DAY 2: October 26th

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Please Change Partners!
Thank You!!

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AP Physics 1&2 Workshop

Capital University of Economics and Business
Beijing, China

Oather Strawderman

International Lead AP Physics Consultant

October 25 - 26, 2025

Schedule

8:30am - 10:00am: AM 1 Session

10:00am - 10:15am Tea Break

10:15am - 12:00pm: AM 2 Session

12:00pm - 1:15pm: Lunch

1:15pm - 1:30pm: Check-in

1:30pm - 3:00pm: PM 1 Session

3:00pm - 3:15pm: Tea Break

3:15pm - 4:45pm: PM 2 Session

Sunday

AM1

- Translation Between Representations
- Types of Representation: Diagrams & Sketches

AM2

- AP Classroom / Instructional Planning Reports
- Instructional Strategies / Vocabulary in AP Physics

PM1

- Qualitative/Quantitative Translation FRQs
- Labs: Decay Constant Lab and Density of Air Lab

PM2

- TIPERs & Ranking Tasks
- LAB FRQ Simulation Labs

Workshop Links & Documents

www.PhluidPhysics.com/Resources

Translation Between Representations Free Response Question

FRQ #2
12 Points

TBR

Translation Between Representations Tasks

- Open up your Physics CEDs
- Find Question #2 the TBR FRQ
- P1 page 194
- P2 page 204

- Read through the CED TBR FRQ and the Practice Exam TBR FRQ linked in the agenda and identify what tasks they ask students to do
- Record how many points per part

Translation Between Representations FRQ #2

Translation Between Representations FRQ

The Translating Between Representations question assesses students' ability to connect different representations of a scenario.

(a) Students will be expected to **create a visual representation** that describes a given scenario. (3 pts)

(b) Students will **derive equations** that are relevant to the scenario. (4pts)

(c) Students will **sketch graphs** that relate quantities within the scenario. (3pts)

(d) Finally, students will be asked to do any **one of the following**: (2pts)

- Justify why their answers to any two of the previous parts do/do not agree with each other.
- Use their representations, mathematical analysis, or graph to make a prediction about another situation and justify their prediction using that reasoning or analysis.
- Use their representations, mathematical analysis, or graph to make a prediction about how those representations would change if properties of the scenario were altered and justify that claim using consistent reasoning or analysis.

FRQ Booklet: Which Version?

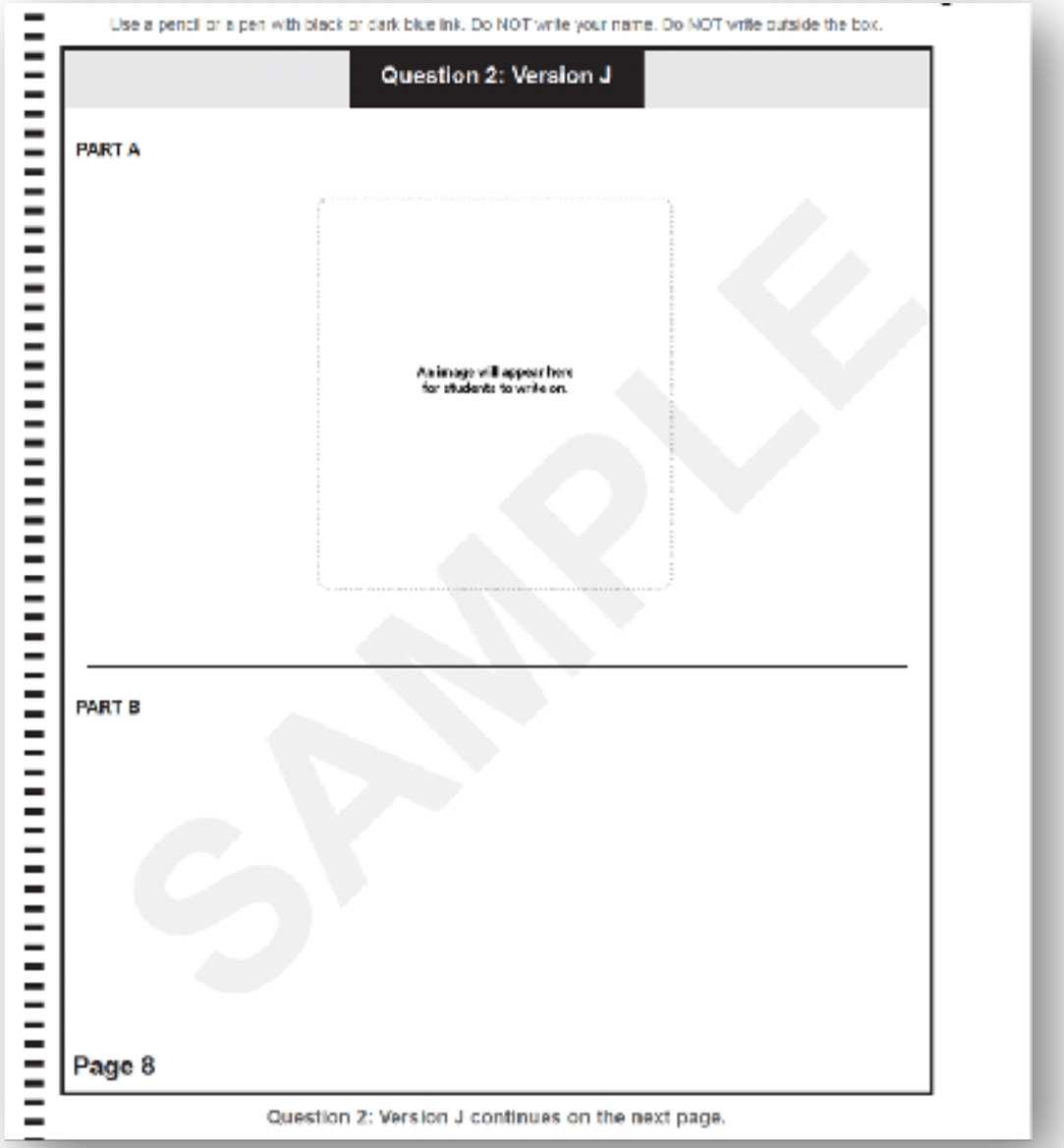
Question 2

There are four versions of Question 2; you will only be answering one version.

Bluebook will indicate which version to answer (J, K, L, or M) and the page number in the booklet.

Make sure you respond in the correct space in the booklet.

FRQ Booklet Structure: Question #2 TBR


Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 2: Version J

PART A

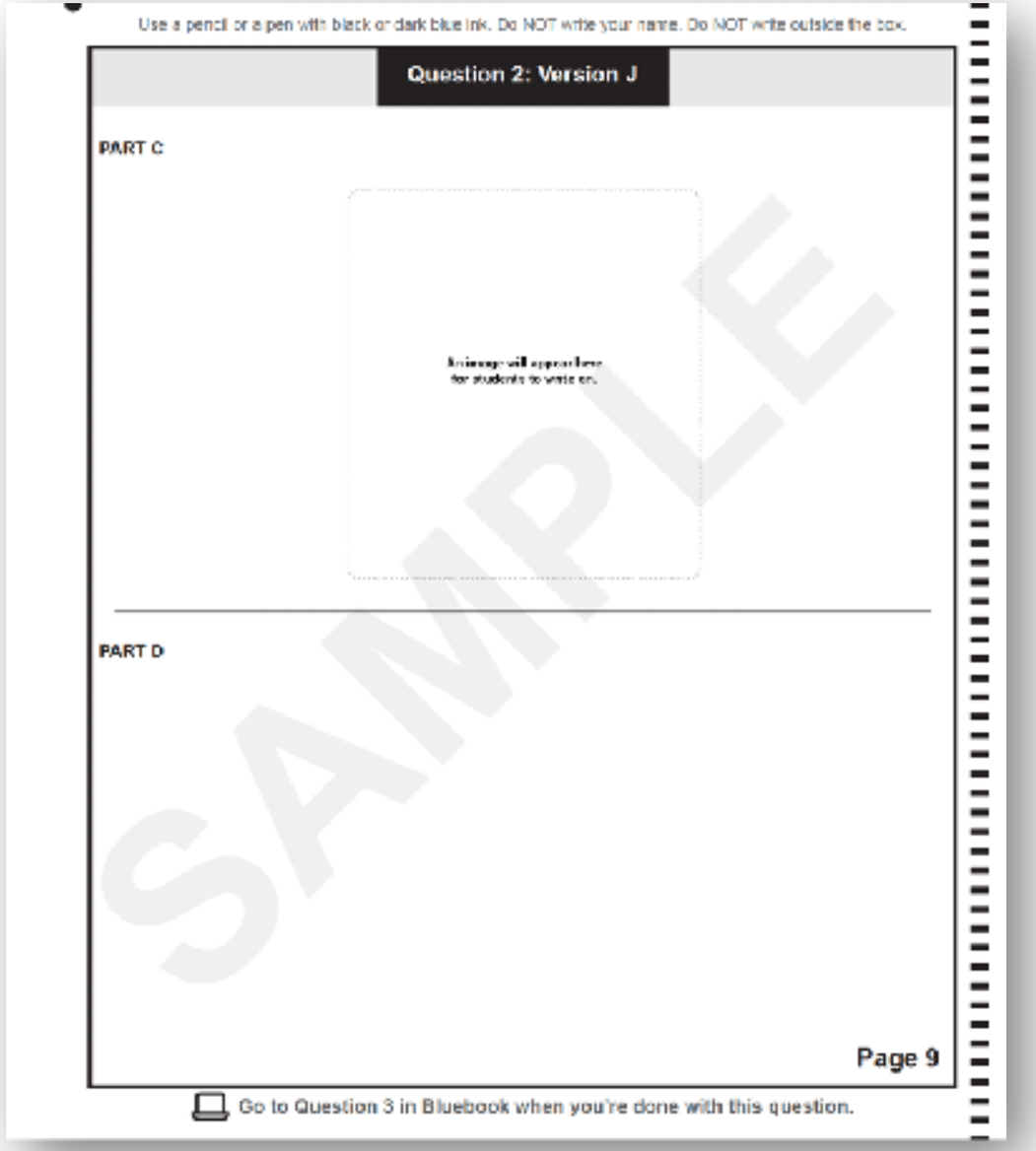
An image will appear here for students to write on.

PART B

Page 8

Question 2: Version J continues on the next page.

SAMPLE


Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 2: Version J

PART C

An image will appear here for students to write on.

PART D

Page 9

Go to Question 3 in Bluebook when you're done with this question.

SAMPLE

Translation Between Representations FRQ #2

Representations Discussion

What are the diagrams and sketches you teach in each course?

- AP Physics 1
- AP Physics 2
- AP Physics C: Mech
- AP Physics C: E&M

- What representations are used in all courses?
- Which representations are course specific?
- How do you teach your students how to make and use each representation?

P1 Units

Algebra Based course meant to replicate 1st Semester College Physics.

Designed as year long course.

Unit Number	Unit Title
1	Kinematics
2	Force and Translational Dynamics
3	Work, Energy, and Power
4	Linear Momentum
5	Torque and Rotational Dynamics
6	Energy and Momentum of Rotating Systems
7	Oscillations
8	Fluids

P2 Units

Algebra Based course meant to replicate 2nd Semester College Physics.

Designed as year long course.

Unit Number	Unit Title
9	Thermodynamics
10	Electric Force, Field and Potential
11	Electric Circuits
12	Magnetism and Electromagnetism
13	Geometric Optics
14	Waves, Sound and Physical Optics
15	Modern Physics

Unit Number	Mechanics Units
1	Kinematics
2	Force and Translational Dynamics
3	Work, Energy, and Power
4	Linear Momentum
5	Torque and Rotational Dynamics
6	Energy and Momentum of Rotating Systems
7	Oscillations

Unit Number	E&M Units
8	Electric Charges, Fields, and Gauss's Law
9	Electric Potential
10	Conductors and Capacitors
11	Electric Circuits
12	Magnetic Fields and Electromagnetism
13	Electromagnetic Induction

TBR Skills: 1.A 1.C 2.A 2.D 3.B 3.C

Practice 1

Creating Representations 1

Create representations that depict physical phenomena.

Practice 2

Mathematical Routines 2

Conduct analyses to derive, calculate, estimate, or predict.

Practice 3

Scientific Questioning and Argumentation 3

Describe experimental procedures, analyze data, and support claims.

SKILLS

1.A Create diagrams, tables, charts, or schematics to represent physical situations.

1.B Create quantitative graphs with appropriate scales and units, including plotting data.

1.C Create qualitative sketches of graphs that represent features of a model or the behavior of a physical system.

2.A Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.

2.B Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.

2.C Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.

2.D Predict new values or factors of change of physical quantities using functional dependence between variables.

3.A Create experimental procedures that are appropriate for a given scientific question.

3.B Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

3.C Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

P1 2025

QUESTION 2 TRANSLATION BETWEEN REPRESENTATIONS (TBR)	12		6.1
TBR PART A POINT 1	1		0.8
TBR PART A POINT 2	1		0.8
TBR PART A POINT 3	1		0.7
TBR PART B POINT 1	1		0.6
TBR PART B POINT 2	1		0.5
TBR PART B POINT 3	1		0.4
TBR PART B POINT 4	1		0.2
TBR PART C POINT 1	1		0.6
TBR PART C POINT 2	1		0.5
TBR PART C POINT 3	1		0.4
TBR PART D POINT 1	1		0.5
TBR PART D POINT 2	1		0.2

P2 2025

QUESTION 2 TRANSLATION BETWEEN REPRESENTATIONS (TBR)	12		8.1
TBR PART A POINT 1	1		0.8
TBR PART A POINT 2	1		0.6
TBR PART A POINT 3	1		0.8
TBR PART B POINT 1	1		0.9
TBR PART B POINT 2	1		0.6
TBR PART B POINT 3	1		0.4
TBR PART B POINT 4	1		0.5
TBR PART C POINT 1	1		0.9
TBR PART C POINT 2	1		0.5
TBR PART C POINT 3	1		0.8
TBR PART D POINT 1	1		0.7
TBR PART D POINT 2	1		0.4

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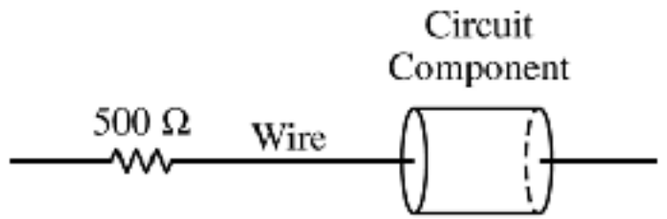
Electric Circuit Diagram

2. (12 points, suggested time 25 minutes)

Students are given an unknown circuit component that is connected in series to a resistor with known resistance 500 Ω.

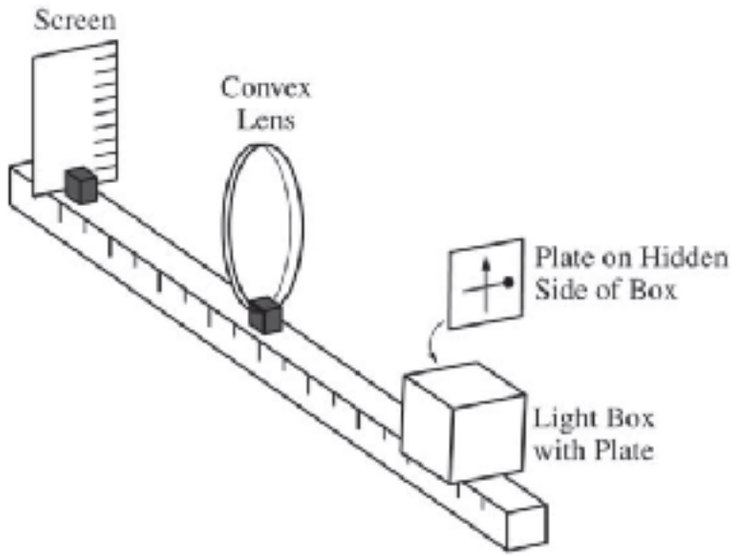
(a) The students are asked to experimentally determine whether the component is a resistor or an uncharged capacitor.

i. Complete the following diagram to show how to use standard circuit equipment to determine whether the component is a resistor or an uncharged capacitor.



Optics Ray Diagram

2017 AP® PHYSICS 2 FREE-RESPONSE QUESTIONS



3. (12 points, suggested time 25 minutes)

Some students are asked to determine the focal length of a convex lens. They have the equipment shown above, which includes a waterproof light box with a plate on one side, a lens, and a screen. The box has a bright light inside, and the plate on the side has shapes cut out of it through which the light shines to create a bright object. This particular plate has a cutout that is a vertical arrow and a horizontal bar with a circle at one end. In the view shown above, the circle is near the right edge of the plate.

With the screen and light box on opposite sides of the lens, the box is aligned so that the plate is 20 cm from the center of the lens, and an image of the arrow and bar is formed on the screen. The students find that the image is clear on the screen when the screen is 30 cm from the center of the lens.

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Translating Between Representations

Translation Between Representations FRQ

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(b) Students will **derive equations** that are relevant to the scenario. (4pts)

(c) Students will **sketch graphs** that relate quantities within the scenario. (3pts)

(d) Finally, students will be asked to do any **one of the following**: (2pts)

- Justify why their answers to any two of the previous parts do/do not agree with each other.
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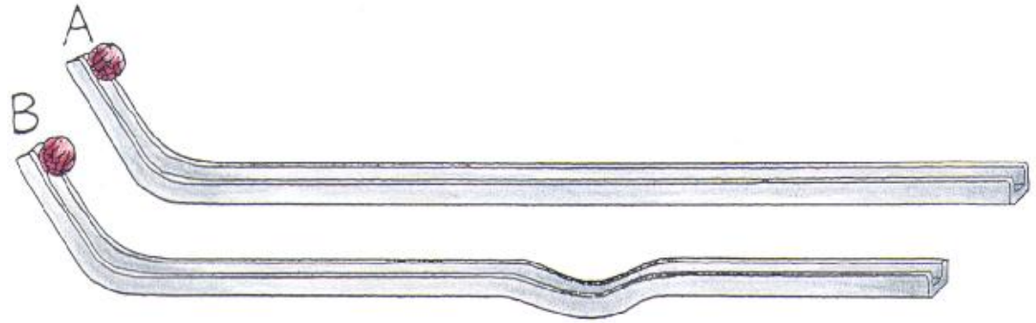
- Use their representations, mathematical analysis, or graph to make a prediction about how those representations would change if properties of the scenario were altered and justify that claim using consistent reasoning or analysis.

TBR

Example of a Sketch

CONCEPTUAL Physics

NEXT-TIME QUESTION



Tracks A and B are made from pieces of channel iron of the same length. They are bent identically except for the same dip in Track B as shown. When the balls are simultaneously released on both tracks as indicated, the ball that races to the end of the track first is on

a) Track A.
b) Track B.
c)...Both reach the end at the same time.

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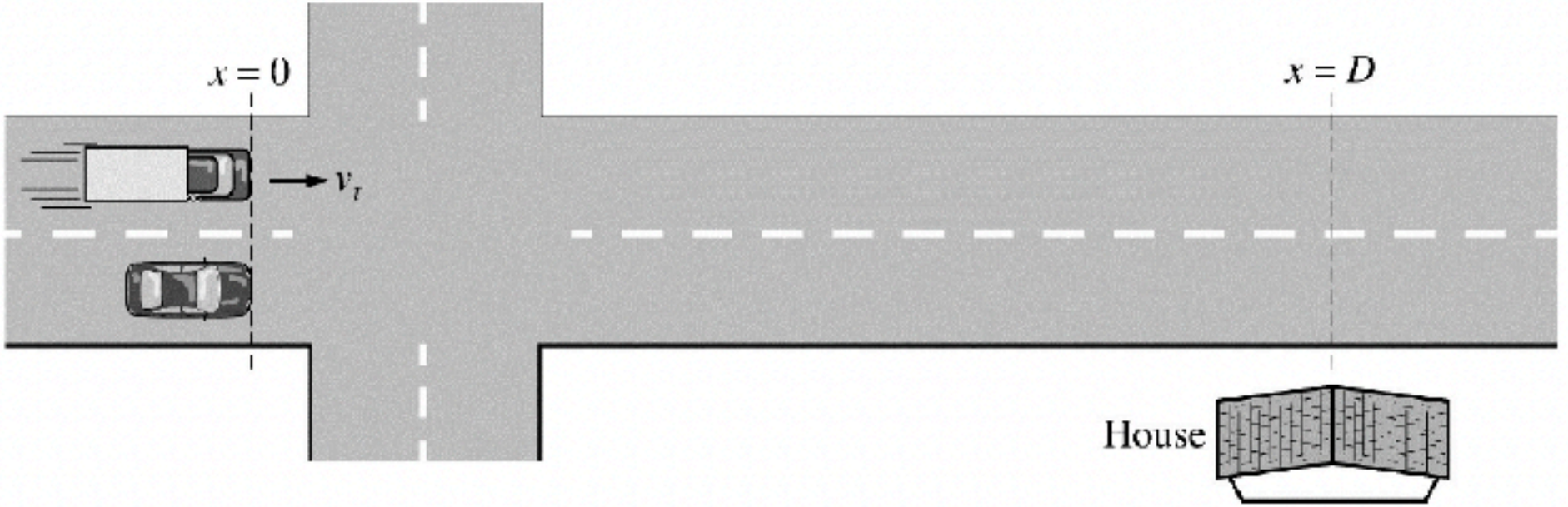
TOOLS THAT TEACH.

Hewitt Drew It!

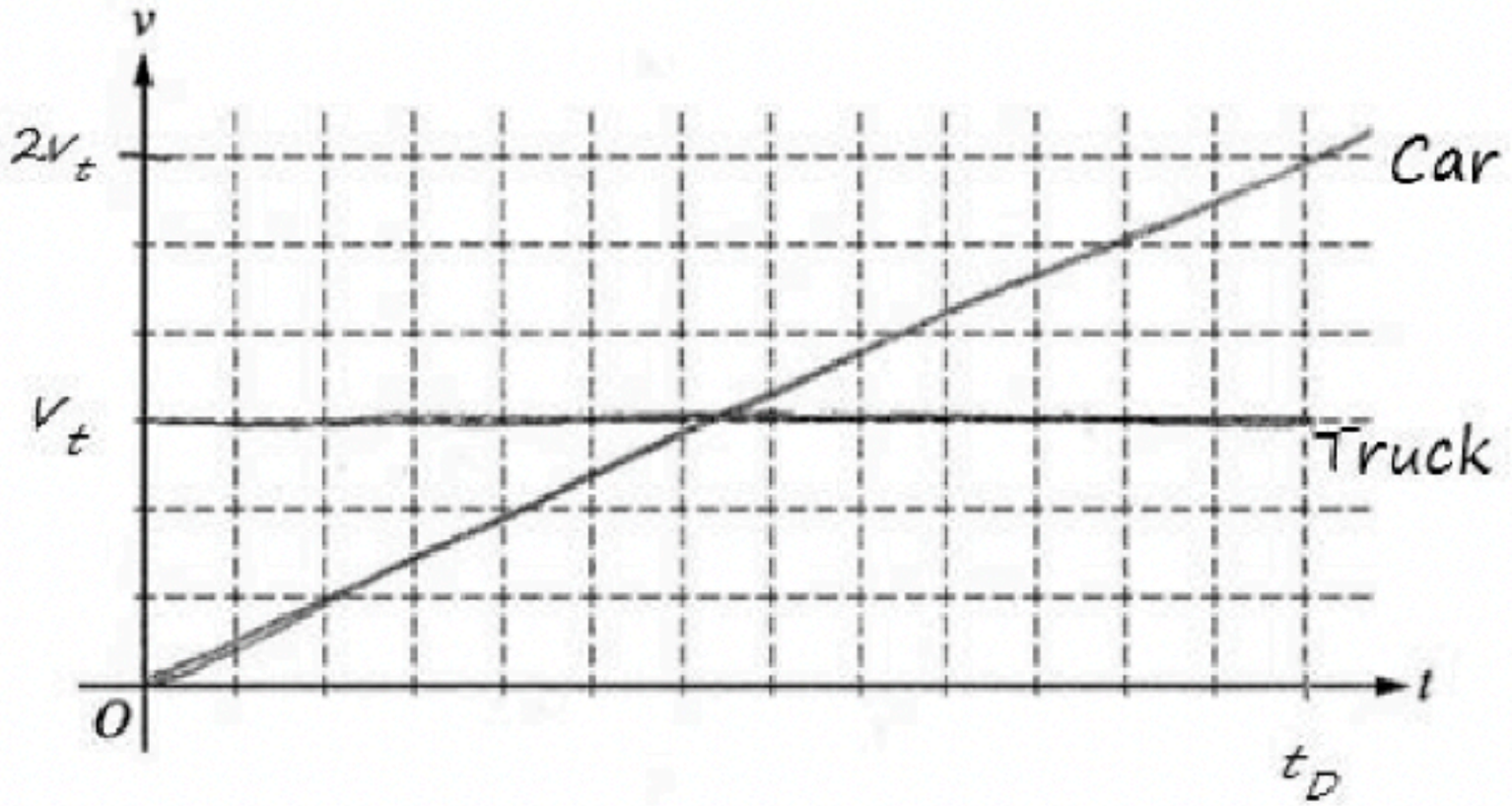


2. (12 points, suggested time 25 minutes)

A car is stopped at a traffic light. The light turns green, and at time $t = 0$ the car starts moving and travels with a constant acceleration. At that instant a truck traveling at constant speed v_t is alongside the car, with the front of each vehicle at position $x = 0$, as shown above. The truck passes the car, but the car later catches up to the truck in front of a house, such that at time t_D the front of each vehicle is at position $x = D$.

(a) On the axes below, sketch and label graphs of the velocity of the car and the velocity of the truck as a function of time. Indicate any important velocities or times.

3 points



For a clearly labeled horizontal line for the truck 1 p

For a clearly labeled straight line with positive slope for the car 1 p

For the speed of the car ending higher than the speed of the truck at a time labeled to indicate that the house has been reached 1 p

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Representing Forces with Diagrams

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NEXT-TIME QUESTION

CONCEPTUAL Physics

She holds the book stationary against the wall as shown. Friction on the book by the wall acts

a) upward.
b) downward.
c) Can't say.

thanx to Arnold Arons

ARBOR SCIENTIFIC
TOOLS THAT TEACH.

AP Free Body Diagram Guidelines

- Pointing away from the dot
- Touching the dot
- Labeled: Various conventions accepted
- Straight, use ruler
- Relative length on grid
- NO Components

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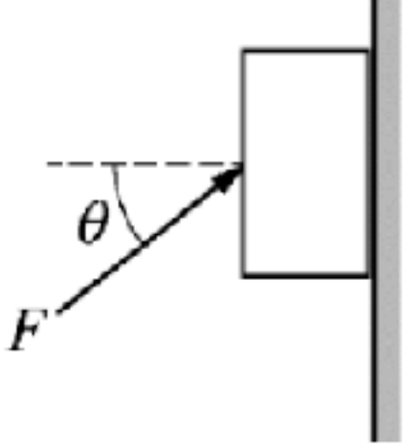

47. A block is held at rest against a wall by a force of magnitude F exerted at an angle θ from the horizontal, as shown in the figure above. Let $\vec{F}_g$ be the gravitational force exerted by Earth on the block, $\vec{F}_N$ be the normal force exerted by the wall on the block, and $\vec{F}_f$ be the frictional force exerted by the wall on the block. Which of the following statements about the magnitudes of the forces on the block must be true? Select two answers.

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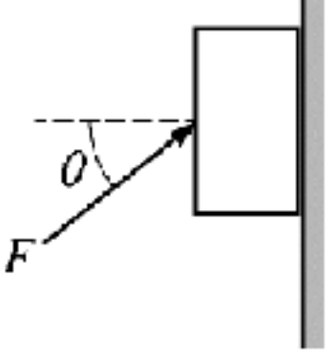

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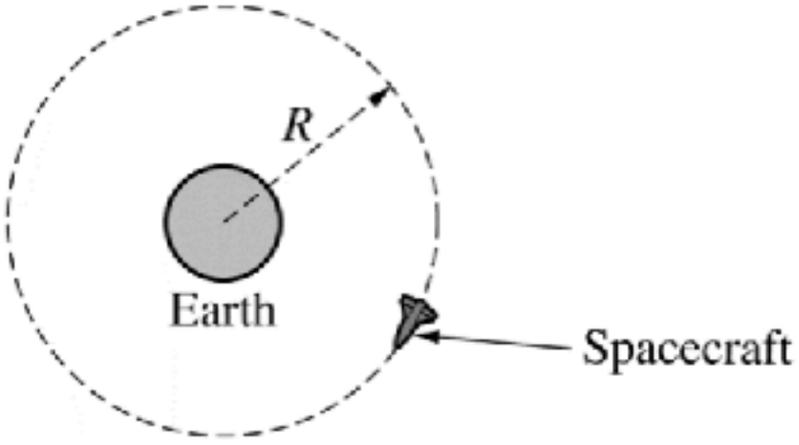
(A) $F - F_g / \sin\theta$

(B) $F\cos\theta = F_N$

(C) $F\sin\theta - F_g \pm F_f$

(D) $F = F_g + F_N \pm F_f$

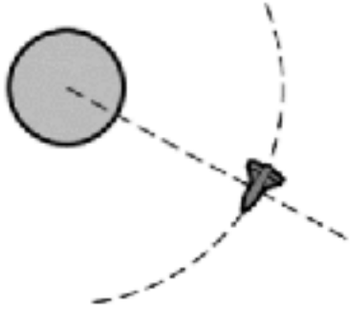


Note: Figure not drawn to scale.

1. (7 points, suggested time 13 minutes)

   A spacecraft of mass m is in a clockwise circular orbit of radius R around Earth, as shown in the figure above. The mass of Earth is M_E.

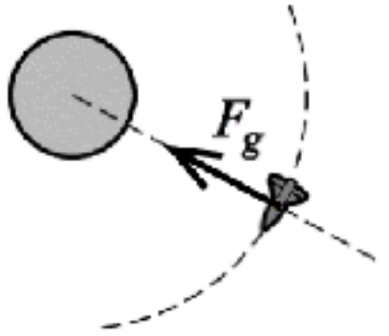
   (a) In the figure below, draw and label the forces (not components) that act on the spacecraft. Each force must be represented by a distinct arrow starting on, and pointing away from, the spacecraft.



Note: Figure not drawn to scale.

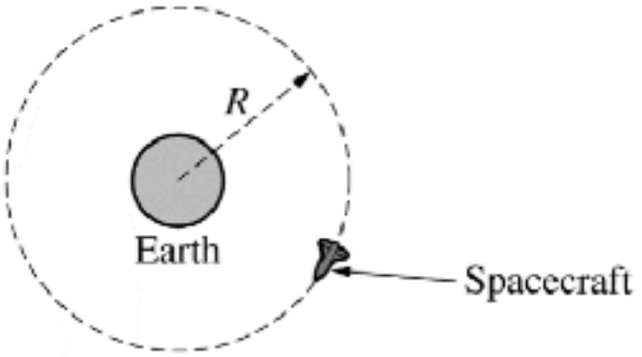
(a) LO / SP: 3.A.2.1 / 1.1; 3.B.2.1 / 1.1, 1.4
2 points

In the figure below, draw and label the forces (not components) that act on the spacecraft. Each force must be represented by a distinct arrow starting on, and pointing away from, the spacecraft.



Note: Figure not drawn to scale.

For an arrow directed toward Earth's center		1 point
For a correct label on the arrow representing the gravitational force, where the arrow is pointing toward Earth's center		1 point
Note: A maximum of 1 point may be earned if extraneous forces are present.		



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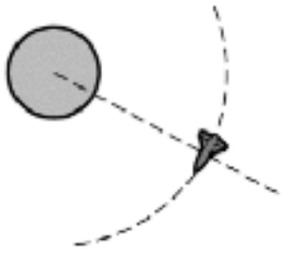


Note: Figure not drawn to scale.

(b)

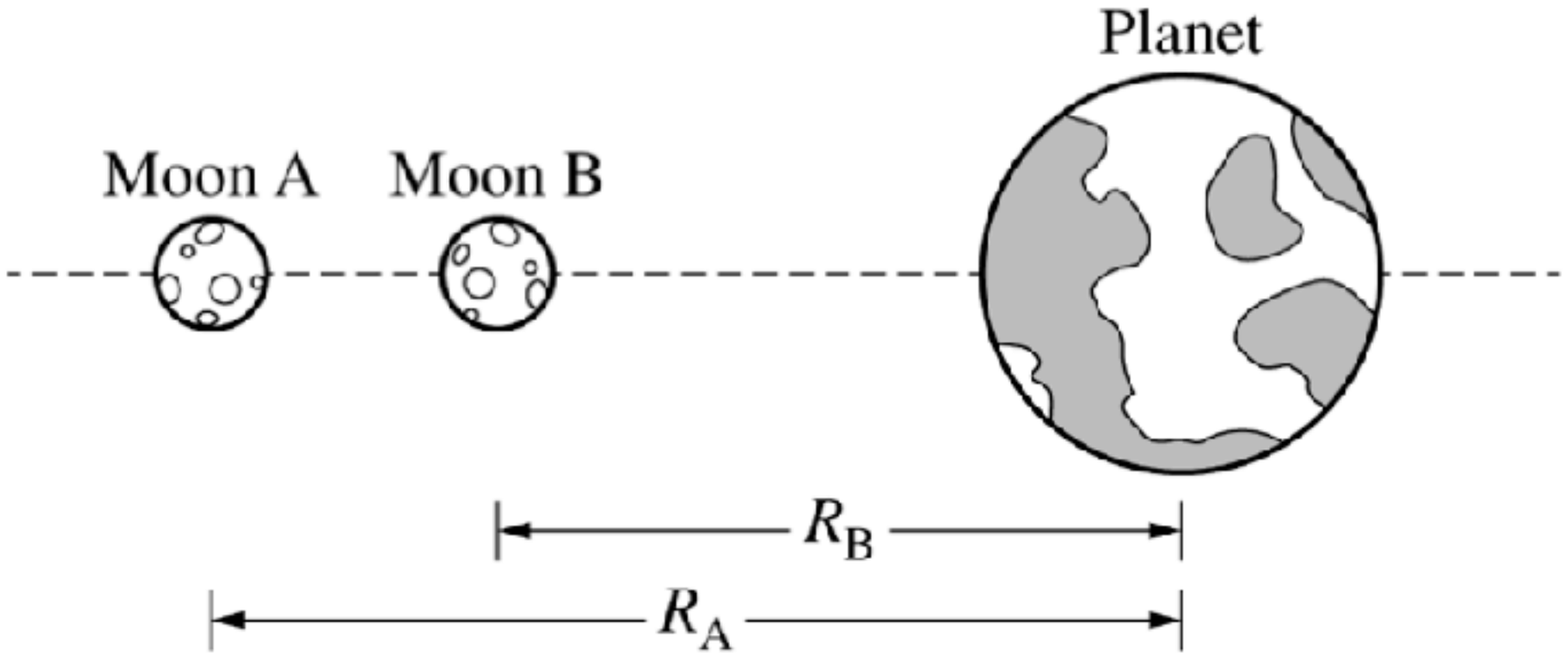
i. Derive an equation for the orbital period T of the spacecraft in terms of m, M_E, R, and physical constants, as appropriate. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

(b) LO / SP: 2.B.2.1 / 2.2; 3.A.1.1 / 1.5, 2.2; 3.B.1.3 / 1.5, 2.2; 3.B.2.1 / 1.1, 1.4, 2.2, 3.C.1.2 / 2.2
4 points

i. 3 points

Derive an equation for the orbital period T of the spacecraft in terms of m, M_E, R, and physical constants, as appropriate. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

For using (or implying) Newton's second law and equating the centripetal force to the gravitational force: $F_g = ma = \frac{mv^2}{R}$ $\qquad$ $\frac{GmM_E}{R^2} = \frac{mv^2}{R}$		1 point
For explicitly or implicitly determining that the speed of the spacecraft is: $v = \frac{2\pi R}{T}$		1 point
For a correct answer algebraically equivalent to: $T = \sqrt{\frac{4\pi^2 R^3}{GM_E}}$		1 point
Note: It is acceptable to leave answer in terms of T^2 $T^2 = \frac{4\pi^2 R^3}{GM_E}$		



(a) The following dots represent the two moons when they are at the locations shown in the previous figure. On each dot, draw and label the forces (not components) exerted on Moon A and on Moon B. Each force must be represented by a distinct arrow starting on, and pointing away from, the appropriate dot.

Moon A

Moon B

a.	For two forces directed to the right on Moon A, correctly labeled, with no extraneous forces	**1 point**
	For two horizontal forces in opposite directions on Moon B. The labels on the forces must be correct and distinguishable from each other, with no extraneous forces.	**1 point**

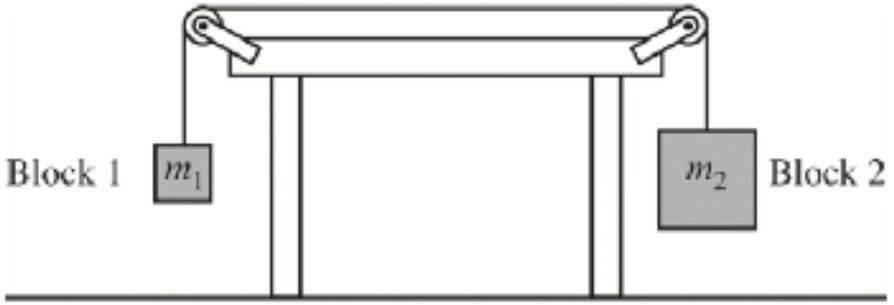
Scoring Notes:

Acceptable labels for forces include: F_{AB}, $F_{A\text{ on }B}$, F_{planet}, F_{moon}, F_{0}, F_{p}, F_{gA}, etc.

Maximum 1 point can be earned if the arrows do not start on the dot.

Example Response

Total for part a. 2 points

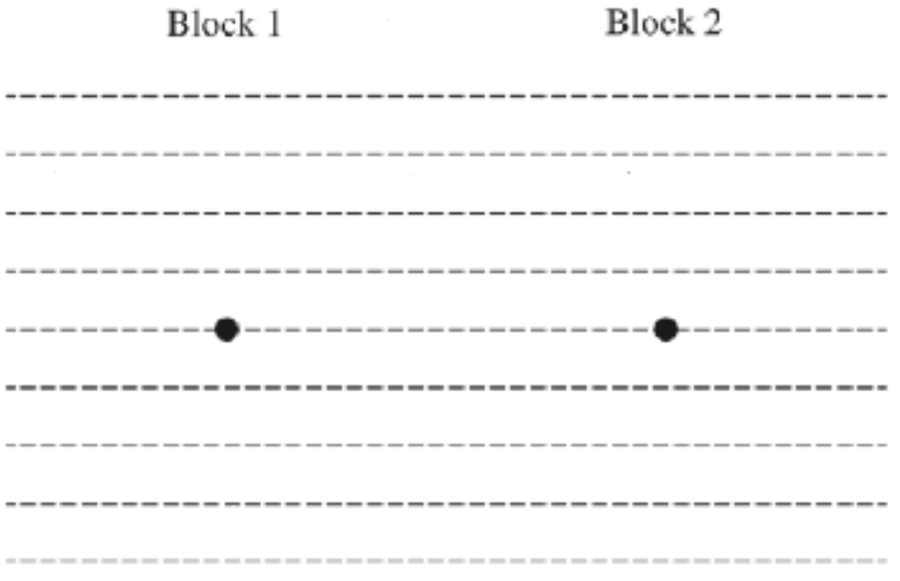


Note: Figure not drawn to scale.

1. (7 points, suggested time 13 minutes)

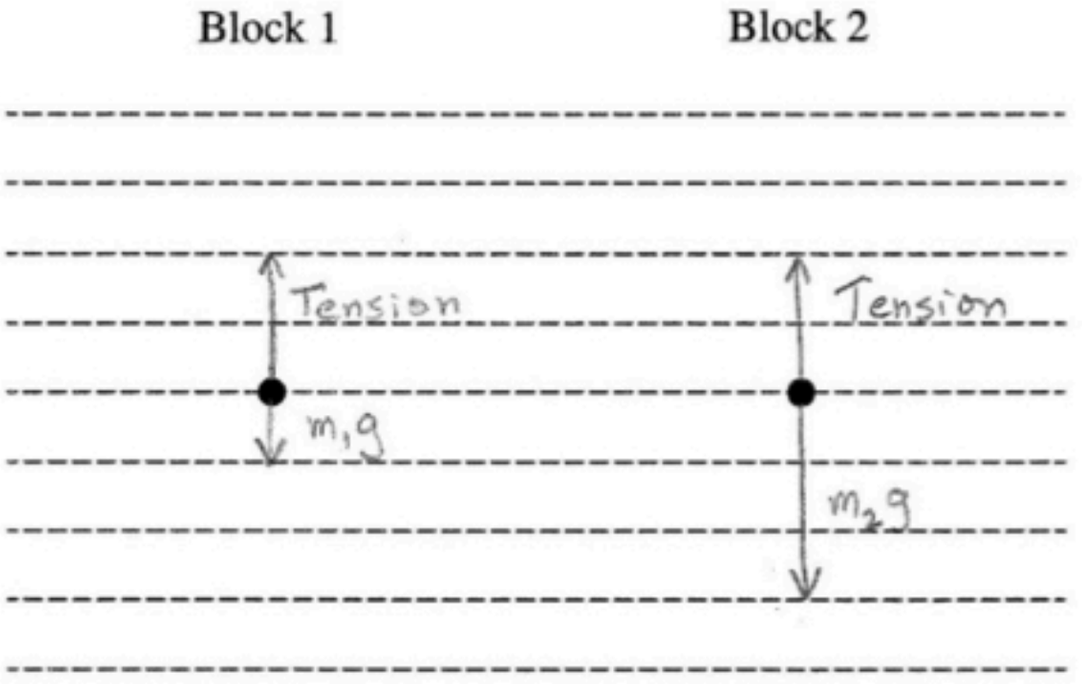
   Two blocks are connected by a string of negligible mass that passes over massless pulleys that turn with negligible friction, as shown in the figure above. The mass m_2 of block 2 is greater than the mass m_1 of block 1. The blocks are released from rest.

   (a) The dots below represent the two blocks. Draw free-body diagrams showing and labeling the forces (not components) exerted on each block. Draw the relative lengths of all vectors to reflect the relative magnitudes of all the forces.



of points

(a) 2 points

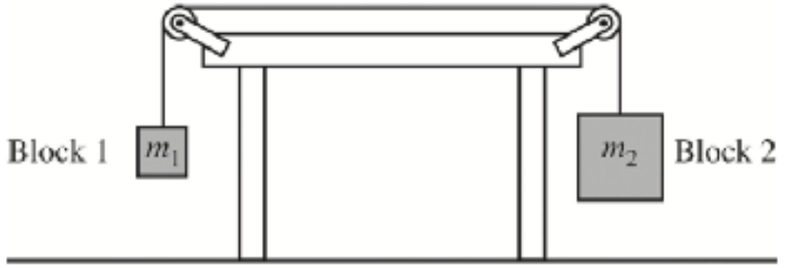


For drawing two vectors starting on the dots that point upward, have the same length and are labeled as the tension force — 1 point

For drawing two vectors starting on the dots that point downward, where the vector for block 1 is smaller than the vector for block 2 and both are labeled as the gravitational force — 1 point

One earned point is deducted for drawing any extraneous vectors.

One earned point is deducted for vector lengths that do not allow the system to accelerate in the proper direction.



Note: Figure not drawn to scale.

1. (7 points, suggested time 13 minutes)

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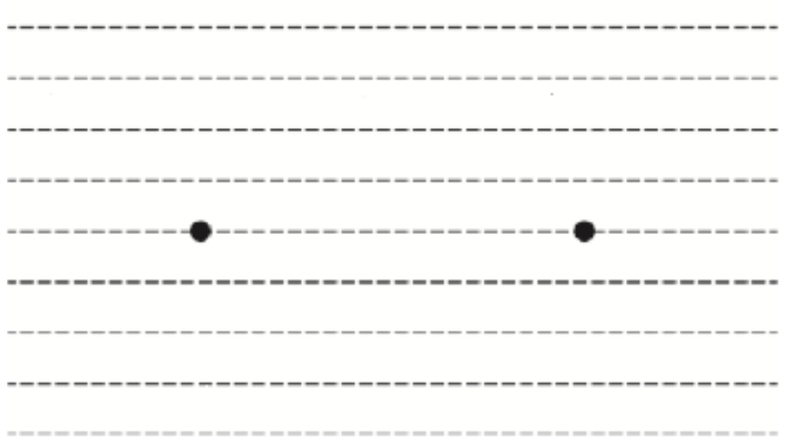
Block 1 Block 2



(b) Derive the magnitude of the acceleration of block 2. Express your answer in terms of m_1, m_2, and g.

(b) 3 points

For writing an equation for Newton's second law for block 1 — 1 point

$m_1 a = T - m_1 g$

For writing an equation for Newton's second law for block 2 — 1 point

$m_2 a = m_2 g - T$

For eliminating T to obtain an equation that can be solved for the acceleration — 1 point

$T = m_1 a + m_1 g$

$m_2 a = m_2 g - m_1 a - m_1 g$

$(m_2 + m_1) a = (m_2 - m_1) g$

$a = (m_2 - m_1) g / (m_2 + m_1)$

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Question 1 (continued)

Distribution of points

(b) (continued)

Alternate solution — *Alternate points*

The system of two blocks must move as a unit, so the acceleration of the system is the acceleration of block 2.

For writing an equation showing that the net force acting on the system is the difference in masses times the acceleration of gravity — *1 point*

$F_{net} = (m_2 - m_1)g$

For writing an equation that relates the net force to the sum of the masses and the acceleration of the system — *1 point*

$F_{net} = (m_2 + m_1)a$

For writing an equation that can be solved for the acceleration in terms of the variables used in the summation of forces equations — *1 point*

$(m_2 + m_1)a = (m_2 - m_1)g$

$a = (m_2 - m_1)g/(m_2 + m_1)$

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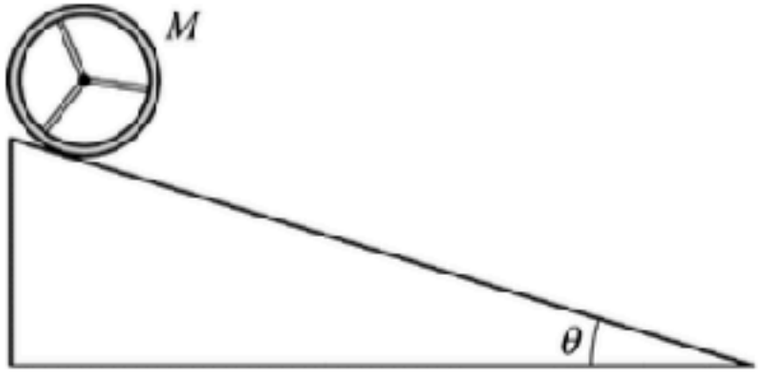
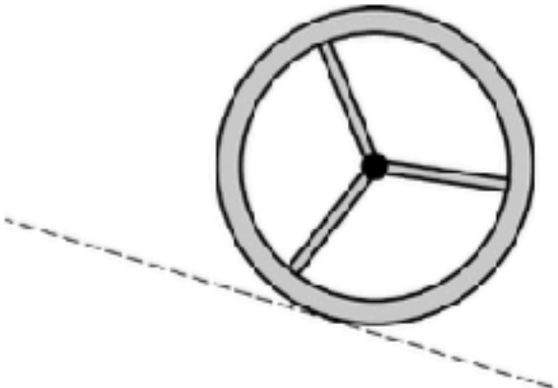


1. (7 points, suggested time 13 minutes)

A wooden wheel of mass M, consisting of a rim with spokes, rolls down a ramp that makes an angle θ with the horizontal, as shown above. The ramp exerts a force of static friction on the wheel so that the wheel rolls without slipping.

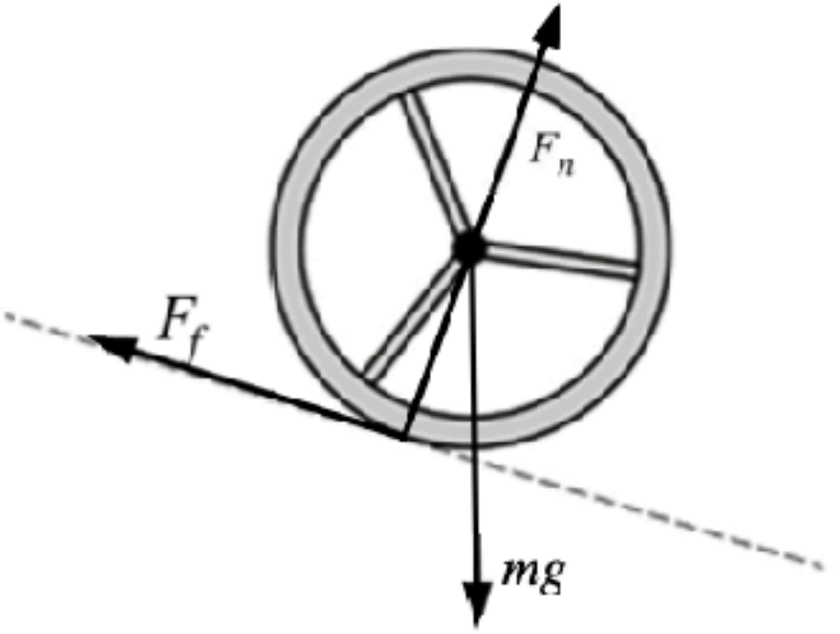
(a)

i. On the diagram below, draw and label the forces (not components) that act on the wheel as it rolls down the ramp, which is indicated by the dashed line. To clearly indicate at which point on the wheel each force is exerted, draw each force as a distinct arrow starting on, and pointing away from, the point at which the force is exerted. The lengths of the arrows need not indicate the relative magnitudes of the forces.



(a)

i. 2 points



For a labeled arrow representing the gravitational force, starting at the wheel's center and directed downward — 1 point

For labeled arrows representing the friction and normal forces or a single arrow representing the resultant of the friction and normal forces (i.e., the force exerted on the wheel by the surface), with no extraneous forces — 1 point

The friction force should start at the wheel-ramp contact and be directed up and left along the ramp.

The normal force should start at the wheel-ramp contact and be perpendicular to the ramp and toward the wheel's center. It does not have to go exactly through the center but must come reasonably close.

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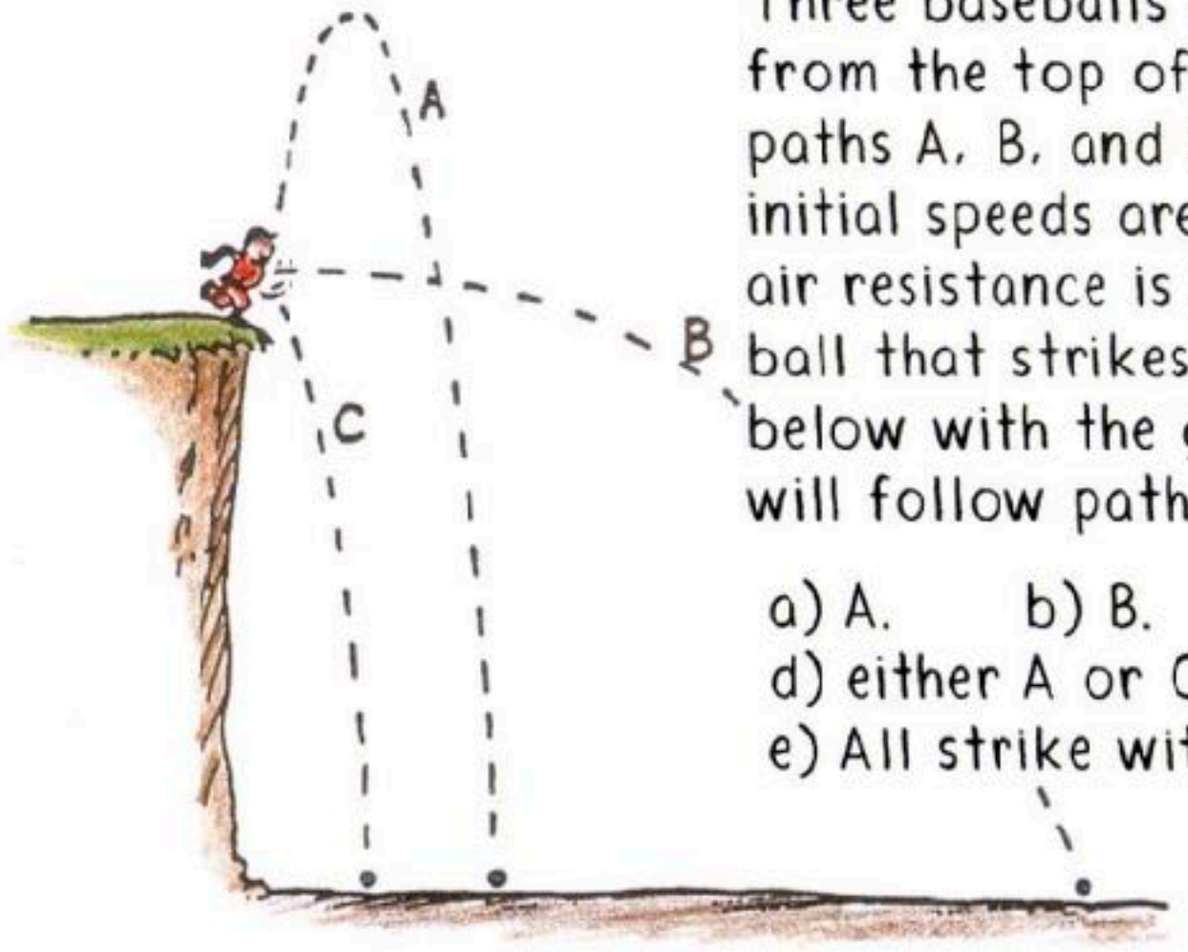
NEXT-TIME QUESTION

CONCEPTUAL Physics



Three baseballs are thrown from the top of the cliff along paths A, B, and C. If their initial speeds are the same and air resistance is negligible. The ball that strikes the ground below with the greatest speed will follow path

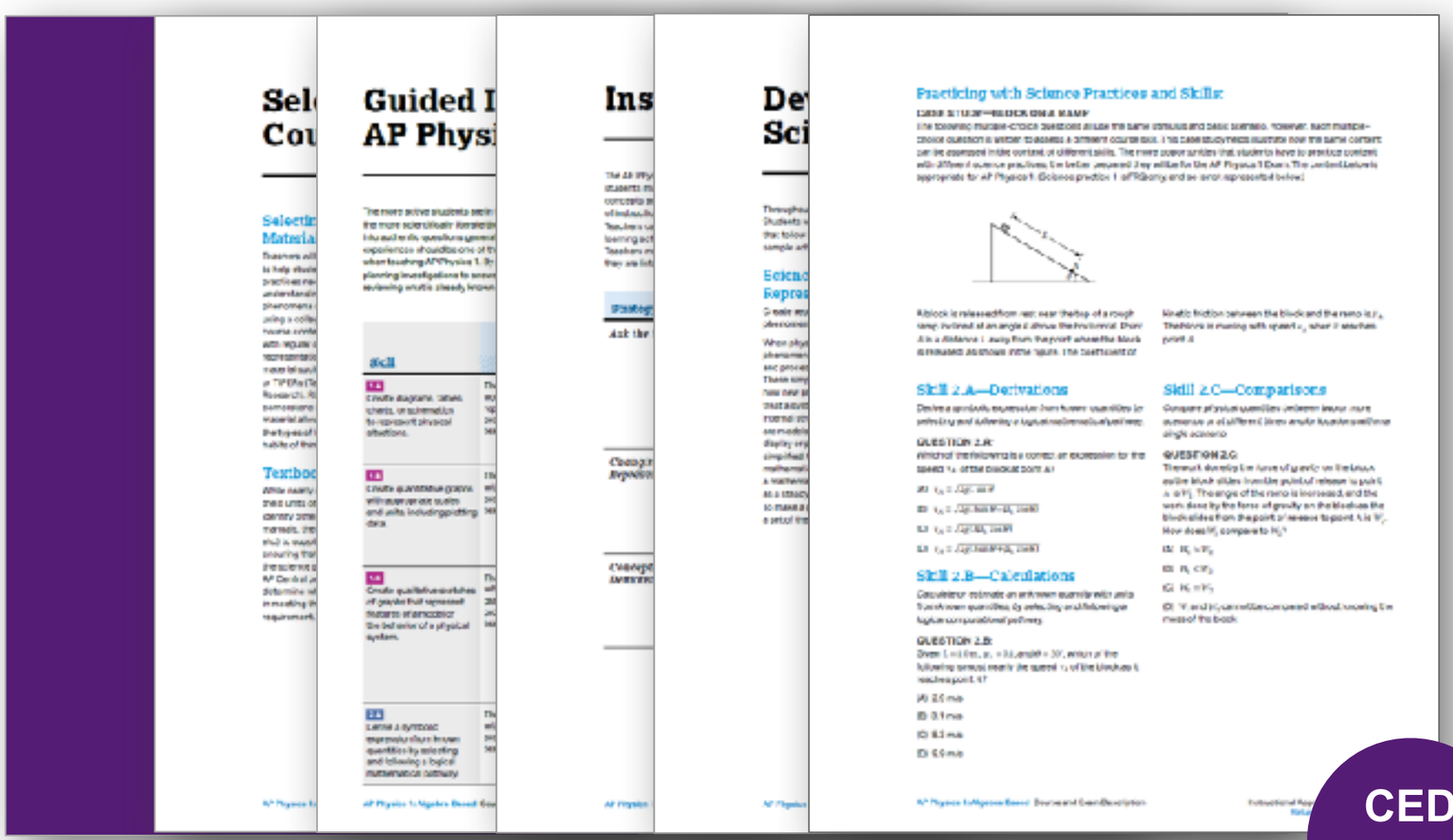
a) A. b) B. c) C.
d) either A or C.
e) All strike with the same speed.

ARBOR SCIENTIFIC
TOOLS THAT TEACH

Instructional Approaches offer recommendations on integrating skills and content

Elements included:

- Selecting and Using Course Materials
- Guided Inquiry in AP Physics
- Instructional Strategies (with examples from different topics of the course)
- Developing Mathematical Practices (with key questions and sample activities that address different skills)
- Practicing with Science Practices and Skills: Case Study



CED pp. 155-174

Course and Exam Description Instructional Strategy

Strategy	Description	Example
Four-Square Problem Solving	Students are given a scenario, perhaps one that came from a traditional, "plug-and-chug" calculation problem. They divide a sheet of paper into four quadrants. In each quadrant, students put some representation of what is going on in the problem—for example, motion maps or graphs, free-body diagrams, energy bar graphs, momentum bar graphs, mathematical models (i.e., equations with symbols), well-labeled diagrams, or written explanation (i.e., two to three strong, clear sentences).	Assign students the scenario of a disk rolling without slipping down an incline. For the four-squares, have students A. sketch a force diagram of the disk, B. sketch an energy bar chart of the translational kinetic, rotational kinetic, and gravitational potential energy of the disk–Earth system when the disk is at the top and bottom of the incline, C. derive an equation for the translational speed of the disk at the bottom of the incline, and D. make a claim about the final speed of a hoop (with the same mass and radius) if it were released from rest at the top of the same incline.

CED
p. 162

Translating Between Representations FRQ

The Translating Between Representations (TBR) question assesses students' ability to connect different representations of a scenario. Students will be expected to **create a visual representation** that describes a given scenario. Students will **derive equations** that are mathematically relevant to the scenario. Students will **draw graphs** that relate quantities within the scenario. Finally, students will be asked to do any **one of the following**:

- Justify why their answers to any two of the previous parts do/do not agree with each other.
- Use their representations, mathematical analysis, or graph to make a prediction about another situation and justify their prediction using that reasoning or analysis.
- Use their representations, mathematical analysis, or graph to make a prediction about how those representations would change if properties of the scenario were altered and justify that claim using consistent reasoning or analysis.

Diagram	**Graph**
Mathematical Representation	**Qualitative Analysis**

Rapid Compression of a Gas: Fire Syringe

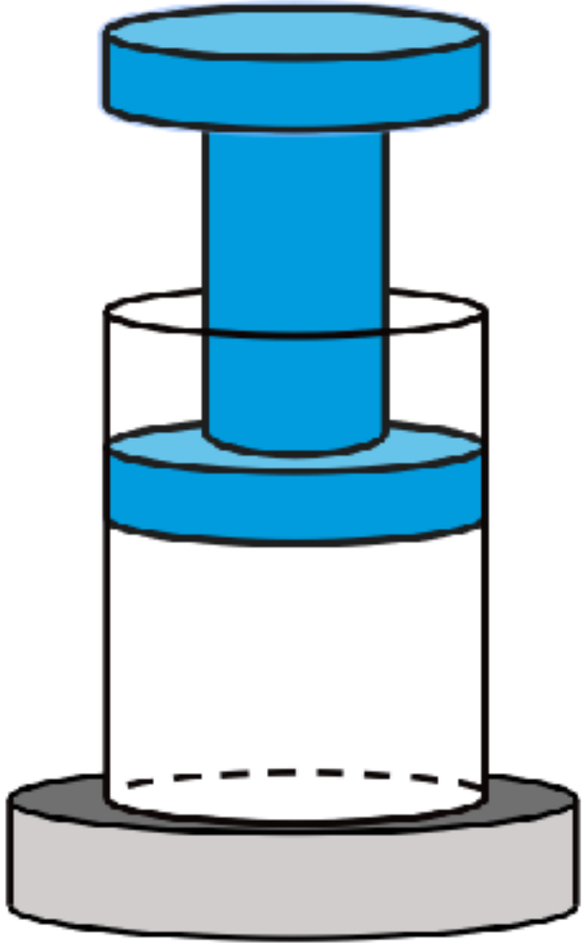
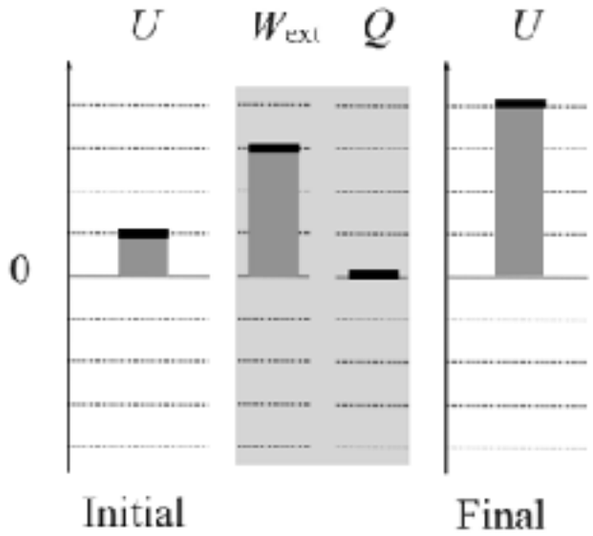
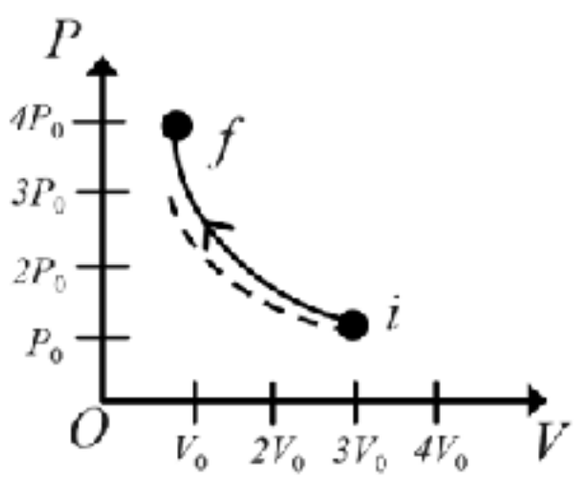


Diagram	**Graph**
Mathematical Representation	**Qualitative Analysis**

Diagram



Graph



Mathematical Representation

Qualitative Analysis

The gas is compressed, so positive work is done on the gas adding energy to the gas, therefore W = +. Because the gas is compressed rapidly, there is not time for energy to transfer to/ from the gas via a heating process, so Q = 0. The change in internal energy is the sum of the energy added/removed by heating and the work done on the gas, so the internal energy of the gas increases. Because internal energy is directly proportional to temperature, the temperature of the gas also increases. By the ideal gas law, the temperature of the gas is proportional to the product of pressure and volume. Therefore, because the temperature of the gas increases, the product of PV is greater in the final state than in the initial state.

Two Positively Charged Particles

A system consists of two positively charged particles. The particle on the left is fixed in place. The particle on the right moves towards the particle on the left at constant velocity.

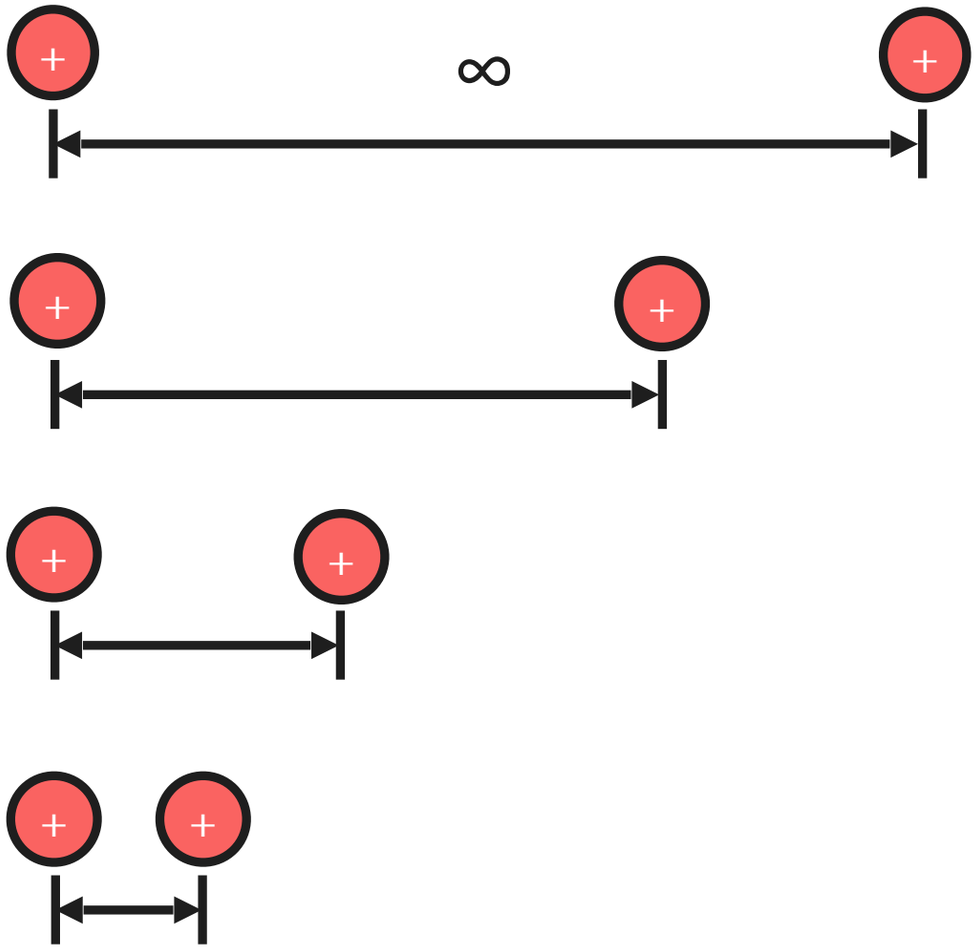
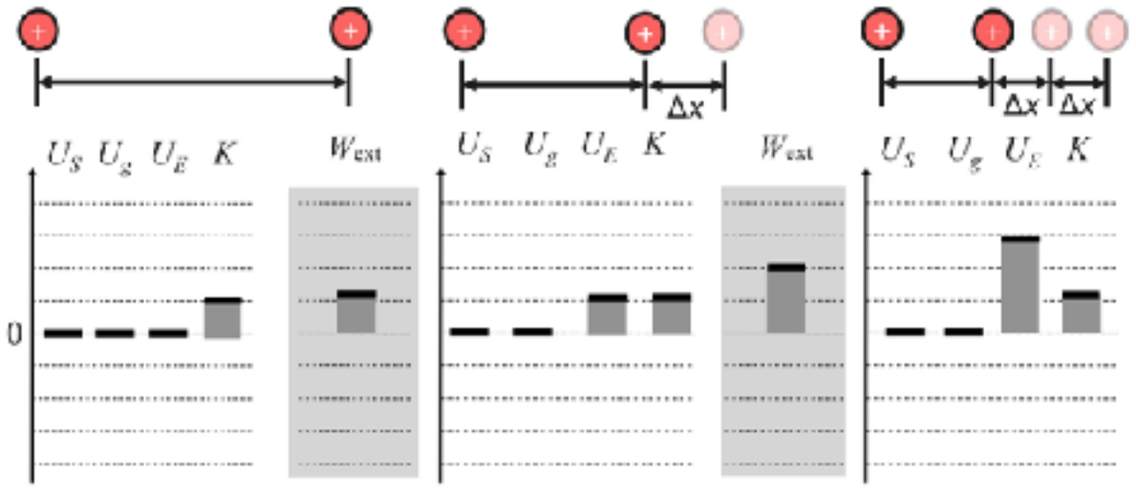
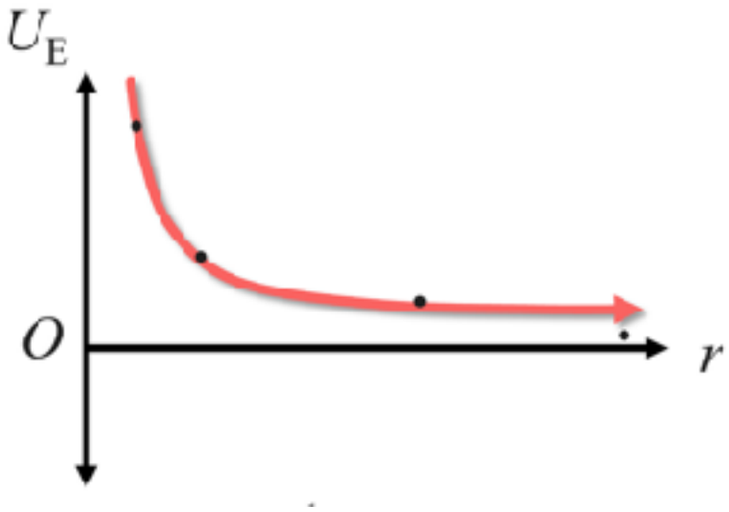


Diagram	**Graph**
Mathematical Representation	**Qualitative Analysis**

Diagram



Graph



Mathematical Representation

Qualitative Analysis

When the charges are an infinite distance apart, the potential energy is zero. Because the electric force, which is internal to the system, is repulsive, for the charges to move closer together at constant velocity an external force must push the charges toward each other. The kinetic energy of the system is constant, but the external force does positive work, so the energy of the two-charge system increases. As a result, the electric potential energy is greater for each new configuration because of the work done by the external force.

As the charges move closer together, more force is needed to move the charge through each equal distance interval, so more work must be done and the potential energy changes at a greater rate for smaller separation distances.

Two Objects Submerged in Liquid

Two objects of identical mass are attached to strings and submerged in a large tank of liquid, as shown at right. The fluid is filled to a depth of 2.0 m.

Object A has a volume of 1.0×10^{-5} m^3 and a density of 1300 kg/m^3. The tension in the string to which object A is attached is 0.0098 N.

Object B is tied to the bottom of the tank. The tension in the string to which object B is attached is 0.1104 N.

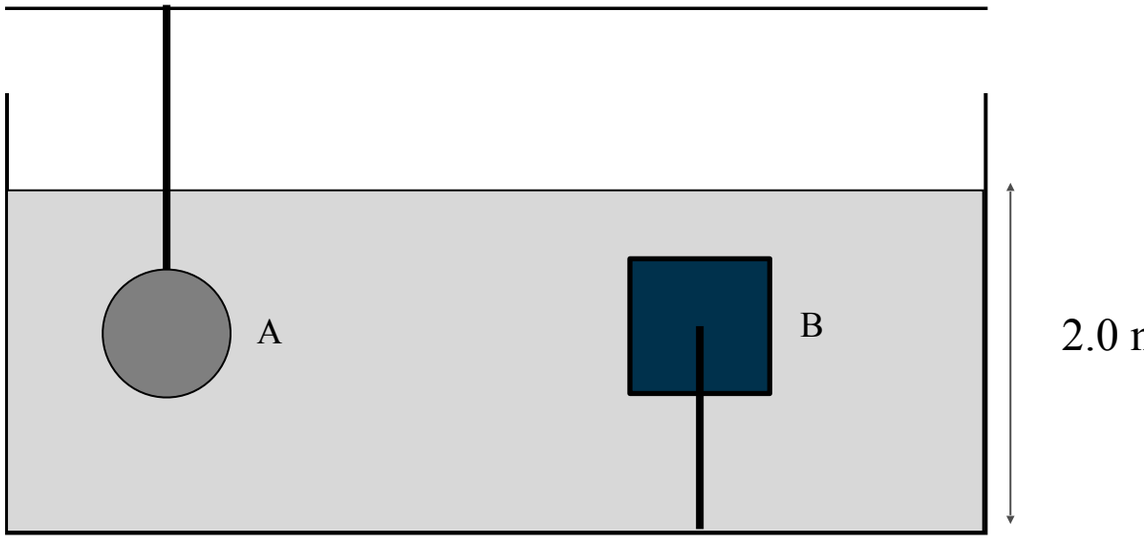


Diagram	**Graph**
Mathematical Representation	**Qualitative Analysis**

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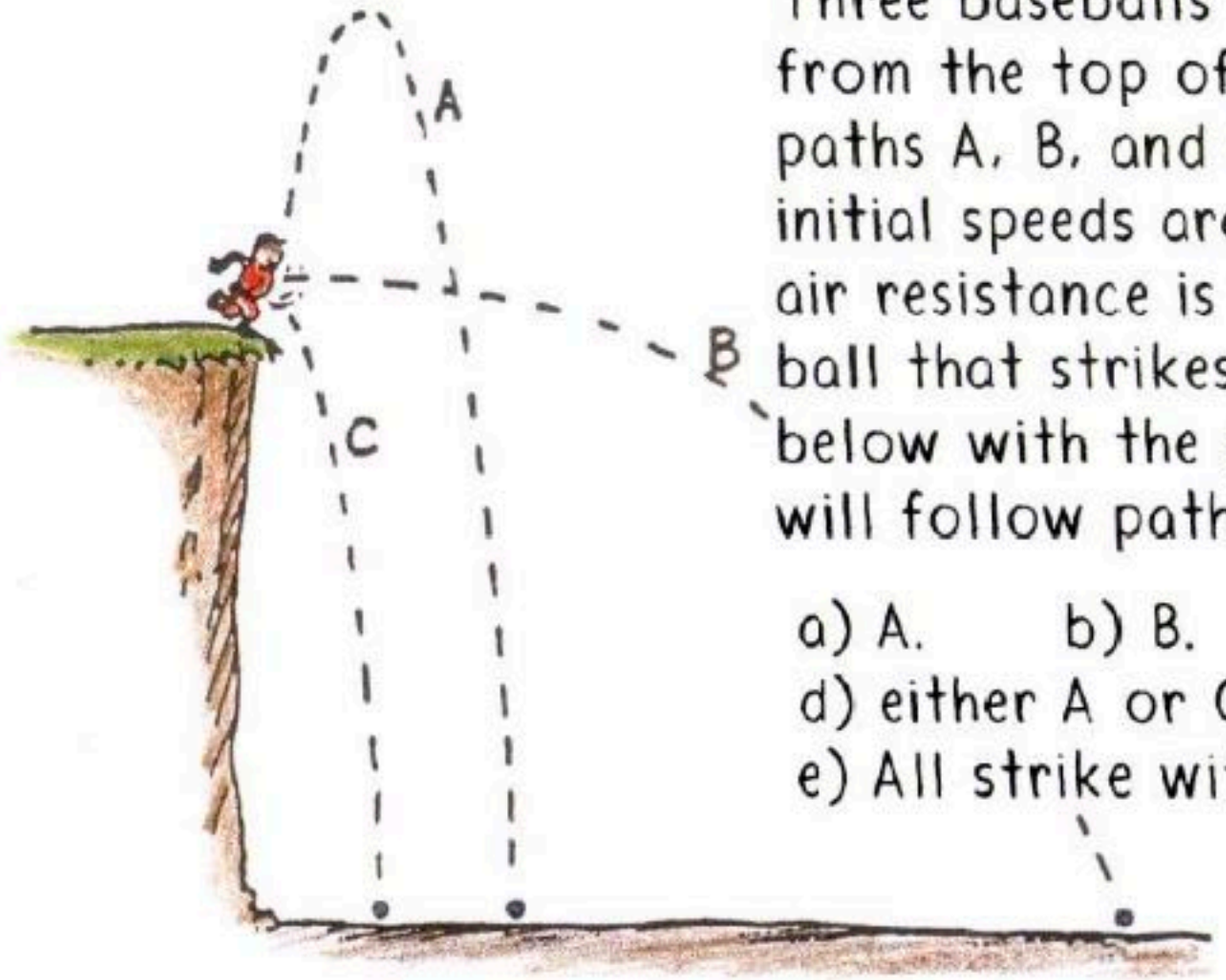
Systems and Energy

Oather Strawderman

International Lead AP Physics Consultant

NEXT-TIME QUESTION

CONCEPTUAL Physics

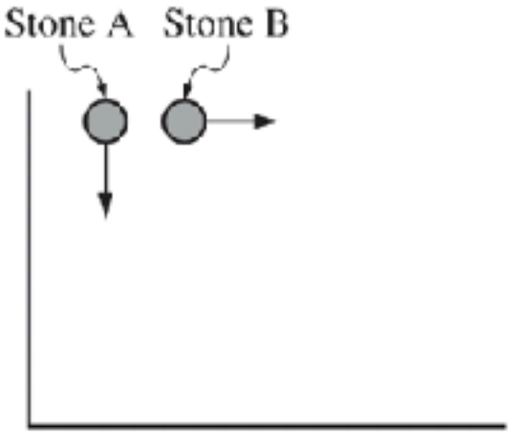


Three baseballs are thrown from the top of the cliff along paths A, B, and C. If their initial speeds are the same and air resistance is negligible. The ball that strikes the ground below with the greatest speed will follow path

a) A. b) B. c) C.
d) either A or C.
e) All strike with the same speed.

Tool Choice

- Hammer/Screwdriver Example
- It is just as important to teach when to use a tool as it is to teach how to use a tool
- Talk out loud before starting each problem describing what made you choose to use the tool you are using
- Make sure and include problems from previous units in every unit exam
- Don’t save review till the Spring



10. Two stones are thrown from the same height and with the same initial speed. Stone A is thrown vertically downward, and Stone B is thrown horizontally, as shown. If the stones are thrown at the same time and air resistance is negligible, which of the following is true?

(A) The two stones reach the ground at the same time with the same speed.

(B) The two stones reach the ground at the same time but with different speeds.

(C) Stone A reaches the ground first, but the two stones have the same speed just before they hit the ground.

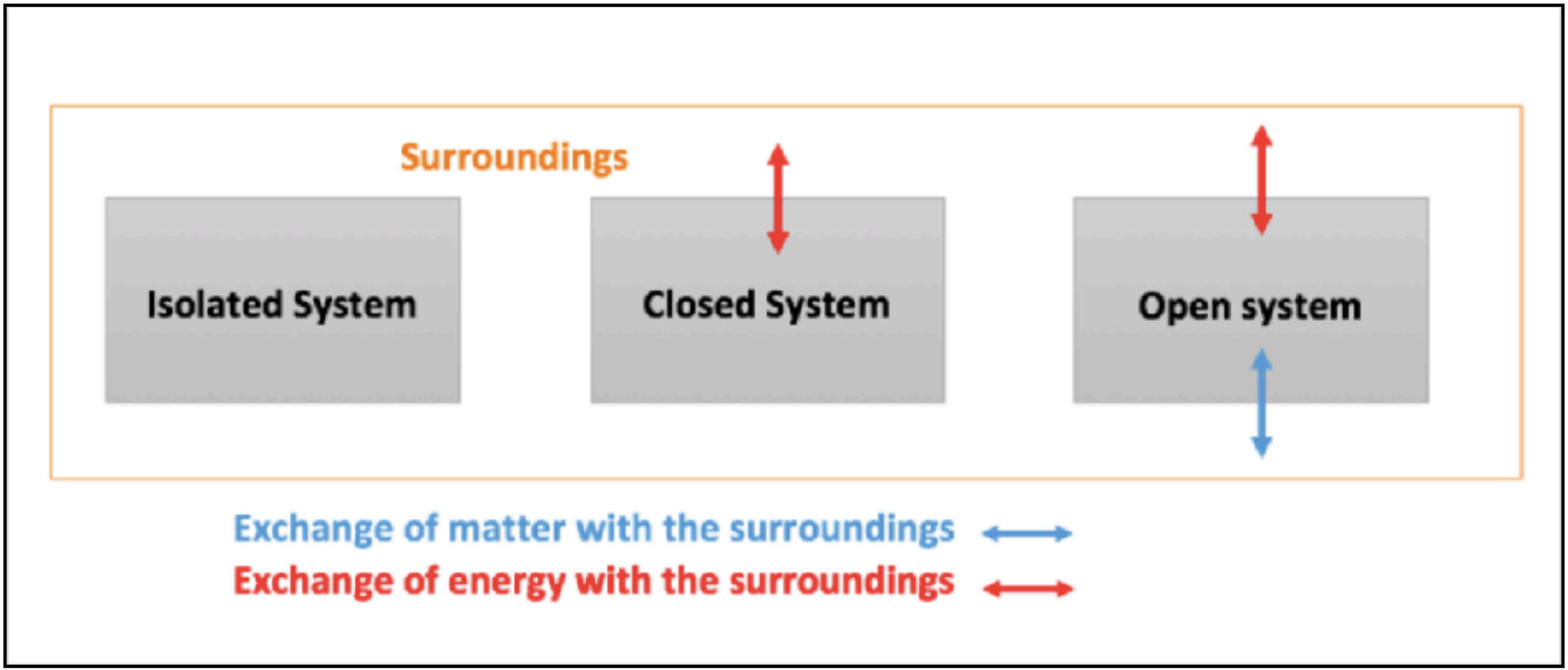
(D) Stone A reaches the ground first and has greater speed just before hitting the ground.

Energy

- Mechanical Energy
  - -Kinetic Energy
  - -Elastic Potential Energy
  - -Electric Potential Energy
    - Requires a system
  - -Gravitational Potential Energy
    - Requires Earth as part of the system

- Energy Transferred through Heating or Cooling
  - Atomic level Kinetic Energy transferred through friction, heating or cooling

Types of Systems



Types of Systems

Examples of Systems

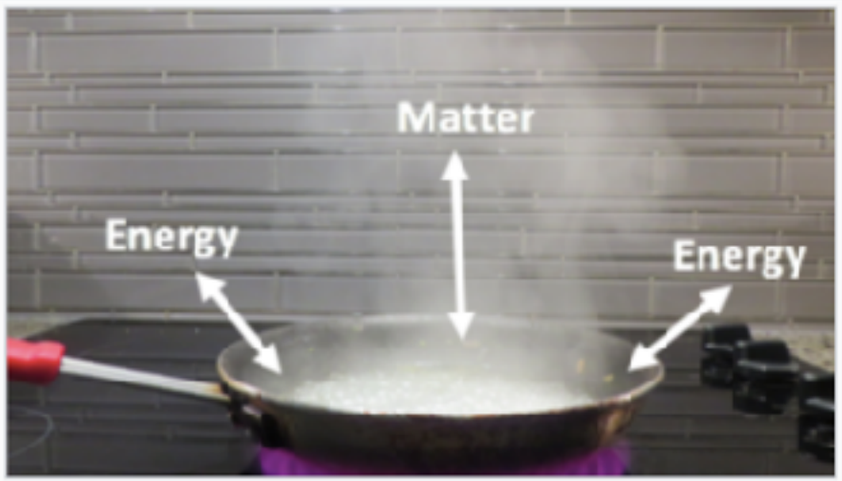


Figure 2. This is an open system. The system is the pan and the surrounding is the kitchen.[2]

Figure 4. This is a closed system. The system is the pan/lid and the surrounding is the kitchen.[2]

Figure 4. This is an isolated system. The system is the thermos and the surrounding is the kitchen.[2]

Systems MCQ: 2017 IPE

5. A sled slides down a hill with friction between the sled and hill but negligible air resistance. Which of the following must be correct about the resulting change in energy of the sled-Earth system?

   (A) The sum of the kinetic energy and the gravitational potential energy changes by an amount equal to the energy dissipated by friction.
   (B) The gravitational potential energy decreases and the kinetic energy is constant.
   (C) The decrease in the gravitational potential energy is equal to the increase in kinetic energy.
   (D) The gravitational potential energy and the kinetic energy must both decrease.

Systems MCQ: 2014 Practice Exam

19. A rocket is continuously firing its engines as it accelerates away from Earth. For the first kilometer of its ascent, the mass of fuel ejected is small compared to the mass of the rocket. For this distance, which of the following indicates the changes, if any, in the kinetic energy of the rocket, the gravitational potential energy of the Earth-rocket system, and the mechanical energy of the Earth-rocket system?

	Rocket Kinetic Energy	System Gravitational Potential Energy	System Mechanical Energy
(A)	Increasing	Increasing	Increasing
(B)	Increasing	Increasing	Constant
(C)	Increasing	Decreasing	Decreasing
(D)	Decreasing	Increasing	Constant

Reading Kelly O'Shea Blog

Energy Bar Charts (LOL Diagrams)

"LOL diagrams are my life." –Honors Physics student, May 2013

I have to admit, first of all, that I wasn't expecting to love energy bar charts (when I first heard about them). I didn't originally learn to solve energy problems that way, and when I first saw them, I thought it was a silly waste of time. I especially hated the name ("LOL diagrams"). I thought it just served to emphasize how ridiculous the entire exercise was.

When I first met them with my classes (fully as they seemed, I wasn't going to ignore them entirely until I found out that they were useless for the kids, too!), I was shocked at how effective they were at helping students structure their thinking about how energy is stored, how energy is transferred, and how energy is conserved. The next year, I used them with my Honors Physics students, too. These classes wouldn't believe it if I told them how much energy we'd talk about. More importantly, when we started tackling more difficult energy problems later that year (momentum problems, etc.), those students found the new problems to be trivial. They immediately just drew LOL's and were able to solve the problems every time. The year before (with an incredibly strong class), that topic had been one of the hardest of the year. I was sold.

What are LOL diagrams?

I'll layout the first few LOL diagrams that we review in class. To start, we take this first problem and work through it a few times (the first couple times together, then I let them do the other variations on their own). Then we whiteboard them. I'll put the diagrams first, then outline some of the features below.

A car on a frictionless roller coaster track, launched by a huge spring, makes it to the top of the loop.

With each LOL, we also practice using the diagram to write an equation for the conservation of energy in this situation. So after making this sketch, we would write this:

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Energy Bar Charts (LOL Diagrams)

BLOGROLL

Action Reaction

Adventures with the Clever Carp

Always Formative

Non-Verbal Thinking

Paper, Brain, Teeth

Play-Doh Physics

The Talent Code

Think, Think, Think

BLOG STATS

847,206 views and counting

ABOUT ME

I teach high school (10th grade) physics at a progressive, independent day school in NYC. Thoughts and opinions expressed here are my own and not my school's. I ask for wonder, more thinking.

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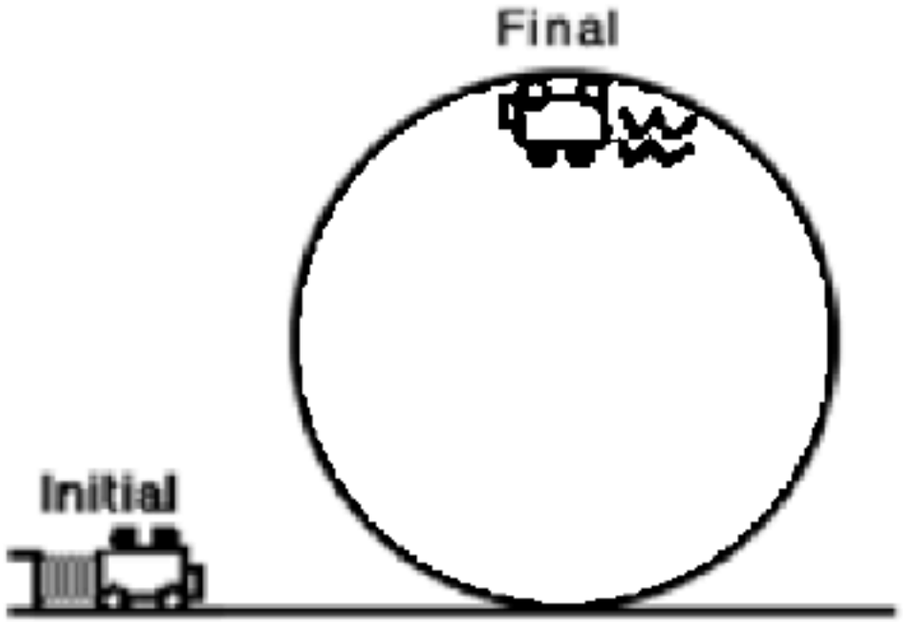
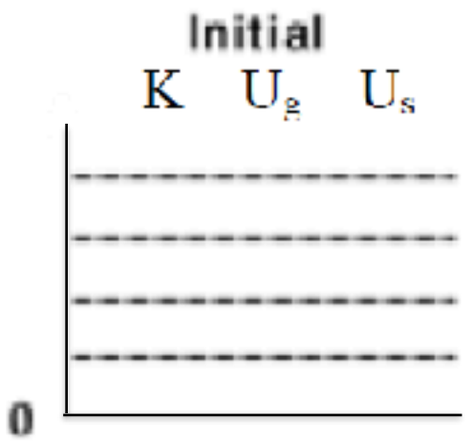
Energy Bar Graphs

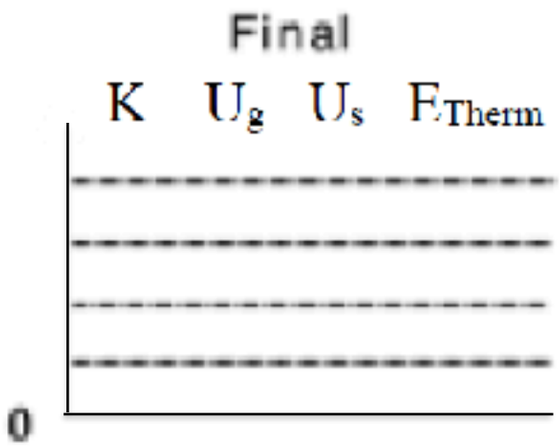
- The “Free Body Diagrams” of the Energy Unit
- Can be used during Fluids, Thermo and E&M in P2
- Three parts
  - First graph represents the energy in the system prior to the event
  - The Circle tells you the system you are analyzing and shows any work done on or by the system
  - Second graph represents the energy in the system after the event

Energy Bar Graphs WS

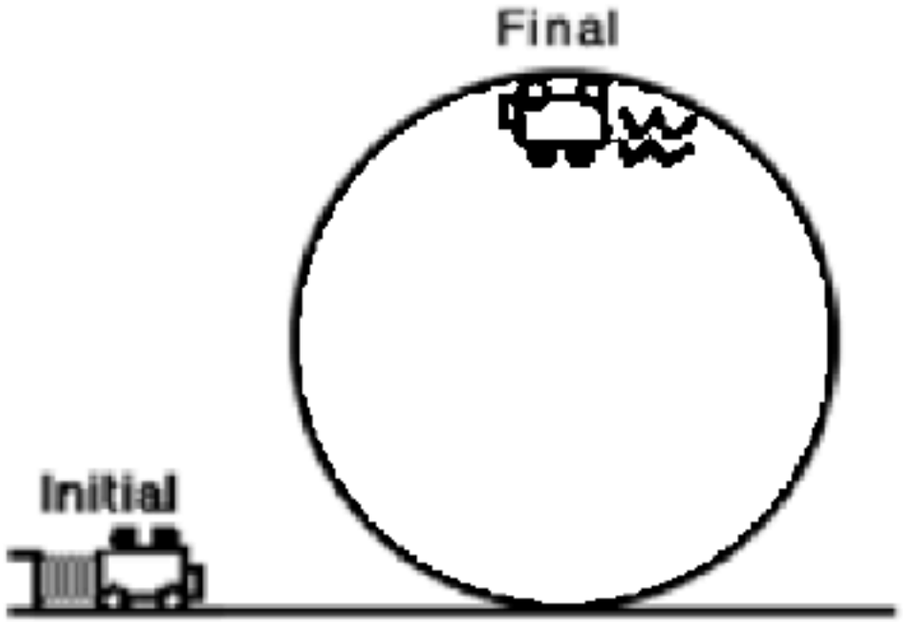


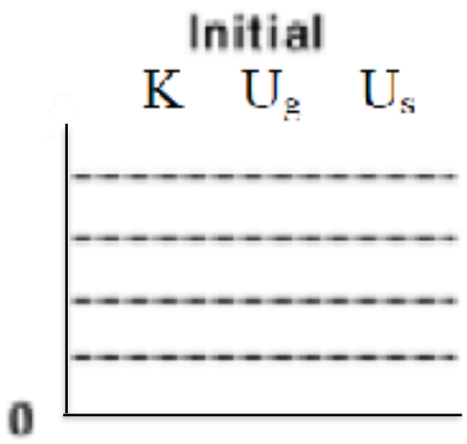


Energy Flow Diagram

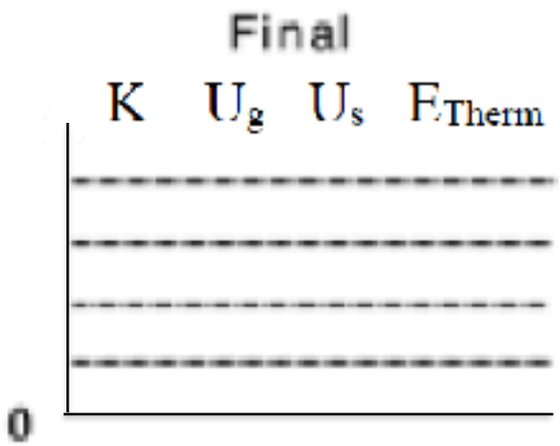


Energy Bar Graphs WS

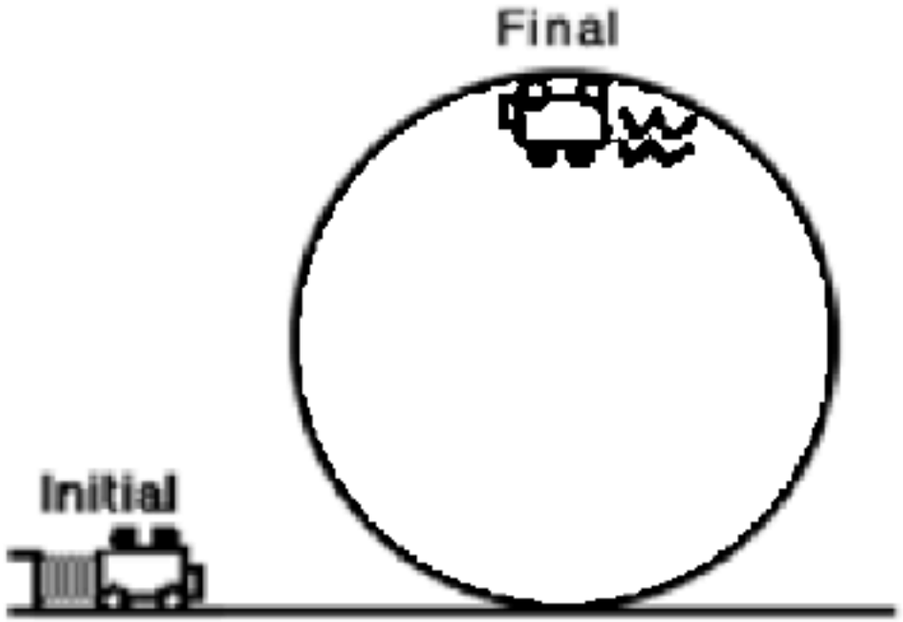


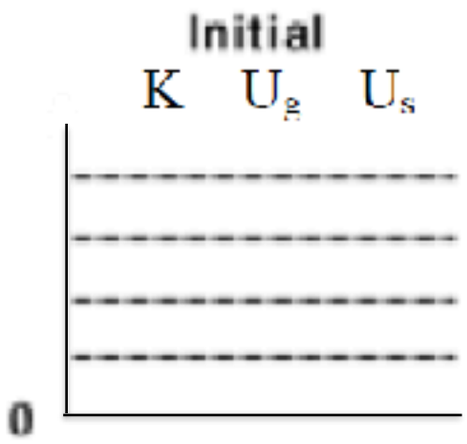


Energy Flow Diagram

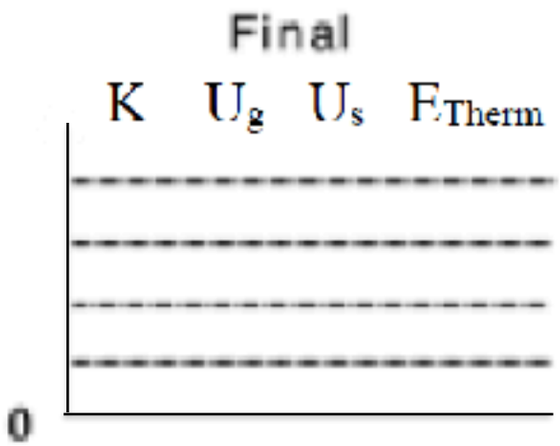


Energy Bar Graphs WS



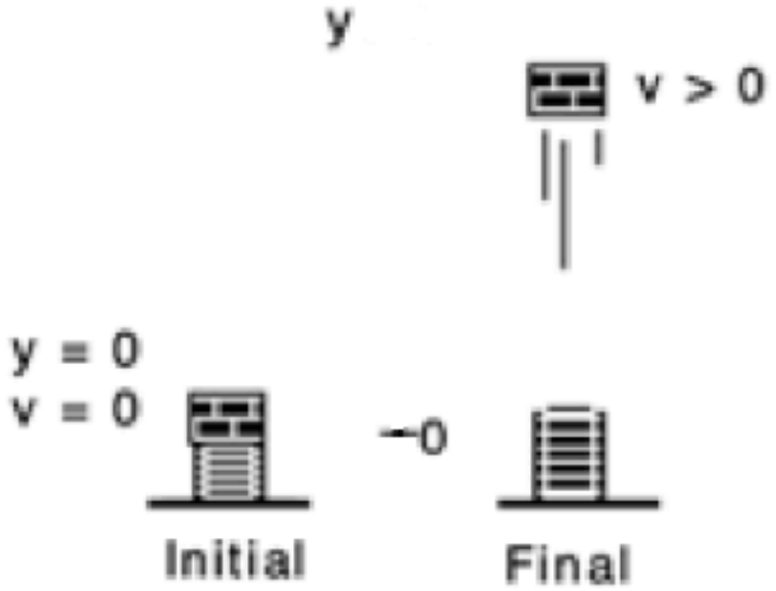


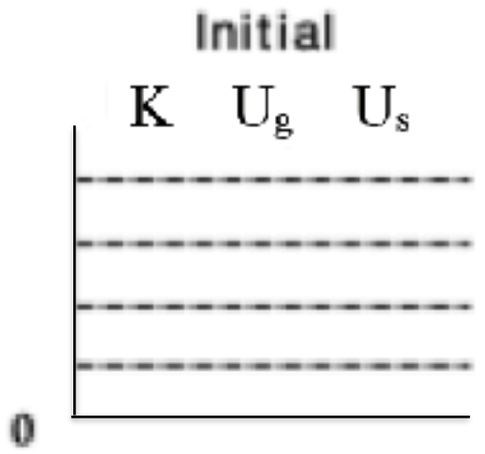
Energy Flow Diagram



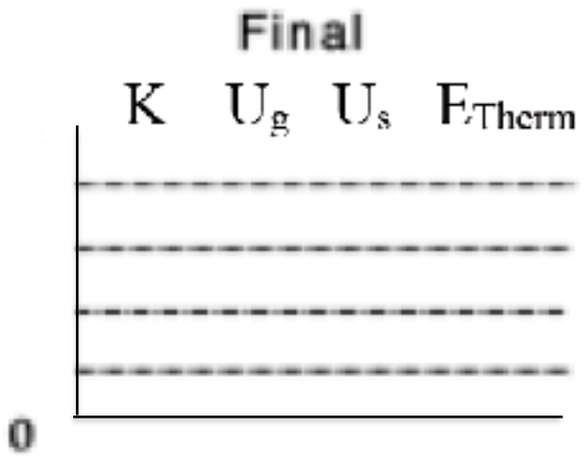
Energy Bar Graphs WS

5. A load of bricks rests on a tightly coiled spring, and then is launched into the air.



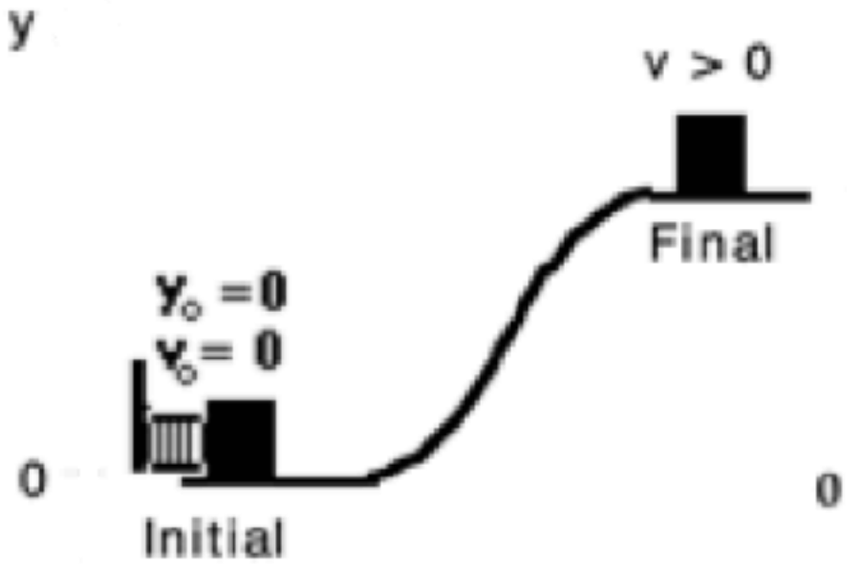


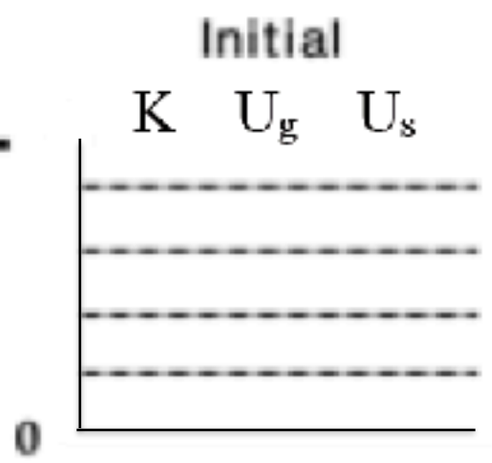
Energy Flow Diagram



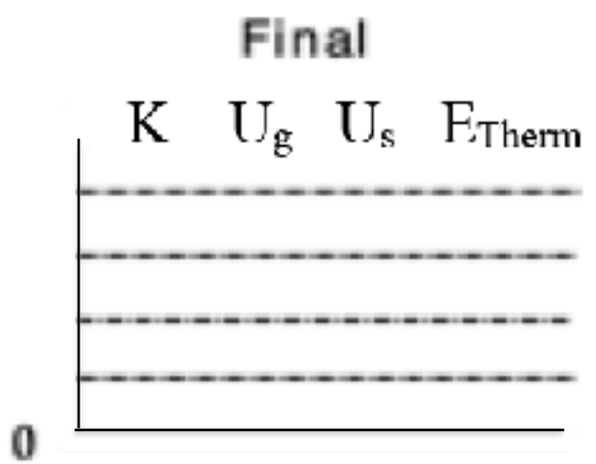
Energy Bar Graphs WS

6. A crate is propelled up a hill by a tightly coiled spring.



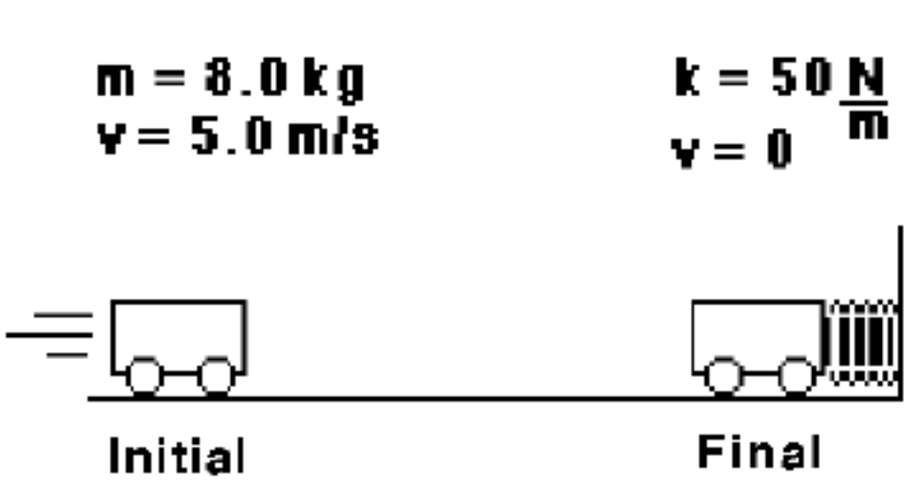


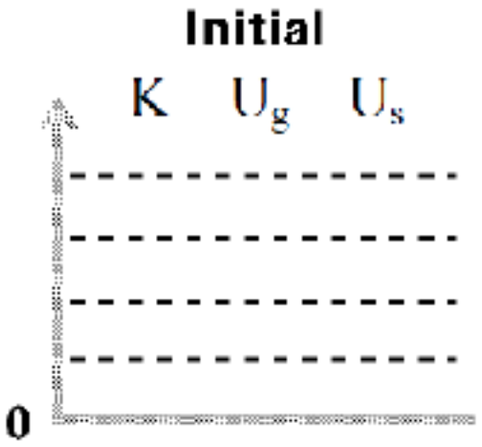
Energy Flow Diagram



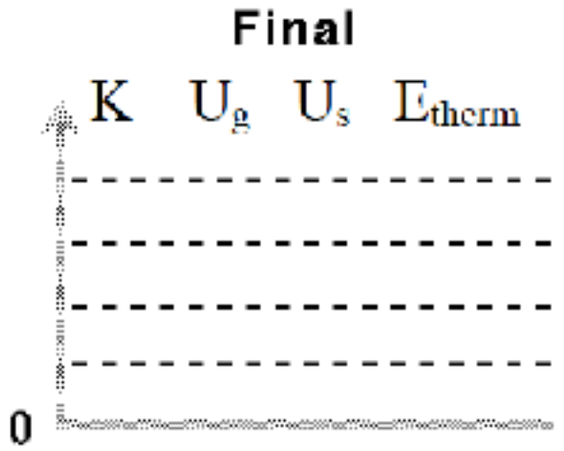
Energy Bar Graphs WS

1. A moving cart hits a spring, traveling at 5.0 m/s at the time of contact. At the instant the cart is motionless, by how much is the spring compressed?



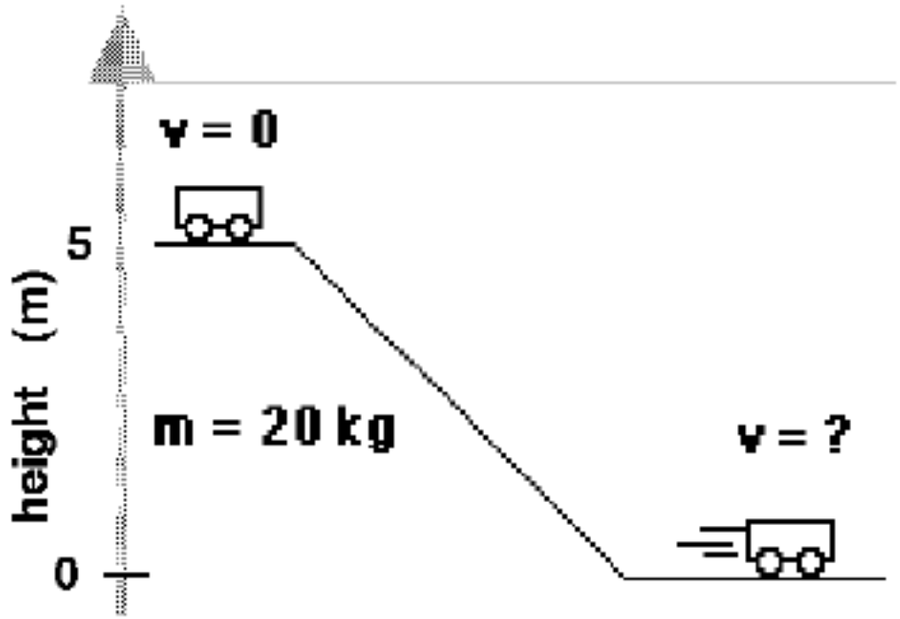


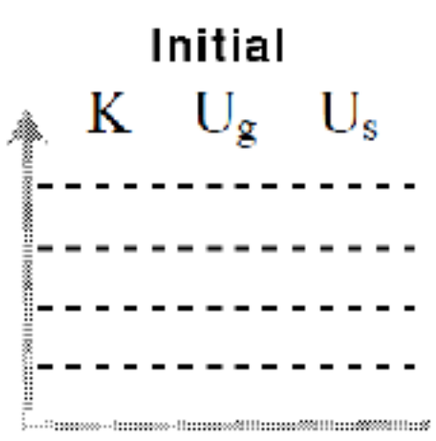
Energy Flow Diagram



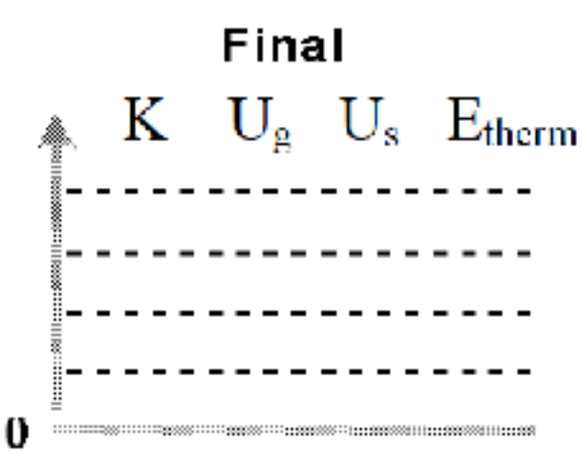
Day 2 Folder: Energy Bar Graphs WS

3. Determine the final velocity of the cart, assuming that **20%** of the energy is dissipated by friction.





Energy Flow Diagram

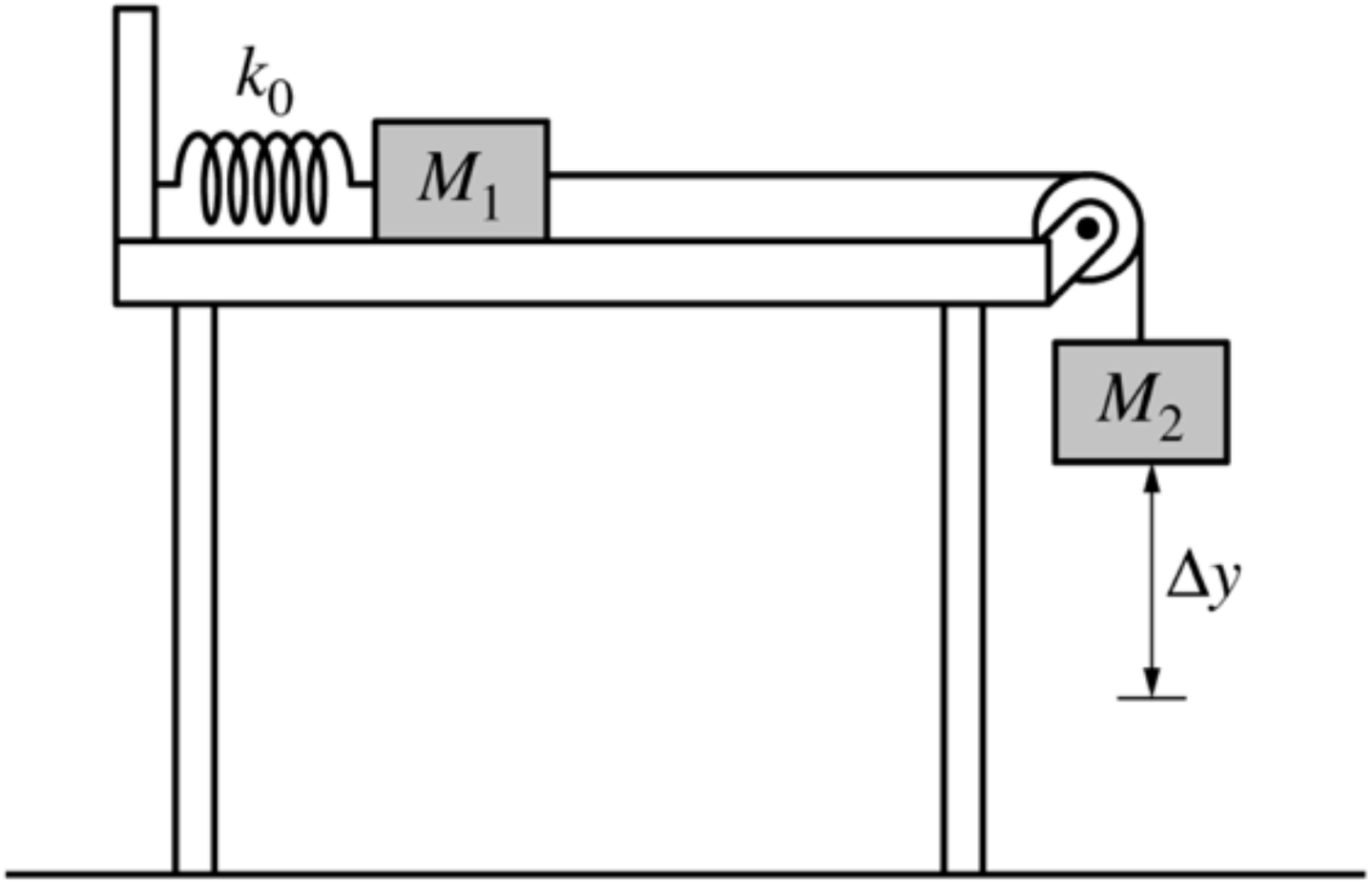


Energy Bar Graph MCQ: 2017 IPE

4. A rubber ball with mass 0.20 kg is dropped vertically from a height of 1.5 m above a floor. The ball bounces off of the floor, and during the bounce 0.60 J of energy is dissipated. What is the maximum height of the ball after the bounce?

(A) 0.30 m
(B) 0.90 m
(C) 1.2 m
(D) 1.5 m

AP Physics 1 2022 Exam FRQ #1



Consider the system that includes the spring, Earth, both blocks, and the string, but not the surface. Let the initial state be when the blocks are at rest just before they start moving, and let the final state be when the blocks first come momentarily to rest. Diagram A at left below is a bar chart that represents the energies in the scenario where there is negligible friction between block 1 and the surface.

The shaded-in bars in the energy bar charts represent the potential energy of the spring and the gravitational potential energy of the blocks-Earth system, U_s and U_g, respectively, in the initial and final states. Positive energy values are above the zero-point line ("0") and negative energy values are below the zero-point line.

Diagram A: Negligible Friction

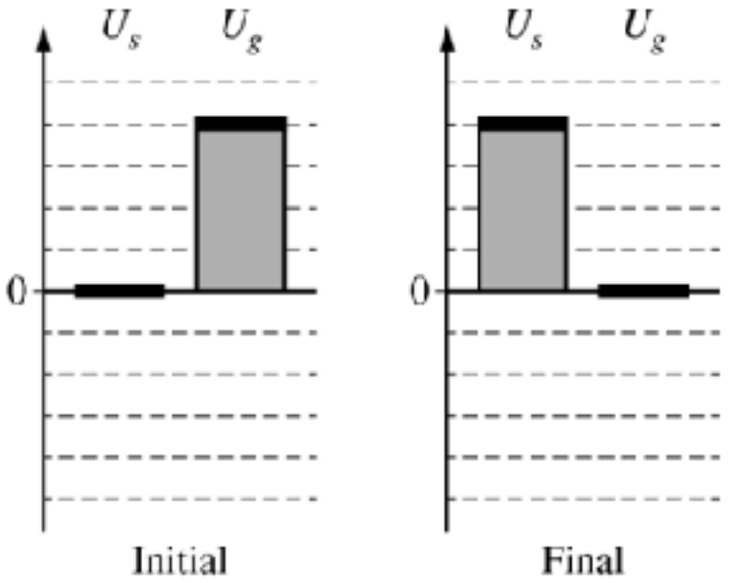
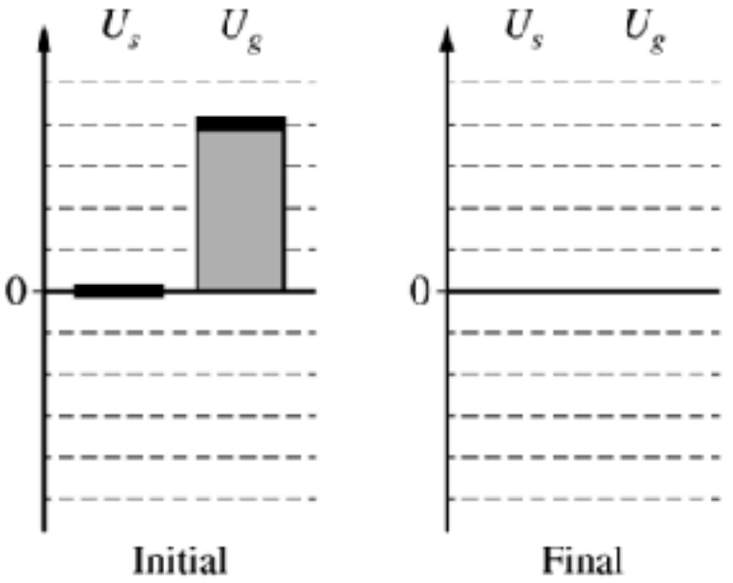


Diagram B: Nonnegligible Friction



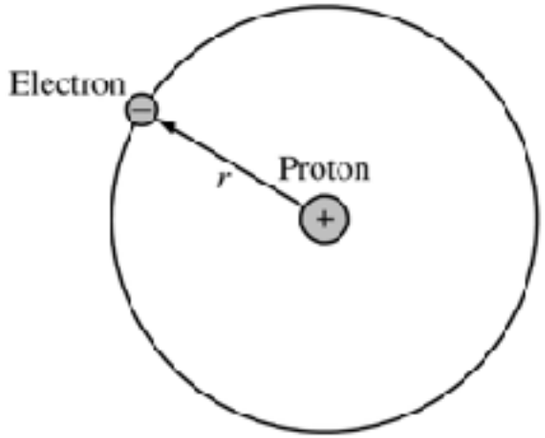
(c) Complete diagram B (at right above) for the scenario in which friction is nonnegligible. The energies for the initial state are already provided. Shade in the energies in the final state using the same scale as in diagram A.

- Shaded regions should start at the solid line representing the zero-point line.
- Represent any energy that is equal to zero with a distinct line on the zero-point line.

AP Physics 2 2022 Exam FRQ #3

AP® Physics 2 2022 Free-Response Questions

Begin your response to **QUESTION 3** on this page.



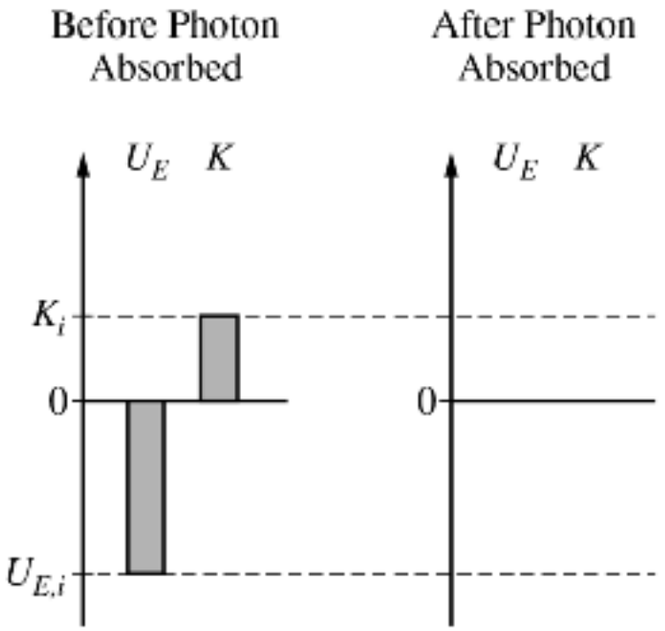
Note: Figure not drawn to scale.

3. (12 points, suggested time 25 minutes)

A hydrogen atom can be modeled as an electron in a circular orbit of radius r about a stationary proton, as shown above. The gravitational force between the proton and electron is negligible compared to the electrostatic force between them.

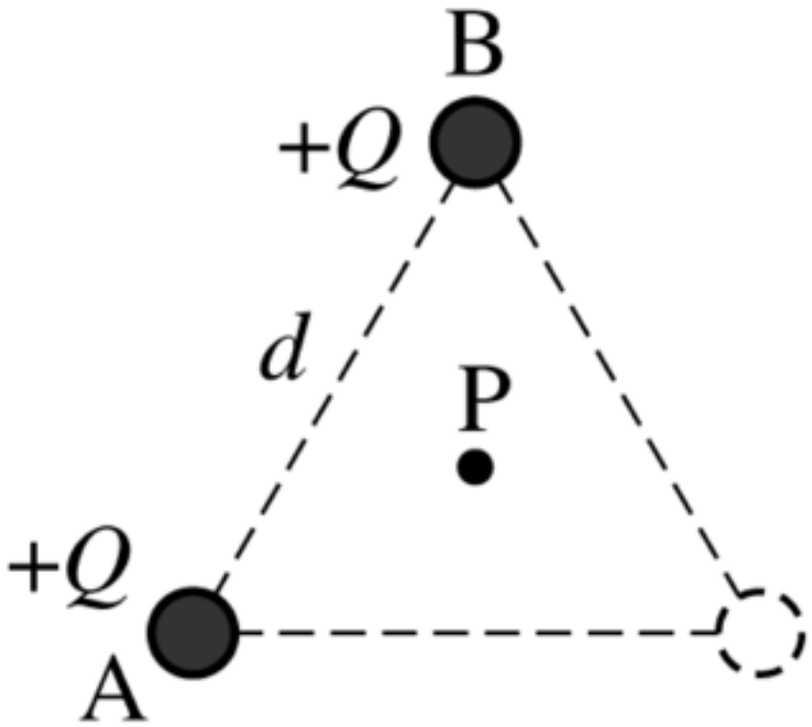
(a) Derive an equation for the speed v of the electron in terms of r and physical constants, as appropriate.

AP Physics 2 2022 Exam FRQ #3

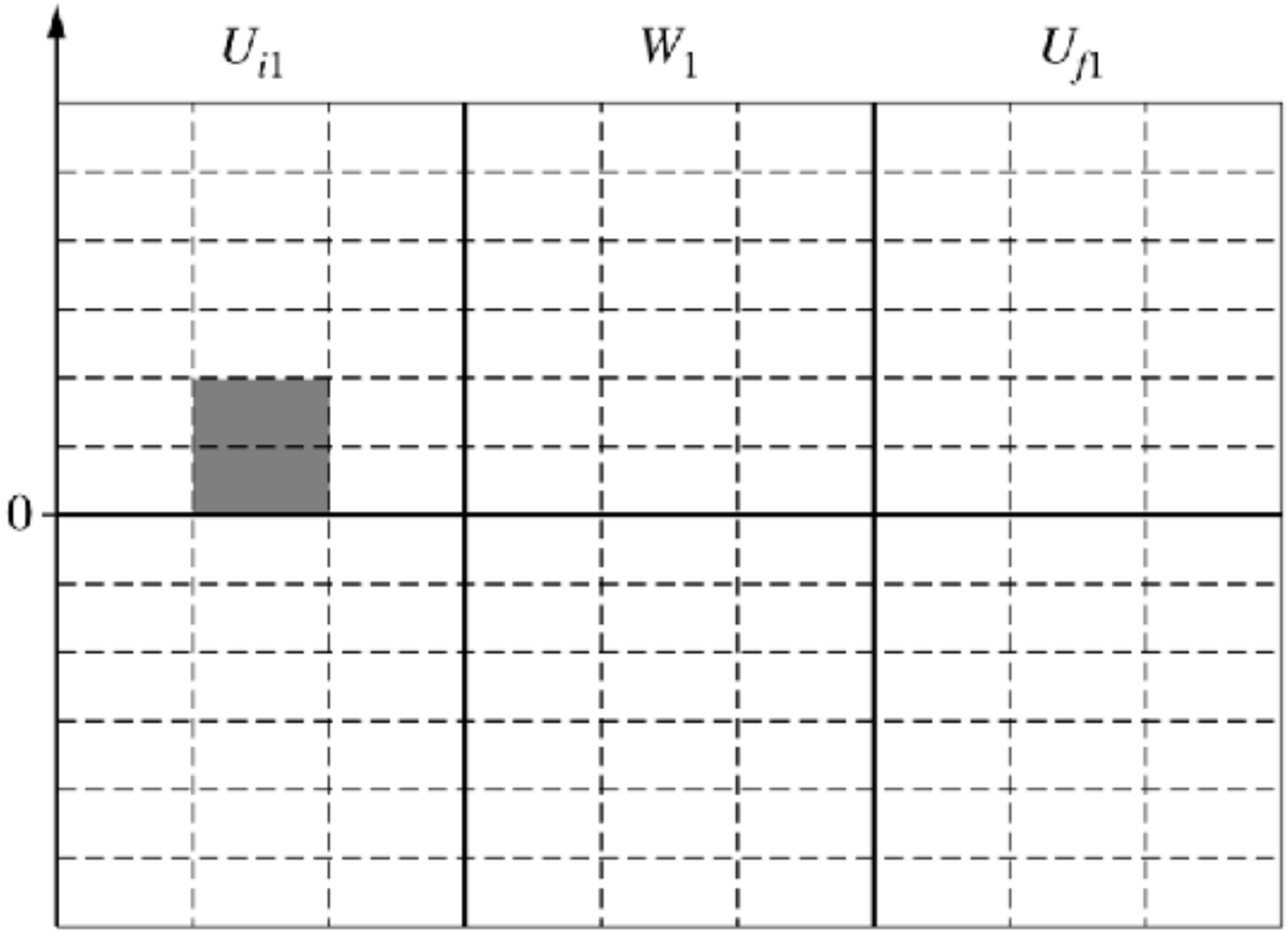


iii. The left bar chart in the figure above is complete and represents the initial electric potential energy $U_{E,i}$ of the atom and the initial kinetic energy K_i of the electron before the photon is absorbed. In the space provided on the right, draw a bar chart to represent a possible final electric potential energy of the atom and final kinetic energy of the electron.

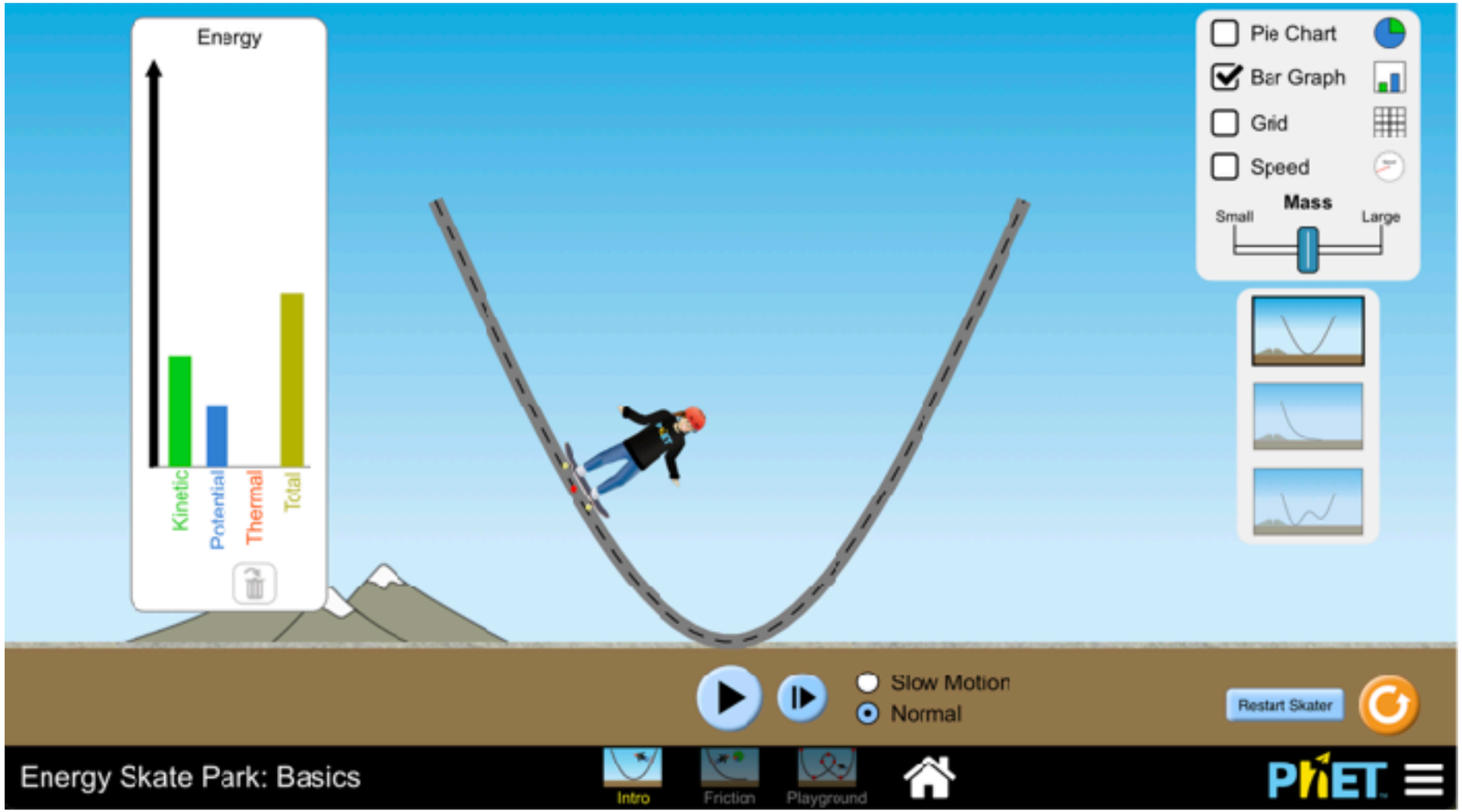
AP Physics 2 2023 Exam FRQ #4



AP Physics 2 2023 Exam FRQ #4

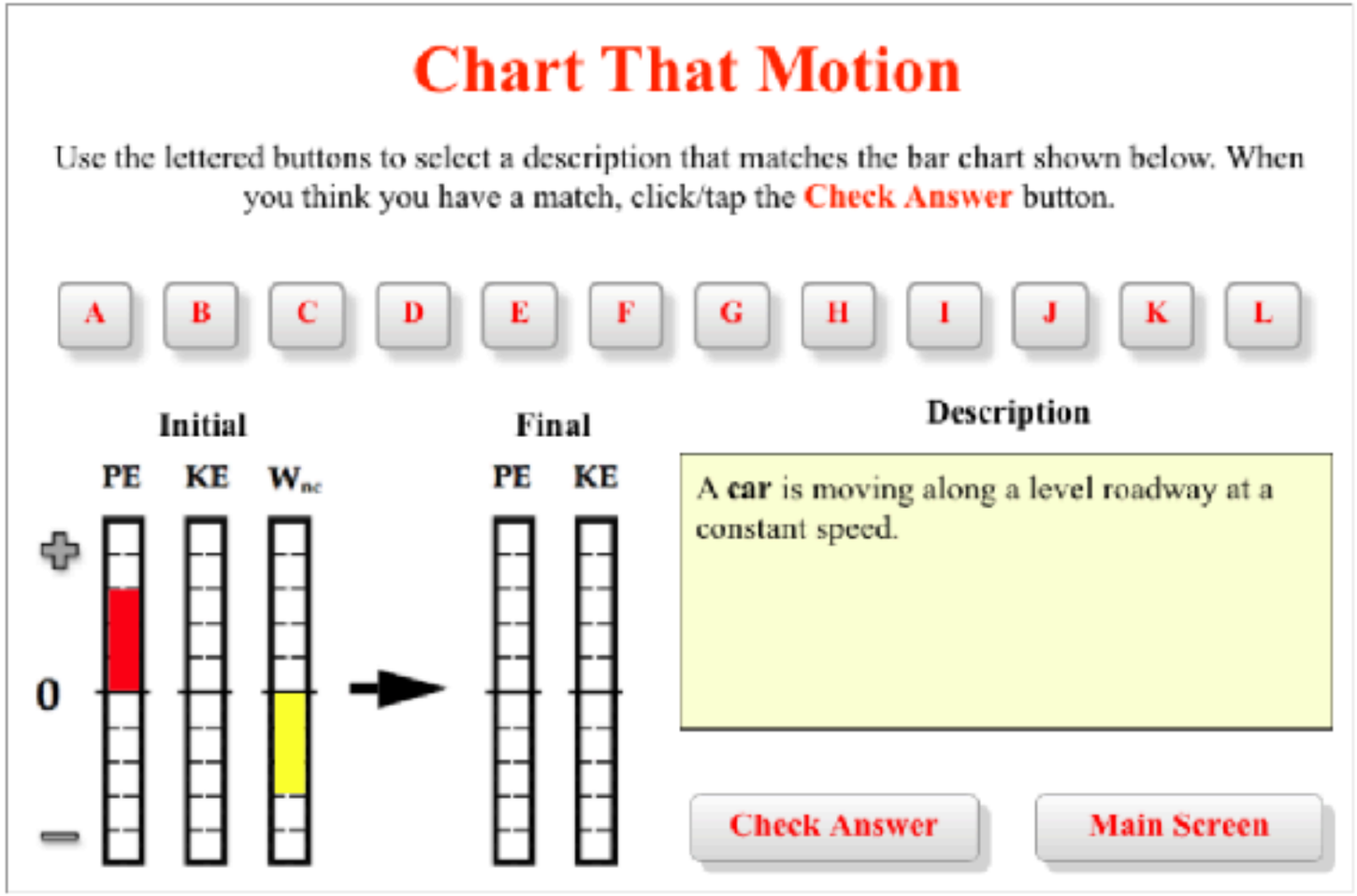


PhET: Energy Skate Park



Access the Simulation at: https://phet.colorado.edu/sims/html/energy-skate-park/latest/energy-skate-park_en.html

The Physics Classroom



Access the Simulation at: https://www.physicsclassroom.com/Physics-Interactives/Work-and-Energy/Work-Energy-Bar-Charts/Work-Energy-Bar-Charts-Interactive

NEXT-TIME QUESTION

CONCEPTUAL Physics

Two oppositely charged particles, an alpha particle with 2 positive charges and a less-massive electron with a single negative charge are attracted to each other. Compared to the force that the alpha particle exerts on the electron, the electron exerts a force on the alpha particle that is

a) greater. b) the same. c) less.

The particle with the most acceleration is the

d) alpha particle. e) electron. c) same for each.

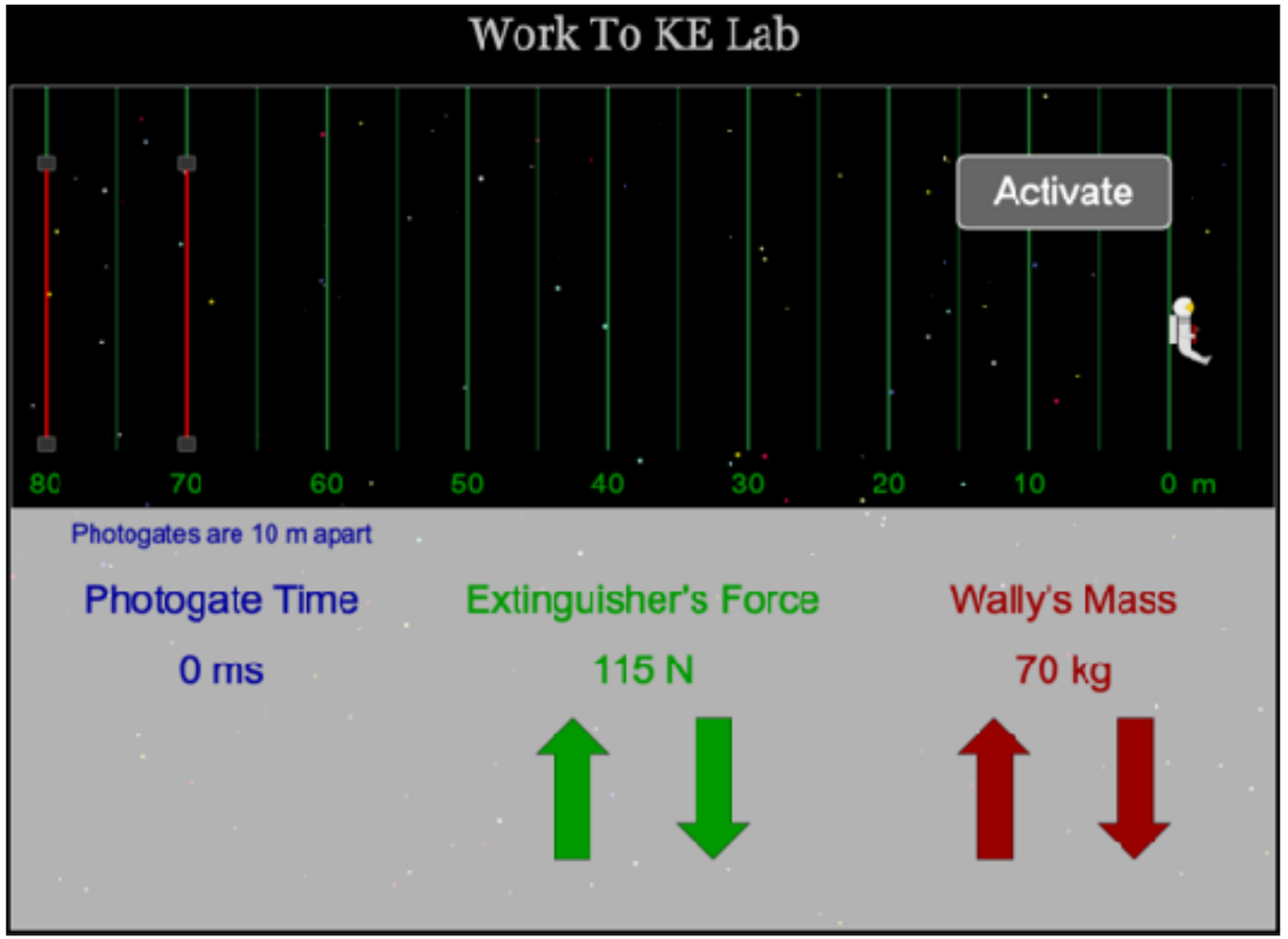
As the particles get closer to each other, each experiences an <u>increase</u> in

g) force. h) speed. i) acceleration.
j) all of the above. k) none of the above.

ARBOR SCIENTIFIC
TOOLS THAT TEACH.

Hewitt Drew it!

The Physics Aviary

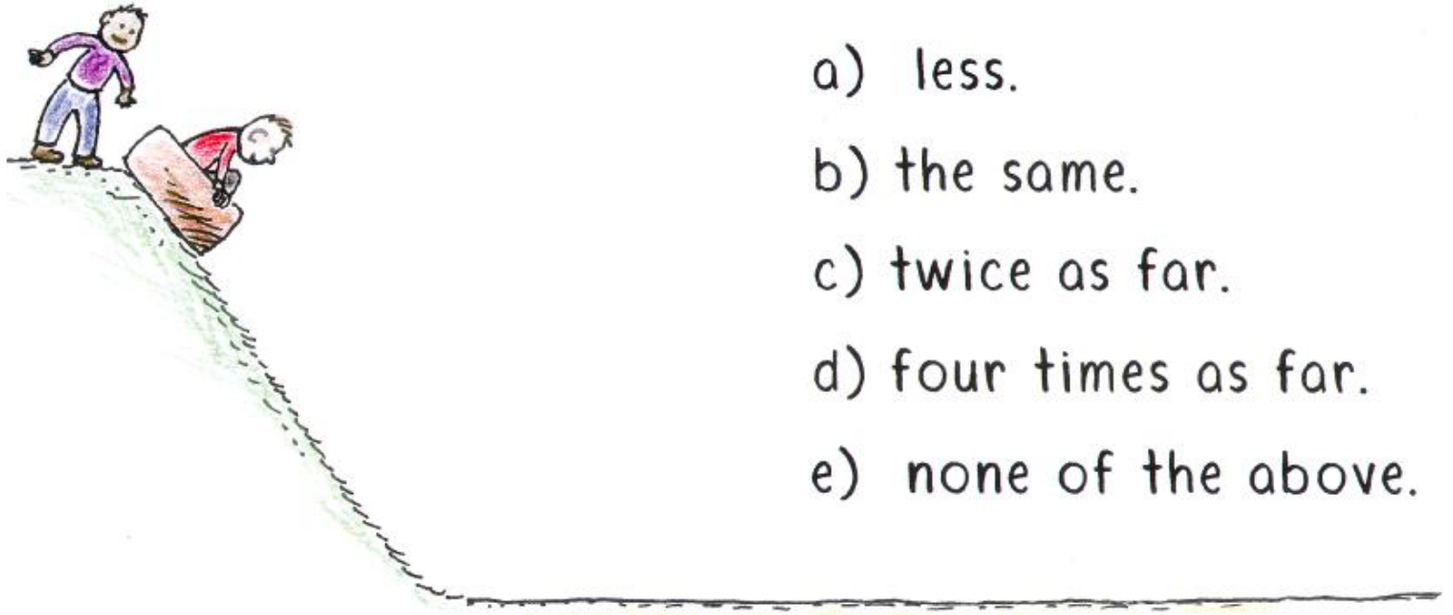


Access the Simulation at: https://www.thephysicsaviary.com/Physics/Programs/Labs/WorkToKELab/

NEXT-TIME QUESTION

CONCEPTUAL Physics

Little Larry slides down an icy grass slope in a cardboard box and skids to a stop across the flat ground. If Larry's friend were also in the box, giving it twice the mass and starting from the same height, the skidding distance would be



a) less.

b) the same.

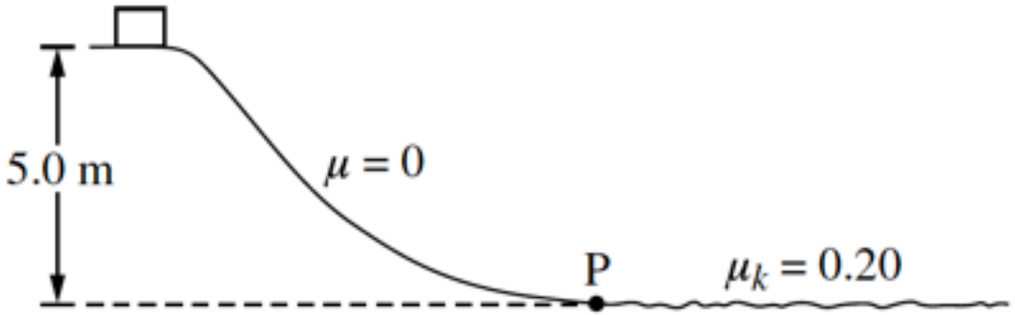
c) twice as far.

d) four times as far.

e) none of the above.

ARBOR SCIENTIFIC
TOOLS THAT TEACH.

Hewitt Drew it!



1. A block is released from rest and slides down a track with negligible friction, descending a vertical distance of 5.0 m from its initial position to Point P, as shown in the figure. The block then slides on a horizontal surface where the coefficient of kinetic friction μ_k between the block and the horizontal surface is 0.20. How far does the block slide on the horizontal surface before coming to rest?

(A) 1.0 m

(B) 5.0 m

(C) 10 m

(D) 25 m

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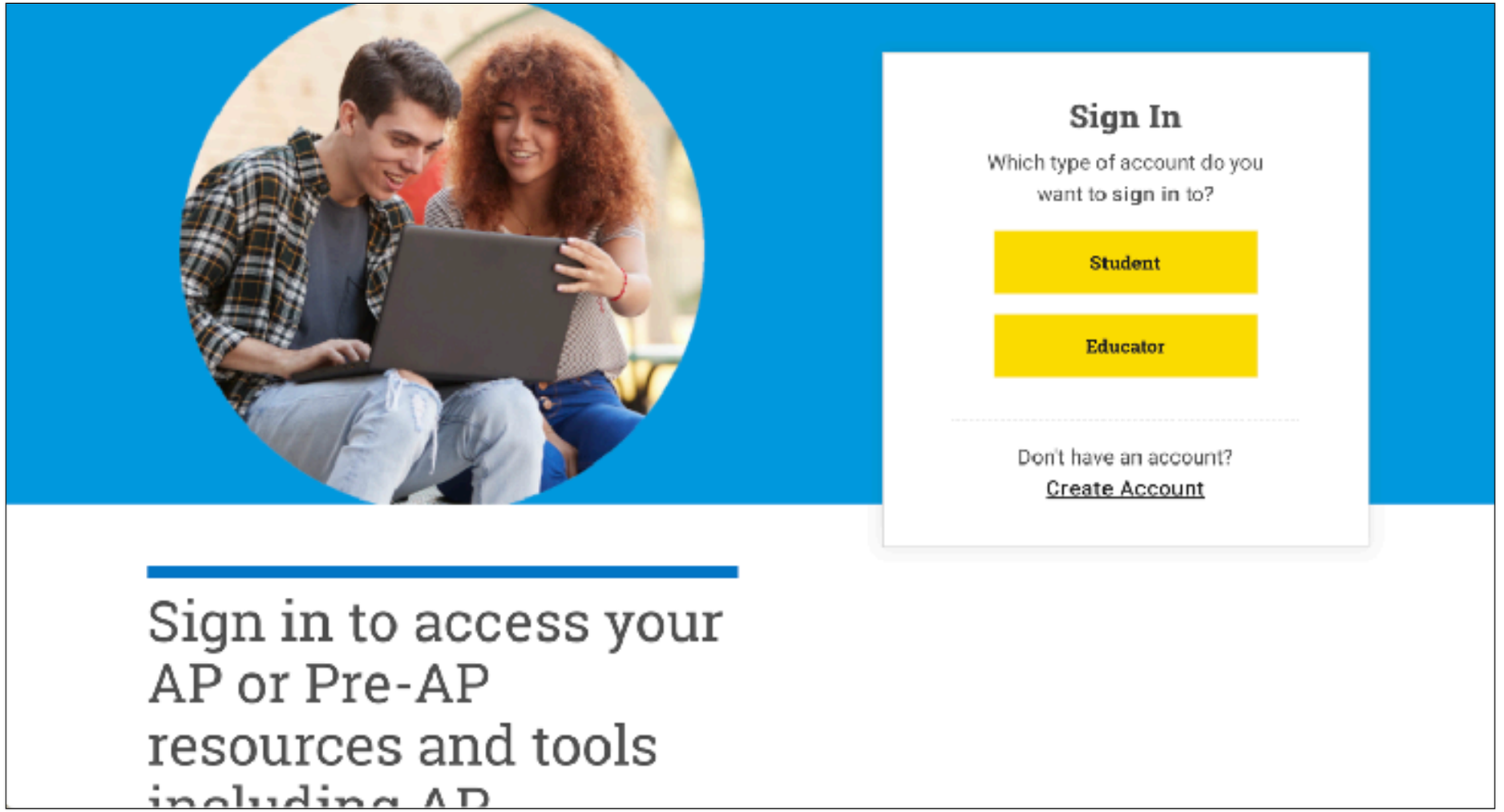
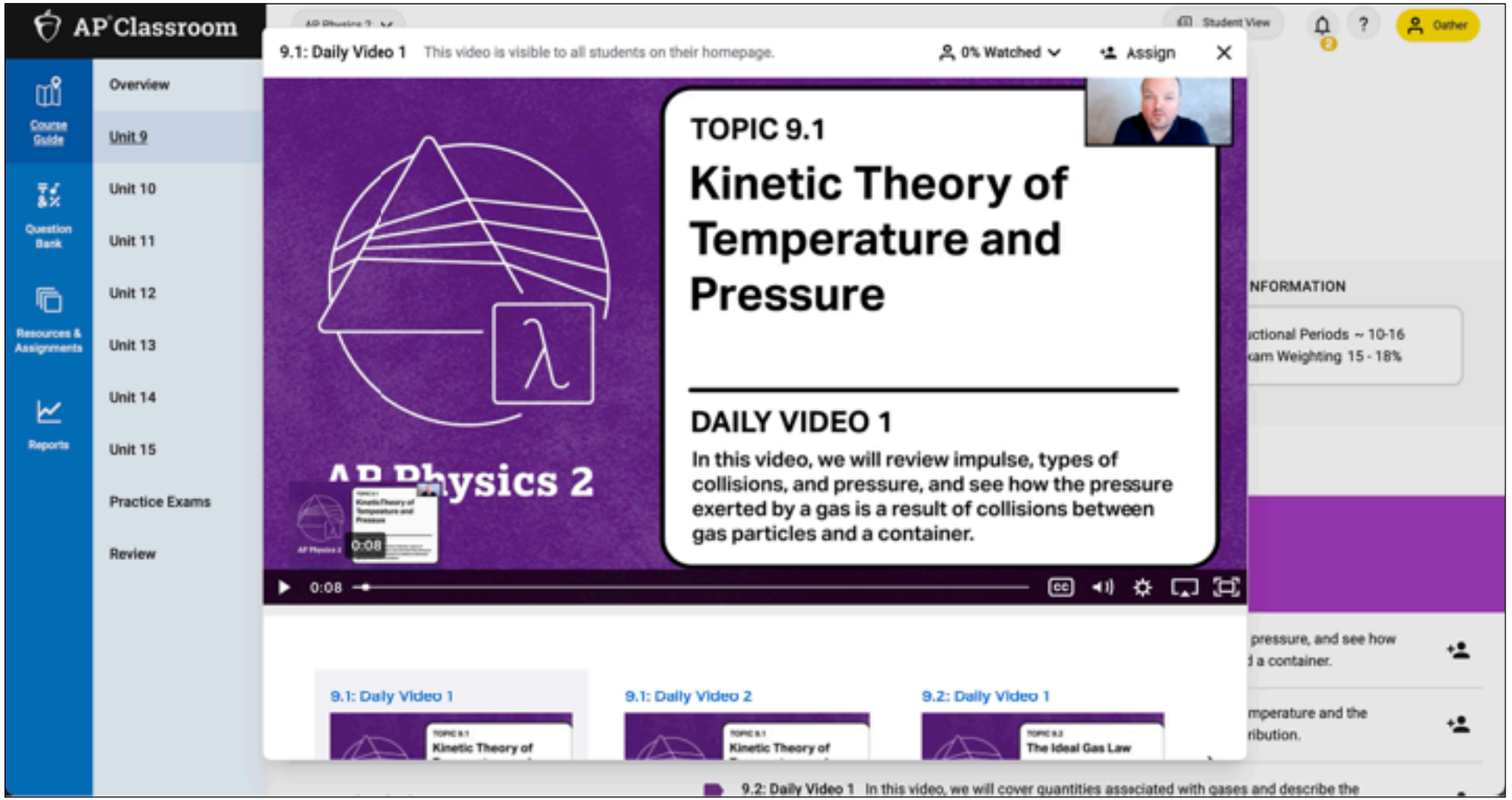
AP Classroom

Consistent use increases AP score by 1 full point!!!

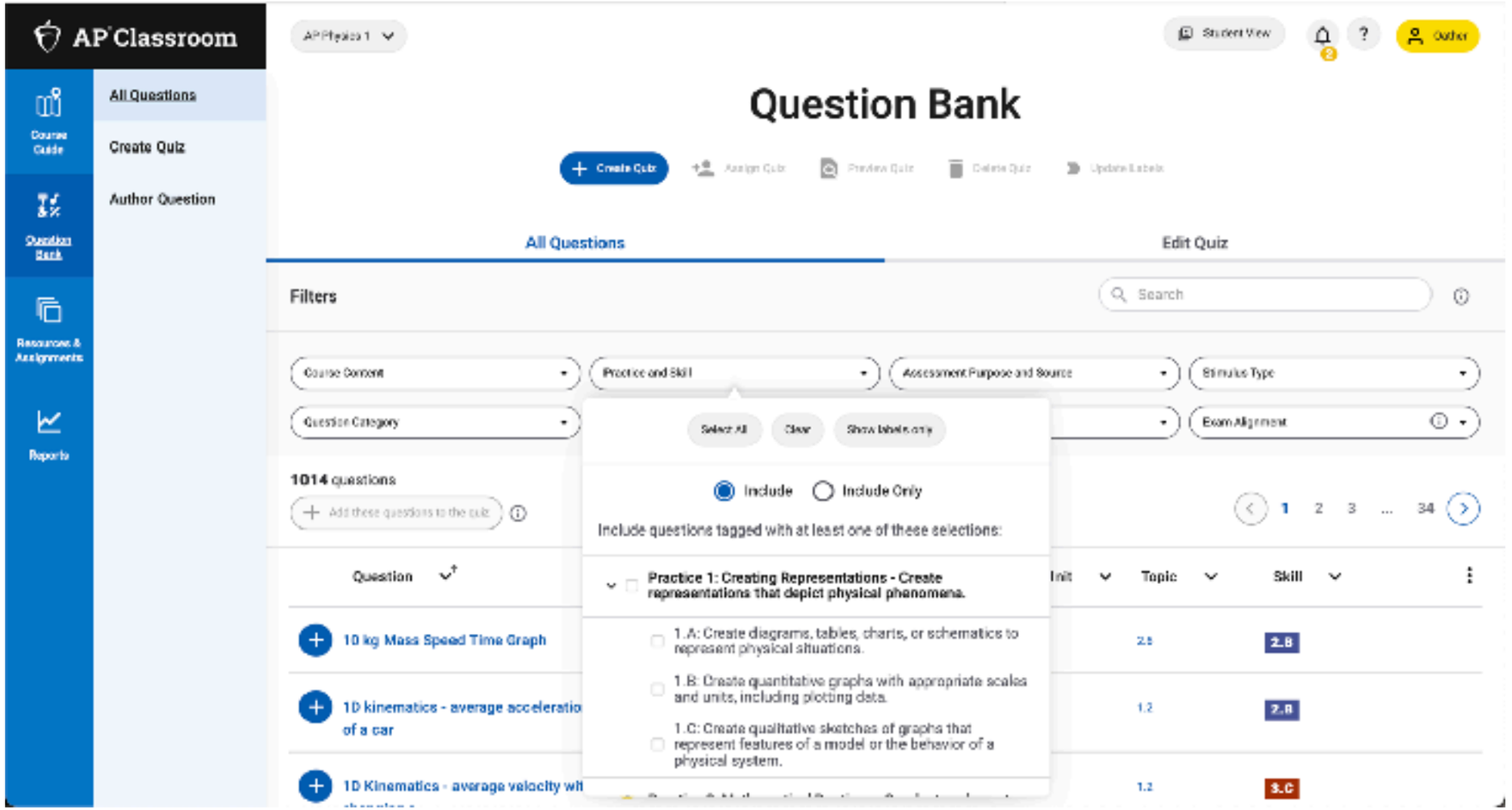
MyAP.CollegeBoard.org



AP Classroom - AP Daily Videos: AP Physics 2



AP Classroom - Question Bank: AP Physics 1



AP Educators YouTube Channel

CollegeBoard

Qualitative / Quantitative Translation

FRQ #4 - 8 points

Qualitative/Quantitative Translation Tasks

- Find Question #4 the QQT FRQ
- P1 page 198
- P2 page 208

- Read through the CED QQT FRQ and the Practice Exam QQT FRQ linked in the agenda and identify what tasks they ask students to do
- Recored how many points per part

QQT
FRQ
FRQ #4

Qualitative/Quantitative Translation FRQ

The Qualitative/Quantitative Translation (QQT) question assesses students' ability to connect the nature of the scenario, the physical laws that govern the scenario, and mathematical representations of that scenario to each other.

(a) Students will be asked to **make and justify a claim** about a given scenario. (3 pts)

(b) Students will then be asked to **derive an equation** related to that scenario. (3 pts)

(c) Finally, students will be asked to **do any one of the following**: (2 pts)

- Justify why their answers to the previous parts do *(do not)* agree with each other.
- Use their representations or mathematical analysis to make a prediction about another situation and justify their prediction using that reasoning or analysis.
- Use their representations and mathematical analysis to make a prediction about how those representations would change if properties of the scenario were altered and justify that claim using consistent reasoning or analysis.

ERC

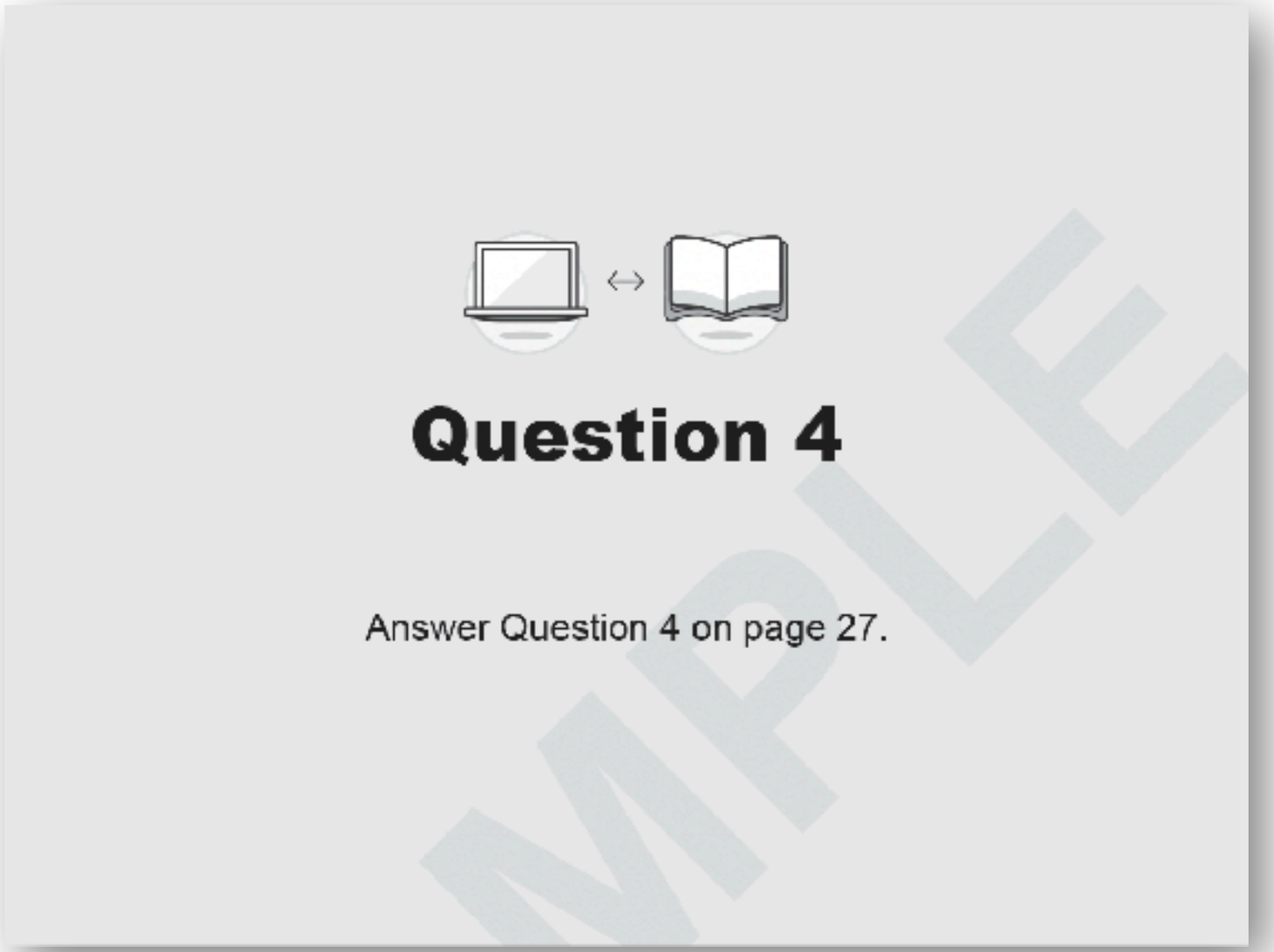
Evidence

Reasoning

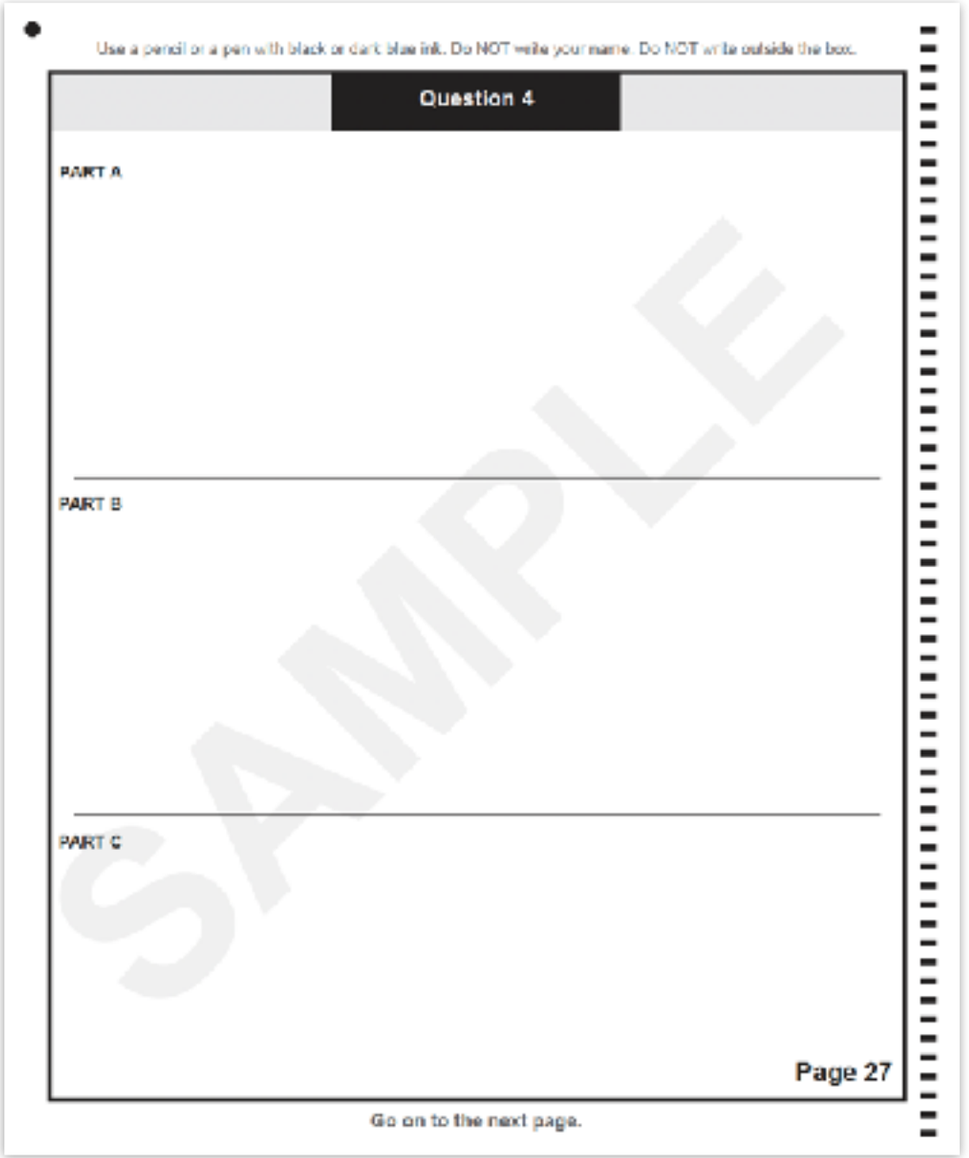
Claim

- **Evidence**: information from the question or event description
- **Reasoning**: using Physics principles to synthesize your evidence into your Claim
- **Claim**: short statement that answers the question

FRQ Booklet: Which Version?



FRQ Booklet Structure: Question #4 QQT



Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 4

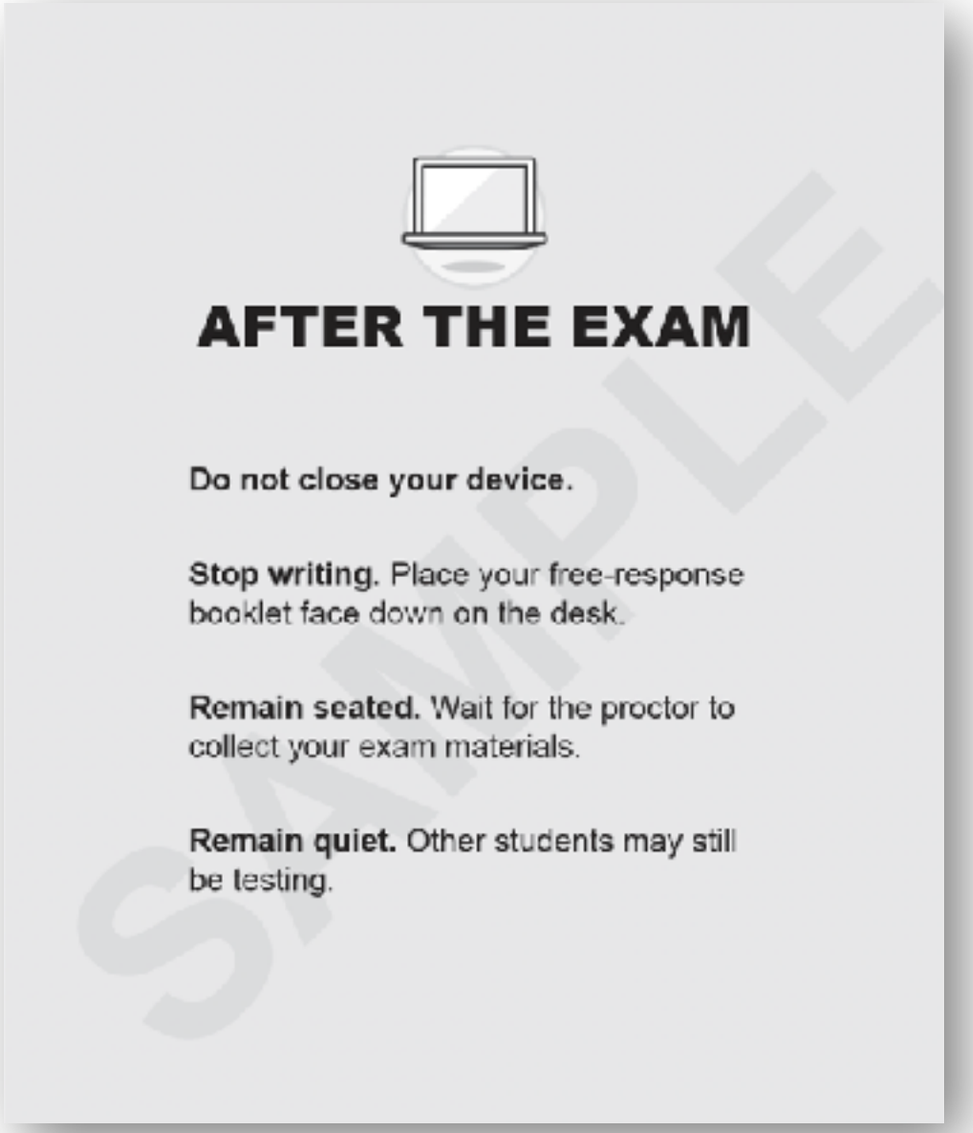
PART A

PART B

PART C

SAMPLE

Last Question…Now What?



AFTER THE EXAM

Do not close your device.

Stop writing. Place your free-response booklet face down on the desk.

Remain seated. Wait for the proctor to collect your exam materials.

Remain quiet. Other students may still be testing.

SAMPLE

QQT Skills: 2.A 2.D 3.B 3.C

Practice 1	Practice 2	Practice 3
Creating Representations 1 Create representations that depict physical phenomena.	*Mathematical Routines* 2 Conduct analyses to derive, calculate, estimate, or predict.	*Scientific Questioning and Argumentation* 3 Describe experimental procedures, analyze data, and support claims.
SKILLS		
1.A Create diagrams, tables, charts, or schematics to represent physical situations.	2.A Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.	3.A Create experimental procedures that are appropriate for a given scientific question.
1.B Create quantitative graphs with appropriate scales and units, including plotting data.	2.B Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.	3.B Apply an appropriate law, definition, theoretical relationship, or model to make a claim.
1.C Create qualitative sketches of graphs that represent features of a model or the behavior of a physical system.	2.C Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.	3.C Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.
	2.D Predict new values or factors of change of physical quantities using functional dependence between variables.	

P1 2025

QUESTION 4 QUALITATIVE QUANTITATIVE TRANSLATION (QQT)	8		4.6
QQT PART A POINT 1	1		0.7
QQT PART A POINT 2	1		0.3
QQT PART A POINT 3	1		0.5
QQT PART B POINT 1	1		0.7
QQT PART B POINT 2	1		0.7
QQT PART B POINT 3	1		0.4
QQT PART C POINT 1	1		0.7
QQT PART C POINT 2	1		0.6

P2 2025

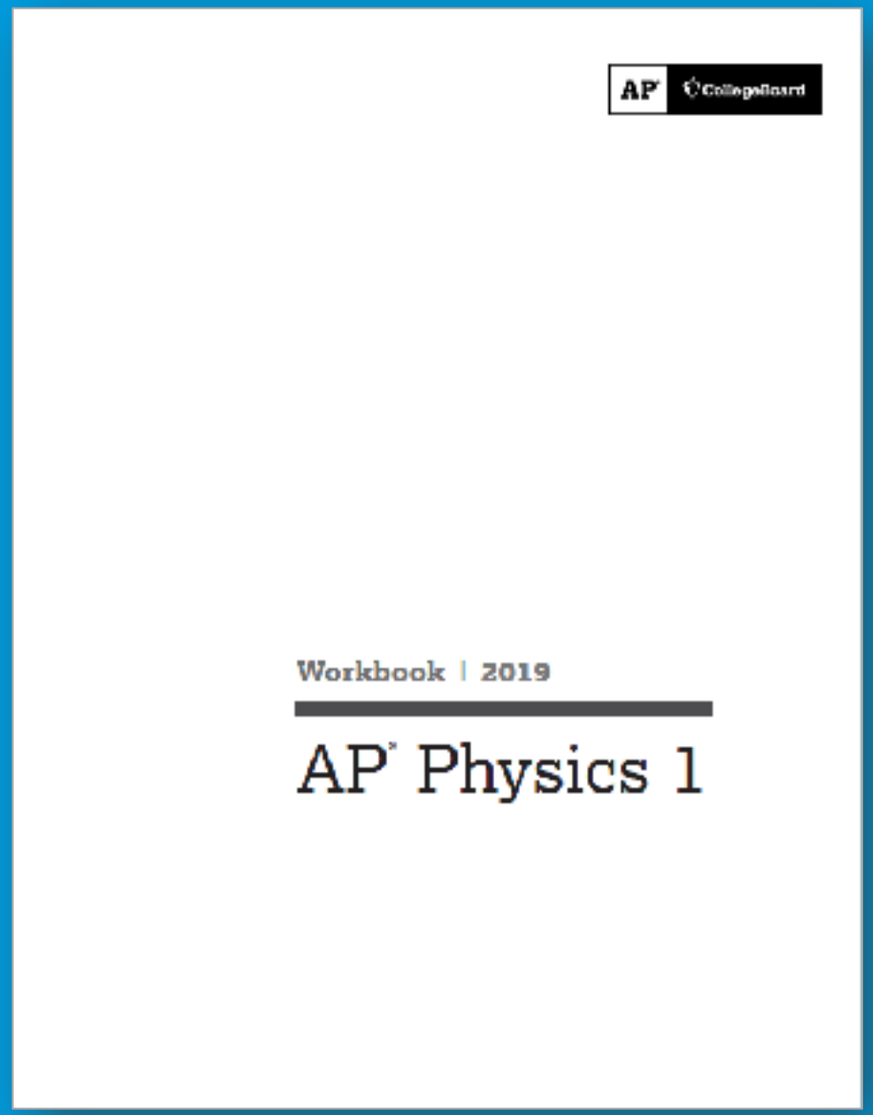
QUESTION 4 QUALITATIVE QUANTITATIVE TRANSLATION (QQT)	8		5.4
QQT PART A POINT 1	1		0.9
QQT PART A POINT 2	1		0.7
QQT PART A POINT 3	1		0.4
QQT PART B POINT 1	1		0.9
QQT PART B POINT 2	1		0.8
QQT PART B POINT 3	1		0.3
QQT PART C POINT 1	1		0.8
QQT PART C POINT 2	1		0.7

CollegeBoard

AP Physics 1:
Using the Student Workbook to Scaffold Content and Skill Instruction

Oather Strawderman

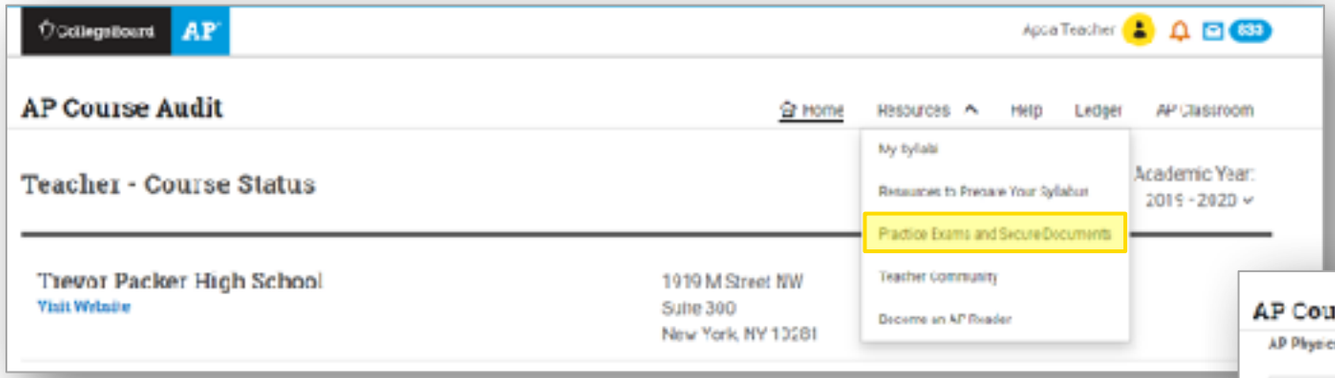
International Lead AP Physics Consultant



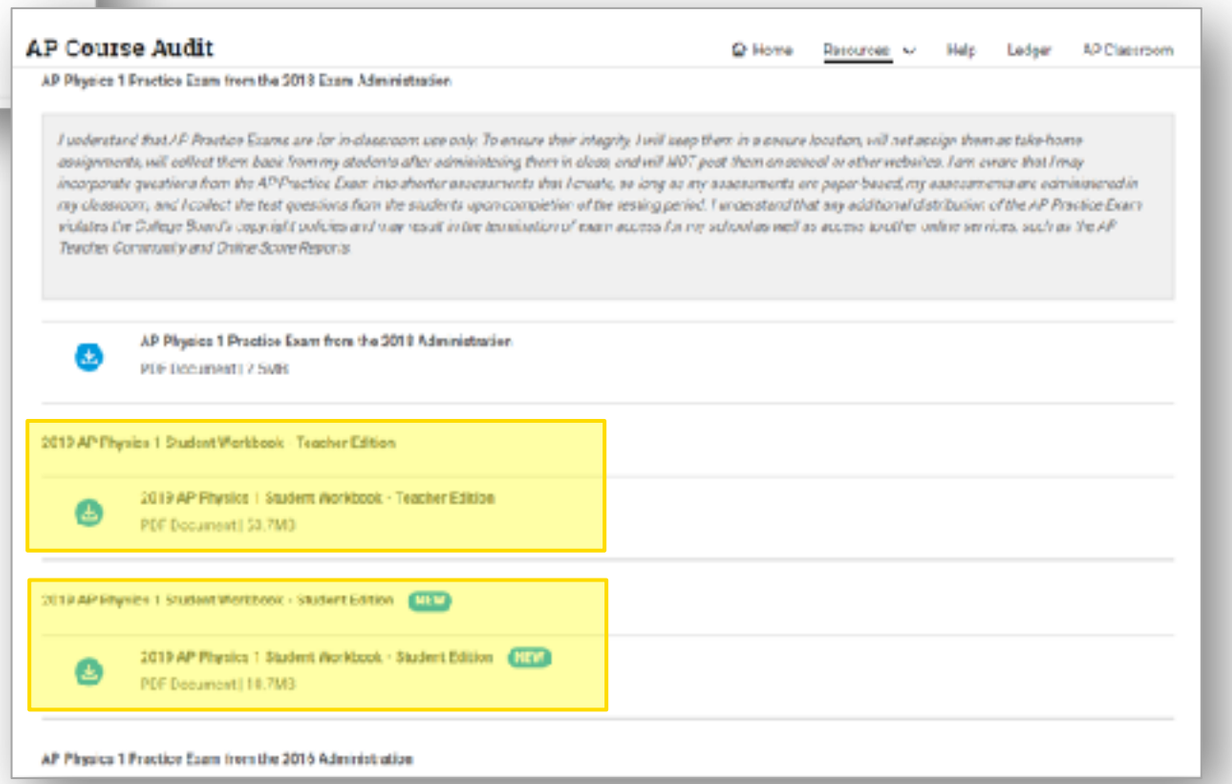
What is the Student Workbook?

- **Print** instructional resource, available as a digital PDF
- Developed by a team of experienced educators—from both high schools and higher education institutions—to help AP Physics 1 teachers **support students in their learning of college-level physics content and skills**
- Contains **159** individual scenarios, **aligned to specific units, essential knowledge statements, and science practices** from the AP Course and Exam Description (CED)
- Designed to guide students through the processes of **thinking about physics both conceptually and mathematically**, as well as **writing about physics**
- Includes an Appendix with a **summary of graphical methods** and specific **tips for writing in physics**

Where can I access it?



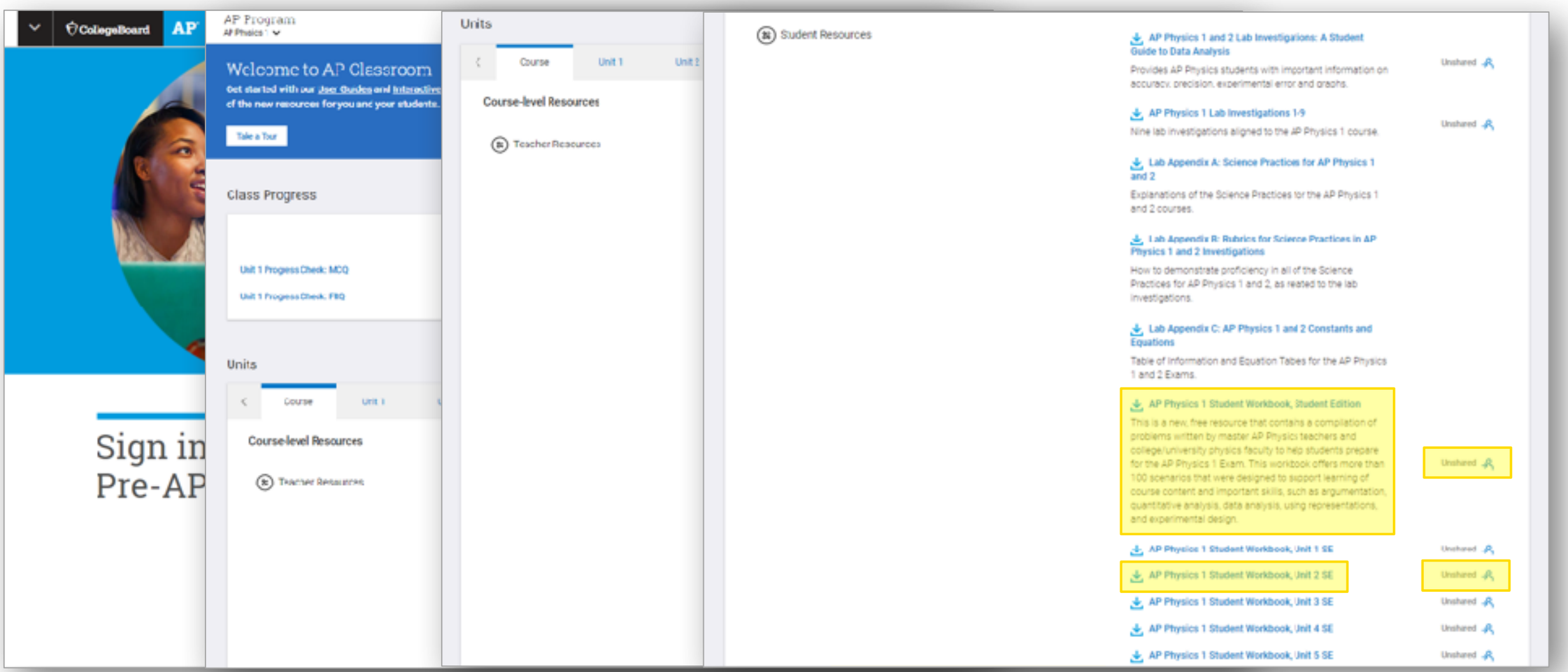
Option #1: AP Course Audit
apcentral.collegeboard.org/ap-course-audit

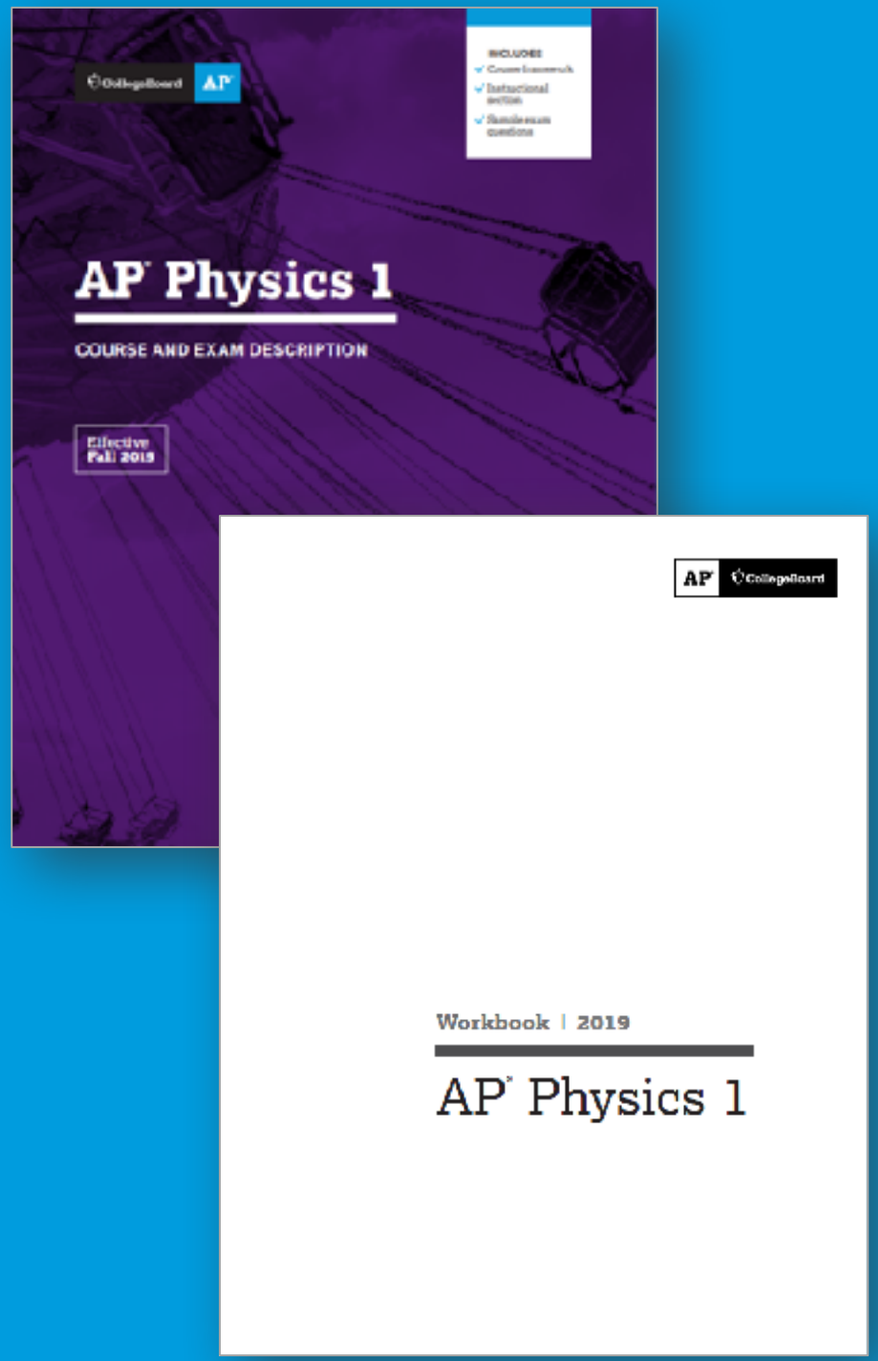


- You must be a course-authorized AP Physics 1 teacher to access the Student Workbook
- Student version may be printed and distributed to students
- Teacher version should not be shared with students

Where can I access it?

Option #2: AP Classroom
myap.collegeboard.org





Why did we make them?

- To **facilitate exploration** of the required course content and skills in the CED
- To **provide scaffolded skill instruction** and practice using the course Science Practices
- To **shift focus** from just mathematical understanding of physics to full conceptual understanding of physics
- To **support teachers in making connections** between course content and skills
- To **model strategies** that students can use on their own to support efficient study and true understanding

Scaffolded Approach

AP Physics 1 Student Workbook

How does it work?

- The units in the workbook are scaffolded so that students can learn the skills such as **argumentation**, **quantitative analysis**, and **data analysis**, alongside **course content**, so that they will be prepared for the AP Exam by May.
- As you read through the problems, you will see that the **scaffolding slowly falls away** as students progress from unit to unit. By Unit 10, students are expected to be able to demonstrate all skills without support.
- Teachers are encouraged to **modify the problems in the workbook as necessary**, so that they meet students' needs. If appropriate, consider adding your own scaffolding to the scenarios.

SCAFFOLDING

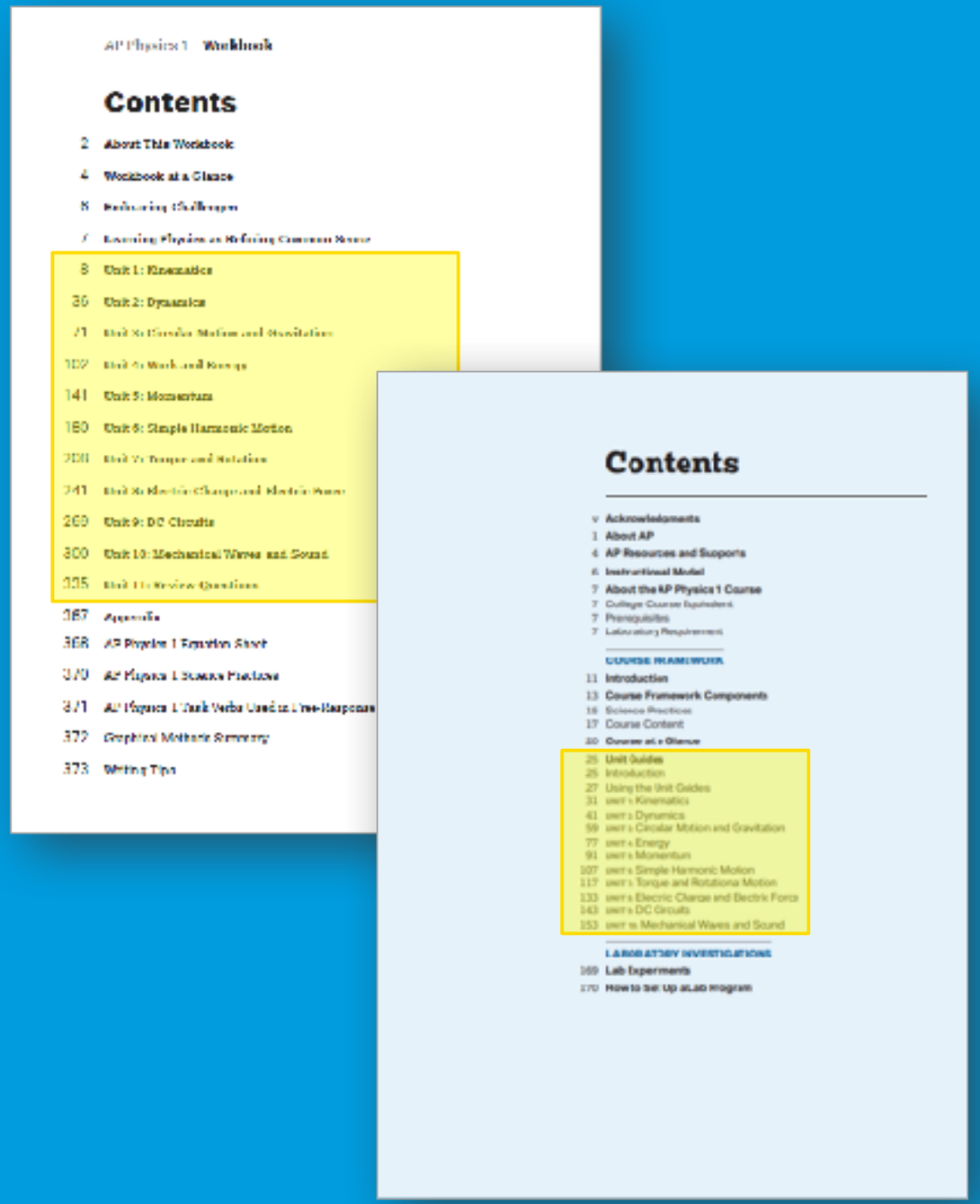
- Instructional technique used to move students progressively toward stronger understanding and, ultimately, greater independence in the learning process
- Provides success levels of temporary support that help students reach higher levels of content comprehension and skill acquisition
- Supports are incrementally removed when they are no longer needed, as the student gradually takes additional ownership of their learning

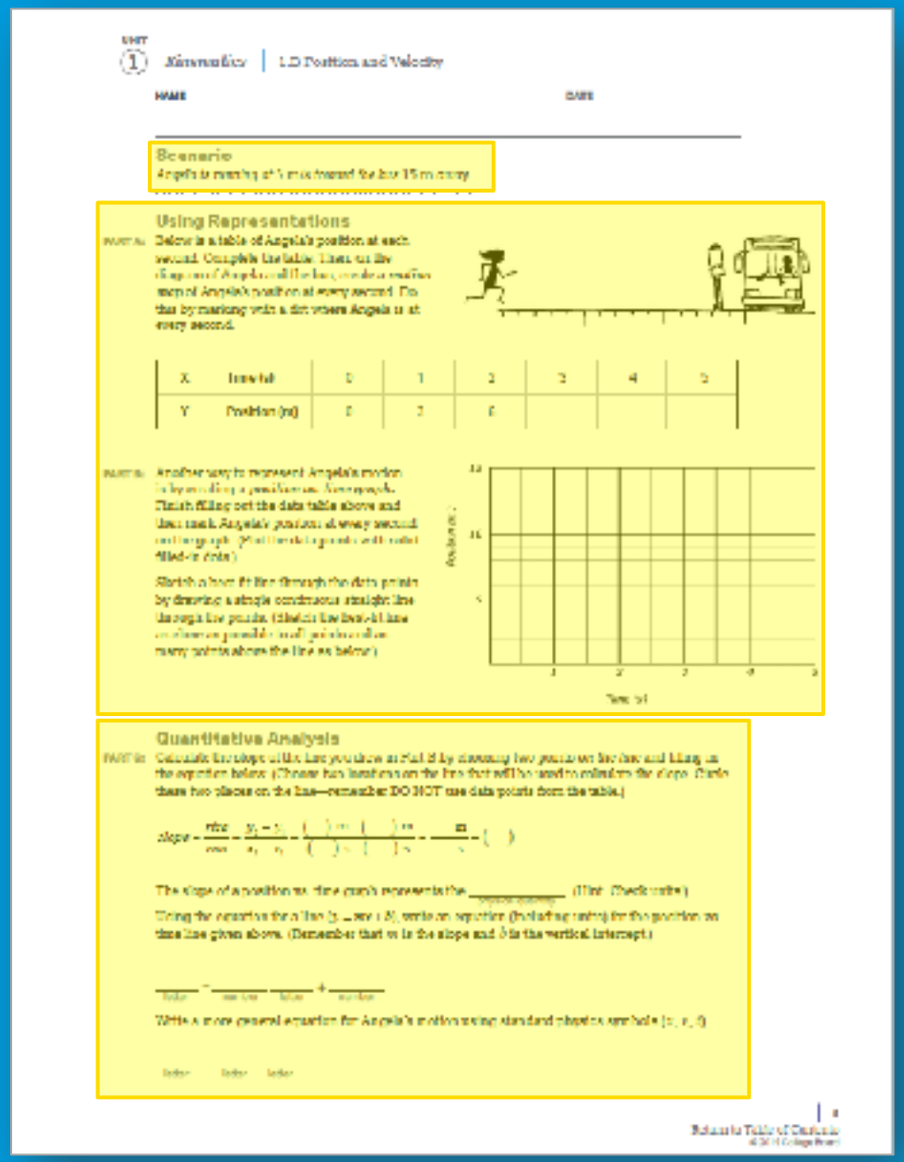
What's Covered?

AP Physics 1 Student Workbook

Workbook units align to CED units …

• **Unit 1:** Kinematics	15 scenarios
• **Unit 2:** Dynamics	15 scenarios
• **Unit 3:** Circular Motion and Gravitation	15 scenarios
• **Unit 4:** Work and Energy	15 scenarios
• **Unit 5:** Momentum	15 scenarios
• **Unit 6:** Simple Harmonic Motion	12 scenarios
• **Unit 7:** Torque and Rotation	15 scenarios
• **Unit 8:** Electric Charge and Force	12 scenarios
• **Unit 9:** DC Circuits	15 scenarios
• **Unit 10:** Mechanical Waves and Sound	15 scenarios
• **Unit 11:** Review Questions	15 scenarios
	159 scenarios

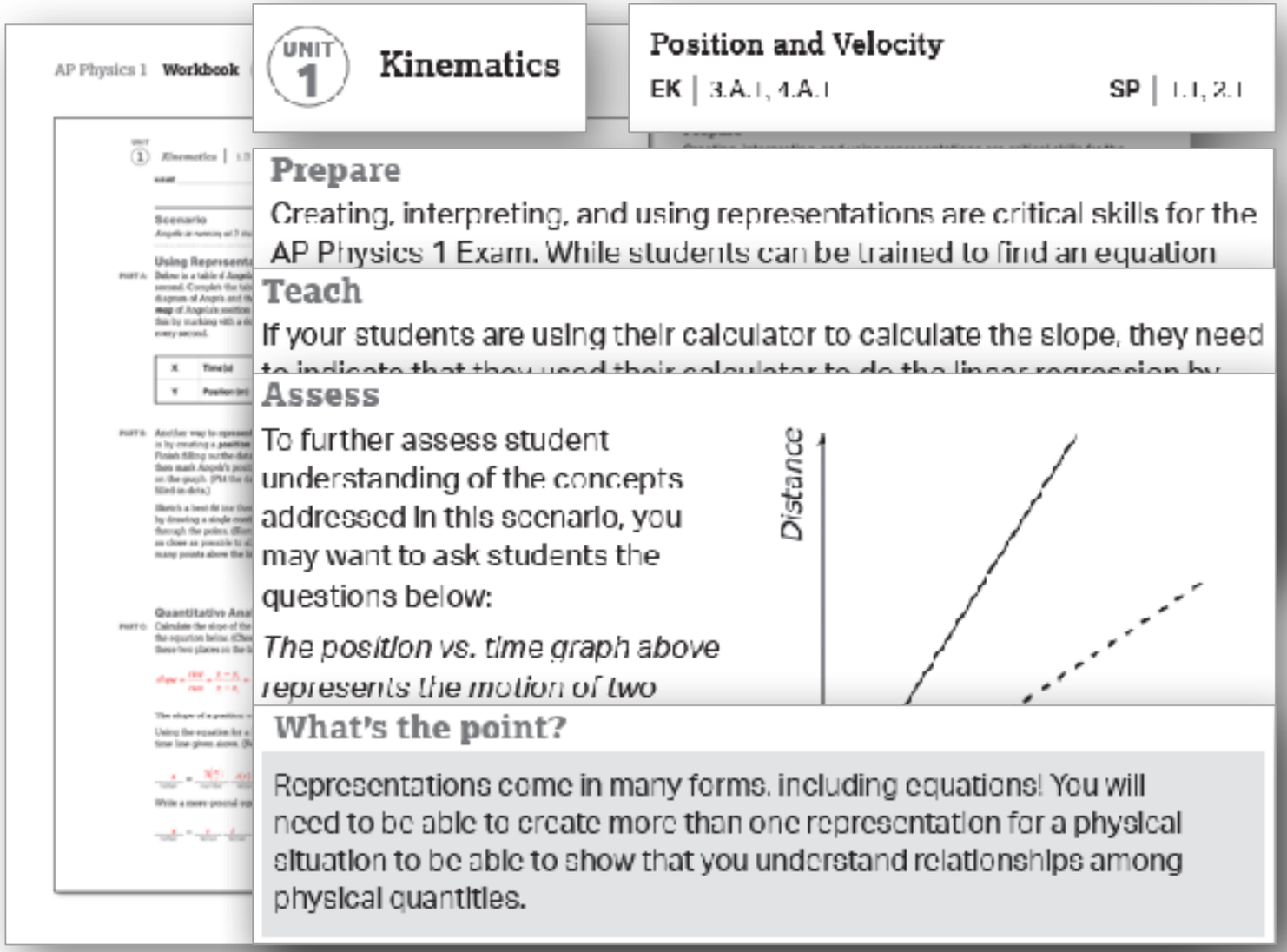




How does it work?

- Each **unit** in the workbook is **unique** and focuses on content, skills, and learning objectives for that unit.
- However, the **overall format** of each unit and each scenario is **similar**.
- Each page includes a **scenario**, which acts as the prompt to focus students' attention on key elements of the problem.
- Each problem is then broken down into several parts, and **headings** are added to provide guidance to the students—to key them into the type of question they're going to be asked. The major headings are:
  - Using Representations
  - Quantitative Analysis
  - Argumentation
  - Data Analysis
  - Experimental Design

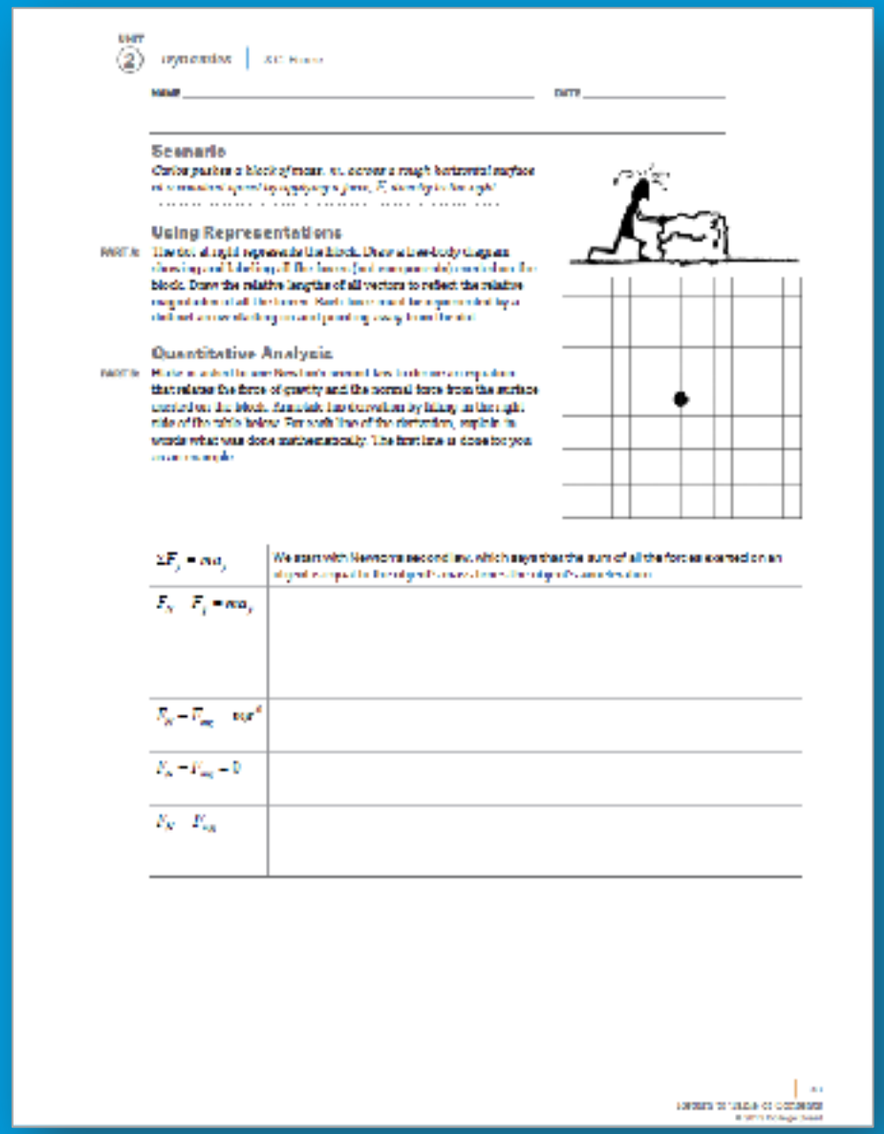
There's more for teachers …



Teacher pages include the **Unit**, **Essential Knowledge**, and **Science Practices** that are linked to each scenario.

Teacher pages also include notes about how to **Prepare** for assigning the page, use it in your classroom (**Teach**) and **Assess** that your students have learned key concepts and/or skills. Some of the teacher notes include quick quizzes, lab ideas, or other suggestions for extensions.

The **What's the point?** section will help you emphasize the main idea of the entire scenario with your students.



Scenario

Using Representations

Quantitative Analysis

How can I use the workbook?

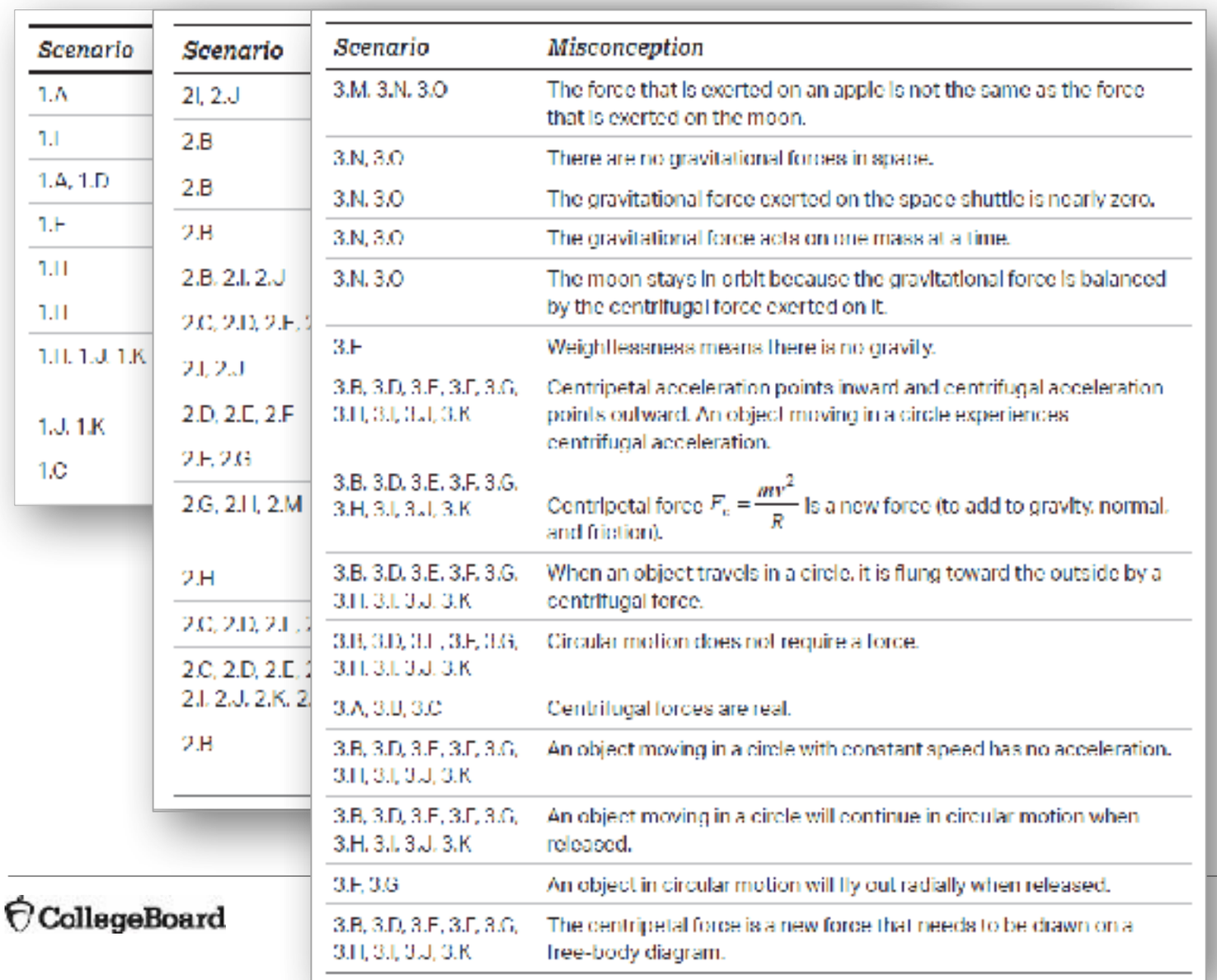
Teachers can:

- Assign scenarios as pre-work before class discussion or instruction
- Assign scenarios as homework after class instruction
- Work through a scenario with students in class
- Use the teacher notes to create related extensions: desktop experiments, lab investigations, quick quizzes, etc.
- Assign the lab questions as pre- or post-lab exercises
- Have students work through the scenario and articulate the “So What?” for themselves
- Assign specific parts that are most relevant for your students
- Use their own scaffolding to modify scenarios
- Use the style of the scenarios to create their own “AP-like” questions from textbook exercises
- Use as exam-prep work in the Spring

Student Misconceptions

AP Physics 1 Student Workbook

Student Misconceptions

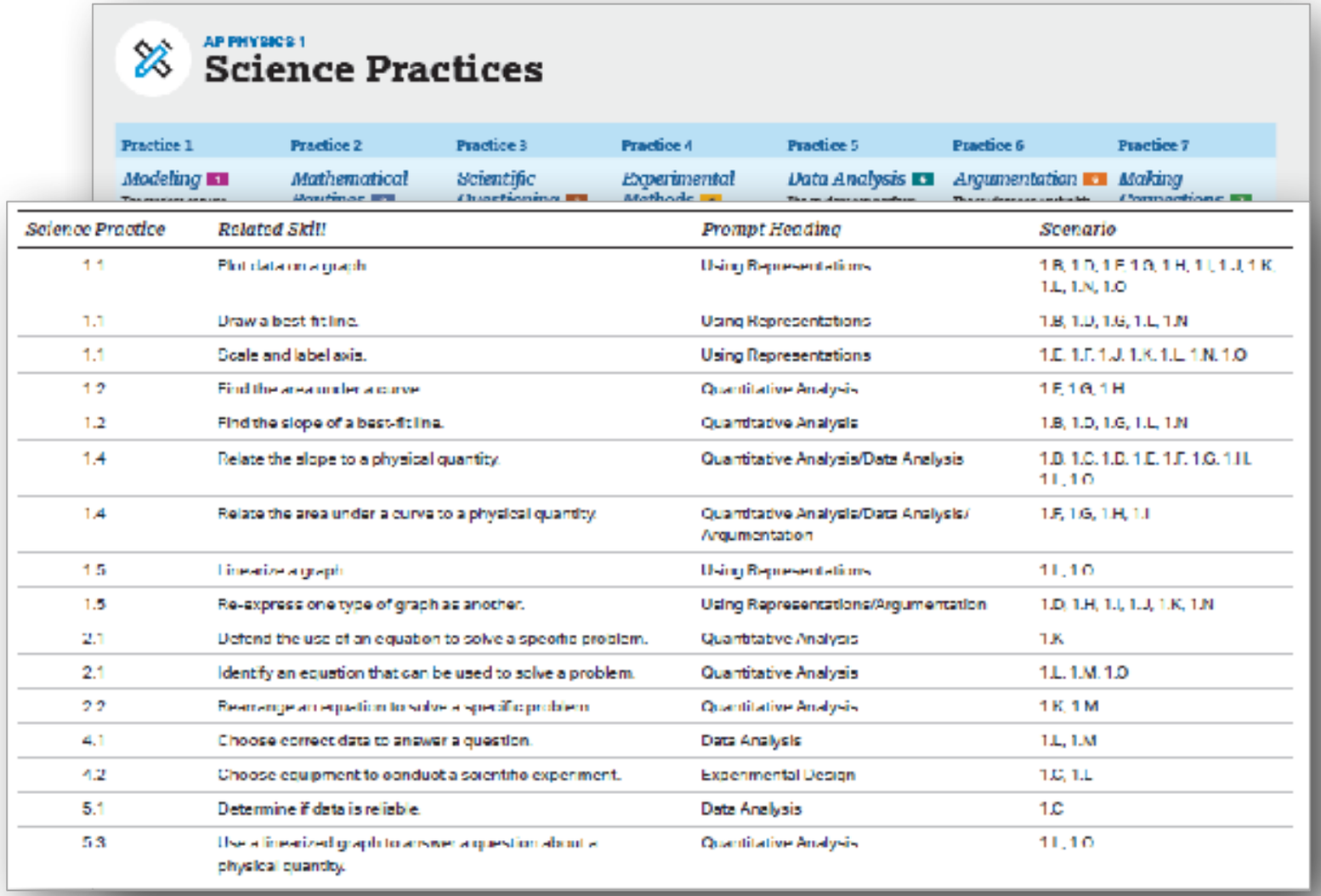


Scenario	Misconception
3.M, 3.N, 3.O	The force that is exerted on an apple is not the same as the force that is exerted on the moon.
3.N, 3.O	There are no gravitational forces in space.
3.N, 3.O	The gravitational force exerted on the space shuttle is nearly zero.
3.N, 3.O	The gravitational force acts on one mass at a time.
3.N, 3.O	The moon stays in orbit because the gravitational force is balanced by the centrifugal force exerted on it.
3.F	Weightlessness means there is no gravity.
3.B, 3.D, 3.F, 3.Γ, 3.G, 3.H, 3.I, 3.J, 3.K	Centripetal acceleration points inward and centrifugal acceleration points outward. An object moving in a circle experiences centrifugal acceleration.
3.B, 3.D, 3.E, 3.F, 3.G, 3.H, 3.I, 3.J, 3.K	Centripetal force $F_c = \frac{mv^2}{R}$ is a new force (to add to gravity, normal, and friction).
3.B, 3.D, 3.E, 3.F, 3.G, 3.H, 3.I, 3.J, 3.K	When an object travels in a circle, it is flung toward the outside by a centrifugal force.
3.H, 3.D, 3.I , 3.F, 3.G, 3.H, 3.I, 3.J, 3.K	Circular motion does not require a force.
3.A, 3.B, 3.C	Centrifugal forces are real.
3.B, 3.D, 3.F, 3.Γ, 3.G, 3.H, 3.I, 3.J, 3.K	An object moving in a circle with constant speed has no acceleration.
3.B, 3.D, 3.F, 3.Γ, 3.G, 3.H, 3.I, 3.J, 3.K	An object moving in a circle will continue in circular motion when released.
3.F, 3.G	An object in circular motion will fly out radially when released.
3.B, 3.D, 3.F, 3.Γ, 3.G, 3.H, 3.I, 3.J, 3.K	The centripetal force is a new force that needs to be drawn on a free-body diagram.

- Students may struggle with in-depth conceptual understanding and resort to using memorized terms to answer conceptual questions.
- Teachers are encouraged to set the stage for learning by helping students understand that their preconceived notions may just based on *incomplete* understanding, not incorrect understanding.
- Teachers are also encouraged to identify their students' misconceptions and then provide a forum for students to confront them.

More on addressing skills …

- The design of the AP Physics 1 course and exam focuses on seven overarching science practices that capture important aspects of the work of scientists.
- Science practices describe the skills and abilities that students should learn and demonstrate, integrated with content knowledge, to reach a goal or complete a learning activity.
- While the skills listed in the charts associated with each unit are critical to student success, most of them are scaffolded skills necessary for students to be successful at the science practice listed with each skill.



AP PHYSICS 1

Science Practices

Practice 1	Practice 2	Practice 3	Practice 4	Practice 5	Practice 6	Practice 7
Modeling	*Mathematical*	*Scientific*	*Experimental*	*Data Analysis*	*Argumentation*	*Making*

Science Practice	*Related Skill*	*Prompt Heading*	*Scenario*
1.1	Plot data on a graph	Using Representations	1.B, 1.D, 1.F, 1.G, 1.H, 1.I, 1.J, 1.K, 1.L, 1.N, 1.O
1.1	Draw a best-fit line.	Using Representations	1.B, 1.D, 1.G, 1.L, 1.N
1.1	Scale and label axis.	Using Representations	1.E, 1.F, 1.J, 1.K, 1.L, 1.N, 1.O
1.2	Find the area under a curve	Quantitative Analysis	1.F, 1.G, 1.H
1.2	Find the slope of a best-fit line.	Quantitative Analysis	1.B, 1.D, 1.G, 1.L, 1.N
1.4	Relate the slope to a physical quantity.	Quantitative Analysis/Data Analysis	1.D, 1.C, 1.D, 1.E, 1.F, 1.G, 1.I, 1.L, 1.O
1.4	Relate the area under a curve to a physical quantity.	Quantitative Analysis/Data Analysis/ Argumentation	1.F, 1.G, 1.H, 1.I
1.5	Linearize a graph	Using Representations	1.I, 1.O
1.5	Re-express one type of graph as another.	Using Representations/Argumentation	1.D, 1.H, 1.I, 1.J, 1.K, 1.N
2.1	Defend the use of an equation to solve a specific problem.	Quantitative Analysis	1.K
2.1	Identify an equation that can be used to solve a problem.	Quantitative Analysis	1.L, 1.M, 1.O
2.2	Rearrange an equation to solve a specific problem	Quantitative Analysis	1.K, 1.M
4.1	Choose correct data to answer a question.	Data Analysis	1.L, 1.M
4.2	Choose equipment to conduct a scientific experiment.	Experimental Design	1.C, 1.L
5.1	Determine if data is reliable.	Data Analysis	1.C
5.3	Use a linearized graph to answer a question about a physical quantity.	Quantitative Analysis	1.I, 1.O

Student Resources: AP Physics 1 Student Workbook

CollegeBoard

AP Physics 1 Workbook at a Glance

NAME _____ DATE _____

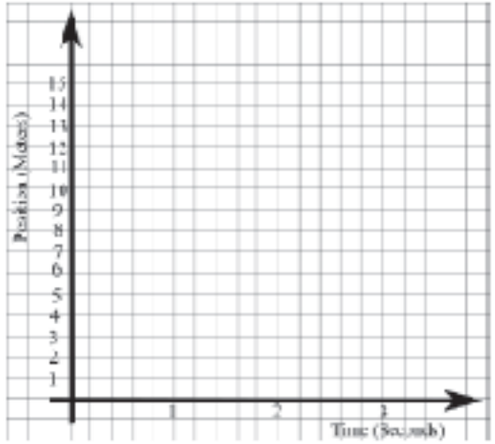
Scenario

Angela and Blake are running toward each other from 15 m away. At time t = 0 s, Angela runs to the right at 5m/s, and Blake runs to the left at 3m/s.

Using Representations

PART A: Complete the table and draw a position vs. time graph for Angela and Blake for the first three seconds. Make each graph a different color and include a key.

Time (Seconds)	*Angela's Position (meters)*	*Blake's Position (meters)*
1		
2		
3		



Quantitative Analysis

PART B: Calculate the **slope** of the line you drew in Part A for Angela by choosing two points on the line and filling in the equation below:

$$slope = \frac{rise}{run} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{(\quad)m - (\quad)m}{(\quad)s - (\quad)s} = \frac{m}{s} = (\quad)$$

PART C: Calculate the **slope** of the line you drew in Part A for Blake by choosing two points on the line and filling in the equation below:

$$slope = \frac{rise}{run} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{(\quad)m - (\quad)m}{(\quad)s - (\quad)s} = \frac{m}{s} = (\quad)$$

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AP Physics 1 Workbook at a Glance

UNIT 1 Kinematics | Velocity is a Vector!

NAME _____ DATE _____

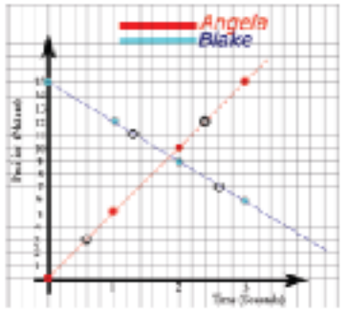
Scenario

Angela and Blake are running toward each other from 15 m away. At time t = 0 s, Angela runs to the right at 5 m/s, and Blake runs to the left at 1 m/s.

Using Representations

PART A: Complete the table and draw a position vs. time graph for Angela and Blake for the first three seconds. Make each graph a different color and include a key.

Time (Seconds)	Angela's Position (meters)	Blake's Position (meters)
1	5	12
2	10	7
3	15	2



Quantitative Analysis

PART B: Calculate the slope of the line you drew in Part A for Angela by choosing two points on the line and filling in the equation below:

$$slope = \frac{rise}{run} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{12m - 2m}{2.4s - 0.6s} = \frac{9m}{1.8s} = 5\frac{m}{s}$$

PART C: Calculate the slope of the line you drew in Part A for Blake by choosing two points on the line and filling in the equation below:

$$slope = \frac{rise}{run} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{7m - 11m}{3.6s - 1.2s} = \frac{-4m}{1.8s} = -3\frac{m}{s}$$

Velocity is a Vector!

EK | 3.A.1, 4.A.1 SP | 1.1, 1.4, 1.5, 2.2, 6.1

Prepare

If students are still unsure about position and velocity with one object, they may need more scaffolding for this worksheet. The key takeaways here are that velocity and displacement are vectors and direction matters!

Teach

Follow up Questions:

When do Angela and Blake meet? How do you know? What other evidence could you produce to show that they meet at this time?

What would a graph of someone running at 10m/s look like? How would that graph show an increased speed?

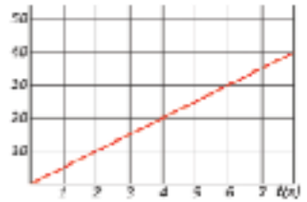
What would a graph of position vs. time look like for someone who took a break in the middle of running?

Suggested Activities: Walking Graphs Lab

Have students act out for themselves the suggested lab in the AP Physics B question #2 from 2006.

Assess

To further assess student understanding of the concepts addressed in this scenario, you may want to ask students the questions below:



The following graph represents the position as a function of time for an object moving in a straight line to the right. Which of the following is true?

A. The object increases its velocity.
B. The object decreases its velocity.
C. The object's velocity remains unchanged.
D. The object stays at rest.
E. More information is required.

Explain

What's the point?

The slope relationship between position and velocity is one in a series of relationships you will discover throughout the course. In math class, the slope of a line is a number. In physics, it correlates with a physical quantity.

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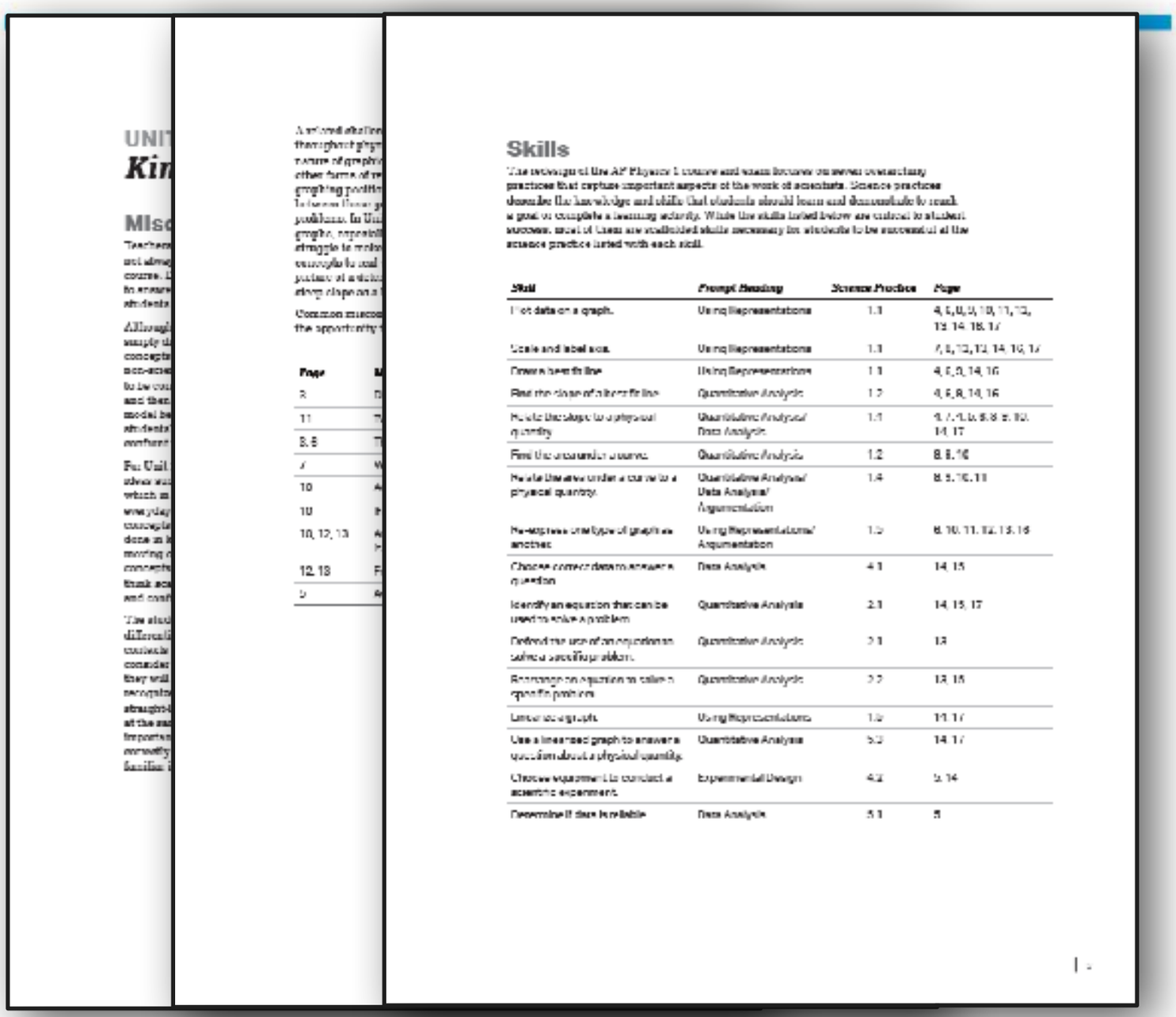
AP Physics 1 Workbook

Misconceptions and Skills Tables



Skills

The redesign of the AP Physics 1 course and exam focuses on seven overarching practices that capture important aspects of the work of scientists. Science practices describe the knowledge and skills that students should learn and demonstrate to reach a goal or complete a learning activity. While the skills listed below are critical to student success, most of them are scaffolded skills necessary for students to be successful at the science practice listed with each skill.

Skill	Prompt Heading	Science Practice	Page
Plot data on a graph.	Using Representations	1.1	4, 6, 8, 9, 10, 11, 12, 13, 14, 16, 17
Scale and label axis.	Using Representations	1.1	7, 8, 12, 13, 14, 16, 17
Draw a best fit line	Using Representations	1.1	4, 6, 8, 14, 16
Find the slope of a best fit line	Quantitative Analysis	1.2	4, 6, 8, 14, 16
Relate the slope to a physical quantity	Quantitative Analysis/ Data Analysis	1.4	4, 7, 4, 6, 8, 9, 10, 14, 17
Find the area under a curve.	Quantitative Analysis	1.2	8, 9, 10
Relate the area under a curve to a physical quantity.	Quantitative Analysis/ Data Analysis/ Argumentation	1.4	8, 9, 10, 11
Re-express one type of graph as another.	Using Representations/ Argumentation	1.5	8, 10, 11, 12, 13, 16
Choose correct data to answer a question	Data Analysis	4.1	14, 15
Identify an equation that can be used to solve a problem	Quantitative Analysis	2.1	14, 15, 17
Defend the use of an equation to solve a specific problem.	Quantitative Analysis	2.1	13
Rearrange an equation to solve a specific problem	Quantitative Analysis	2.2	13, 15
Linearize a graph.	Using Representations	1.5	14, 17
Use a linearized graph to answer a question about a physical quantity.	Quantitative Analysis	5.3	14, 17
Choose equipment to conduct a scientific experiment.	Experimental Design	4.2	5, 14
Determine if data is reliable	Data Analysis	5.1	5

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Physics 1
Student Workbook

Scaffolded Sample Tasks

AP CollegeBoard

Experimental Design

Task: Experimental Design

2018 AP Physics 1: Algebra-Based Exam

(c) Describe an experimental procedure to determine whether or not the resistivity of the dough cylinders depends on the temperature of the dough. Give enough detail so that another student could replicate the experiment. As needed, include a diagram of the experimental setup. Assume equipment usually found in a school physics laboratory is available.

Task: Experimental Design

Unit 1, Physics 1 Student Workbook 1.C

EXPERIMENTAL DESIGN:

Part A: The students decide that they need to collect distance and time data for each car to test the company's claim. The students design a procedure.

Cross out any extraneous steps and order the remaining procedural steps:

_____ Turn the car on and release along the measured path.

Gather equipment.

_____ Repeat to reduce error.

_____ Measure and record the time the car took to travel the 2 meters with a stopwatch.

_____ Measure a 2-meter-long path on the floor.

_____ Draw a data table in your notebook.

Task: Experimental Design

Unit 5, Physics 1 Student Workbook 5.H

EXPERIMENTAL DESIGN:

Part A: Edit Dominique's procedure for length and clarity. Cross out any unnecessary statements, change the order of statements, correct statements for errors, or write new sentences if necessary.

1. Gather all materials.
2. Record the mass of the cart.
3. Plug in both the motion detector and the force sensor.
4. Check that each device is working.
5. Secure the motion detector to the ring stand.
6. Attach the cardboard target to the cart so that it can be "seen" by the motion sensor.
7. Align the motion sensor with the target cardboard.
8. Create a data table in your notebook.
9. Set the motion sensor to record in cart mode.
10. Begin recording force and motion data with the computer.
11. Give the cart a push toward the force sensor and away from the motion detector.
12. After the cart collides with the force sensor and has bounced back, stop recording force and motion data.
13. Determine the impulse.
14. Repeat steps 9-12 with different initial pushes to reduce error.
15. Clean up the lab station and put away all materials.

Task: Experimental Design

Unit 5, Physics 1 Student Workbook 5.K

EXPERIMENTAL DESIGN:

Part A: Outline a procedure that Blake could follow to make measurements that could be used to answer all three questions above. Give each measurement a meaningful algebraic symbol and state with what equipment each measurement is made. Draw a labeled diagram showing each piece of equipment being used.

What Needs to Be Measured & Algebraic Symbols	Procedure:
Labeled Diagram of the Setup	

Task: Experimental Design

Unit 10, Physics 1 Student Workbook 10.M

SCENARIO: Blake is given the equipment listed below and asked to use it to obtain a precise value for the speed of sound in air.

_____ Meterstick _____ Stopwatch _____ Sound Intensity Meter _____ Barrel filled with water

Tuning forks (Each has its frequency printed on the handle.) Pipe (as long as the barrel is tall)

_____ Speaker who can generate a single tone (The tone can be varied, and the speaker displays the frequency.)

EXPERIMENTAL DESIGN:

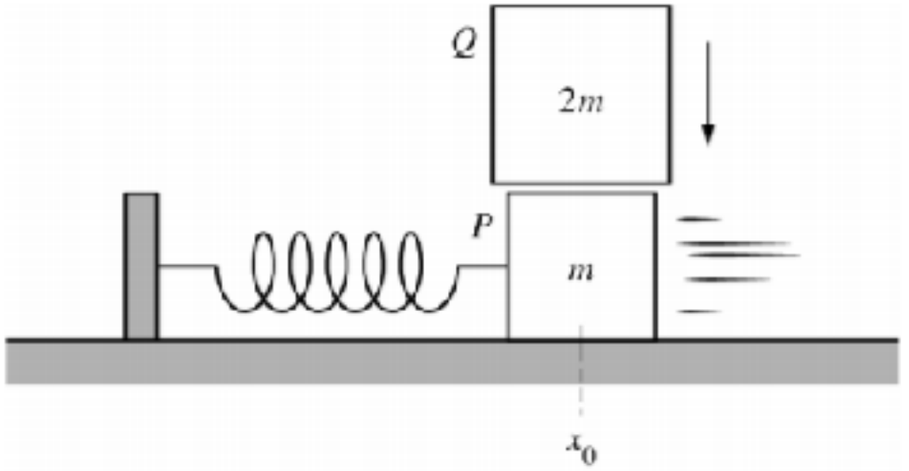
Part A: Select equipment from the above list that Blake could use to determine the speed of sound in air.

Part B: Outline a procedure that Blake could follow to make a single set of measurements that can be used to calculate an estimate of the speed of sound in air. Include a labeled diagram of the experimental setup. Explain how the measurements can be used to make the calculation.

Writing About Physics

Task: Writing About Physics

2018 AP Physics 1: Algebra-Based Exam



(b) The figure is reproduced above. How does the amplitude of oscillation A_{PQ} of the two-block system compare with the original amplitude A_P of block P alone?

____ $A_{PQ} < A_P$ ____ $A_{PQ} = A_P$ ____ $A_{PQ} > A_P$

In a clear, coherent paragraph-length response that may also contain diagrams and/or equations, explain your reasoning.

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Task: Writing About Physics

Unit 1, Physics 1 Student Workbook 1.A

ARGUMENTATION:

Part C: You are asked to make a ***claim*** about the *physical meaning* of Angela's *displacement* in Part B. Fill in the blanks below to complete the Claim, Evidence and Reasoning paragraph.

Evidence: When Angela gets to the bus stop, her position is _____ (number) meters. Angela's initial position was _____ (number) meters.

Reasoning: Displacement is equal to the final position minus the initial position. ($\Delta x = x_f - x_i$ or $\Delta x = x - x_f$)

Claim: Therefore, Angela's displacement is _____ (number) meters minus _____ (number) meters which equals _____ (number) meters.

Task: Writing About Physics

Unit 2, Physics 1 Student Workbook 2.B

ARGUMENTATION:

PART C: The following statement is written to describe what will happen after the first 5 seconds when Blake is no longer pushing. Cross out any incorrect statements and explain why they are incorrect.

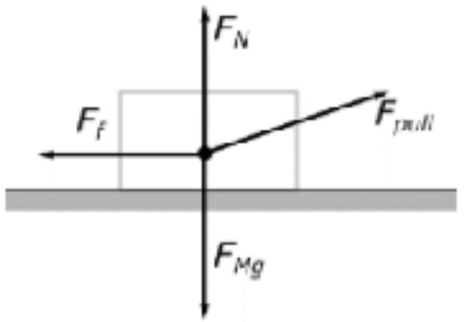
"After Blake stops pushing, Angela will travel at a constant speed for a few seconds before she runs out of force. Then she will decelerate and stop."

Task: Writing About Physics

Unit 2, Physics 1 Student Workbook 2.C

ARGUMENTATION:

Part C: Carlos gets tired of pushing and instead begins to pull with force F_{pull} at an angle to the horizontal. The block slides along the rough horizontal surface at a constant speed. A free-body diagram for the situation is shown to the right. Blake makes the following claim about the free-body diagram:



Blake: "The velocity of the block is constant, so the net force acting on the block must be zero. Thus, the normal force F_N equals the weight F_{Mg} and the force of friction f_k equals the applied force F_{pull}."

What, if anything, is wrong with this statement? If something is wrong, identify it and explain how to correct it. If this statement is correct, explain why.

Checklist	
√	I answered the question directly.
	I stated a law of physics that is always true.
	I connected the law or laws of physics to the specific circumstances of the situation.
	I used physics vocabulary (force, mass, acceleration, velocity, coefficient, friction).

Task: Writing About Physics

Unit 3, Physics 1 Student Workbook 3.D

Dominique: "The net force on the ball at the top position is 7N since the net force is the same as the tension."

Carlos: "No, the net force on the ball includes the centripetal force, tension, and weight. The tension and the weight are acting downward and have to be added. Then you need to figure out the centripetal force $\left(\frac{mv^2}{r}\right)$ and include it in the net force."

ARGUMENTATION:

Part A: Cross out the incorrect statements for each student's argument and circle the correct statements.

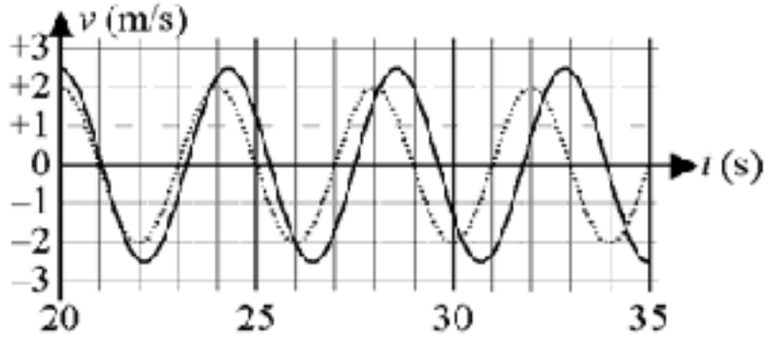
Part B: In a few short sentences, state the net force on the ball at the top of the circle, and support your claim with evidence.

Task: Writing About Physics

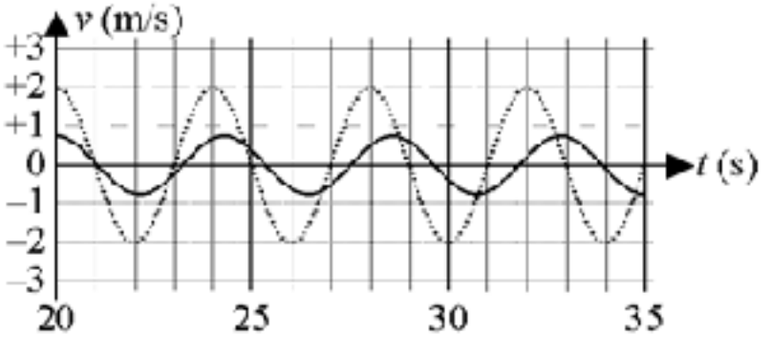
Unit 6, Physics 1 Student Workbook 6.I

A dart is shot to the right into the cart at a moment in time when the cart's momentum has greater magnitude than the dart's momentum. In Case 1, the dart is shot into the cart at time t = 12 s. In Case 2, the experiment is repeated exactly as before, but the dart is shot into the cart at time t = 14 seconds. The dart embeds itself into the cart in both cases. The graphs below show the velocity of the cart as a function of time for both cases for the interval 20 s < t < 35 s. The dotted graph in each case is the graph of the cart's velocity vs. time had the dart not been shot into the cart.

Case 1



Case 2



ARGUMENTATION:

Part B: In a clear, coherent, paragraph-length response, explain how and why the maximum speed and period shown in each case is different from the maximum speed and period had the dart not been shot into the cart. Discuss specific physical principles as appropriate.

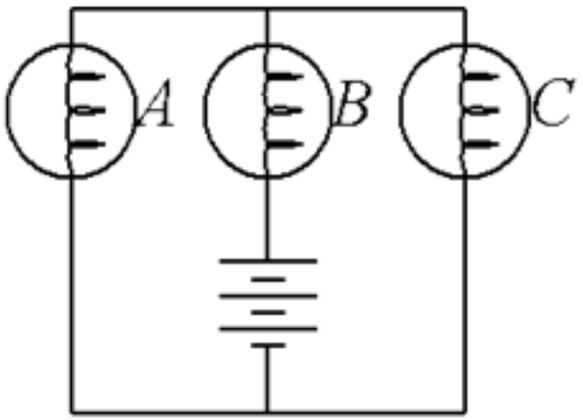
Checklist	
√	I answered the question directly.
	I stated a law of physics that is always true.
	I connected the law or laws of physics to the specific circumstances of the situation.
	I compared the situation (stated what was the same in all cases).
	I contrasted the situations (stated what was different in all cases).
	I used physics vocabulary (period, mass, spring constant, force, velocity, displacement, equilibrium, momentum, energy).

Task: Writing About Physics

Unit 9, Physics 1 Student Workbook 9.J

ARGUMENTATION:

Part C: Blake connects the three bulbs as shown in the diagram to the right. He measures the luminosity of Bulb **A** with a photometer ard determines that Bulb *A* emits one-eighth as much light energy each second as Bulb *B*. In a clear, coherent, paragraph-length response that references both the circuit diagram and the above graph, explain why this is the case.



Graphing

Task: Graphing

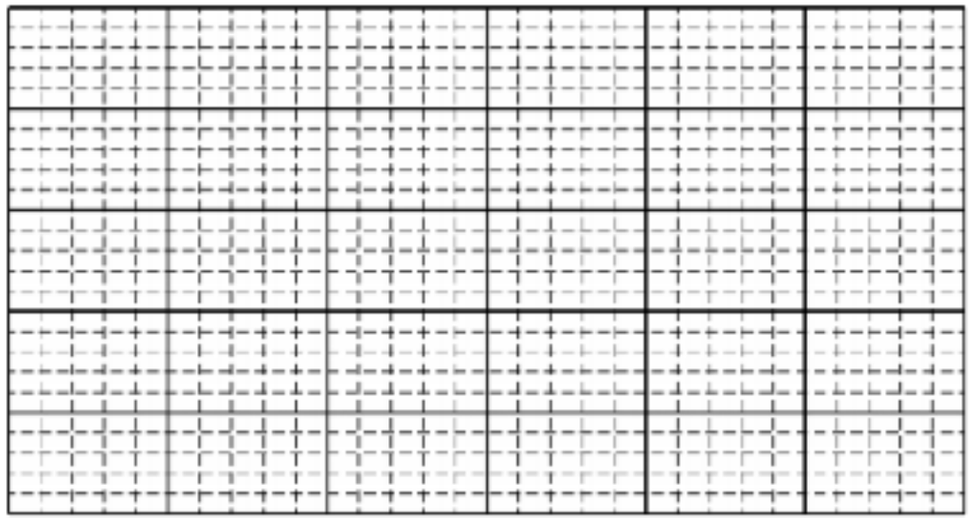
2018 AP Physics 1: Algebra-Based Exam

(a) The students want to determine the resistivity of the dough cylinders.

i. Indicate below which quantities could be graphed to determine a value for the resistivity of the dough cylinders. You may use the remaining columns in the table above, as needed, to record any quantities (including units) that are not already in the table.

Vertical Axis: _____ Horizontal Axis: _____

ii. On the grid below, plot the appropriate quantities to determine the resistivity of the dough cylinders. Clearly scale and label all axes, including units as appropriate.



iii. Use the above graph to estimate a value for the resistivity of the dough cylinders.

Task: Graphing

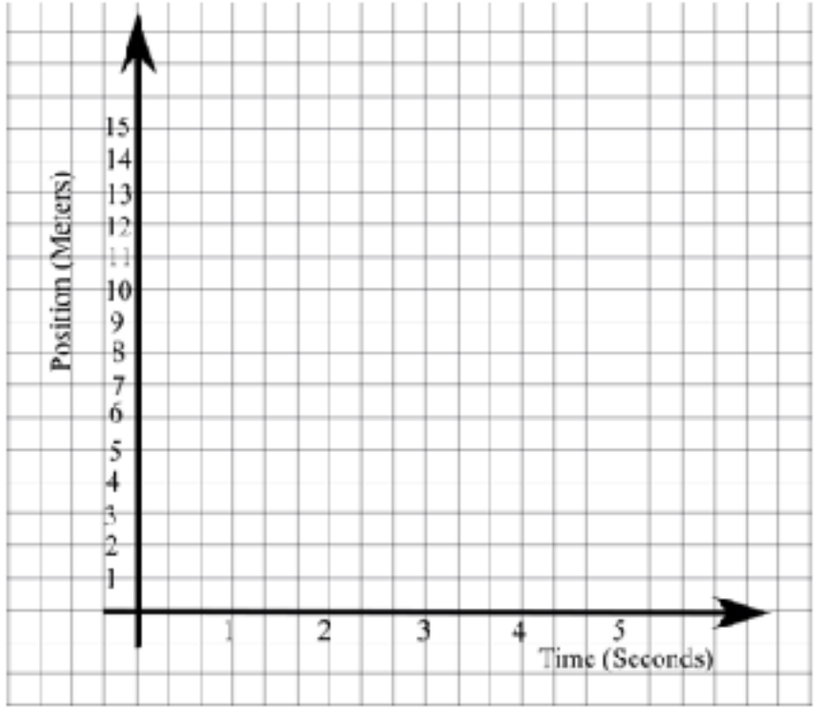
Unit 1, Physics 1 Student Workbook 1.B

SCENARIO: Angela is running at 3m/s toward the bus stop, 15 m away.

USING REPRESENTATIONS:

Part A: At right is a table of Angela's position at each second. Complete the table. Then, on the diagram above, create a ***motion map*** of Angela's position at every second. Do this by marking with a dot, where Angela is at every second.

Part B: Another way to represent Angela's motion is by creating a ***position vs. time graph***. Finish filling out the data table to the right and then mark Angela's position at every second on the graph. (Plot the data points with solid filled-in dots.) Sketch a best fit line through the data points by drawing a straight line through the points. (Sketch the best fit line with the same number of data points above and below the line if needed.)



X	Y
Time (s)	Position (m)
0	0
1	3
2	6
3	
4	
5	

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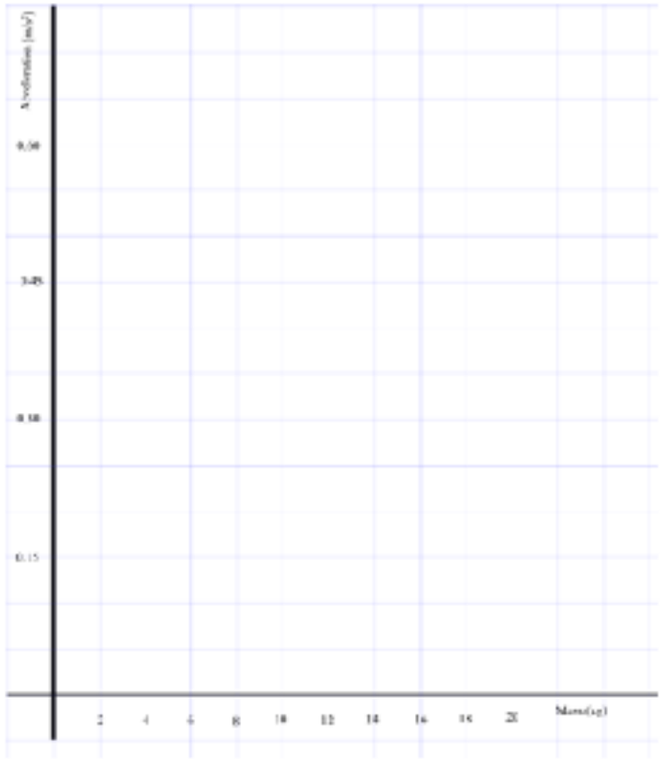
Task: Graphing

Unit 2, Physics 1 Student Workbook 2.A

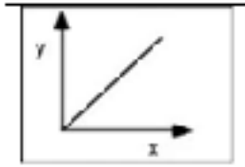
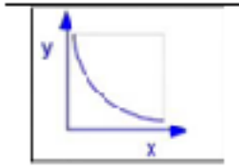
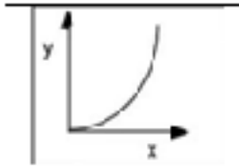
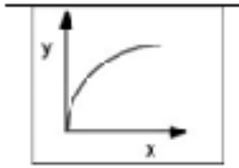
SCENARIO: Carlos and Dominique collect the following data from an experiment where they applied the same force, F, to identical boxes with different masses and recorded the acceleration.

Trial	Mass	Acceleration
1	2 kg	1.5
2	4 kg	0.75
3	5 kg	0.60
4	7 kg	0.40
5	12 kg	0.30
6	15 kg	0.20
7	18 kg	0.15



USING REPRESENTATIONS:

Part A: Plot the acceleration of the boxes versus the mass of each box.

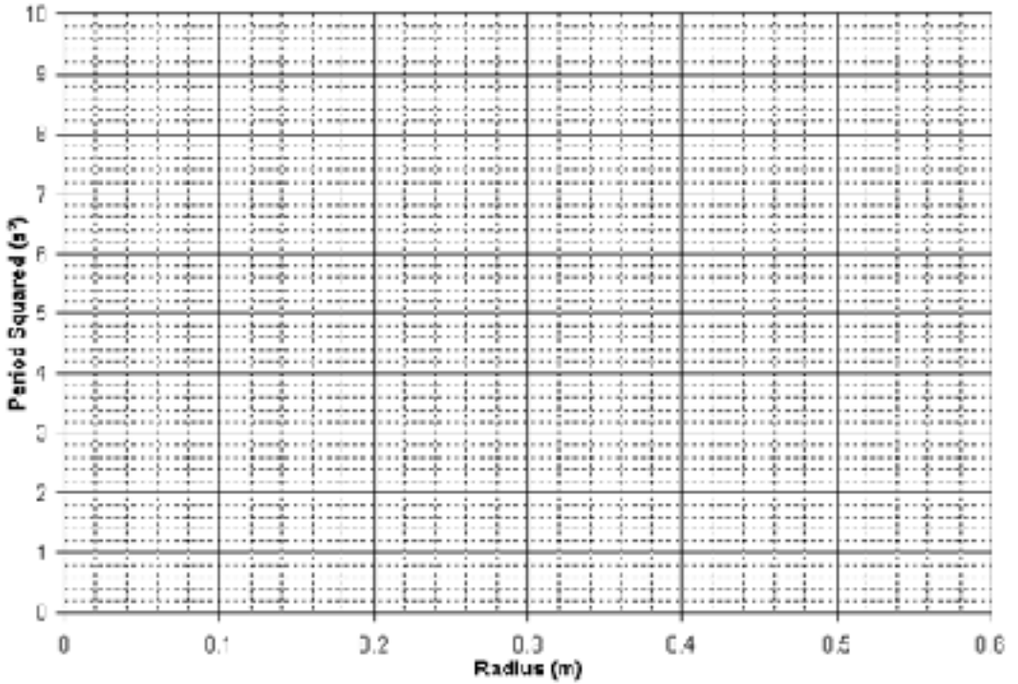
GRAPH	RELATIONSHIP
	As *x* increases, *y* increases proportionally. *Y* is directly proportional to *x*.
	As *x* increases, *y* decreases. *Y* is inversely proportional to *x*.
	*Y* is proportional to the square of *x*.
	The square of *y* is proportional to *x*.

Task: Graphing

Unit 3, Physics 1 Student Workbook 3.K

R (m)	T (s)	T^2 (s^2)
0.1	1.4	1.96
0.2	2.0	4.00
0.3	2.3	5.29
0.4	2.7	7.29
0.5	2.9	8.41

The student collects the data shown in the table above.



Part C: Plot the data on the T^2 vs. r graph shown on the right. Draw a best-fit line to the data.

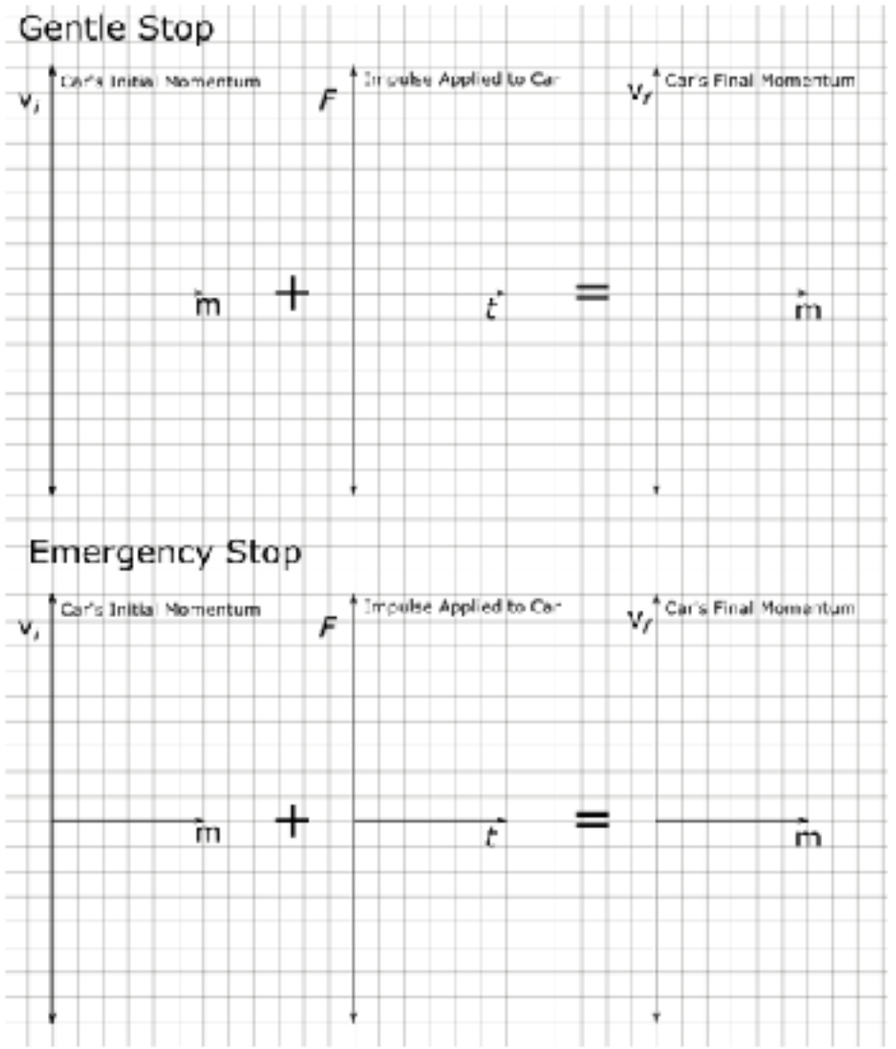
Task: Graphing

Unit 5, Physics 1 Student Workbook 5.C

SCENARIO: A truck has a mass of M and initially moves with a speed of v_i. Consider two cases: the truck makes a "gentle" stop, and the truck makes an "emergency" stop.

USING REPRESENTATIONS:

Part A: Show on the diagrams what a "gentle" stop and an "emergency" stop might look like.

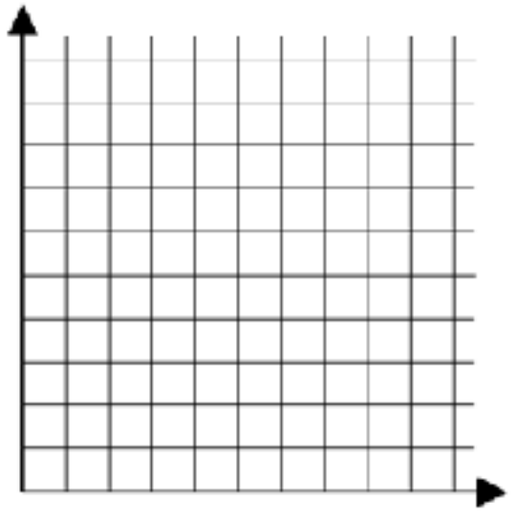


Task: Graphing

Unit 8, Physics 1 Student Workbook 8.H

Part C: Using the diagram, fill in the table below left of charge q of a single particle and height y of a single particle. Also note that you are asked to calculate the quantity y^2.

Charge q (C)	Height y (m)	y^2 (m^2)



Part D: Graph q vs. y^2 from your data table on the grid above and to the right. Draw a best fit line. Use the slope of the best fit line (not an average or a single data point) to calculate the mass m of the pollen particles.

Derivations

Task: Derivations

2018 AP Physics 1: Algebra-Based Exam

i. Derive an equation for the orbital period T of the spacecraft in terms of m, M_E, R, and physical constants, as appropriate. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

ii. A second spacecraft of mass $2m$ is placed in a circular orbit with the same radius R. Is the orbital period of the second spacecraft greater than, less than, or equal to the orbital period of the first spacecraft?

____ Greater than ____ Less than ____ Equal to

Briefly explain your reasoning.

Task: Derivations

Unit 1, Physics 1 Student Workbook 1.O

QUANTITATIVE ANALYSIS:

The data taken by the engineer are shown in the table.

Part A: Using the assumption that the crossbow darts were projected horizontally, derive an expression for T in terms of H and g. (Remember that derivations should start with a fundamental equation of physics, i.e., an equation given on the AP Physics 1 equation sheet.)

Step 1: Step 2:
Step 3:
Step 4:

Horizontal Distance to Target $D(m)$	Vertical Distance Dart Falls $H(m)$	Time the Dart Is a Projectile $T(s)$
5.00	0.084	
10.00	0.169	
15.00	0.408	
20.00	0.677	
25.00	0.975	

Task: Derivations

Unit 2, Physics 1 Student Workbook 2.C

QUANTITATIVE ANALYSIS:

PART B: Blake is asked to use Newton's second law to derive an equation that relates the force of gravity and the normal force from the surface acting on the block. Annotate his derivation by filling in the right side of the table below. For each line of the derivation, explain mathematically what was done (i.e., annotate your derivation). The first line is done for you as an example.

$\Sigma F = ma$	We start with Newton's second law, which says that the sum of all the forces acting on an object is equal to the object's mass times the object's acceleration
$F_N - F_{mg} = ma$	
$F_N - F_{mg} = ma^0$	
$F_N \quad F_{mg} = 0$	
$F_N - F_{mg}$	

Task: Derivations

Unit 5, Physics 1 Student Workbook 5.J

QUANTITATIVE ANALYSIS:

Part B: Derive expressions for v_A and v_C, Angela and Carlos's final speeds for time $t > T$ in terms of M, m, and v.

	System is Carlos and ball. There are no net external forces, so the momentum of the system is conserved.
	Initially Carlos and the ball are at rest, so their initial momentum is zero, so their final momentum must also be zero.
	Equation for v_C in terms of M, m and v. For the second part of the problem, the system is the ball and Angela. There are no net external forces, so the momentum of the system is conserved. Initially Angela is at rest and the ball has momentum mv, which means that the final momentum must also equal mv. After the collision, the ball and Angela have a new velocity v_A. Equation for v_A in terms of M, m and v.

Task: Derivations

Unit 9, Physics 1 Student Workbook 9.I

Part C: Derive an expression for P, the power delivered to the light bulb, in terms of ε, r, and R.

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How can you use TIPERs as **Formative Assessments**?

- Classroom starters
- Review of previous topics
- Class discussion
- Combined with a demonstration
- Pre-lab activity

PER Resources

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Practice 1

Creating Representations 1

Create representations that depict physical phenomena.

Practice 2

Mathematical Routines 2

Conduct analyses to derive, calculate, estimate, or predict.

Practice 3

Scientific Questioning and Argumentation 3

Describe experimental procedures, analyze data, and support claims.

SKILLS

1.A Create diagrams, tables, charts, or schematics to represent physical situations.

1.B Create quantitative graphs with appropriate scales and units, including plotting data.

1.C Create qualitative sketches of graphs that represent features of a model or the behavior of a physical system.

2.A Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.

2.B Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.

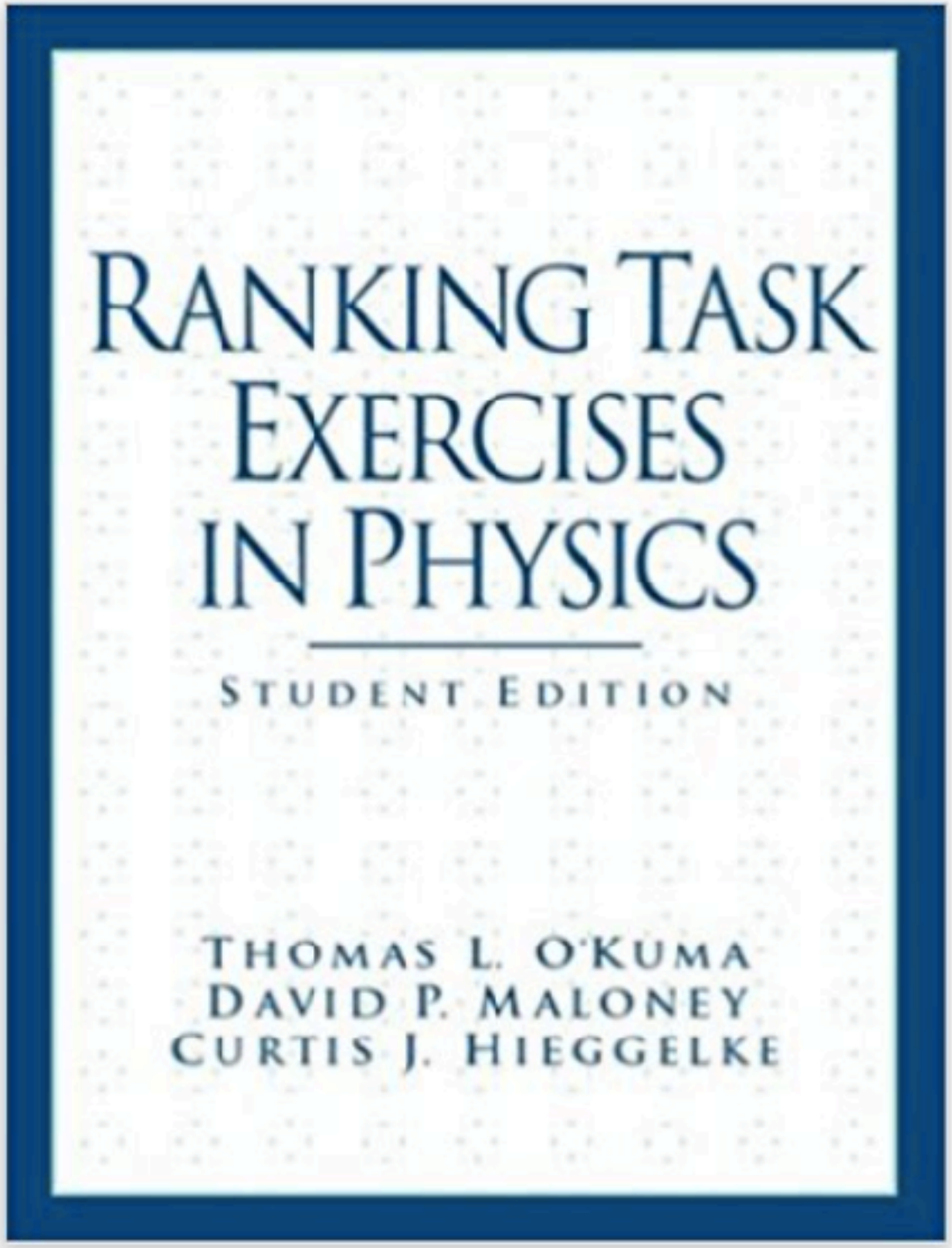
2.C Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.

2.D Predict new values or factors of change of physical quantities using functional dependence between variables.

3.A Create experimental procedures that are appropriate for a given scientific question.

3.B Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

3.C Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.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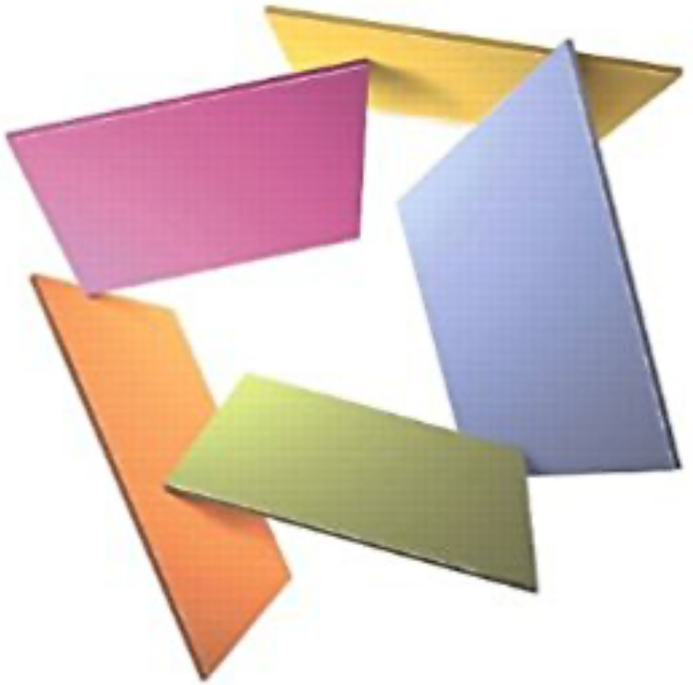
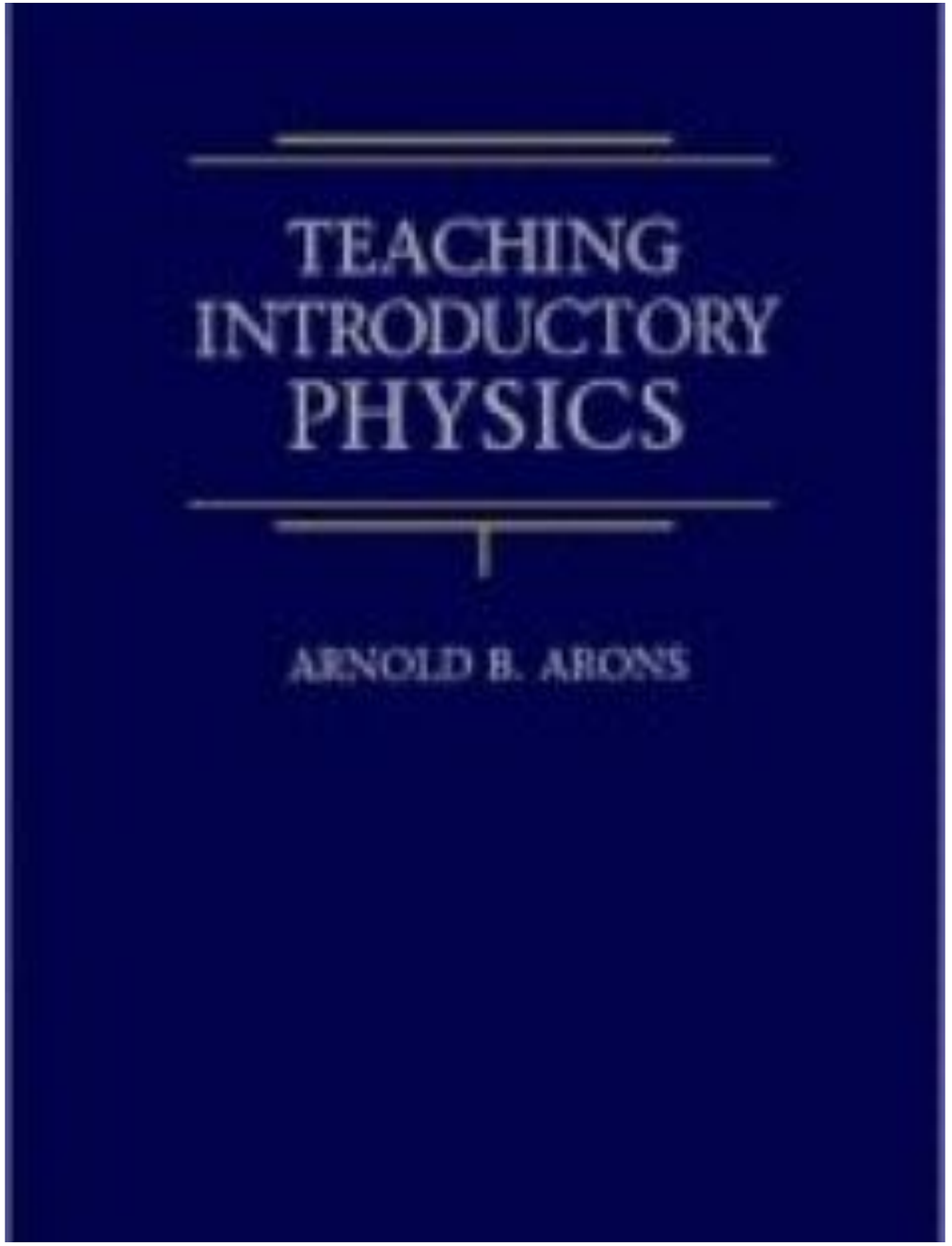


Randall D. Knight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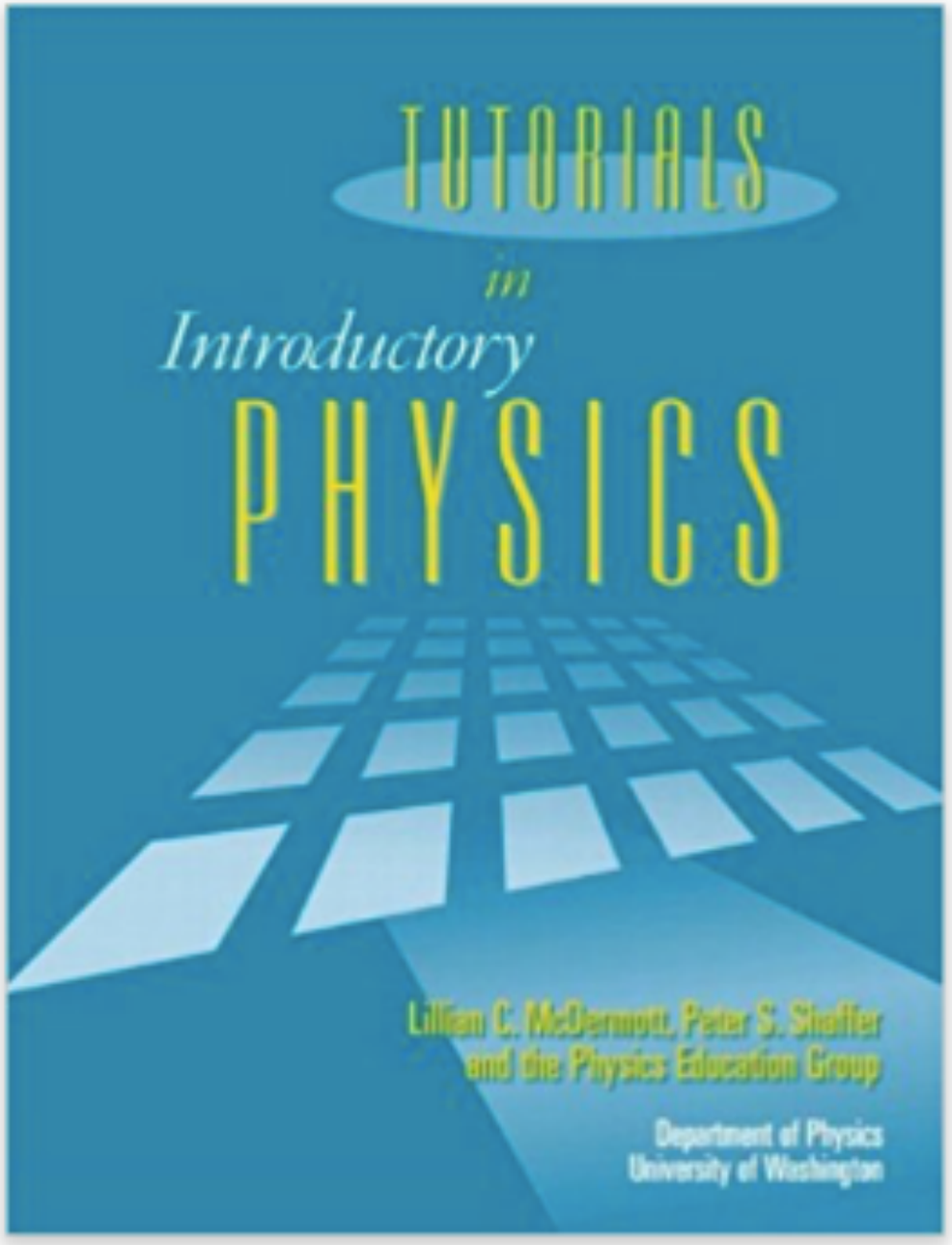
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VOLUME 1

MECHANICS LAB INVESTIGATIONS for GRADES 9–12

Victor Sampson, Todd L. Hutner, Daniel FitzPatrick,
Adam LaMee, and Jonathon Grooms

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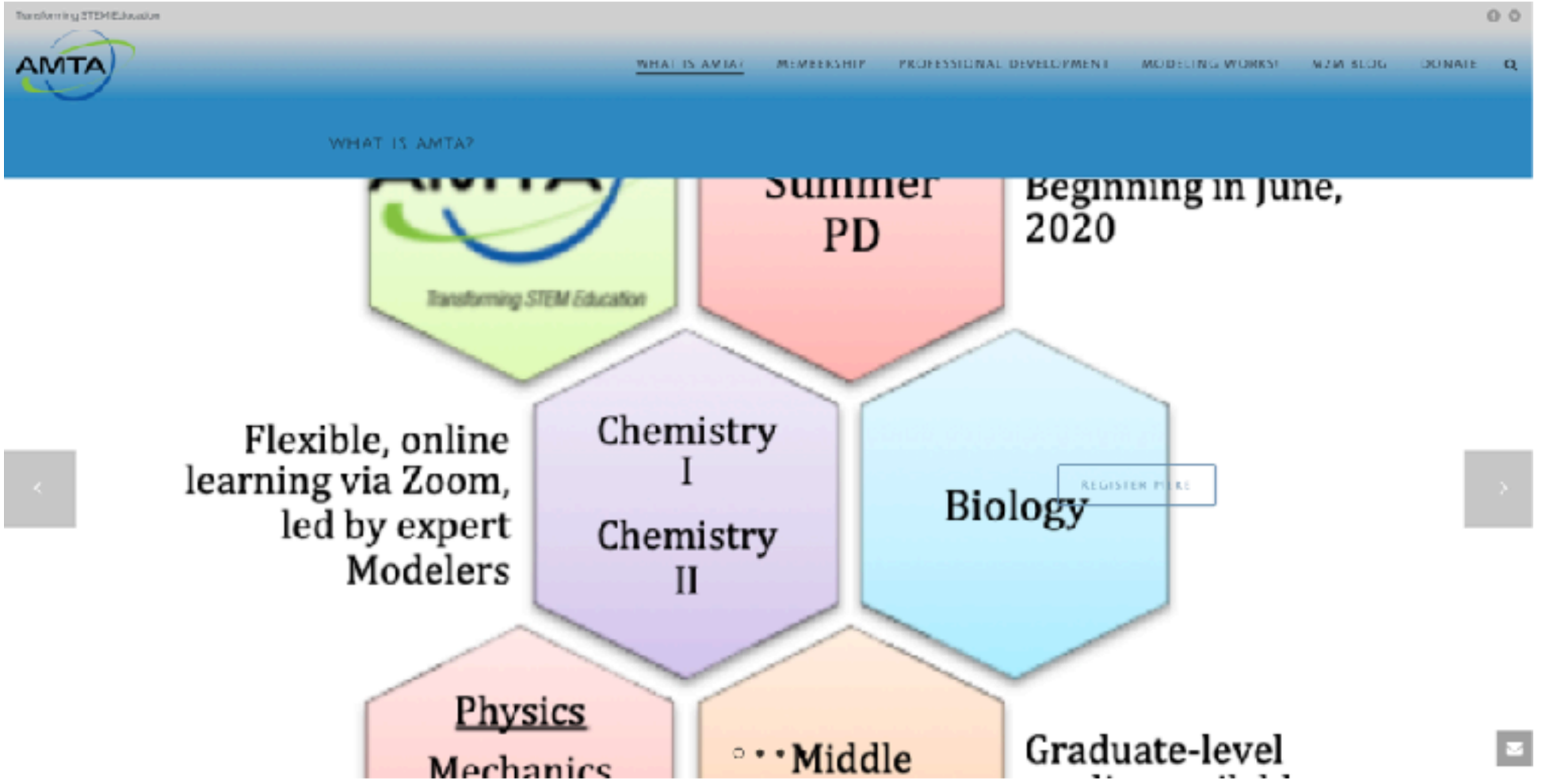
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Ranking Tasks

- Composed of a question with several contextually similar situations
- Rank situation according to some other physical quantity, with justification
- Provide a justification for the answers

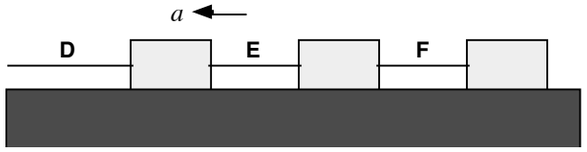
Ranking Task Exercises: Common Elements

- Should not require use of a calculator, all math should be ‘easy’
- Sometimes are ‘tricky’ to drive home a point
- The explanation is not to be glossed over but the most important part
- “How sure were you?” ranking very important

Ropes Pulling Boxes—Rope Tension [27]

The figures below show boxes that are being pulled by ropes along frictionless surfaces, accelerating toward the left. All of the boxes are identical, and the acceleration is the same in each figure. As you can see, some of the boxes are pulled by ropes attached to the box in front of them.

Rank the ropes from greatest to least on the basis of the tension in the rope.



Greatest 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ Least

Or, all of the tensions will be the same. _____

Please carefully explain your reasoning.

How sure were you of your ranking? (circle one)

Basically Guessed				Sure				Very Sure	
1	2	3	4	5	6	7	8	9	10

[27] S. Loucks

Ropes Pulling Boxes—Rope Tension [27]

The figures below show boxes that are being pulled by ropes along frictionless surfaces, accelerating toward the left. All of the boxes are identical, and the acceleration is the same in each figure. As you can see, some of the boxes are pulled by ropes attached to the box in front of them.

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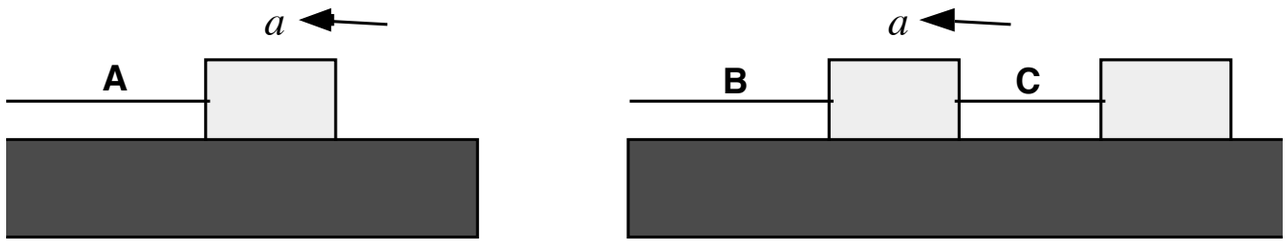
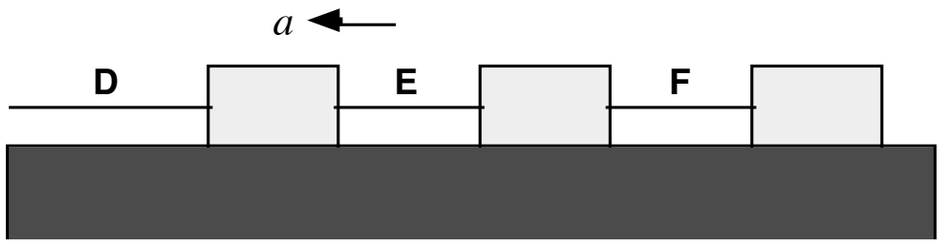




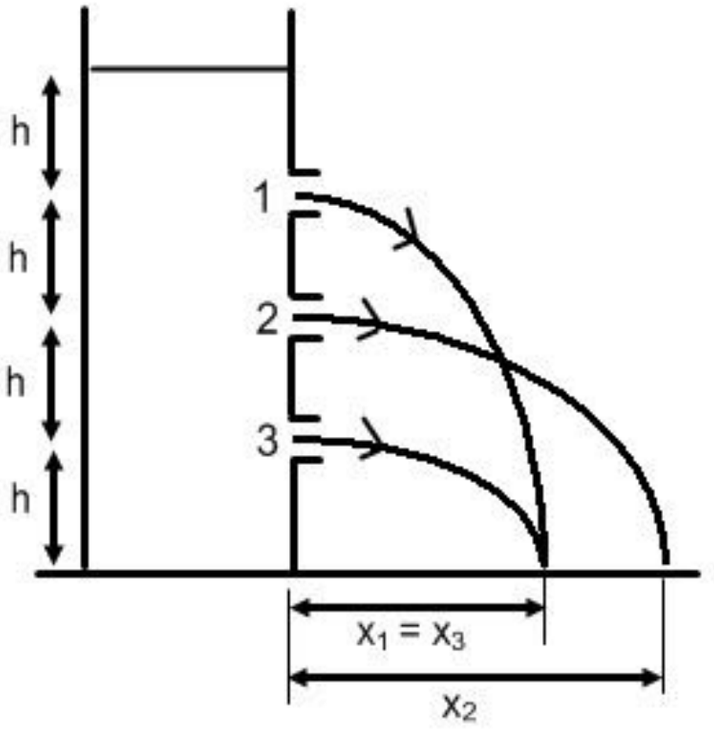
Greatest 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ Least

Or, all of the tensions will be the same. _____

Please carefully explain your reasoning.

Ranking Task

A physics experiment is performed with a can full of water that has three openings spaced at equal intervals **h** above the base of the can. The can is open to the atmosphere, and the speed of the water at the top of the can is approximately equal to zero. The result of the experiment is shown on the diagram.



Rank in order from greatest to least, the magnitude of the **exit velocity** of the water at each of the openings at the instant the holes are opened.

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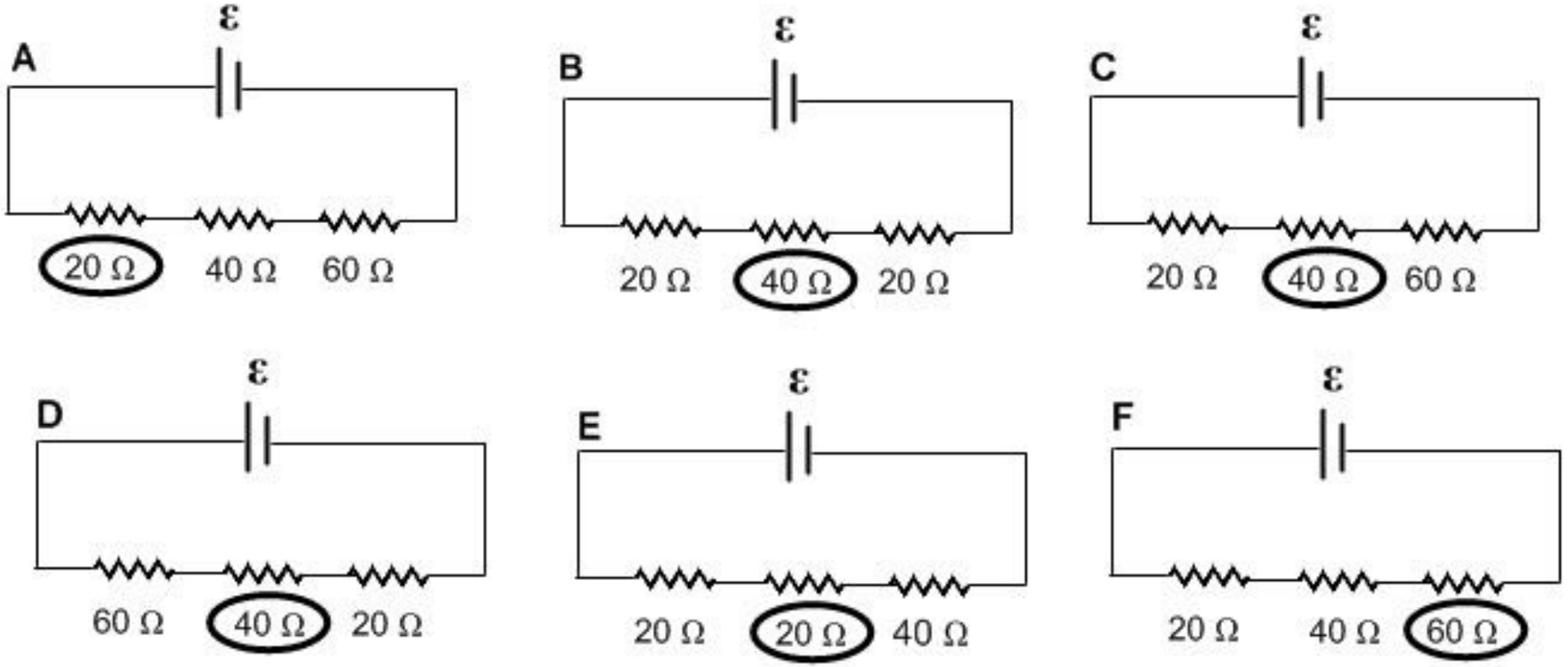
The six circuits below all have one battery and three resistors. All of the batteries are identical. All of the wires in these circuits are identical, of equal length and negligible resistance.
Rank these circuits, from greatest to least, on the basis of the **potential difference** across the circled resistor. Place ties in the same blank.



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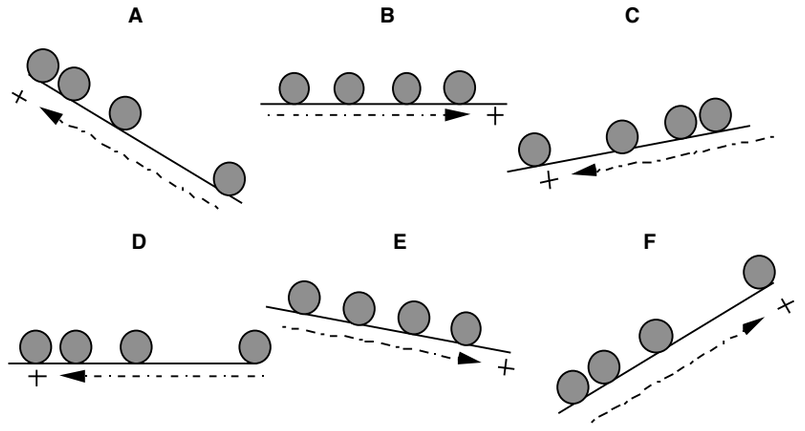
Ball Motion Diagrams—Acceleration II [4]

The following drawings indicate the motion of a ball subject to one or more forces on various surfaces from left to right. Each circle represents the position of the ball at succeeding instants of time. Each time-interval between successive positions is equal.

Rank each case from the highest to the lowest acceleration, based on the drawings. Assume all accelerations are constant and use the coordinate system specified in the drawing. Note: Zero is greater than negative acceleration, and ties are possible.



Highest 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ Lowest

Or, all have the same acceleration. _____

Please carefully explain your reasoning.

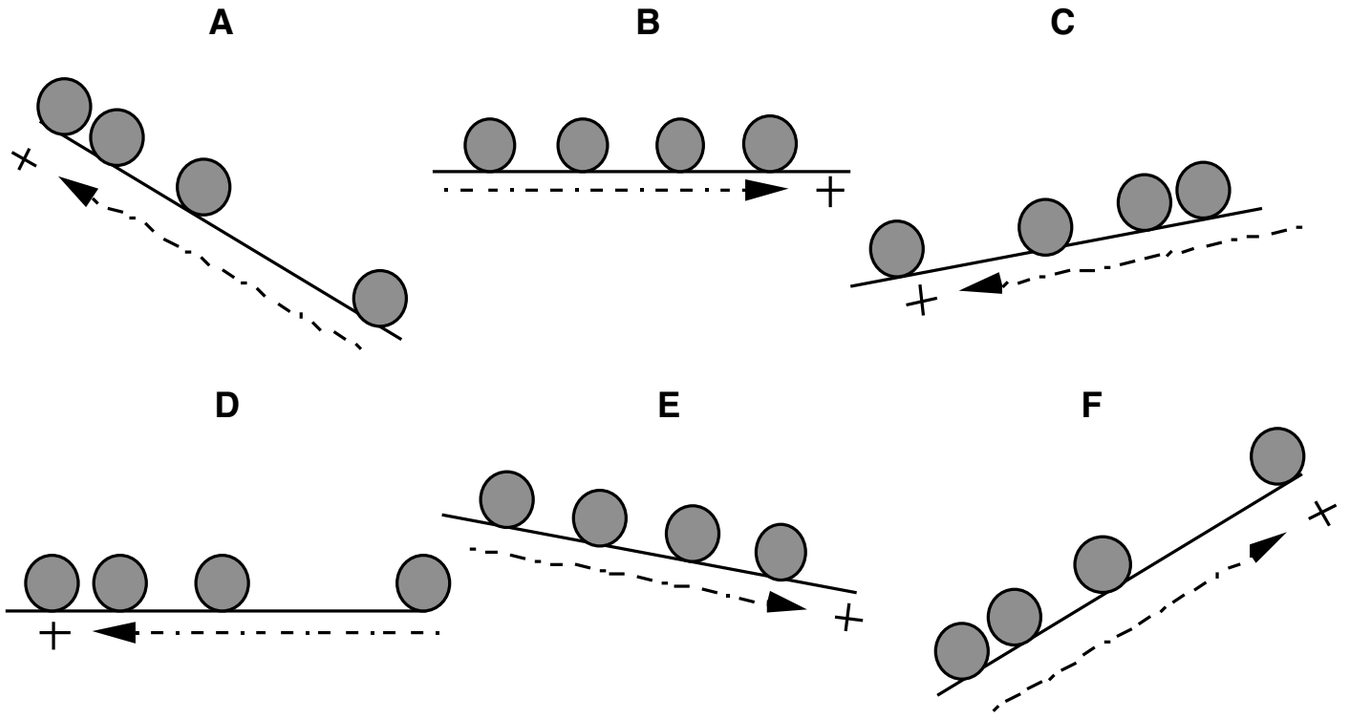
How sure were you of your ranking? (circle one)

Basically Guessed				Sure				Very Sure	
1	2	3	4	5	6	7	8	9	10

[4] D. Schramme, C. Fang, B. Speers, C. Hieggelke, D. Maloney, T. O'Kuma

The following drawings indicate the motion of a ball subject to one or more forces on various surfaces from left to right. Each circle represents the position of the ball at succeeding instants of time. Each time-interval between successive positions is equal.

Rank each case from the highest to the lowest acceleration, based on the drawings. Assume all accelerations are constant and use the coordinate system specified in the drawing. Note: Zero is greater than negative acceleration, and ties are possible.



Highest 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ Lowest

Or, all have the same acceleration. _____

Please carefully explain your reasoning.

Create a ranking task that addresses one of the following Essential Knowledge

Mechanics - EK 3.2.A.4

"The work-energy theorem states that the change in an object's kinetic energy is equal to the sum of the work (net work) being done by all forces exerted on the object."

E&M - EK 12.2.B.1

"A magnetic field will exert a force on a charged object moving within that field, with magnitude and direction that depend on the cross-product of the charge's velocity and the magnetic field."

Create a ranking task that addresses one of the following Essential Knowledge

P1/C:Mech

"The work-energy theorem states that the change in an object's kinetic energy is equal to the sum of the work (net work) being done by all forces exerted on the object."

P2/E&M

"The magnitude of the force exerted by a magnetic field on a moving charged object is proportional to the magnitude of the charge, the magnitude of the charged object's velocity, and the magnitude of the magnetic field and also depends on the angle between the velocity and magnetic field vectors."

Conflicting Contentions Tasks: Teaching Strategy

The **think-pair-share** strategy can be used with this type of task.

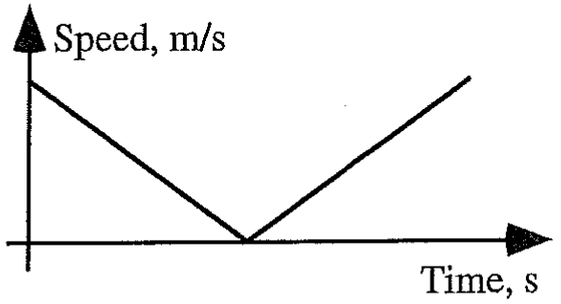
- Students first work individually and write down their answers.
- Then they share their answers with one partner and see if they agree or disagree with each other.
- After each of the exercises, you can ask a couple of teams to share their answers with the class.

Conflicting Contentions Tasks

- Present students with disagreeing statements
- Students indicate which is correct and why
- Contrast students' alternate conceptions with physically accepted statements

B1-SCT25: Ball Thrown Upward—Graph of Speed-Time

A ball is thrown straight upward and falls back to the same height. A student makes the graph of the speed of the ball as a function of time. Three students who are discussing this graph make the following contentions:



Akira: *"I don't think this can be correct because the sign of the acceleration changes on this graph, but the acceleration on the ball will be constant."*

Burt: *"No, I think this is right because it is only showing what happens to the speed, which will decrease to zero at the top and then increase as the ball falls. Since the slopes for both segments are the same except for sign that means the acceleration is constant."*

Catalina: *"This graph makes sense to me because it shows the speed decreasing on the way up. But I disagree with Burt, because I think this means the acceleration is also decreasing until the ball gets to the top and stops. Then both the speed and acceleration increase as the ball falls down again."*

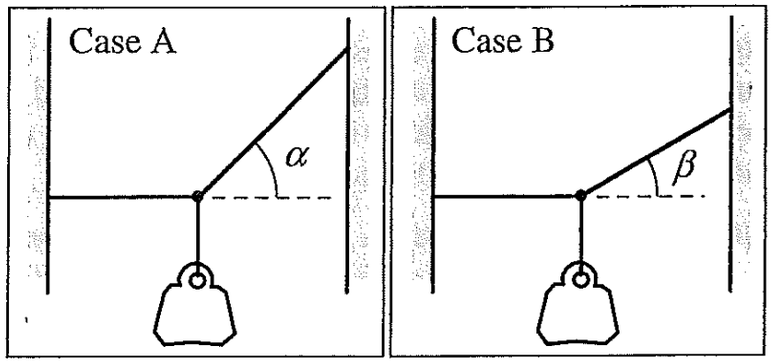
With which, if any, of these three students do you agree?

Akira _____ Burt _____ Catalina _____ None of them_____

Explain your reasoning.

B3-SCT78: Hanging Mass—Tension in Three Strings

A hanging mass is suspended midway between two walls. The string attached to the left wall is horizontal while the string attached to the right wall makes an angle with the horizontal as shown. This angle (α) in Case A is larger than the angle (β) in Case B. Four students make the following claims about the tensions in the strings:



Abbie: *"I think the tensions in any string in Case A is going to be the same as the equivalent string in Case B. The weight is the same, and the weight is still going to be divided up among the three ropes."*

Bobby: *"I think the tensions in the horizontal and vertical strings are the same, because they are exactly the same in both cases. But in Case B the diagonal rope is shorter, so the tension is more concentrated there."*

Che: *"The diagonal string still has to hold the weight up by itself, because the horizontal string can't lift anything. So the diagonal string still has the same tension. But in Case B it's pulling harder against the horizontal string because of the angle, so the tension in the horizontal string has to go up."*

Damian: *"But the diagonal string is fighting harder against the weight in Case A—it is pointing more nearly opposite the weight. So it has to have a greater tension in Case A. And since the tension in the diagonal string is greater, and the tension in the vertical string is the same, the tension in the horizontal string must be less in Case A. The tensions still have to balance out so that they are the same in both cases."*

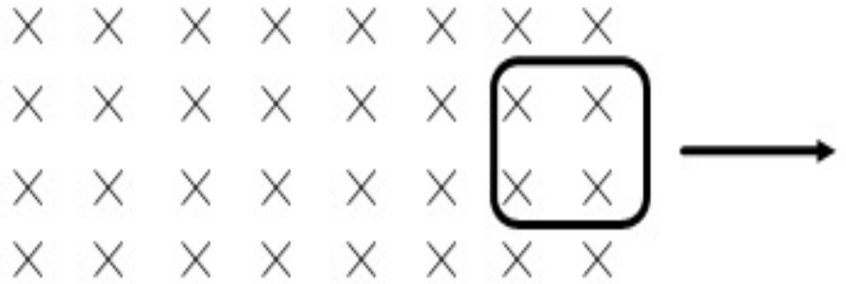
With which, if any, of these students do you agree?

Abbie _____ Bobby _____ Che _____ Damian _____ None of them_____

Explain your reasoning.

Conflicting Contentions Task P2

A square wire loop with sides of length L and resistance R is being pulled to the right at velocity v through a region with a magnetic field of strength B directed into the page as shown below:



Three students are working on this problem and make the following statements regarding the direction of the induced current:

Conflicting Contentions Task P2

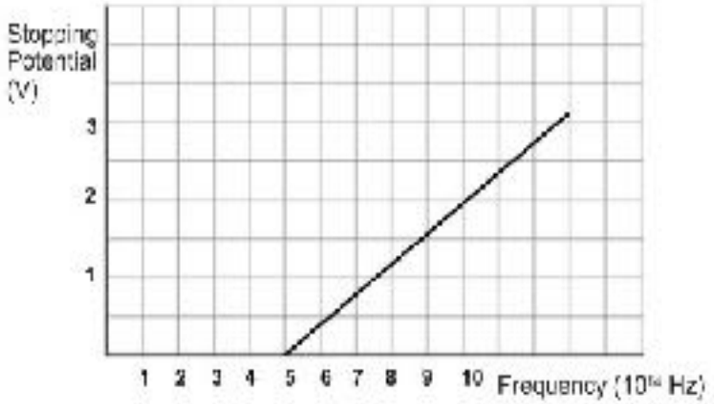
Student A: *The current must be counterclockwise. As the loop is moved out of the magnetic field, it increases the flux and the induced field acts in opposition to it. By applying Lenz's law, I determined that the current must flow counterclockwise.*

Student B: *There is no induced current since the loop is only halfway inside the magnetic field and does not receive the full effect of the magnetic field region.*

Student C: *As the loop is moved to the right, the flux decreases so the induced field must act in the same direction of the applied field to try to keep the flux constant. In order to produce an induced magnetic field into the page, the current must flow clockwise.*

Conflicting Contentions Task P2

The graph below represents the data obtained in a photoelectric effect experiment for a range of frequencies. The students graphed the stopping potential as a function of frequency as shown below:



Students in a physics class were asked to draw an expected graph for a different metal surface with a threshold frequency of 7.0×10^{14} Hz. Three students' responses to this task are given.

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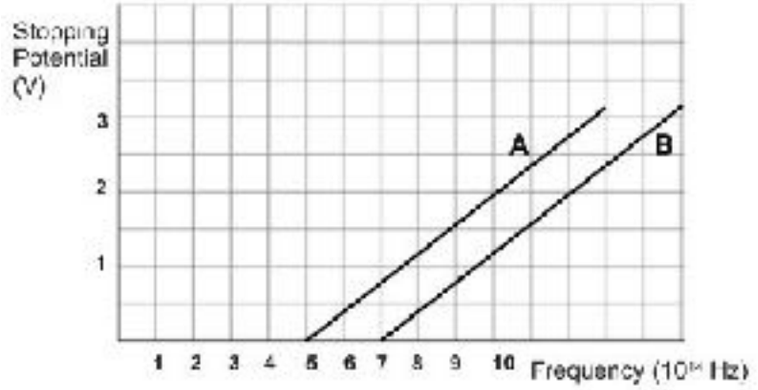
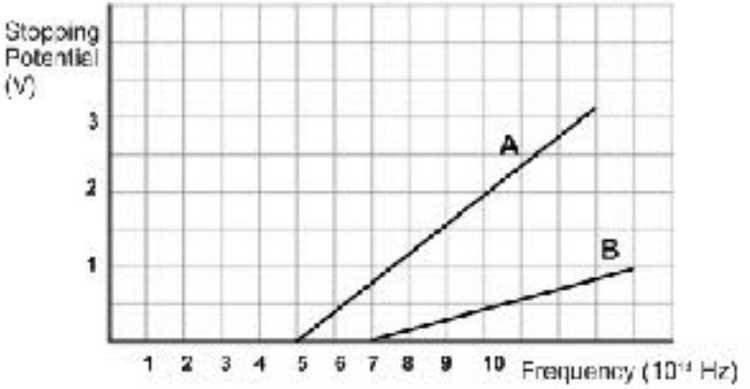
Conflicting Contentions Task P2

Student A



Student B



- **Student C**

A metal surface with a threshold value of 7.0 x 10^{14} Hz will not be able to eject electrons unless the light intensity is increased.

CollegeBoard

Conflicting Contentions Tasks

P1/Mech

"Qualitatively predict, in terms of linear momentum and kinetic energy, how the outcome of a collision between two objects changes depending on whether the collision is elastic or inelastic."

P2/E&M

"The student is able to predict electric charges on objects within a system by application of the principle of charge conservation within a system ."

CollegeBoard

Online Simulation Sites

The ones I use the most!

Browse Filter

SUBJECT

- [x] Physics
  - [x] Motion
  - [x] Sound & Waves
  - [x] Work, Energy & Power
  - [x] Heat & Thermo
  - [x] Quantum Phenomena
  - [x] Light & Radiation
  - [x] Electricity, Magnets & Circuits
- [ ] Chemistry
  - [ ] General Chemistry
  - [ ] Quantum Chemistry
- [ ] Math
  - [ ] Math Concepts
  - [ ] Math Applications
- [ ] Earth Science
- [ ] Biology

GRADE LEVEL +

COMPATIBILITY

- [x] HTML5
- [x] Java via CheerpJ
- [ ] Java
- [ ] Flash

ACCESSIBILITY +

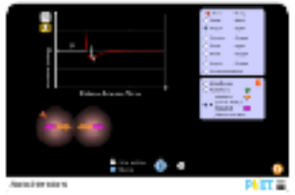
LOCALE +

91 Results

A-Z

Physics × Java via CheerpJ × HTML5 ×

Alpha Decay

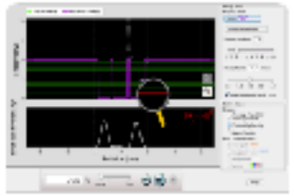


Atomic Interactions

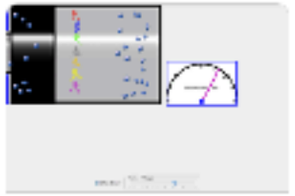
Balancing Act

Balloons & Buoyancy

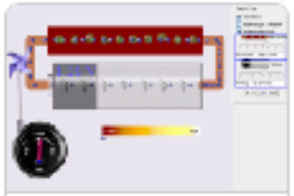
Balloons and Static Electricity



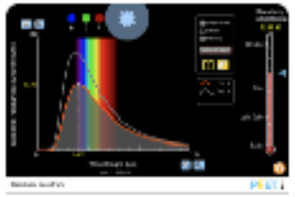
Band Structure



Battery Voltage

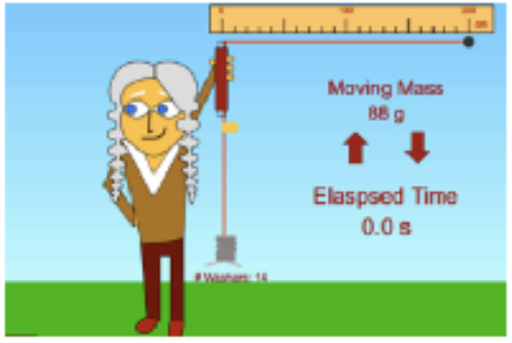


Battery-Resistor Circuit



The Physics Aviary

Welcome to the Physics Aviary. Since 2013 we have been making cross-platform, run-anywhere, programs to help physics students around the world master the big ideas in physics. Use the navigation links above to explore the site.



I make all of these resources available ad-free and free of charge to all who will find them of some use. As Thomas Jefferson said, "He who receives an idea from me, receives instruction himself without lessening mine; as he who lights his taper at mine, receives light without darkening me. That ideas should freely spread from one to another over the globe, for the moral and mutual instruction of man, and improvement of his condition, seems to have been peculiarly and benevolently designed by nature."

If you can't find what you are looking for among my resources above, check out the other sites listed below. Check back here often for updates and new programs. You can Follow @mcculley to get immediate notice of updates.

Other Resources

- Simbucket
- Boston University Simulations

oPhysics: Interactive Physics Simulations

Select a simulation from one of the above categories or click on a category to see descriptions of the simulations for that category.

About oPhysics

The oPhysics website is a collection of interactive physics simulations. It is a work in progress, and likely always will be. Content will be added as time allows.

About The Author

All of the content on this site was created by me, Tom Walsh. I recently retired after teaching high school physics for 27 years, and AP Physics for 25 years. Please click my name above to send me feedback about these simulations or suggestions for new simulations I could create. Being retired now, I actually have more free time to work on new projects.

About GeoGebra

Most of the animated illustrations and all of the interactive simulations on this site were created using the wonderful GeoGebra software. GeoGebra is a free program that makes it very easy to create animations and simulations for anyone with a good understanding of math or physics.

For more information about the software please visit their website: www.geogebra.org.

To browse or search for pre-made math and physics simulations (including those used on this site) visit: tube.geogebra.org.

Permissions

Please feel free to use any of the content on this site for non-profit educational purposes.

My Favorite Sites

- PhET.Colorado.edu
- www.ThePhysicsAviary.com
- www.oPhysics.com

- www.walter-fendt.de/html5/phen/
- www.falstad.com/mathphysics.html
- www.physicsclassroom.com/Physics-Interactives

- Your favorites??

Experimental Design FRQs and Online Simulations

Great way to prepare students for the exam!

Uses

- Pre-Lab Activity: Better understanding of what the lab will be investigating
- Ability to vary difficult to vary IVs like g or n
- Lab makeup
- WS replacement
- Determining Unknown Constants
  - -Replicates FRQ Experimental Design Questions
- Linearization Practice
- Replicates expensive equipment
- Helps visualize unseeable things

Experimental Design Rubrics

Duplicate items in lab reports

- Look at the released Experimental Design Questions for lab ideas
- Also carefully examine the rubrics to see common points
- Make sure students are doing those things in lab and on lab reports
- C: Mechanics look at P1 FRQs
- C: E&M look through E&M P2 FRQs

- Basic basic basic!!!

2. (12 points, suggested time 25 minutes)

A group of students is given several long, thick, cylindrical conducting rods of the same unknown material with various lengths and diameters and asked to experimentally determine the resistivity of the material using a graph. The available equipment includes a voltmeter, an ammeter, connecting wires, a variable-output DC power supply, and a metric ruler.

(a)

i. Describe a procedure the students could use to collect the data needed to create the graph, including the measurements to be taken and a labeled diagram of the circuit to be used. Include enough detail that another student could follow the procedure and obtain similar data.

Draw a labeled diagram here.

Write your procedure here.

ii. Describe how the data could be graphed in a way that is useful for determining the resistivity of the material. Describe how the graph could be analyzed to calculate the resistivity.

The students are now given a rectangular rod of the material, as shown below, whose dimensions are not known. The students are asked to experimentally determine the resistance of the rod. They obtain the data in the table below for the potential difference ΔV across the rod and the current I in it.

ΔV (V)	6.0	5.0	3.5	2.5	2.0	1.5
I (A)	0.078	0.070	0.044	0.036	0.027	0.018

CollegeBoa

AP® PHYSICS 2
2017 SCORING GUIDELINES

Question 2

12 points total | **Distribution of points**

(a)

i. 5 points

For drawing a circuit with the battery, rod, and ammeter in series (rods can be drawn to look like rods, or schematically as resistors)	1 point
For drawing the voltmeter parallel to the rod, or indicating that the setting on the power supply will be used	1 point
For measuring potential difference and current for a rod	1 point
For measuring the length and diameter of a rod	1 point
For including multiple trials with appropriate controls Examples: 1) Use one rod and apply different potential differences 2) Use different rods	1 point

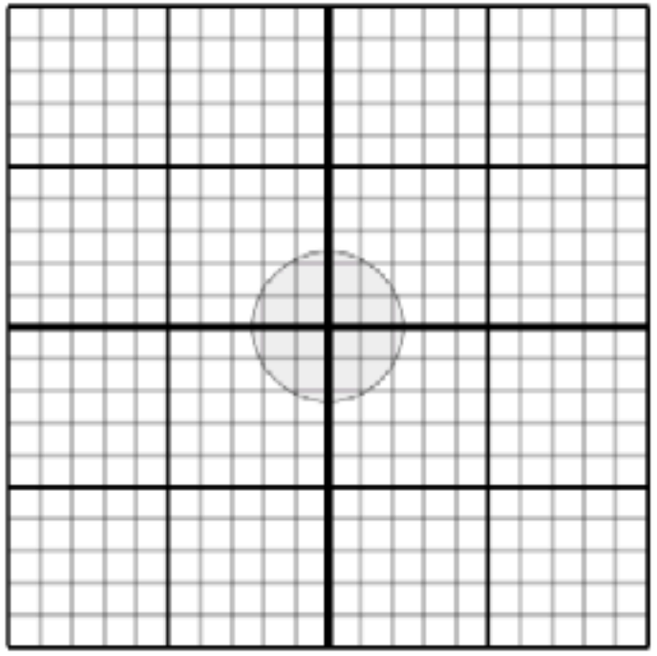
ii. 2 points

For graphing appropriate quantities whose slope can be used to calculate resistance directly or indirectly	1 point
For correctly stating how the slope relates to the resistivity	1 point

Resistance of a Wire Lab

Wire Cross Section

Each Block is 0.1 mm



Wire Resistance

15.41 Ω

Wire Type

Nichrome

2017 AP® PHYSICS 1 FREE-RESPONSE QUESTIONS

2. (12 points, suggested time 25 minutes)

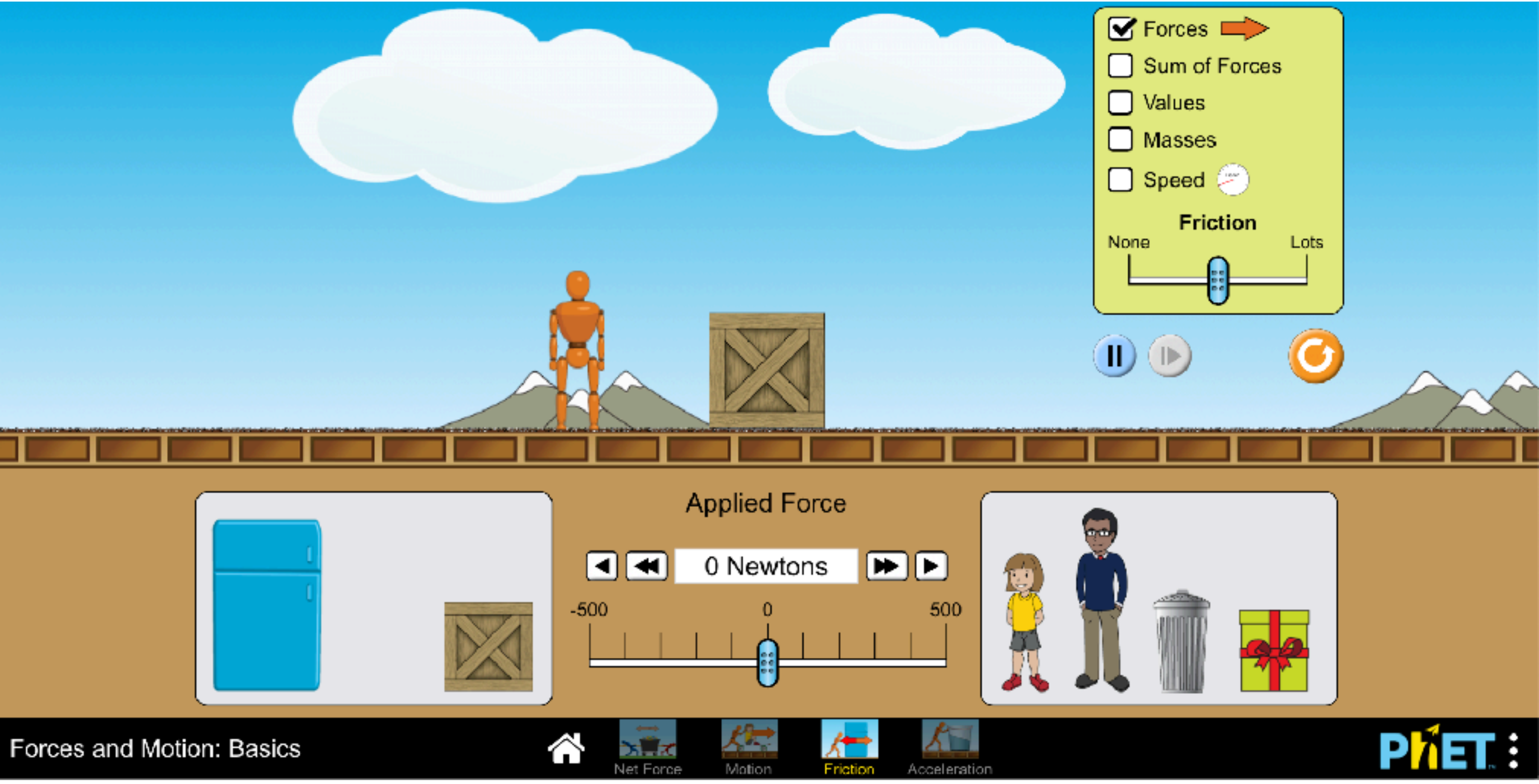
A student wants to determine the coefficient of static friction between a long, flat wood board and a small wood block.

(a) Describe an experiment for determining the coefficient of static friction between the wood board and the wood block. Assume equipment usually found in a school physics laboratory is available.

i. Draw a diagram of the experimental setup of the board and block. In your diagram, indicate each quantity that would be measured and draw or state what equipment would be used to measure each quantity.

ii. Describe the overall procedure to be used, including any steps necessary to reduce experimental uncertainty. Give enough detail so that another student could replicate the experiment.

(b) Derive an equation for the coefficient of static friction in terms of quantities measured in the procedure from part (a).


Forces
Sum of Forces
Values
Masses
Speed
Friction
None
Lots
Applied Force
0 Newtons
-500
0
500
Forces and Motion: Basics
Net Force
Motion
Friction
Acceleration
PhET

(a)

i. 3 points

For drawing a diagram of an experimental setup to measure the coefficient of friction that is feasible in a school physics lab	1 point
For indicating the measurements necessary for calculating the coefficient of friction	1 point
For indicating equipment necessary for measuring the quantities required to calculate the coefficient of friction	1 point

ii. 3 points

For a description that is consistent with the diagram in part (a)(i), in enough detail that another student could replicate the experiment	1 point
For a description that is a conceptually valid method to find quantities that would allow a calculation of a friction coefficient	1 point
For including a valid method for reducing experimental error	1 point

(b) 3 points

Note: In order to earn full credit for part (b), all terms (variables) must be indicated in the diagram and/or procedure of part (a).

For using Newton's second law (or reasoning in terms of zero net force) in one dimension, parallel to the board's surface, either explicitly or implicitly — 1 point

For using Newton's second law (or reasoning in terms of zero net force) in one dimension, perpendicular to the board's surface, either explicitly or implicitly — 1 point

Note: Replacing the normal force with mg is "implicit" use of Newton's second law in the perpendicular direction for a horizontal surface. For a tilted surface, the appropriate trigonometric term should be included.

For a correct derived expression of the coefficient of static friction in terms of quantities indicated in part (a) — 1 point

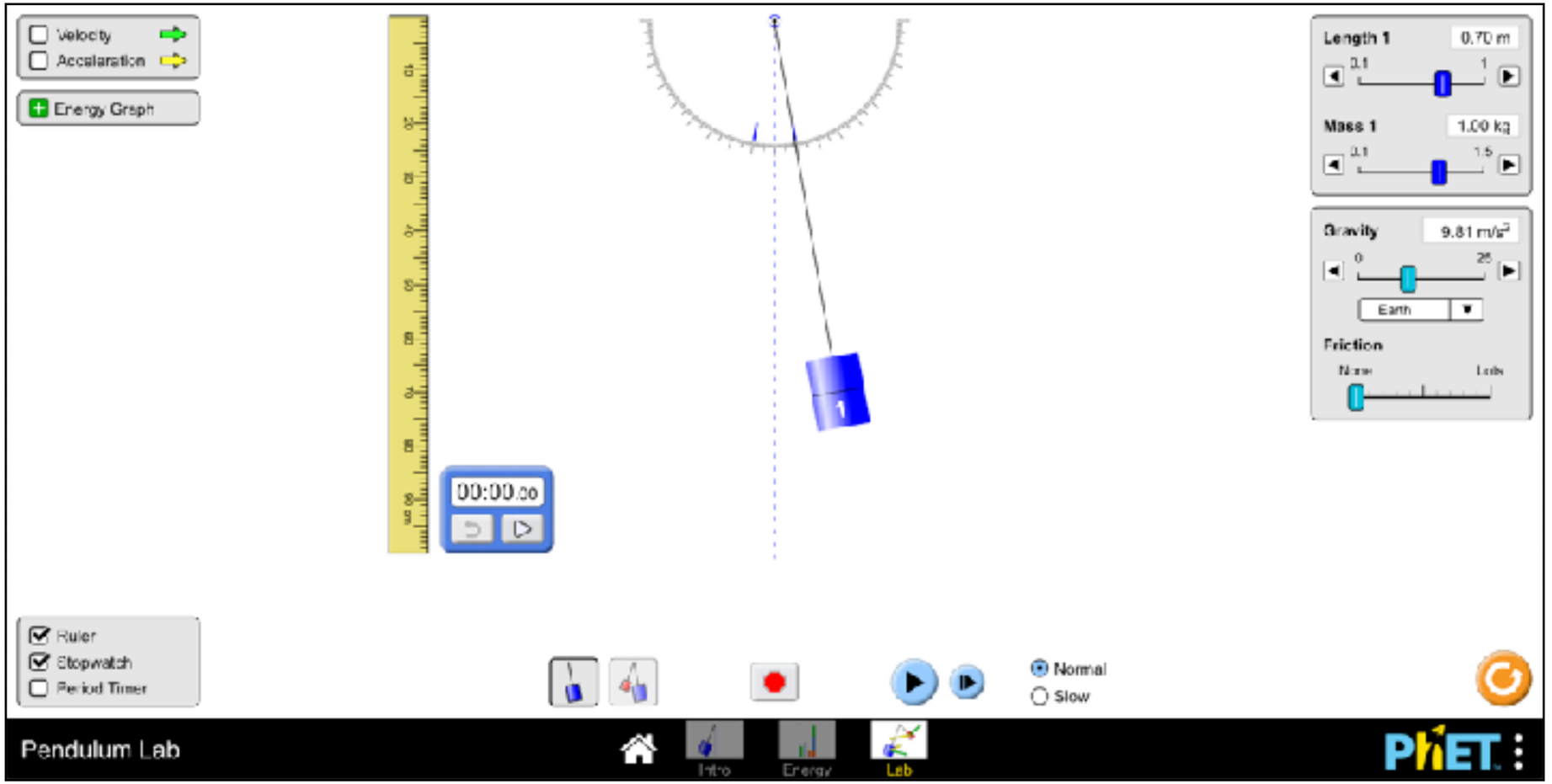
Pre-Lab and Post-Lab Uses for Online Simulations

Supplement Hands-On Lab Experiences

Use as a Pre-Lab Activity

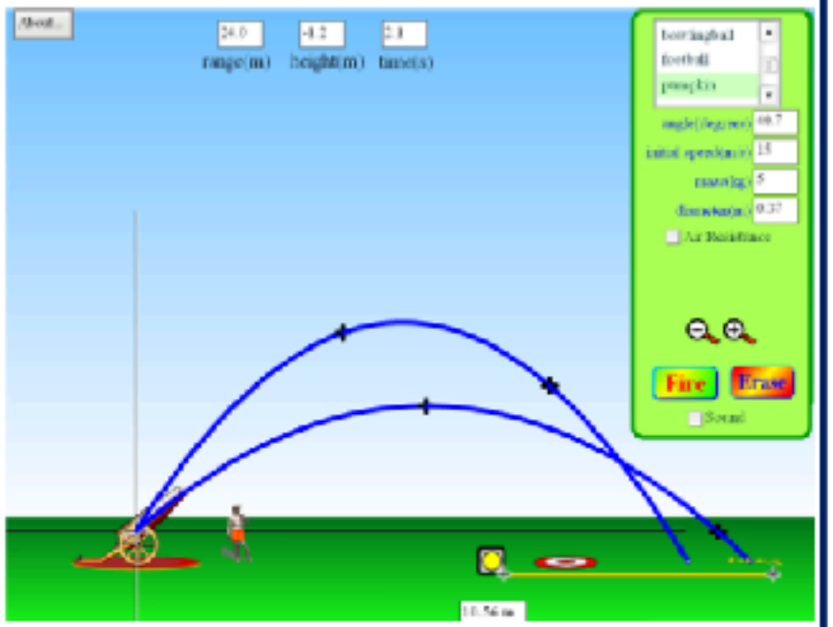
- See a basic image of the setup
- Have students begin to investigate possible Independent Variables and how they affect the Dependent Variable (directly or inversely)
- Start to make a list of required equipment and measuring devices
- Reinforces what values to measure and how to measure them

Pendulum Lab: PhET.Colorado.edu



Using PhET sims prior to instruction.

Here, the instructor elicits students ideas about an everyday action and then has them explore the *Projectile Motion* sim to begin developing a framework of ideas about what is important when considering projectile motion, providing a foundation for class discussion.



1. One day after school, you are enjoying a soda in the back yard. When the can is empty, you decide to throw it in the trashcan. What effects whether or not it gets in the can?

2. Use *Projectile Motion* to test your ideas about the things that affect the landing location of a projectile.

- Make a complete list of things that affect the landing site of a projectile including your ideas from question #1 and any discoveries you made using the simulation.
- Next to each item, briefly explain why you think the landing location changes.

Post-Lab Uses

- Change unchangeable Independent Variables
  - -Most common is g
- Change Independent Variables that are difficult to change quickly
  - -Example on the next slide of n
- Great for use as Homework to replace worksheets
  - -PhET has a great site about using them as Homework

Planning to Use PhET

Teachers and Students Speak:

A look at the PhET simulations and their uses in college and K-12.

Teacher Tips

Goals for Teachers and Students. A two-page summary of the PhET's goals for students and teachers as they engage in sim-based teaching and learning.

Using PhET Interactive Simulations in Lecture. A two-page overview of uses of PhET simulations in lecture settings.

Using PhET InteractiveSimulations in Homework. A two-page overview of writing effective inquiry-style homework problems using PhET interactive simulations, for college or K-12.

Writing Learning Goals. Tips on writing clear learning objectives for your students.

How do I use PhET simulations in my physics class? Tips on how PhET simulations can be integrated into a course, using college physics as an example.

What are some tips for using PhET in a lab setting? Using PhET in a lab setting has many benefits, such as allowing new possibilities for experiments (such as quantum mechanics), quick repeatability, and making visible the underlying mechanisms.

What are some tips for using PhET with homework? PhET simulations are ideal for use in homework because the simulations are designed to cue students to explore cause-and-effect relationships, even without an instructor present.

Using PhET in Lecture: An Overview

Interactive Lecture Demonstrations

Using PhET with Clickers

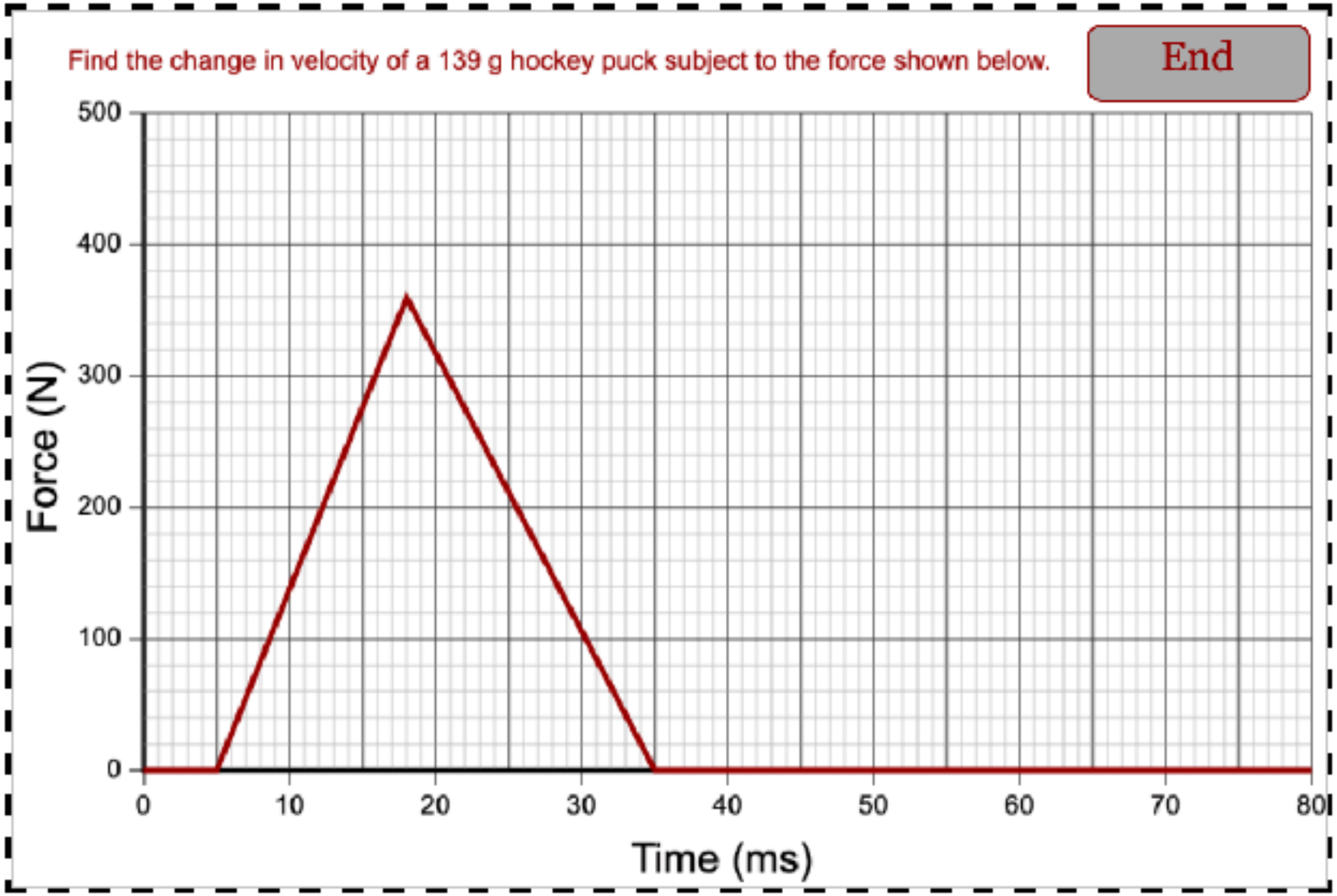
Designing Activities for K12

Facilitating Activities for K12

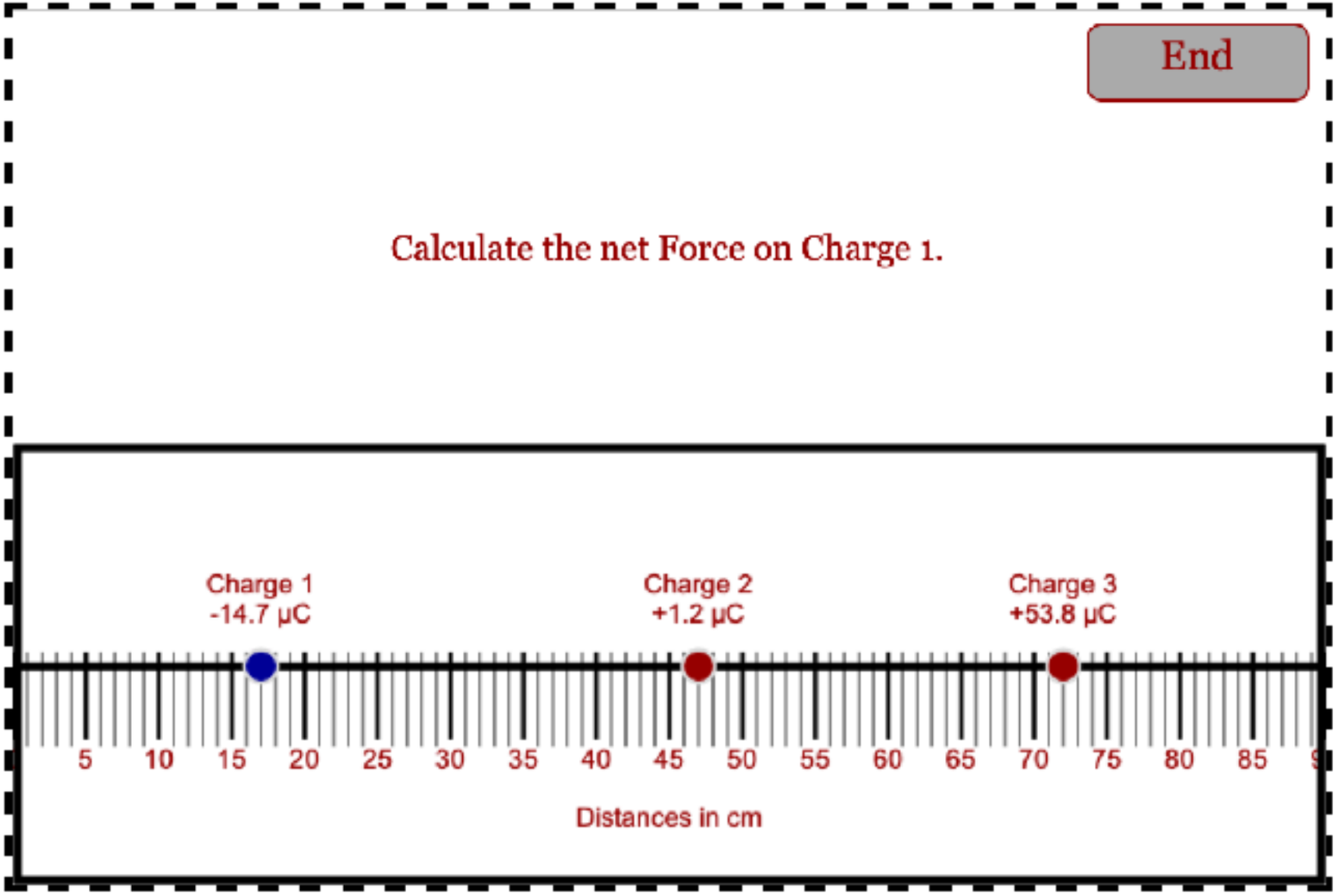
Video Series: Facilitating PhET Activities in K12 Classrooms

Take a Virtual PhET Workshop

Impulse Lab: www.ThePhysicsAviary.com



Force Electric in a Line HW: www.ThePhysicsAviary.com



Force Electric in a Line HW: www.ThePhysicsAviary.com

Force Electric in a Line HW: www.ThePhysicsAviary.com

Actual Force was 25.3 N. Student Response was N.

Actual Force Direction was Right . Student Response was Right.

Your answers were not good enough. Refresh this page and try again.

16118529190 25

Thank You!!!

oather@PhluidPhsyics.com

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