square no inkjet printer, letters are built up by squirting drops of ink a square as shown in the figure to the single use 8.5 x 11" paper that can be adjusted. A 30 design approach reflect (in class/team) metacognition Instruction ¥ ¥ 1. Estimate the number of atoms present in a droplet of ink. -Jet Printing. -Jet Printing. -Jet Printing. -Jet Printing. estimate the number of atoms present in a droplet of ink. the upper one has a charge \( q_1 \) that can be shielded. A 30 mg particle with a charge of +8.0 \( \mu C \) can move freely on the pole below the other two. You wish to levitate this particle at a distance of 1.0 m below the lower fixed charge. What should the adjusted plate charge be? 2. Levitation. One possible way of levitating an object might be to use the forces associated with charged objects. For example, you have two charged particles that are fixed on a vertical pole 0.5 m apart. The lower one has a fixed charge of 3.0 \( \mu C \). The upper one has a charge \( q_2 \) that can be shielded. A 30 mg particle with a charge of +8.0 \( \mu C \) can move freely on the pole below the other two. You wish to levitate this particle at a distance of 1.0 m below the lower fixed charge. What should the adjusted plate charge be? 3. Charge Square. Four charged particles are arranged in a square as shown in the figure to achieve this feat? The net force on the particle at the upper right right, with \( q = 3.9 \times 10^{-4} \) C and \( a = 6.9 \) mm. What is the net force on the particle at the upper right corner due to the other three?
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 set 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 Answer**
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.

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 the first stage, you may only use red ink to write on your problem sets. Pens will be provided in class. After 15 minutes, your team will be provided with a solution set which you may use to check your work. Additionally, 45 minutes, your team must submit the marked-up problem sheets for the entire team and a team scoring sheet.

It is the team’s responsibility to ensure solutions together with a completed reflection sheet. This is the only team score. This must be submitted at the beginning of class. No late submissions are accepted.
### Individual phase (at home): From the time you receive a problem set to the time it is due to work on the problem set alone. The work you complete during this phase will be evaluated for 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)

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Getting Started</strong></td>
<td>State the important information and summarize the problem. If possible, include a diagram. Note any assumptions you’re making.</td>
</tr>
<tr>
<td><strong>Devise Plan</strong></td>
<td>Devise a plan of attack before diving into the solution. Break down the problem into manageable segments. Identify which physical relationships you can apply.</td>
</tr>
<tr>
<td><strong>Execute Plan</strong></td>
<td>Carry out your plan, explaining each step. The argument should be easy to follow. Articulate your thought process at each step (including roadblocks). Any values defined, and your diagrams should be labeled.</td>
</tr>
<tr>
<td><strong>Evaluate Answer</strong></td>
<td>Check each solution for reasonableness. There are many ways to justify your reasoning: check the symmetry of the solution, evaluate limiting or special cases, situations with known solutions, check units, use dimensional analysis, evaluate order of magnitude of an answer.</td>
</tr>
</tbody>
</table>

You can consult the textbook and online resources, and you may consult the teaching staff by posting questions to the course discussion on the course Web site. However, you may not consult other people, nor collaborate 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 work on the problem set alone.

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. After an individual phase (at home), you will be provided with a solution set which you may use to confirm your solutions. Each problem set involves both individual and team work.
**Individual phase (at home):** From the time you receive a problem set to the time it is due, you will 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 set. Follow the 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 major steps of the problem and identify which physical laws or relations 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 defined, and your diagrams should be labeled.

**Evaluate Answer**
Check each solution for reasonableness. There are many ways to justify your reasoning: check units, use dimensional analysis, check the symmetry of the solution, evaluate limiting or special cases, situations with known solutions, check units, use dimensional analysis, check the order of magnitude of an answer.

You can consult the textbook and online resources, and you may consult the teaching staff by posting questions to AP50 online.

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1 design
2 approach
(1) Estimate damping coeff. for a shock absorber on a midsize car.

Getting started.

\[ F = m \cdot a \]

Damping coeff. (c)

\[ F_s = -kx \]
\[ F_d = -cv \]

Create a plan.

Set \( F_s + F_d \) equal to force of car moving forward and solve for c.

- Approximate \( k \) of spring = 490.5 N/m
- \( x \) (distance compressed) = 0.1 m

Execute plan.

\[ \sum F_x = F_{G} - F_{sc} = \Delta mg - k(xe - x_0) \]
\[ F_{Ec} \]

Translational eq = \( \sum F_x = 0 \)

\[ F_{G} \]

Estimate mass of midsize car = 1500 kg

Est. accel. of midsize car: 5 m/s

\[ K = \Delta mg \]
1. **Design**

   Estimate damping coeff. for a shock absorber on a midsize car.

   **Getting started.**

   Car moving forward

   \[ F = m \cdot a \]

   Damping coeff. (c)

   \[ F_s = -k \cdot x \]
   \[ F_d = -c \cdot v \]

2. **Approach**

   Create a plan.

   Set \( F_s + F_d \) equal to force of car moving forward and solve for \( c \).

   \[ \text{Approximate } k \text{ of spring} = 490.5 \text{ N/m} \]

   \[ x \text{ (distance compressed)} = 0.1 \text{ m} \]

   Execute plan.

   \[ F = m \cdot a \]

   Estimate mass of midsize car = 1500 kg

   Est. accel. of midsize car: 5 m/s

   \[ k = \frac{4mg}{x} \]
1. Design

Estimate damping coeff. for a shock absorber on a midsize car.

2. Approach

Getting started:

- Car moving forward:
  \[ F = m \cdot a \]

Damping coeff. (c):

Create a plan:

- Ed equal to force of car moving forward and solve for c.

- Approximate k of spring = 490.5 N/m
  \[ x \text{ (distance compressed)} = 0.1 \text{ m} \]

Execute plan:

- Mass of midsize car = 1500 kg
- Initial accel. of midsize car: 5 m/s

\[ k = \frac{4mg}{x} \]
with your peers. It’s ok to try hard and not succeed at first (only your effort is evaluated) on every problem. If you reach the Evaluate stage and find that your answer does not 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 to improve and/or correct your solutions, reflect on your work, and determine what you need to do next. During this stage, you may only use red ink to write on your problem sets (pens will be provided in class). After an additional 45 minutes, your team will be provided with a solution set which you may use to confirm your work. After an additional 45 minutes, your team must submit the marked-up problem sets together with any appropriate 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 correct solutions together with a completed reflection sheet, because your team’s submitted work will be used as the team score. This means that if you do not put in adequate effort before the Team/Reflect phase, you may only use red ink to write on your problem sets (pens will be provided in class). After an additional 45 minutes, your team must submit the marked-up problem sets together with any appropriate sheets for the entire team and a team scoring sheet.

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

1 design  2 approach
Team/Reflect phase (in class): On the due date of the problem set, you will work with your peers. It’s ok to try hard and not succeed at first (only your effort is evaluated, not the outcome). If you reach the Evaluate stage and find that your answer does not make sense, describe your thought process so you are prepared for a discussion with your team in class.

In class:
1. Design
2. Approach

mark up/improve solutions
complete reflection sheet

It is the team’s responsibility to ensure that all team members hand in complete and correct solutions together with a completed reflection sheet, because your team’s submitted work will contribute to your team score. This means that if you do not put in adequate effort before the Team/Reflect phase, 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 work. Additional 45 minutes, your team must submit the marked-up problem sets together with sheets for the entire team and a team scoring sheet.

Important: Writing on the problem set in class in any other color but red will be considered as incomplete and you will be required to improve and/or correct your solutions, reflect on your work, and determine what you need to improve. It is the team’s responsibility to ensure that all team members hand in complete and correct solutions together with a completed reflection sheet, because your team’s submitted work will contribute to your team score. This means that if you do not put in adequate effort before the Team/Reflect phase, 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 work. Additional 45 minutes, your team must submit the marked-up problem sets together with sheets for the entire team and a team scoring sheet.

Important: Writing on the problem set in class in any other color but red will be considered as incomplete and you will be required to improve and/or correct your solutions, reflect on your work, and determine what you need to improve.
c) Maximum transverse speed.

Use $\chi = \frac{V}{f}$; solve for $V$.

d) Length would have to be $\lambda$ or $\frac{1}{2}\lambda$ wavelength, etc.

**Execute plan.**

1. $y = 0.2 \sin[\pi(0.5x - 100t)] = 0.5\pi(x - 200t)$

2. $x(t) = A \sin(\omega t + \phi); \quad y = A \sin[k(x - ct)]$
   - amplitude $= 0.2$ cm
   - $\omega = \text{rotational speed} = 0.5\pi$
   - $k = \text{wave #}$
   - $c = \text{wave speed}$
   - $A = \text{amplitude}$
   - $200 \text{ cm/s}$

3. $0.5\pi = \frac{2\pi}{T}$
   - $T = 4 \text{ sec} = \text{period}$
   - $50 \text{ sec}^{-1} = \text{cycles/second = frequency}$

4. $f = \frac{1}{T} = \frac{1}{4 \text{ sec}} = 0.25 \text{ Hz}$
   - $\lambda = \frac{v}{f}$
   - $\lambda = \frac{200}{4} = 50 \text{ cm}$
   - $\chi = \frac{v}{f} = \frac{1}{4 \text{ sec}} = \frac{1}{4 \text{ Hz}} = \frac{\frac{1}{2}}{2} = \frac{0.5\pi}{k}$
   - wave number $= \frac{2\pi}{\lambda} = \frac{1}{2}$
   - $\frac{200}{4} = 50$

(Shifted right)

$y = 0.2 \sin[\pi(0.5x - 100(\frac{1}{200}))]$

$y = 0.2 \sin[(\pi x - 100(0))]$
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?) You may complete this part before coming to class in blue or black ink.

Before coming to class, I learned a lot about waves in music and frequency. I feel really comfortable with concepts of wave speed, amplitude, frequency, and period. I understand beat frequency (although I made a clerical error by forgetting to use the speed of sound twice). I also feel like I now understand how decibels are calculated—before, I didn’t know they were exponential! I know what the concept of intensity means and how to use it.

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

I definitely need to review torque! I had no idea how to use that concept for #3 and I’ll probably need to go over the solutions before I really understand it. Similarly with the damping coefficient estimation problem—I started off in the wrong direction and never really fixed where I went wrong. I also need to review some calculus. The last time I really understood calculus was high school and it’s becoming an issue.
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?). You may complete this part before coming to class in blue or black ink.

Before coming to class, I learned a lot about waves in music and frequency. I feel really comfortable with the concepts of wave speed, amplitude, frequency, and period. I understand beat frequency (although I made a clear error by forgetting to use the speed of a clear plug in my answer). I also feel like I now understand how decibels are calculated—before, I didn’t know they were exponential! I know what the concept of phase credit is and how to use it.

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

I definitely need to review torque! I had no idea how to use that concept for #3 and I’ll probably need to go over the equations before I really understand it. Similarly, with the damping coefficient estimation problem, I started off in the wrong direction and never really fixed where I went wrong. I also need to review some calculus. The last time I really understood calculus was high school and it’s becoming an issue.

-phase

solve (at home/individual) 50%

reflect (in class/team) 50%

credit

50%

50%
“I was inspired and encouraged to do these problems on my own with the promise of collaborative work [the next day]”
"I felt less pressure to find the right answer and more freedom to explore"
In-class activities

**Understand**
- **LC: Learning Catalytics**
  - Instructor poses question
  - Answer alone
  - Discuss in team
  - Answer again
  - **90 min**
- **Tutorial**
  - Work on worksheet with team
  - Explore concepts
  - Discuss with staff
  - **60 min**

**Apply**
- **EA: Estimation Activity**
  - Estimate quantities
  - Develop individual strategy
  - Discuss and solve as team
  - **30 min**
- **EDA: Experimental Design Activity**
  - Conduct experiment with team
  - Take measurements
  - Analyze data
  - Carry out simulations
  - **90 min**

**Evaluate**
- **Problem Set & Reflection**
  - Work problems alone BEFORE class
  - Discuss with team, mark up
  - Self-assess & turn in
  - **90 min**
- **RAA: Readiness Assurance Activity**
  - Part 1: solve problems alone
  - Open book, open internet
  - Part 2: solve with team
  - **90 min**
goal: formative assessment

collaborative learning
Session 389314

This is the individual round; work on these questions on your own.

expression question

What is the derivative of \( f(x) = 3x^2 - 6x \)?

Enter an expression, e.g., \( x^2 \) for \( x^2 \), \( \ln(y) - \sin(x) \) for \( \ln y - \sin x \), \( x/(y+1) \) for \( \frac{x}{y+1} \), \( (1/2)x \) for \( \frac{1}{2}x \). Do not enter a complete equation.

Current team: Blue team  🕯️ Change team  ✨ Change seat  ✉️ Send a message to the instructor  ✉️ Join another

1 design  2 approach
This is the individual round;

**expression question**

What is the derivative of $f(x) = 3x^2 - 6x$?

Enter an expression, e.g., $x^2$ for $x^2$, $\ln(y) - \sin(x)$ for $\ln y - \sin x$. 

1 design  

2 approach
This is the individual round;

**expression question**

What is the derivative of $f(x) = 3x^2 - 6x$?

Enter an expression, e.g., $x^2$ for $x^2$, $\ln(y) - \sin(x)$ for $\ln y - \sin x$.
What is the derivative of $f(x) = 3x^2 - 6x$?

Enter an expression, e.g., $x^2$ for $x^2$, $\ln(y) - \sin(x)$ for $\ln y - \sin x$. 

1 design  
2 approach
1 design  2 approach
<table>
<thead>
<tr>
<th>round</th>
<th>credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>individual</td>
<td>50%</td>
</tr>
<tr>
<td>team</td>
<td>50%</td>
</tr>
</tbody>
</table>

1. design
2. approach
<table>
<thead>
<tr>
<th>round</th>
<th>credit</th>
<th>average score</th>
</tr>
</thead>
<tbody>
<tr>
<td>individual</td>
<td>50%</td>
<td>40%</td>
</tr>
<tr>
<td>team</td>
<td>50%</td>
<td>85%</td>
</tr>
</tbody>
</table>

1 design  2 approach
Self, Peer, and Team assessment
# Team, Peer, and Self assessment

## Self Assessment

<table>
<thead>
<tr>
<th>Self Assessment (you!)</th>
<th>Never</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>About half the time</th>
<th>Most of the time</th>
<th>All of the time</th>
</tr>
</thead>
</table>

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 **take 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
Team, Peer, and Self assessment

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.

<table>
<thead>
<tr>
<th>RELATIVE CONTRIBUTION</th>
<th>Less than fair share</th>
<th>More than fair share</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Almost nothing</td>
<td>Much less</td>
</tr>
<tr>
<td>Self</td>
<td></td>
<td>Somewhat less</td>
</tr>
<tr>
<td>Member 1</td>
<td></td>
<td>Fair share</td>
</tr>
<tr>
<td>Member 2</td>
<td></td>
<td>Somewhat more</td>
</tr>
<tr>
<td>Member 3</td>
<td></td>
<td>Much more</td>
</tr>
<tr>
<td>Member 4</td>
<td></td>
<td>Almost everything</td>
</tr>
</tbody>
</table>
## Assessment Report

### Assessment of You

<table>
<thead>
<tr>
<th></th>
<th>You</th>
<th>Average Peer Assessment</th>
<th>Self Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Participate fully in team activities</td>
<td>4.67</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>2. Come to class well-prepared for all team activities</td>
<td>4.67</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3. Communicate effectively and respectfully with team members:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.83</td>
<td>4</td>
</tr>
<tr>
<td>• Express your opinions respectfully and with clarity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Listen respectfully to the perspectives and contributions of others</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Collaborate effectively with team members to make decisions and resolve conflicts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Attendance:</td>
<td>4.83</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>• You are present for team activities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• On time/punctual</td>
<td>4.83</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5. Take responsibility for your own part of team work and decision-making</td>
<td>4.83</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>6. Are open to change and willing to re-evaluate your own position in light of new information from others</td>
<td>4.67</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

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):

- You were great to work with and a true team player!
- Jacob, Your ideas were a great contribution to our team.
- You come up with good ideas.

---

1. design

2. approach
Team, Peer, and Self assessment

1. Participate fully in team activities: 4.67
2. Come to class well-prepared for all team activities: 4.67
3. Communicate effectively and respectfully with team members:
   - Express your opinions respectfully and with clarity: 4.83
   - Listen respectfully to the perspectives and contributions of others: 4.83
   - Collaborate effectively with team members to make decisions and resolve conflicts: 4.83
4. Attendance:
   - You are present for team activities: 4.83
   - On time/punctual: 4.83
5. Take responsibility for your own part of team work and decision-making: 4.83
6. Are open to change and willing to re-evaluate your own position in light of new information from others: 4.67

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

- You were great to work with and a true team player!
- Your ideas were a great contribution to our team
- You come up with good ideas
- You were really easy to work with and had a contagious enthusiasm

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

- You were great to work with and a true team player!
- Your ideas were a great contribution to our team
- You come up with good ideas
- You were really easy to work with and had a contagious enthusiasm

“I felt as if I was able to effectively communicate my ideas, even though they may have been wrong... (still good for discussion, right?)”

1. Participate fully in team activities
   - Average: 4.67
   - Peer: 4

2. Come to class well-prepared for all team activities
   - Average: 4.67
   - Peer: 4

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
   - Average: 4.83
   - Peer: 4

4. Attendance:
   - You are present for team activities
   - On time/punctual
   - Average: 4.83
   - Peer: 5

5. Take responsibility for your own part of team work and decision-making
   - Average: 4.83
   - Peer: 4

6. Are open to change and willing to re-evaluate your own position in light of new information from others
   - Average: 4.67
   - Peer: 4

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

- You were great to work with and a true team player!
- You were great to work with and a true team player!
- Jacob, Your ideas were a great contribution to our team.
- Jacob, Your ideas were a great contribution to our team.
- You come up with good ideas
- You come up with good ideas
- You were really easy to work with and had a contagious enthusiasm

“I felt as if I was able to effectively communicate my ideas, even though they may have been wrong... (still good for discussion, right?)”
### Team, Peer, and Self assessment

<table>
<thead>
<tr>
<th>Item</th>
<th>Self Assessment</th>
<th>Peer Assessment</th>
<th>Average Year</th>
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<tr>
<td>Participate fully in team activities</td>
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<tr>
<td>Come to class well-prepared for all team activities</td>
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<tr>
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<tr>
<td>Collaborate effectively with team members to make decisions and</td>
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<td>resolve conflicts</td>
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<tr>
<td>You are present for team activities</td>
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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):

1. You were great to work with and a true team player!
2. You were great to work with and a true team player!
3. Jacob, Your ideas were a great contribution to our team.
4. Jacob, Your ideas were a great contribution to our team.
5. You come up with good ideas

You are praised for:

- Design
- Approach

I would suggest being more responsive throughout the project process.

Sometimes you’re not engaged in activities

It was hard to understand what you actually thought about an idea or project

You could be more reasonable about what is actually feasible and what isn’t
Assessment

- self-directed learning
- learning goals
- team work
- professionalism
## Assessment

<table>
<thead>
<tr>
<th>Scale: 3–0</th>
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<tr>
<td><strong>B+</strong> 2, 2, 1, 1</td>
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<tr>
<td><strong>B</strong> 2, 1, 1, 1</td>
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<tr>
<td><strong>B–</strong> 1, 1, 1, 1</td>
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<tr>
<td><strong>C</strong> one zero</td>
</tr>
<tr>
<td><strong>D</strong> two zeroes</td>
</tr>
<tr>
<td><strong>E</strong> more than two zeroes</td>
</tr>
</tbody>
</table>

### Assessment Criteria

- **Self-directed learning**
- **Learning goals**
- **Team work**
- **Professionalism**
Assessment

Scale: 3–0

- NB annotations
- Problem sets
- RAAs
- Project report
- Project presentation
- Peer Assessment
- Participation
- Punctuality
- Ethics

- self-directed learning
- learning goals
- team work
- professionalism

Problem sets

RAAs

Project report

Project presentation

Peer Assessment

Participation

Punctuality

Ethics
Assessment

Scale: 3–0

- NB annotations
- Problem sets
- RAAs
- Project report
- Project presentation
- Peer Assessment
- Participation
- Punctuality
- Ethics

Scale: 3–0

- self-directed learning
- learning goals
- team work
- professionalism

Problem sets

Letter grade

Scale: A–E

- A+ 2, 2, 2, 2
- A 2, 2, 2, 1
- A– 2, 1, 1, 1
- B 2, 1, 1, 1
- B– 1, 1, 1, 1
- C one zero
- D two zeroes
- E more than two zeroes
Assessment

<table>
<thead>
<tr>
<th>Scale: 3–0</th>
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<tbody>
<tr>
<td>NB annotations</td>
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<td>Project report</td>
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<tr>
<td>Project presentation</td>
<td>team work</td>
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<tr>
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<tr>
<td>Punctuality</td>
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<td></td>
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<tr>
<td>Ethics</td>
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</tbody>
</table>

1 design
2 approach
Assessment

Scale: 3–0

- NB annotations
- Problem sets
- RAAs
- Project report
- Project presentation
- Peer Assessment
- Participation
- Punctuality
- Ethics

Scale: 3–0

- self-directed learning
- learning goals
- team work
- professionalism

Scale: A–E

letter grade

1 design

2 approach
Assessment

Scale: 3–0

- NB annotations
- Problem sets
- RAAs
- Project report
- Project presentation
- Peer Assessment
- Participation
- Punctuality
- Ethics

Scale: self-directed learning

- lowest score
- table lookup

Scale: A–E

- A 2, 2, 2, 2
- A– 2, 2, 2, 1
- B+ 2, 2, 1, 1
- B 2, 1, 1, 1
- B– 1, 1, 1, 1
- C one zero
- D two zeroes
- E more than two zeroes

1 design
2 approach
Ownership

Course evaluation: 4.2/5
Ownership

“The structure of the class made what was my least-favorite subject into one of my favorites.
Ownership

“The structure of the class made what was my least-favorite subject into one of my favorites. I was worried that people, including myself, would just slack off and do the bare minimum, but you really need to be on top of your readings and concepts in order to contribute to your team. GREAT CLASS!!!!!!!”
Ownership

“Dear Harvard students, this class will be unlike any class you’ve taken at Harvard, and it will, hopefully, shift the entire foundation upon which you’ve based your education. I truly believe everyone should take this course; prepare to take full ownership of your learning.”
Ownership

Attendance: 94% (AP50a), 97% (AP50b)
Ownership

Attendance: 94% (AP50a), 97% (AP50b)

3 hours and they don’t leave!
Ownership

“I don’t think I am well enough to make it through class. I feel terrible because I don’t want to let my team down by not being there, but I don’t think I’d be very helpful in my current state.”

(via email)
Self-efficacy

1. design
2. approach
3. results
Self-efficacy

(students’ belief in their ability to succeed)
Self-efficacy

![Bar chart showing self-efficacy pre and post for P11b and AP50b.]

- **Pre**
  - P11b: ~70 a.u.
  - AP50b: ~80 a.u.

- **Post**
  - P11b: ~80 a.u.
  - AP50b: ~90 a.u.

### 1 design

### 2 approach

### 3 results
Self-directed learning
Self-directed learning

NB data shows:

- student spend on average 2.3 hrs/chapter
- 600–700 annotations/chapter (8–10/stu)
Conceptual Mastery

![Diagram showing normalized gain (%)]

- **FCI**
- **PS2**

1. design
2. approach
3. results
Conceptual Mastery

![Bar chart showing normalized gain (%)]

- FCI
- PS2
- P11a
- AP50a

1 design  2 approach  3 results
Conceptual Mastery

The graph shows the normalized gain in conceptual gains for different courses.

- **FCI** has the largest conceptual gain in any course past 6 yrs!

Courses:
- PS2
- P11a
- AP50a

**Normalized Gain (%)**
- 60%
- 50%
- 40%
- 30%
- 20%

**Course Comparison**
- PS2: 40%
- P11a: 30%
- AP50a: 60%
Conceptual Mastery

1. design
2. approach
3. results
Conceptual Mastery

![Bar graph showing normalized gain for CSEM P11b]

- **1 design**
- **2 approach**
- **3 results**
Conceptual Mastery

- **CSEM**

<table>
<thead>
<tr>
<th></th>
<th>P11b</th>
<th>AP50b</th>
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<tbody>
<tr>
<td>Normalized Gain (%)</td>
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<tr>
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<td>60</td>
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</tbody>
</table>
Conceptual Mastery

as good as when I do my best teaching!
Can create ownership of learning physics!
Can create ownership of learning physics!
“you come out with so much knowledge and experience and fun”
for a copy of this presentation:

ericmazur.com

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1 design  2 approach  3 results