AP Physics C Workshop

Shenzhen College of International Education
Shenzhen, China

Oather Strawderman

International Lead AP Physics Consultant



October 17-18, 2026

Welcome!

oather@PhluidPhysics.com



Oather Strawderman

- Science Department Chair @ Lawrence Free State High School in Lawrence, Kansas
- AP Physics teacher since 1997
- International Lead AP Physics Consultant since 2013
- Exam Leader at AP Physics Reading since 2012
- Chair of AP Physics Development Committee
- Lead Instructor for AP Classroom
- AP Physics Item Writer and Reviewer
- Chair College Board Science Advisory Committee

Lawrence, Kansas



Introductions

- Name
- Where do you teach?
- How long have you taught Physics/AP Physics?
- Which AP Physics course(s) are you teaching this year?
- What is your favorite Physics topic to teach?

Setting the Stage

- Ask questions and share ideas!
- Participate!!
- Physics
- Switching Seats
- Computers: WiFi & Workshop Resources
- Building logistics: Restrooms
- Workshop Logistics: Breaks / Lunch

Objectives

Participants will:

- Explore each section of the Course and Exam Description (CED) and make connections to the Curricular Requirements
- Develop a semester and/or yearlong instructional plan that incorporates all units, topics and skills of the course, as referenced in the CED.
- Explore the exam design and how students will be assessed in a hybrid-digital environment.
- Identify and explain various instructional strategies and tools that teachers can incorporate in their lesson plans to teach the content and skills in the Course and Exam Description.
- Investigate how AP Classroom can develop skills/practices and be used in lesson plans to reinforce topic and skill/practice connections.

Saturday Schedule

9:15am - 10:15am: AM 1 Session

10:15am - 10:30am Tea Break

10:30am - 12:00pm: AM 2 Session

12:00pm - 1:00pm: Lunch

1:00pm - 2:45pm: PM 1 Session

2:45pm - 3:00pm: Tea Break

3:00pm - 4:45pm: PM 2 Session

Sunday Schedule

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

10:00am - 10:15am Tea Break

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

12:00pm - 1:00pm: Lunch

1:00pm - 2:30pm: PM 1 Session

2:30pm - 2:45pm: Tea Break

2:45pm - 4:00pm: PM 2 Session

Saturday October 17

AM1

- Agenda & Introductions
- Exam Overview / Digital Exams / Multiple Choice Section
- Developing the Science Practices

AM2

- Courses Overview / Course & Exam Descriptions/Textbooks
- Year Long Plan
- Labs / Desmos / Graphing Calculator
- *Fidget Spinner Labs*

PM1

- Experimental Design and Analysis Free Response Questions
- *Resistivity Lab Free Response Question*

PM2

- Mathematical Routines Free Response Questions
- Derivation Strategies
- Calculus on the AP Physics Exams

Sunday October 18

AM1

- *Meterstick Torque Lab Free Response Question*
- Reading / Mock Reading
- AP Classroom / Instructional Planning Reports

AM2

- Translation Between Representations Free Response Questions
- Types of Representation: Diagrams & Sketches
- *Toilet Paper Roll Free Response Question Activity*

PM1

- Qualitative/Quantitative Translation Free Response Questions
- Writing Strategies
- *Dielectric Constant of Paper Lab Free Response Question*

PM2

- TIPERs & Ranking Tasks
- P1 Workbook
- *Online Simulation Labs*

Contact Info:

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oather@PhluidPhysics.com

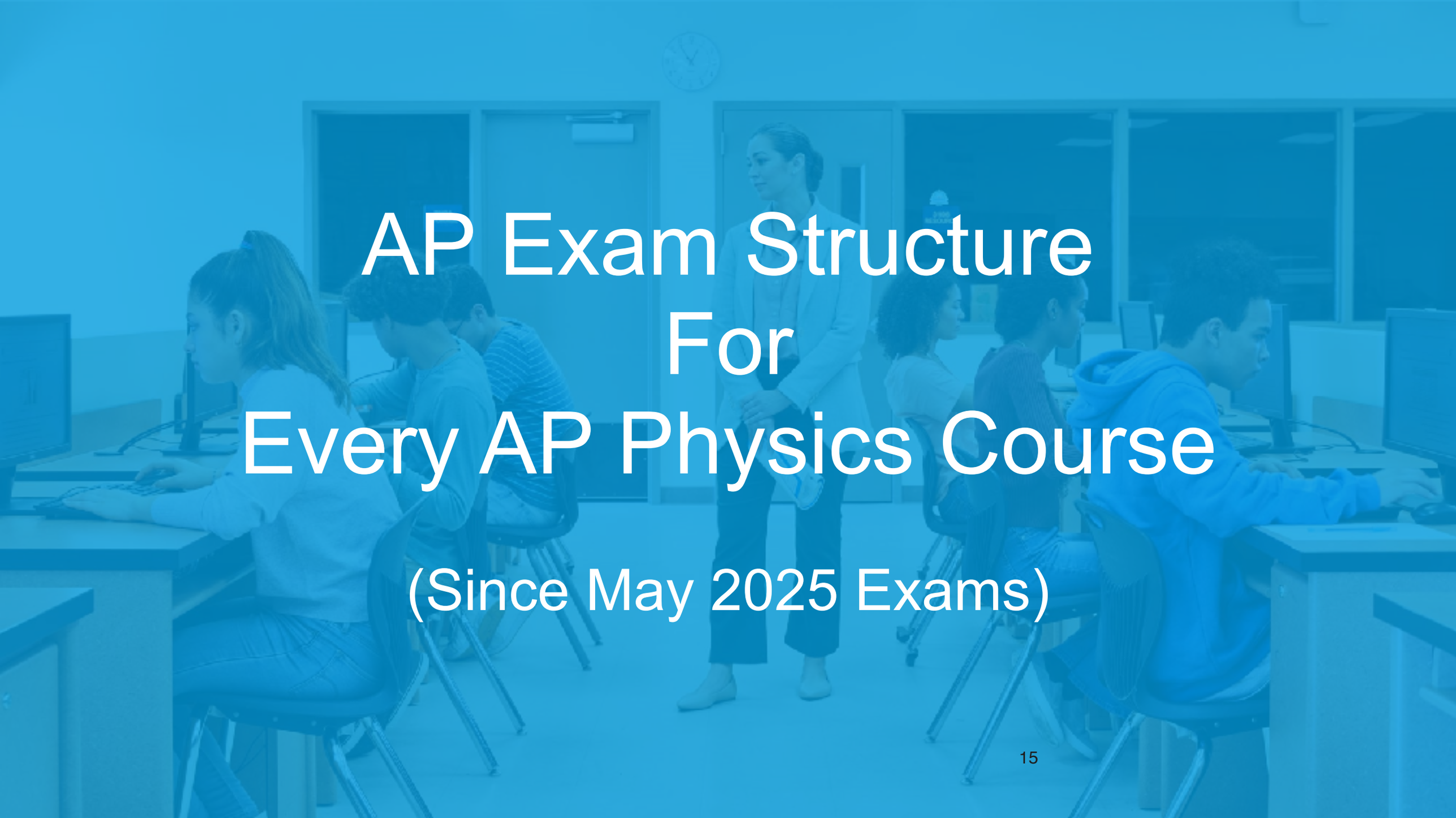
Workshop Links & Documents

www.PhluidPhysics.com/Resources

AP Physics C: Mechanics and E&M Websites

apcentral.collegeboard.org/courses/ap-physics-c-mechanics

apcentral.collegeboard.org/courses/ap-physics-c-electricity-and-magnetism



AP Exam Structure For Every AP Physics Course

(Since May 2025 Exams)

Exam Structure

- **Section 1: Multiple-Choice (50%)**
  - **42 questions, **85** minutes (**2 not scored**)**
  - One correct answer
  - Four answer choices

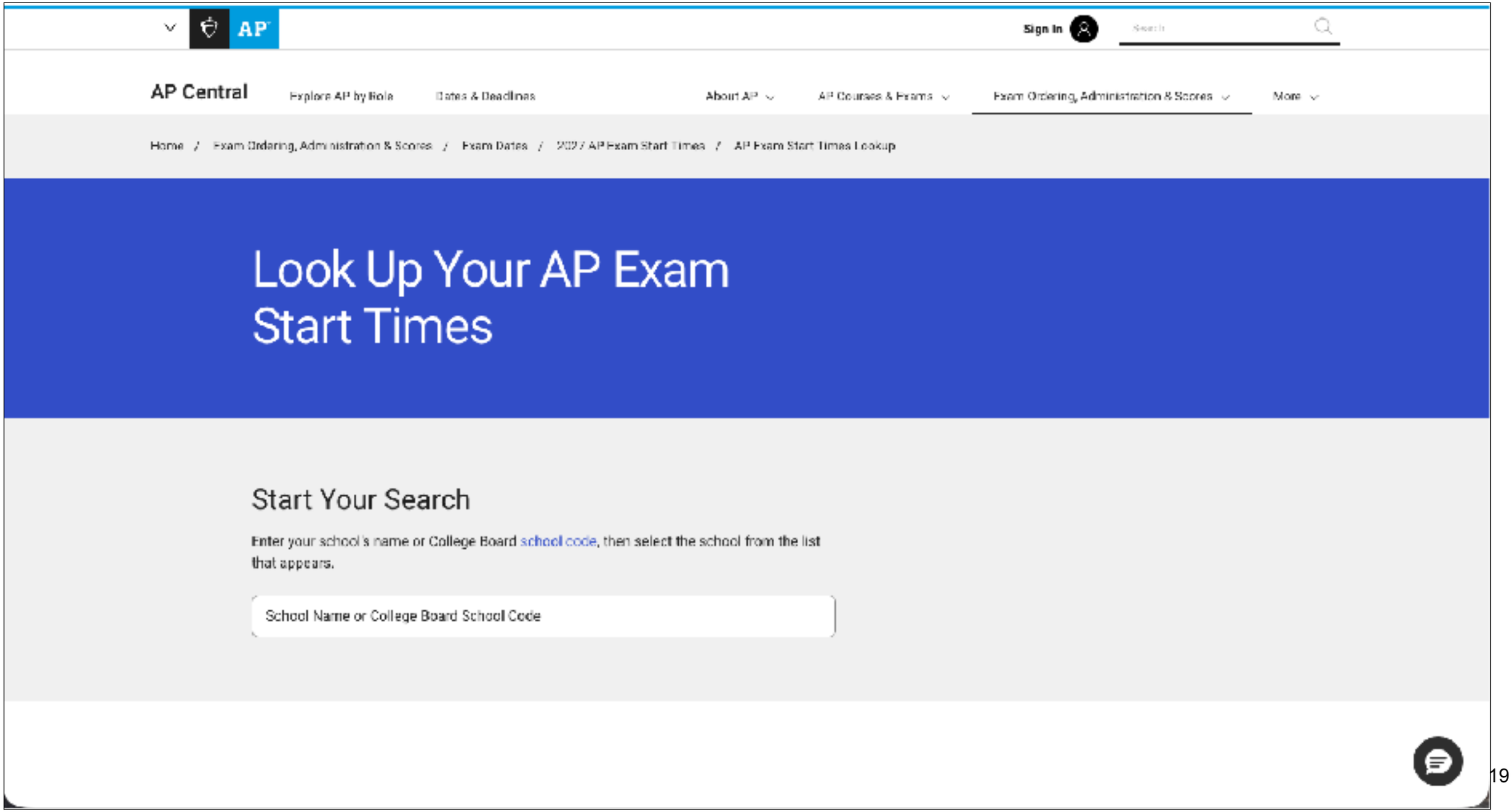
- **Section 2: Free-Response (50%)**
  - **4 questions, **95** minutes**, 40 points
    1. Mathematical Routines (10 points)
    2. Translation Between Representations (12 points)
    3. Experimental Design and Analysis (10 points)
    4. Qualitative/Quantitative Translation (8 points)
  - Same order of Free-Response Questions for every course on every exam

Free-Response Question Types: In this Order

- **Mathematical Routines**
  - Emphasizes problem-solving, calculations, and derivations.
- **Translation Between Representations**
  - Emphasizes fluency between various representations of physical phenomena
- **Experimental Design and Analysis**
  - Design an experiment, analyze the results of an experiment
- **Qualitative/Quantitative Translation**
  - Emphasizes fluency between conceptual and mathematical descriptions of physical phenomena

Exam Information

- Each Multiple Choice Question and Free Response Question point assesses relevant physics content using a given Science Practice
- All content may be assessed with any Science Practice
- **All AP Physics courses have nearly identical exam structures**
- **Exam Dates 2027**
  - P1: Wednesday May 5 - Session 2 (1:00pm)
  - P2: Thursday May 6 - Session 1 (9:00am)
  - Mechanics: Monday May 3 - Session 1 (9:00am)
  - E&M: Wednesday May 5 - Session 2 (1:00pm)


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AP Physics Exam Section 1: Multiple Choice Questions

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Multiple Choice Questions Activity

- Turn to the following pages in the CED:
  - Mech page 175
  - E&M page 151
- Answer the MCQ items in the CED
- Write down your answer to each question on paper
- Focus on both the content of the questions as well as how the questions are formatted and how they ask students to demonstrate their Physics knowledge

Discussion Topics

- What are some things you notice about the questions…content and skill?
- What successes and challenges could your students have with these questions?
- What instructional strategies do you employ to help your students be successful on the Multiple Choice section of the exam?

Information

- Hybrid Digital
- Pacing/Clock
- Equation Sheets
- Scratch Paper
- 10 m/s/s and 10 N/kg
- Discrete Items vs Item Sets
- Calculators, Rulers and Pens/Pencils
- Difficulty and Guessing
- Answers and Rationales

https://bluebook.app.collegeboard.org/

Section I

Directions

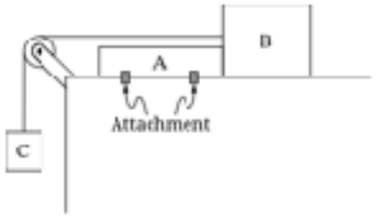
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Highlights & Notes | Calculator | Reference | More

THIS IS A TEST PREVIEW

Blocks A and B, of masses m_A and m_B, respectively, are at rest on a horizontal surface with negligible friction. Block A is attached to the table. Block C of mass m_C is suspended by a string that is tied to Block B and passes over a pulley as shown. The blocks all remain at rest.



1 Mark for Review

Which of the following gives the magnitude of the force exerted by Block A on Block B?

(A) $m_B g$

(B) $m_C g$

(C) $\frac{m_A m_C g}{m_A + m_B}$

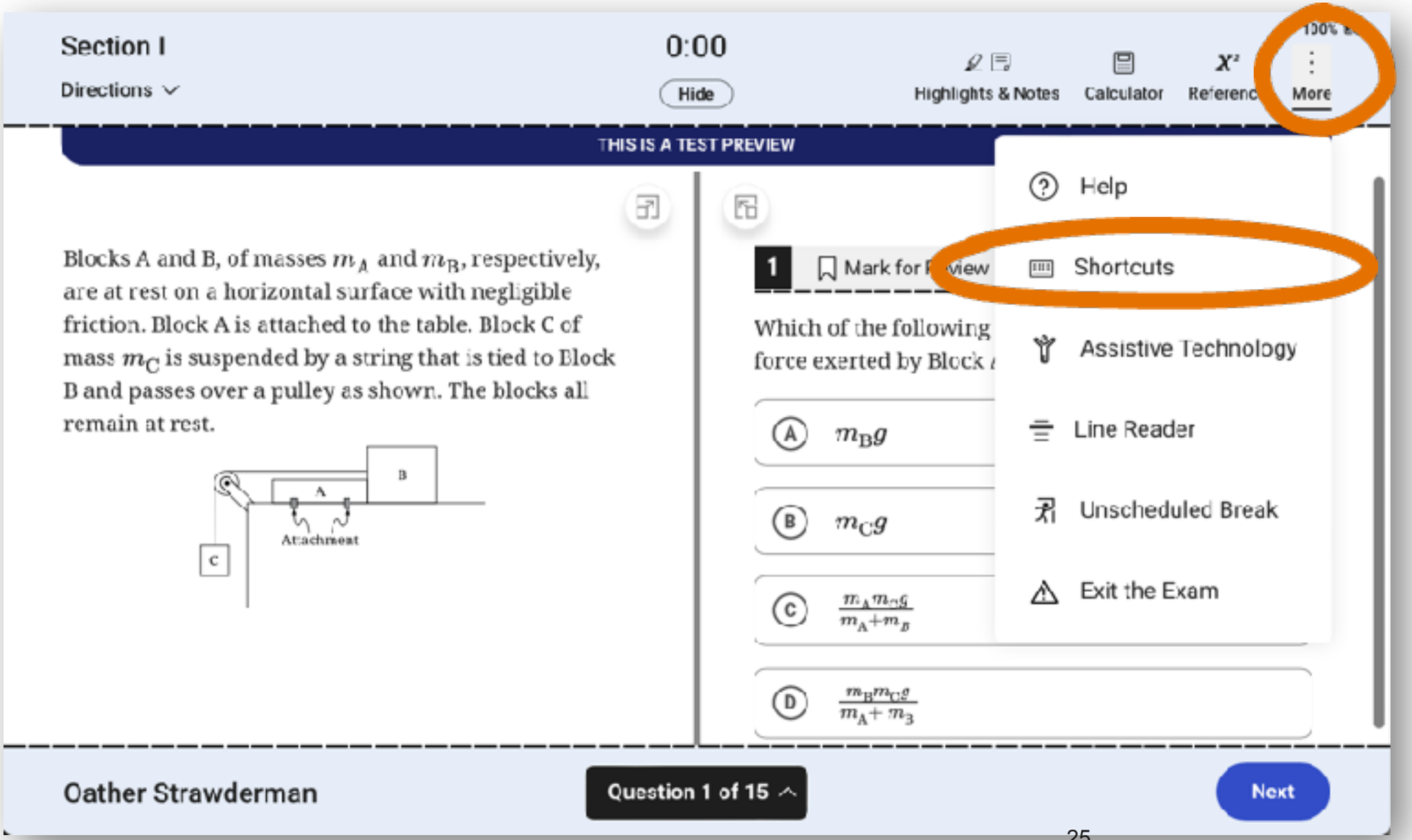
(D) $\frac{m_B m_C g}{m_A + m_B}$

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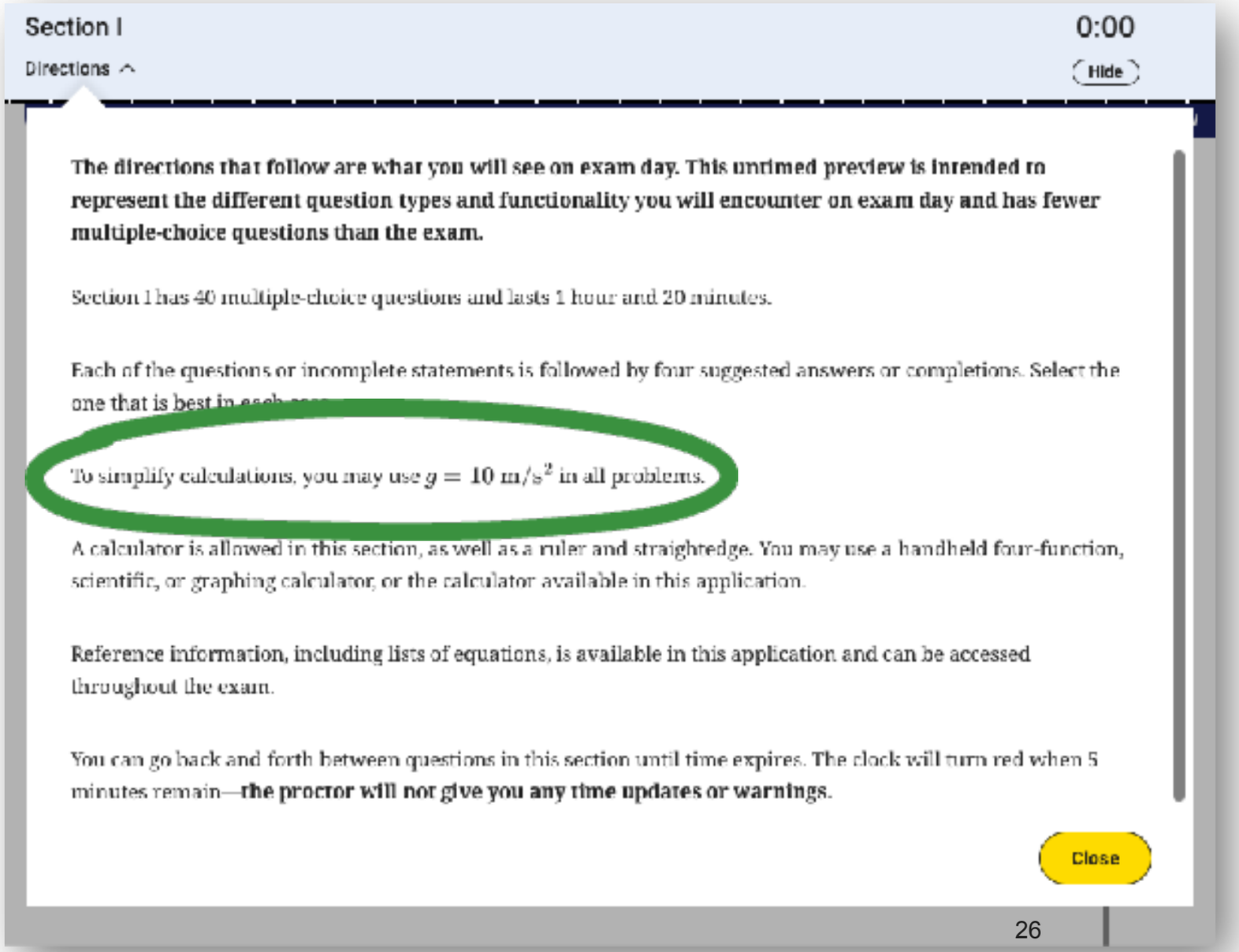
Question 1 of 15

Next

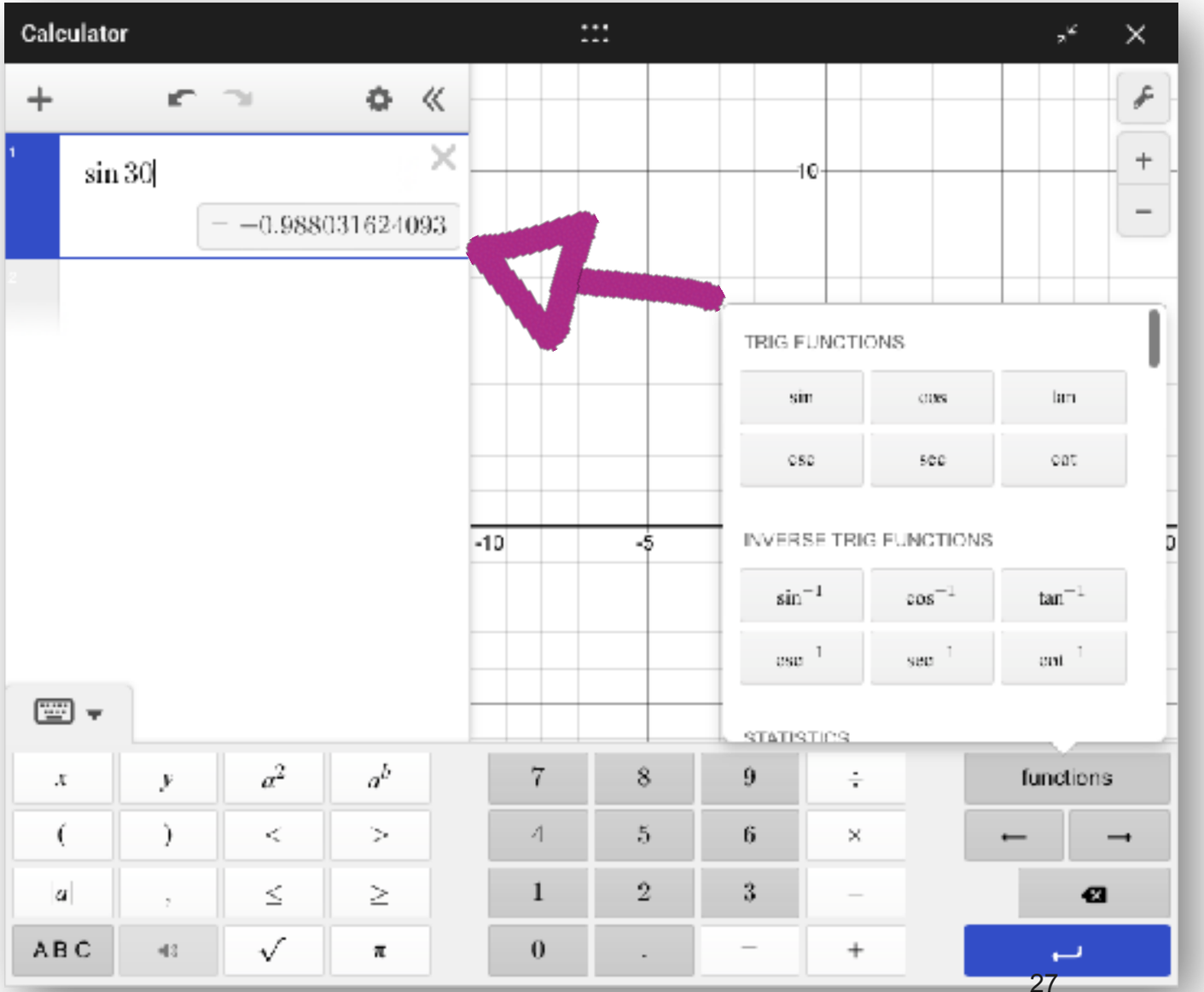
Zooming Shortcuts



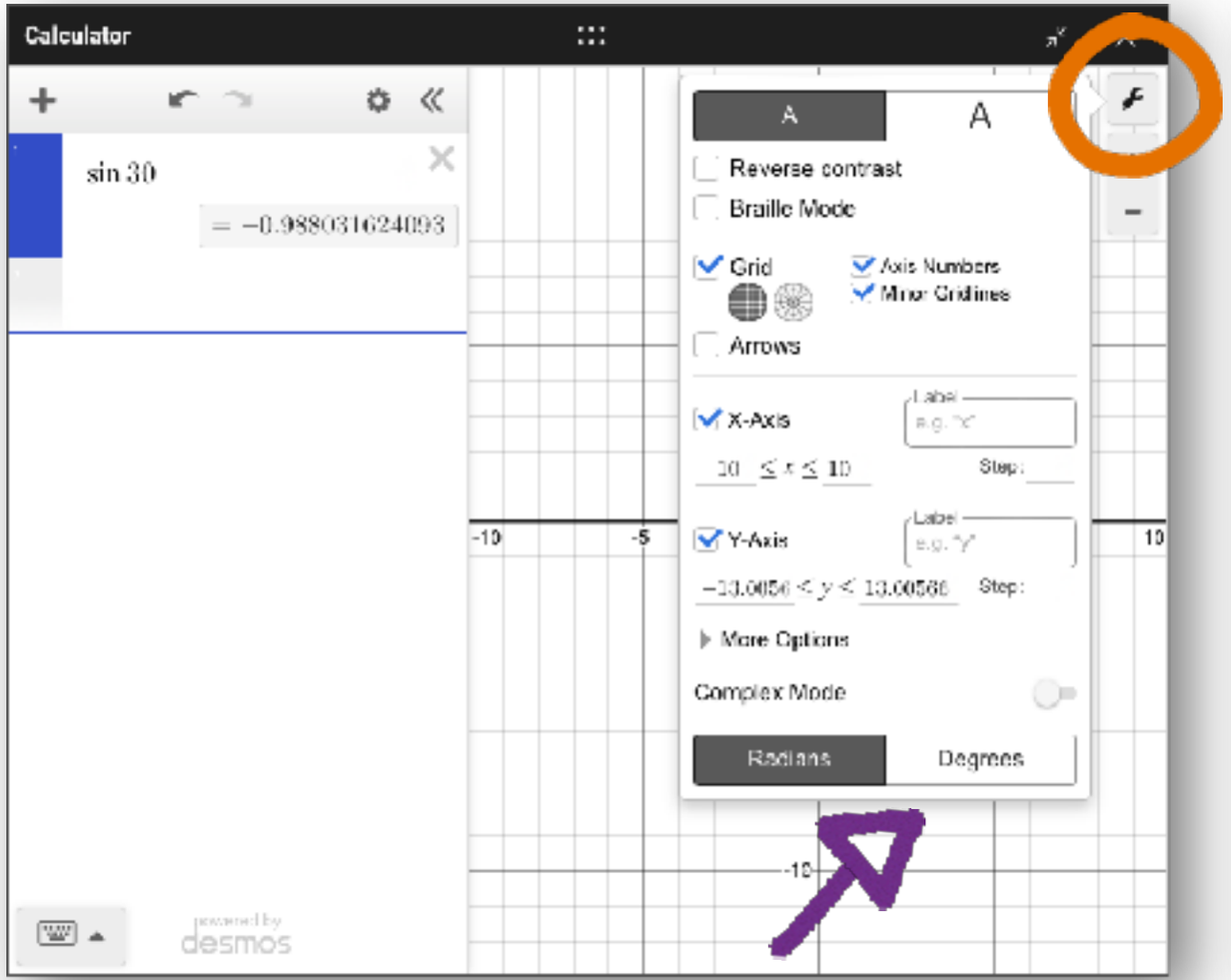
Multiple Choice Section Directions

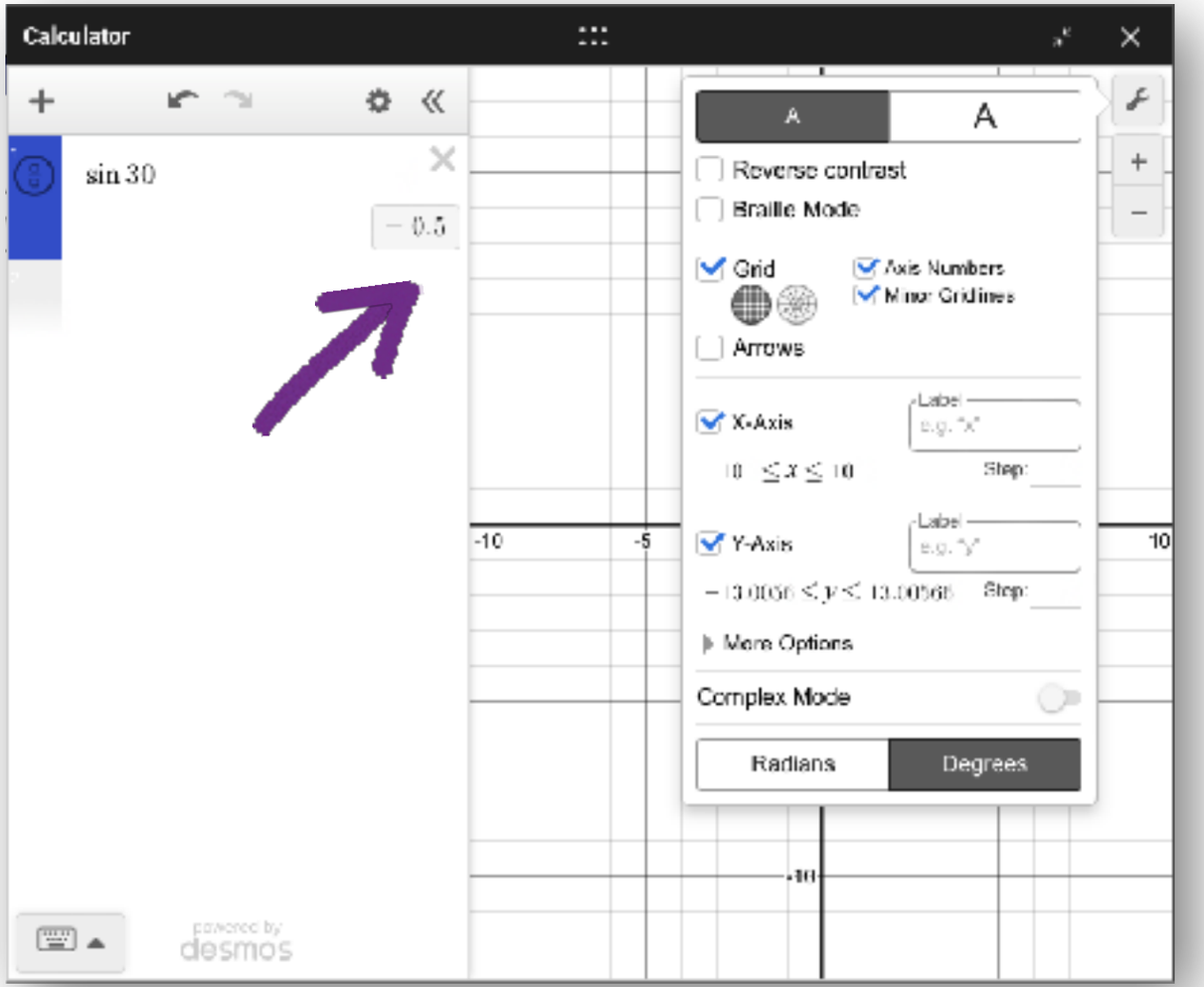


Built-in Desmos Graphing Calculator



Switching Angle Modes in Desmos!!





Strikethrough to help narrow down options!

9 Mark for Review

Which of the following is most nearly the MOMENTUM of Block B after the collision?

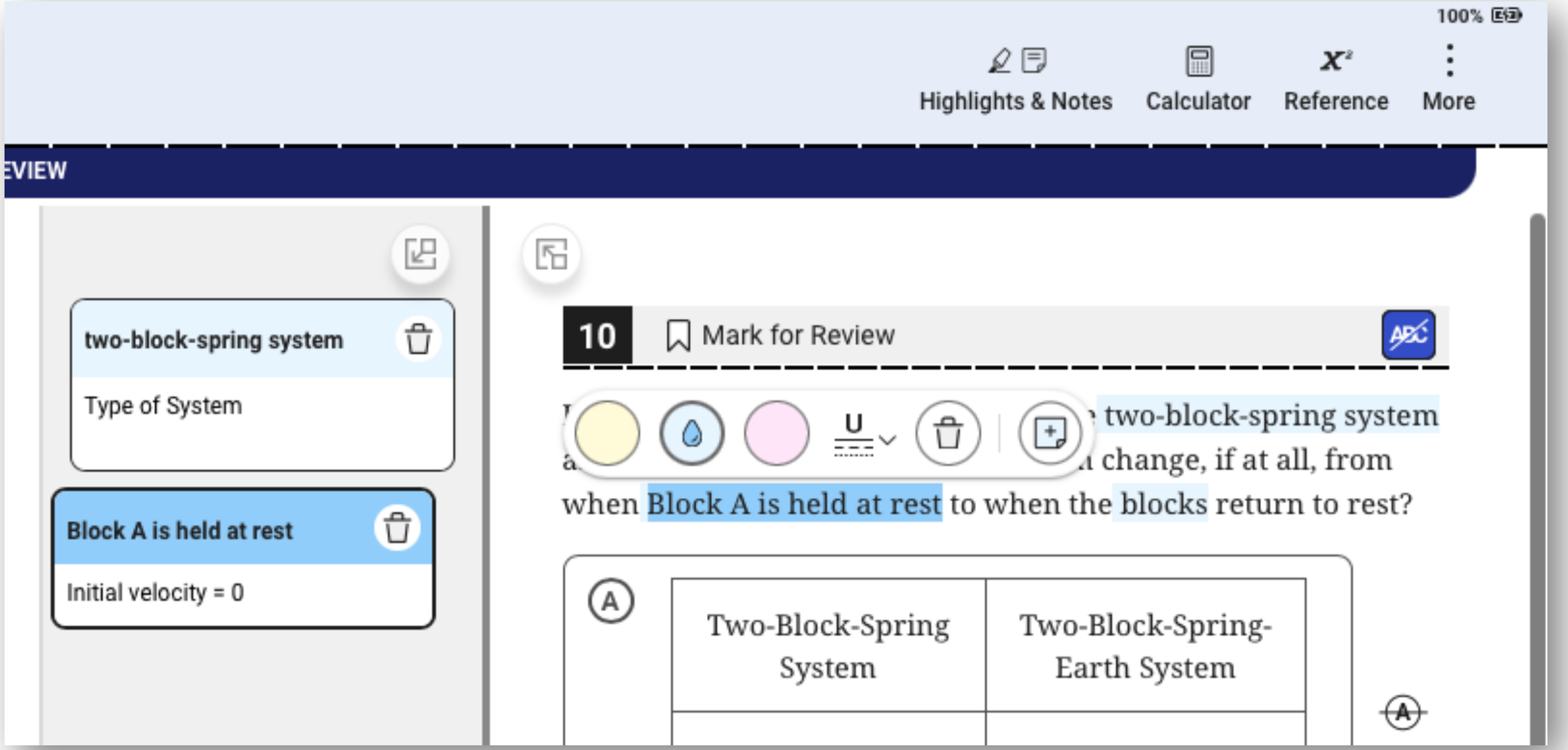
~~A 2.0 kg·m/s~~ Undo

~~B 3.0 kg·m/s~~ Undo

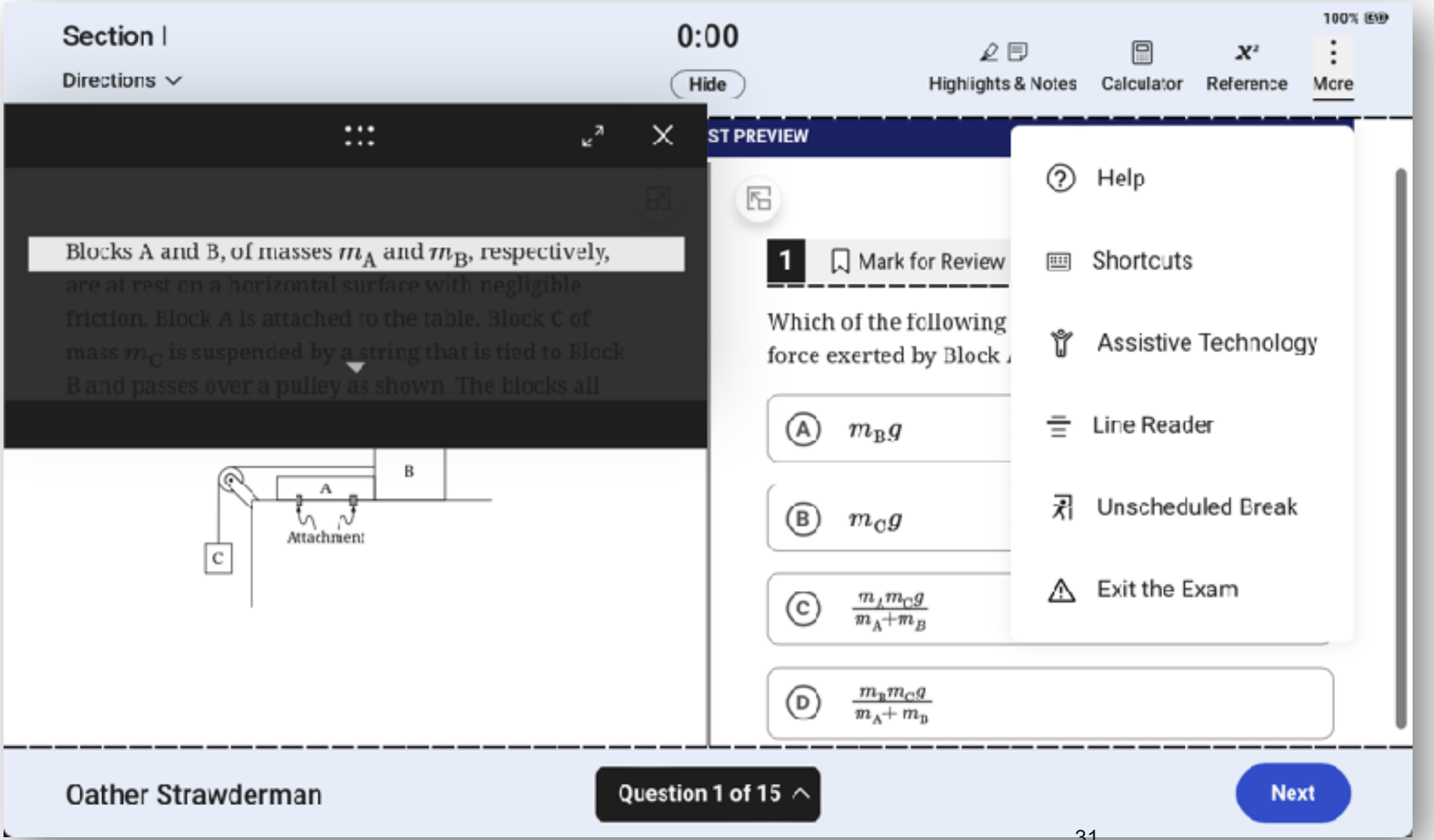
C 4.0 kg·m/s ~~C~~

D 6.0 kg·m/s ~~D~~

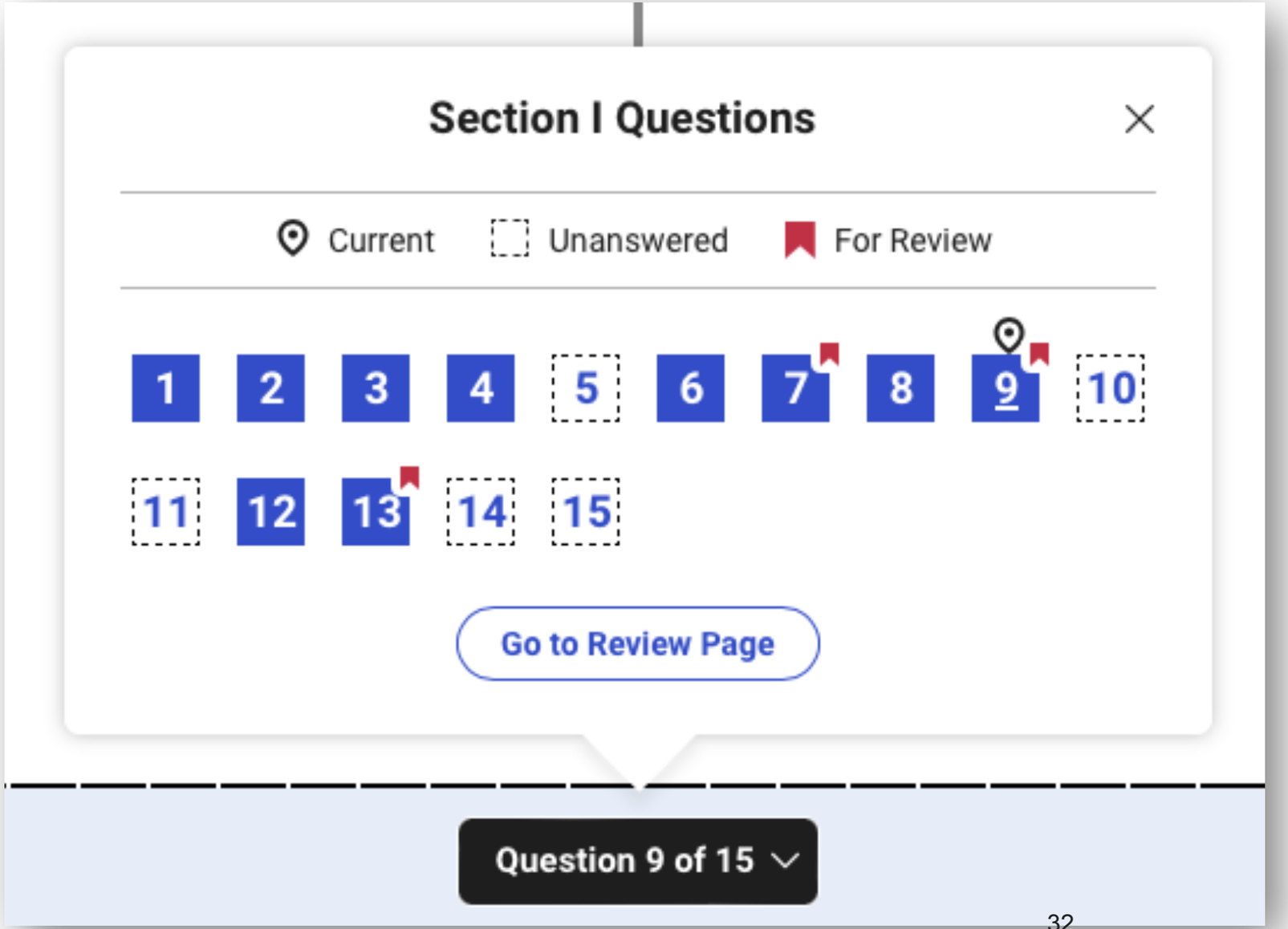
Highlights & Notes



Line Reader


Section I
Directions
0:00
Hide
Highlights & Notes
Calculator
Reference
More
100%
ST PREVIEW
Blocks A and B, of masses m_A and m_B, respectively, are at rest on a horizontal surface with negligible friction. Block A is attached to the table. Block C of mass m_C is suspended by a string that is tied to Block B and passes over a pulley as shown. The blocks all
A
B
C
Attachment
1
Mark for Review
Which of the following
force exerted by Block
(A) $m_B g$
(B) $m_C g$
(C) $\frac{m_A m_C g}{m_A + m_B}$
(D) $\frac{m_B m_C g}{m_A + m_B}$
Help
Shortcuts
Assistive Technology
Line Reader
Unscheduled Break
Exit the Exam
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Question 1 of 15
Next

Section I Questions Review



PC-Mech: Table of Information

ADVANCED PLACEMENT PHYSICS MECHANICS TABLE OF INFORMATION

CONSTANTS AND CONVERSION FACTORS
Universal gravitational constant, $G = 6.67 \times 10^{-11}\ \mathrm{m^3/(kg \cdot s^2)} = 6.67 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$
Acceleration due to gravity at Earth's surface, $g = 9.8\ \mathrm{m/s^2}$
Magnitude of the gravitational field strength at the Earth's surface, $g = 9.8\ \mathrm{N/kg}$

PREFIXES		
Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

UNIT SYMBOLS				
	hertz,	Hz	newton,	N
	joule,	J	second,	s
	kilogram,	kg	watt,	W
	meter,	m		

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES							
θ	0°	30°	37°	45°	53°	60°	90°
$\sin\theta$	0	$1/2$	$3/5$	$\sqrt{2}/2$	$4/5$	$\sqrt{3}/2$	1
$\cos\theta$	1	$\sqrt{3}/2$	$4/5$	$\sqrt{2}/2$	$3/5$	$1/2$	0
$\tan\theta$	0	$\sqrt{3}/3$	$3/4$	1	$4/3$	$\sqrt{3}$	∞

The following assumptions are used in this exam.

- The frame of reference of any problem is assumed to be inertial unless otherwise stated.
- Air resistance is assumed to be negligible unless otherwise stated.
- Springs and strings are assumed to be ideal unless otherwise stated.

PC-Mech: Table of Information Conventions

The following assumptions are used in this exam.

- The frame of reference of any problem is assumed to be inertial unless otherwise stated.
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PC-E&M: Table of Information (OLD)

ADVANCED PLACEMENT PHYSICS ELECTRICITY AND MAGNETISM
TABLE OF INFORMATION

CONSTANTS AND CONVERSION FACTORS	
Coulomb constant,	$k = \frac{1}{4\pi\varepsilon_0} = 9.0\times10^{9}\ \mathrm{N\cdot m^2/C^2}$
Vacuum permittivity,	$\varepsilon_0 = 8.85\times10^{-12}\ \mathrm{C^2/(N\cdot m^2)}$
Vacuum permeability,	$\mu_0 = 4\pi\times10^{-7}\ \mathrm{(T\cdot m)/A}$
Proton mass,	$m_p = 1.67\times10^{-27}\ \mathrm{kg}$
Neutron mass,	$m_n = 1.67\times10^{-27}\ \mathrm{kg}$
Electron mass,	$m_e = 9.11\times10^{-31}\ \mathrm{kg}$
Elementary charge,	$e = 1.60\times10^{-19}\ \mathrm{C}$
1 electron volt,	$1\ \mathrm{eV} = 1.60\times10^{-19}\ \mathrm{J}$
Speed of light,	$c = 3.00\times10^{8}\ \mathrm{m/s}$
1 unified atomic mass unit,	$1\ \mathrm{u} = 1.66\times10^{-27}\ \mathrm{kg} = 931\ \mathrm{MeV/c^2}$
Universal gravitational constant, $G = 6.67\times10^{-11}\ \mathrm{m^3/(kg\cdot s^2)} = 6.67\times10^{-11}\ \mathrm{N\cdot m^2/kg^2}$	
Magnitude of the acceleration due to gravity at Earth's surface, $g = 9.8\ \mathrm{m/s^2}$	
Magnitude of the gravitational field strength at Earth's surface, $g = 9.8\ \mathrm{N/kg}$	

UNIT SYMBOLS	
ampere,	A
coulomb,	C
electron volt,	eV
farad,	F
henry,	H
hertz,	Hz
joule,	J
kilogram,	kg
meter,	m
newton,	N
ohm,	Ω
second,	s
tesla,	T
volt,	V
watt,	W

PREFIXES		
Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES							
θ	0°	30°	37°	45°	53°	60°	90°
$\sin\theta$	0	1/2	3/5	$\sqrt{2}/2$	4/5	$\sqrt{3}/2$	1
$\cos\theta$	1	$\sqrt{3}/2$	4/5	$\sqrt{2}/2$	3/5	1/2	0
$\tan\theta$	0	$\sqrt{3}/3$	3/4	1	4/3	$\sqrt{3}$	∞

The following conventions are used in this exam.

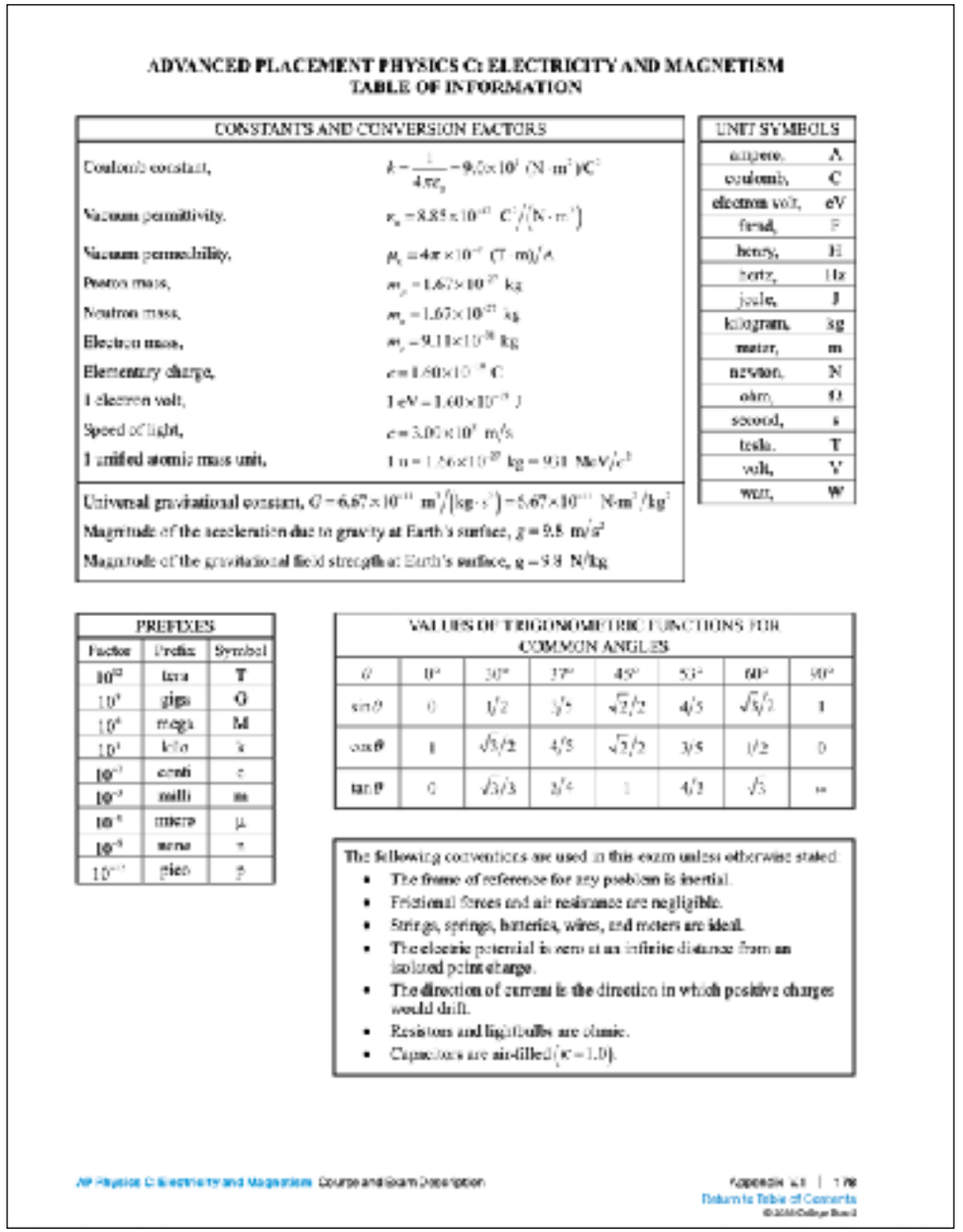
- The frame of reference of any problem is assumed to be inertial unless otherwise stated.
- Air resistance is assumed to be negligible unless otherwise stated.
- Springs and strings are assumed to be ideal unless otherwise stated.
- The electric potential is zero at an infinite distance from an isolated point charge.
- The direction of current is the direction in which positive charges would drift.
- All batteries, wires, and meters are assumed to be ideal unless otherwise stated.

PC-E&M: Table of Information Conventions (OLD)

The following conventions are used in this exam:

- The frame of reference of any problem is assumed to be inertial unless otherwise stated.
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PC-E&M: Table of Information (NEW)



ADVANCED PLACEMENT PHYSICS C: ELECTRICITY AND MAGNETISM
TABLE OF INFORMATION

CONSTANTS AND CONVERSION FACTORS	
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Vacuum permittivity,	$\varepsilon_0 = 8.85\times10^{-12}\ \text{C}^2/(\text{N}\cdot\text{m}^2)$
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Magnitude of the acceleration due to gravity at Earth's surface, $g = 9.8\ \text{m/s}^2$	
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UNIT SYMBOLS	
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kilogram,	kg
meter,	m
newton,	N
ohm,	Ω
second,	s
tesla,	T
volt,	V
watt,	W

PREFIXES		
Factor	Prefix	Symbol
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10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES							
θ	0°	30°	37°	45°	53°	60°	90°
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$\cos\theta$	1	$\sqrt{3}/2$	$4/5$	$\sqrt{2}/2$	$3/5$	$1/2$	0
$\tan\theta$	0	$\sqrt{3}/3$	$3/4$	1	$4/3$	$\sqrt{3}$	∞

The following conventions are used in this exam unless otherwise stated:

- The frame of reference for any problem is inertial.
- Frictional forces and air resistance are negligible.
- Strings, springs, batteries, wires, and meters are ideal.
- The electric potential is zero at an infinite distance from an isolated point charge.
- The direction of current is the direction in which positive charges would drift.
- Resistors and lightbulbs are ohmic.
- Capacitors are air-filled ($\kappa = 1.0$).

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PC-E&M: Table of Information Conventions (NEW)

The following conventions are used in this exam unless otherwise stated:

- The frame of reference for any problem is inertial.
- Frictional forces and air resistance are negligible.
- Strings, springs, batteries, wires, and meters are ideal.
- The electric potential is zero at an infinite distance from an isolated point charge.
- The direction of current is the direction in which positive charges would drift.
- Resistors and lightbulbs are ohmic.
- Capacitors are air-filled $(\kappa = 1.0)$.

Some students have determined the gravitational mass of an object and want to compare it to the object's inertial mass. Procedures that would allow them to accomplish this include which of the following? Select two answers.

(A) Hanging the object vertically from a spring scale and recording the scale reading
(B) Placing the object on one side of a double pan balance, adding objects of known mass to the other side until the masses are balanced, and recording the amount of mass added
(C) Attaching the object to a spring of known spring constant, allowing it to oscillate horizontally on a nearly frictionless surface, and measuring the period
(D) Attaching the object to a force sensor, using the sensor to pull the object across a nearly frictionless horizontal surface, and measuring the acceleration

Developing the Science Practices

How your students will be asked to demonstrate **what** they know

Science Practice/Skills

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.	

ALL Skills Assessed on the FRQ Section

Science Practice/Skills

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.

ONLY Skills Assessed on the MCQ Section

Science Practice/Skills Weighting: AP Physics C Exams

Skill		Approximate MCQ Exam Weighting	Approximate FR Exam Weighting
1.A	Create diagrams, tables, charts, or schematics to represent physical situations.	N/A	20–35%
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.	25–30%	40–45%
2.B	Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.	20–25%	
2.C	Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.	10–15%	
2.D	Predict new values or factors of change of physical quantities using functional dependence between variables.	10–15%	

Skill		Approximate MCQ Exam Weighting	Approximate FR Exam Weighting
3.A	Create experimental procedures that are appropriate for a given scientific question.	N/A	30–35%
3.B	Apply an appropriate law, definition, theoretical relationship, or model to make a claim.	15–25%	
3.C	Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.	5–10%	

AP Physics 1 & 2

Skill		Approximate MCQ Exam Weighting	Approximate FR Exam Weighting
1.A	Create diagrams, tables, charts, or schematics to represent physical situations.	N/A	20–35%
1.B	Create quantitative graphs with appropriate scales and units, including plotting data.	N/A	
1.C	Create qualitative sketches of graphs that represent features of a model or the behavior of a physical system.	N/A	
2.A	Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.	15–20%	30–40%
2.B	Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.	20–25%	
2.C	Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.	10–15%	
2.D	Predict new values or factors of change of physical quantities using functional dependence between variables.	10–15%	
3.A	Create experimental procedures that are appropriate for a given scientific question.	N/A	35–45%
3.B	Apply an appropriate law, definition, theoretical relationship, or model to make a claim.	20–25%	
3.C	Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.	5–10%	

AP Physics C: Mech and E&M

Skill		Approximate MCQ Exam Weighting	Approximate FR Exam Weighting
1.A	Create diagrams, tables, charts, or schematics to represent physical situations.	N/A	20–35%
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.	25–30%	40–45%
2.B	Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.	20–25%	
2.C	Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.	10–15%	
2.D	Predict new values or factors of change of physical quantities using functional dependence between variables.	10–15%	
3.A	Create experimental procedures that are appropriate for a given scientific question.	N/A	30–35%
3.B	Apply an appropriate law, definition, theoretical relationship, or model to make a claim.	15–25%	
3.C	Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.	5–10%	

Developing the Science Practices

Throughout the course, students will develop science practices that are fundamental to the discipline of physics. Students will benefit from multiple opportunities to develop these practices in a scaffolded manner. The tables that follow look at each of the science practices and their associated skills and provide examples of questions with sample activities for incorporating instruction on that skill into the course.

Science Practice 1: Creating Representations

Create representations that depict physical phenomena

When physicists describe and explain complex phenomena, they try to simplify real objects, systems, and processes to make the analysis manageable. These simplifications or models are used to predict how new phenomena will occur. A simple model may treat a system as an object, neglecting the system's internal structure and behavior. More complex models are models of a system of objects, such as a firework display or planets orbiting the sun. A process can be simplified, too. Models can be both conceptual and mathematical. The differential equation relating a velocity dependent force exerted on an object to the acceleration of that object is an example of a mathematical model, while the idea of the object reaching a terminal velocity is a conceptual model. To make a good model, students need to identify a set of the most important characteristics of a phenomenon or system that may simplify analysis. They then need to create a representation of those characteristics. Examples of representations used to model introductory physics concepts are pictures, motion maps, free-body diagrams, force diagrams, graphs, energy bar charts, and momentum charts. Representations help in analyzing phenomena, making predictions and communicating ideas. AP Physics C: Mechanics requires students to use, analyze, and/or re-express models and representations of natural or man-made systems. A special note about free-body diagrams: *AP Physics C: Mechanics only expects students to depict the forces exerted on objects, not the force components on free-body diagrams. On the AP Physics exams, individual forces represented on a free-body diagram must be drawn as individual straight arrows, originating on the dot and pointing in the direction of the force. Individual forces that are exerted in the same direction must be drawn side by side, not overlapping.*

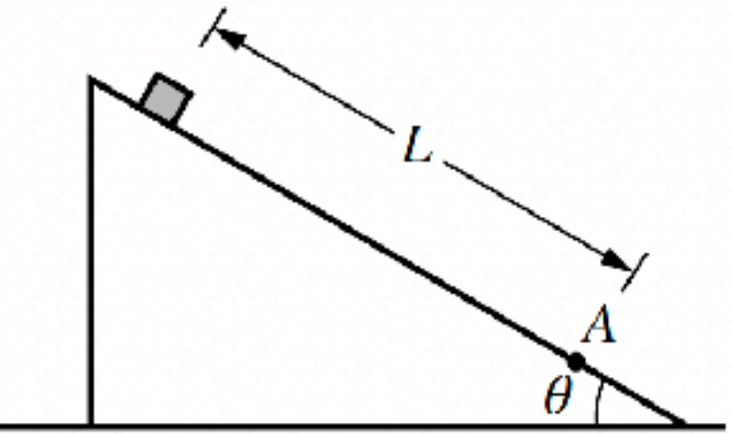
Students often think that to make a graph, they need to connect the data points, or that the best-fit function is always linear. Thus, it is important that they know how to construct a best-fit curve, even for data that do not fit a linear relationship.

The following table provides examples of questions and sample activities for strengthening the skill of creating representations.

Science Practice 1: *Creating Representations*

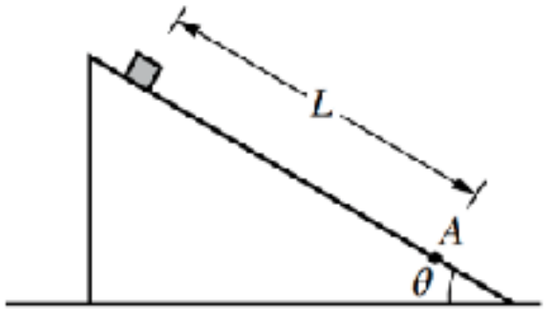
Skill	Questions to Ask Students	Sample Activities
1.A *Create diagrams, tables, charts, or schematics to represent physical situations.*	• What kind of model or representation would be appropriate for this physical scenario? • What physical characteristics can be modeled or represented for this physical scenario? • What features of the representation provide information relevant to the question or problem?	Have students divide their paper into four quarters. In each quarter of the paper, have students create a representation of a provided physical situation. For example, have students create four different representations of two objects during an elastic collision. Representations can include graphs, equations, narratives, bar charts, motion maps, free-body diagrams, or sketches of physical situations. Have students describe the consistency between the representations.
1.B *Create quantitative graphs with appropriate scales and units, including plotting data.*	• What data should be plotted? • What scale and axis labels should be used? What does an appropriately scaled graph look like? • What does a graph need to contain to be considered "correctly labeled"? • How should the data be graphed so that the best-fit curve shows a relationship? • What do the data on the graph show? • Is there a pattern present in the data? How do you know? What does the pattern show about the relationship between quantities? • What data would need to be graphed to create a linear relationship? • What is the physical meaning of the slope and/or area underneath the linearized graph? • What is the physical meaning of the y and/or x intercepts of the linearized graph?	When learning about one-dimensional motion, have students measure the time it takes for an object to fall a specified height. Repeat the measurements for various heights. Have students determine what they should graph so that they can create a linearized graph. Have students identify correct graphs by giving them a "What, If Anything, Is Wrong?" task. Ask students to analyze a set of data and a supposed matching graph, and ask them to identify what, if anything, is wrong with the graph. The "wrong" things can be simple at first (e.g., scales not uniform, labels left off) and then can be scaffolded to be more difficult and address student misconceptions later in the course.

AP Physics C: Mechanics – Skill Based Case Study



A block is released from rest near the top of a rough ramp inclined at an angle θ above the horizontal. Point A is a distance L away from the point where the block is released, as shown in the figure. The coefficient of kinetic friction between the block and the ramp is μ_k. The block is moving with speed v_A when it reaches point A.

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



A block is released from rest near the top of a rough ramp inclined at an angle θ above the horizontal. Point A is a distance L away from the point where the block is released, as shown in the figure. The coefficient of kinetic friction between the block and the ramp is μ_k. The block is moving with speed v_A when it reaches point A.

Derive an expression for the speed v_A in terms of the given quantities and physical constants, as appropriate.

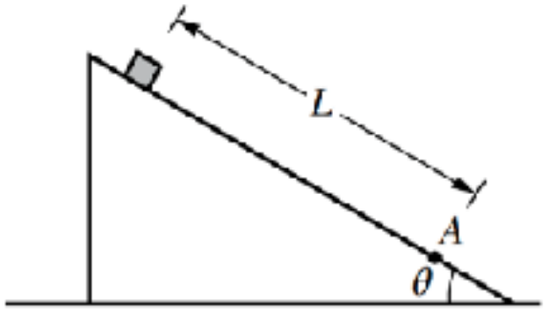
(A) $v_A = \sqrt{2gL \sin\theta}$

(B) $v_A = \sqrt{2gL(\sin\theta - \mu_k \cos\theta)}$

(C) $v_A = \sqrt{2gL(\mu_k \cos\theta)}$

(D) $v_A = \sqrt{2gL(\sin\theta + \mu_k \cos\theta)}$

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



A block is released from rest near the top of a rough ramp inclined at an angle θ above the horizontal. Point A is a distance L away from the point where the block is released, as shown in the figure. The coefficient of kinetic friction between the block and the ramp is μ_k. The block is moving with speed v_A when it reaches point A.

Given $L = 1.0$ m, $\mu_k = 0.1$, and $\theta = 30^\circ$, the speed v_A of the block as it reaches point A is most nearly

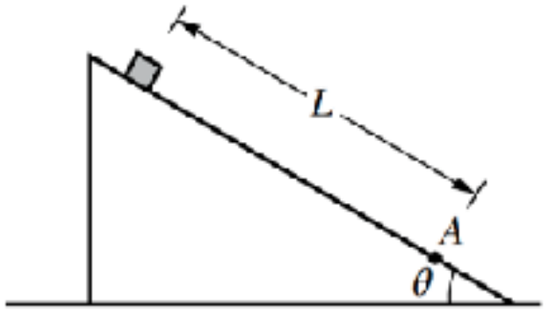
(A) 2.9 m/s

(B) 3.1 m/s

(C) 8.3 m/s

(D) 9.9 m/s

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



A block is released from rest near the top of a rough ramp inclined at an angle θ above the horizontal. Point A is a distance L away from the point where the block is released, as shown in the figure. The coefficient of kinetic friction between the block and the ramp is μ_k. The block is moving with speed v_A when it reaches point A.

The work done by the force of gravity on the block as the block slides from the point of release to point A is W_1. The angle of the ramp is increased, and the work done by the force of gravity on the block as the block slides from the point of release to point A is W_2. How does W_1 compare to W_2?

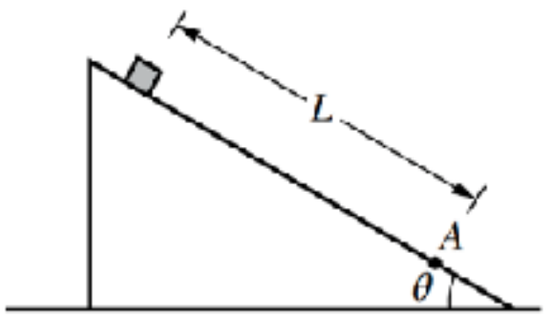
(A) $W_1 > W_2$

(B) $W_1 < W_2$

(C) $W_1 = W_2$

(D) W_1 and W_2 cannot be compared without knowing the mass of the block.

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



A block is released from rest near the top of a rough ramp inclined at an angle θ above the horizontal. Point A is a distance L away from the point where the block is released, as shown in the figure. The coefficient of kinetic friction between the block and the ramp is μ_k. The block is moving with speed v_A when it reaches point A.

The energy dissipated by the frictional force as the block travels from the point of release to point A is E_1. If the coefficient of friction between the block and the ramp is doubled, the energy dissipated by the frictional force as the block travels from the point of release to point A is E_2. What is the ratio $\frac{E_1}{E_2}$?

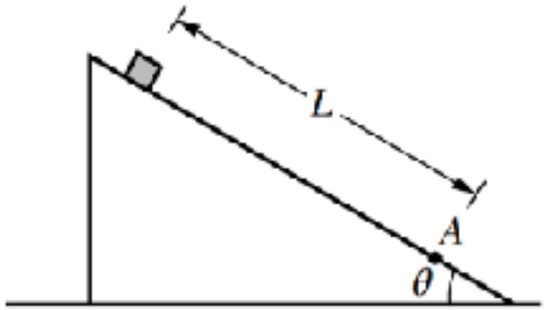
(A) $\frac{1}{2}$

(B) 1

(C) 2

(D) 4

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



A block is released from rest near the top of a rough ramp inclined at an angle θ above the horizontal. Point A is a distance L away from the point where the block is released, as shown in the figure. The coefficient of kinetic friction between the block and the ramp is μ_k. The block is moving with speed v_A when it reaches point A.

Which of the following statements is correct about the total mechanical energy in the scenario above?

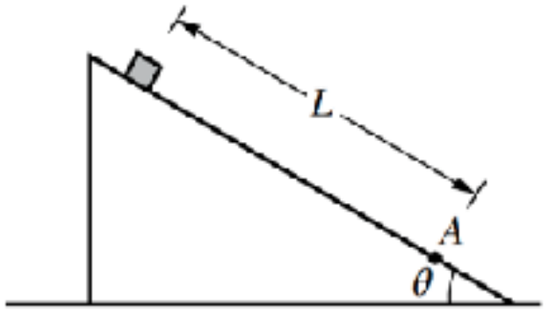
(A) The total mechanical energy of the system consisting of only the block decreases from the time of release until the time when the block reaches point A.

(B) The total mechanical energy of the system consisting of only the block remains constant from the time of release until the time when the block reaches point A.

(C) The total mechanical energy of the system consisting of the block and Earth decreases from the time of release until the time when the block reaches point A.

(D) The total mechanical energy of the system consisting of only the block and Earth remains constant from the time of release until the time when the block reaches point A.

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



A block is released from rest near the top of a rough ramp inclined at an angle θ above the horizontal. Point A is a distance L away from the point where the block is released, as shown in the figure. The coefficient of kinetic friction between the block and the ramp is μ_k. The block is moving with speed v_A when it reaches point A.

Which of the following statements correctly explains why the total mechanical energy of the block–Earth system decreases as the block travels to point A?

(A) The height of the block above the surface of Earth decreases.

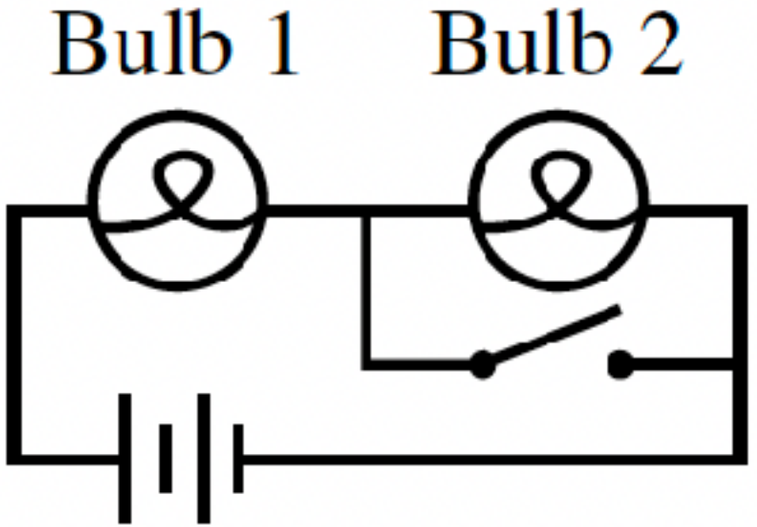
(B) The force of friction removes energy from the block–Earth system.

(C) The downward gravitational force exerted on the block by Earth does negative work on the block–Earth system.

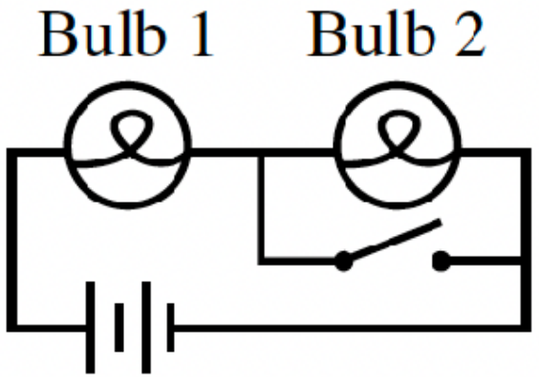
(D) The normal force from the incline does negative work on the block–Earth system.

AP Physics C: E&M – Skill Based Case Study

A circuit contains two identical lightbulbs and a switch connected to a battery, as shown. The switch is initially open.



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



A circuit contains two identical lightbulbs and a switch connected to a battery, as shown. The switch is initially open.

The bulbs each have a resistance R, and the emf supplied by the battery is $\mathcal{E}$. The switch is open. Which of the following expressions correctly represents the power delivered to Bulb 1?

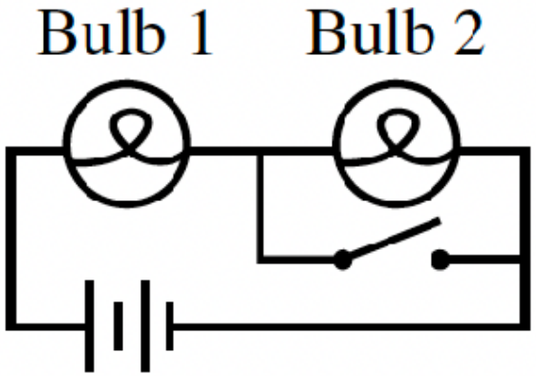
(A) $P = \frac{2\mathcal{E}^2}{R}$

(B) $P = \frac{\mathcal{E}^2}{R}$

(C) $P = \frac{\mathcal{E}^2}{2R}$

(D) $P = \frac{\mathcal{E}^2}{4R}$

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



A circuit contains two identical lightbulbs and a switch connected to a battery, as shown. The switch is initially open.

The bulbs each have a resistance of $2.0\ \Omega$, and the emf supplied by the battery is $9.0\ \text{V}$. The switch is open. Which of the following is most nearly the power delivered to Bulb 1?

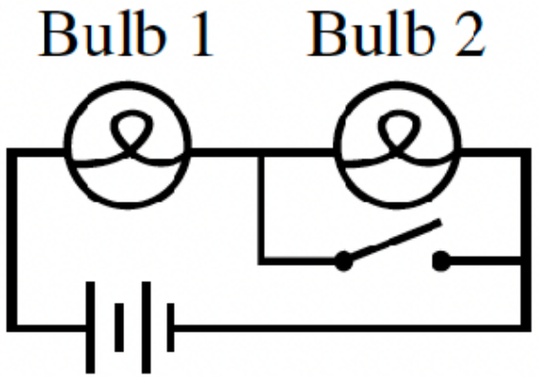
(A) $10\ \text{W}$

(B) $20\ \text{W}$

(C) $40\ \text{W}$

(D) $80\ \text{W}$

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



A circuit contains two identical lightbulbs and a switch connected to a battery, as shown. The switch is initially open.

When the switch is open, the bulbs have equal brightness. When the switch is closed, which of the following occurs to the bulbs?

	Bulb 1	Bulb 2
A	Gets brighter	Gets brighter
B	Gets brighter	Goes out
C	Gets dimmer	Goes out
D	Gets dimmer	Gets brighter

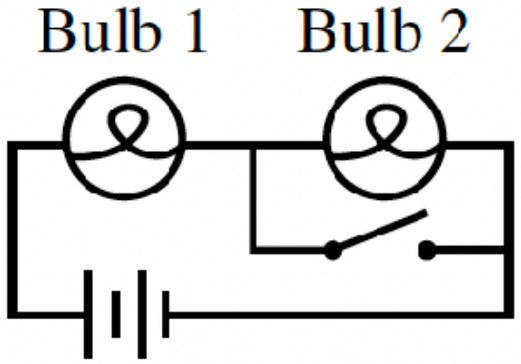
(A) A

(B) B

(C) C

(D) D

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



A circuit contains two identical lightbulbs and a switch connected to a battery, as shown. The switch is initially open.

When the switch is open, the current in Bulb 1 is I_o. When the switch is closed, the current in Bulb 1 is I_c. Which of the following correctly relates I_o to I_c?

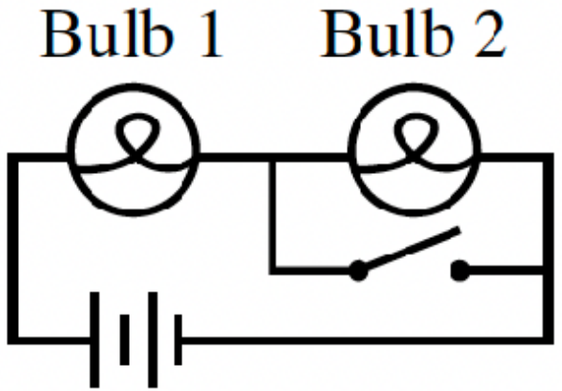
(A) $I_o = 2I_c$

(B) $I_o = I_c$

(C) $I_o = \frac{1}{2} I_c$

(D) $I_o = \frac{1}{4} I_c$

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



A circuit contains two identical lightbulbs and a switch connected to a battery, as shown. The switch is initially open.

Which of the following clams about the arrangement of the circuit is correct?

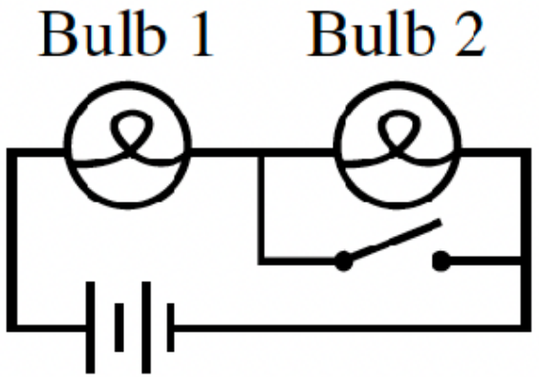
(A) The two bulbs are in series with each other.

(B) Bulb 2 is in parallel with the battery.

(C) Bulb 1 is in parallel with the battery.

(D) Bulb 2 is in series with the switch.

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



A circuit contains two identical lightbulbs and a switch connected to a battery, as shown. The switch is initially open.

The switch is closed, and Bulb 2 is replaced with an uncharged capacitor of capacitance C. The switch is then opened. Which of the following describes the current in the battery after the switch is closed, and provides a correct justification?

(A) The current in the battery is constant because batteries always provide constant current.

(B) The current in the battery is constant because the capacitor and resistor are in series.

(C) The current in the battery decreases because energy is dissipated by the resistor.

(D) The current in the battery decreases because the potential difference across the resistor decreases as the capacitor is charged.

Identify the Science Practice

- Course and Exam Description
  - Mech page 175
  - E&M page 151
- Identify which Science Practice is assessed in each of the Multiple Choice Questions
- Write them down and after you are done check if you are right

Science Practice/Skills

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.

ONLY Skills Assessed on the MCQ Section

AP Physics Courses Overview

Since Fall 2024

College Major Semester	Engineering, Science, Math, Computer Science	Pre-Med and other
1st	AP Physics C: Mechanics	AP Physics 1
2nd	AP Physics C: E&M	AP Physics 2



AP Physics 1
Course Overview

P1 Units: May 2025

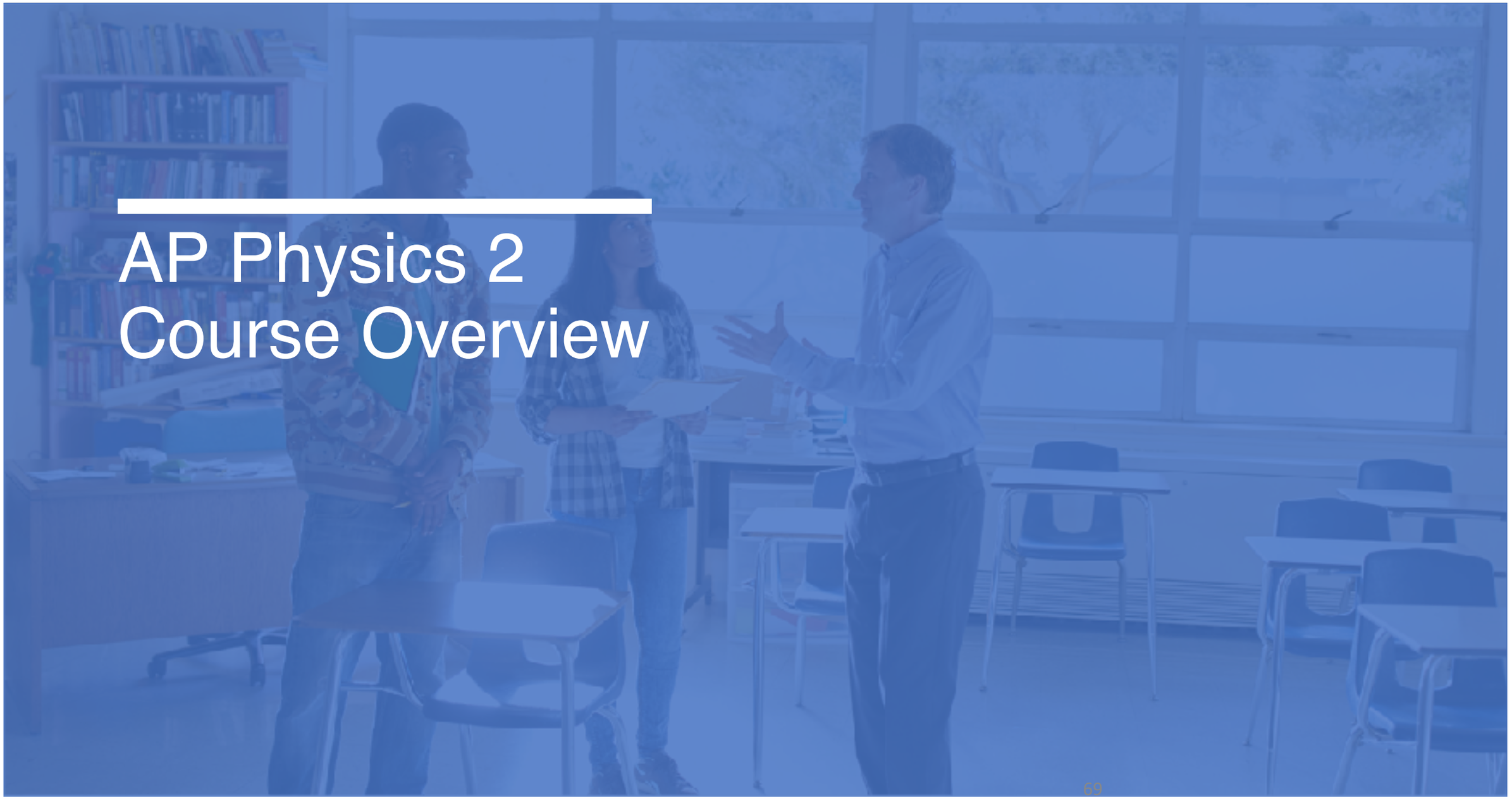
Algebra Based course meant to replicate 1st Semester College Physics.

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

AP Physics 1

Units of Instruction	Exam Weighting
Unit 1: Kinematics	**10–15%**
Unit 2: Force and Translational Dynamics	**18–23%**
Unit 3: Work, Energy, and Power	**18–23%**
Unit 4: Linear Momentum	**10–15%**
Unit 5: Torque and Rotational Dynamics	**10–15%**
Unit 6: Energy and Momentum of Rotating Systems	**5–8%**
Unit 7: Oscillations	**5–8%**
Unit 8: Fluids	**10–15%**



AP Physics 2
Course Overview

P2 Units: May 2025

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

AP Physics 2

Units of Instruction	Exam Weighting
Unit 9: Thermodynamics	**15–18%**
Unit 10: Electric Force, Field, and Potential	**15–18%**
Unit 11: Electric Circuits	**15–18%**
Unit 12: Magnetism and Electromagnetism	**12–15%**
Unit 13: Geometric Optics	**12–15%**
Unit 14: Waves, Sound, and Physical Optics	**12–15%**
Unit 15: Modern Physics	**12–15%**



AP Physics C: Mechanics Course Overview

C: Mechanics Units: May 2025

Calculus Based course meant to replicate 1st Semester University Physics.

Can be taught as a semester long course or a 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

AP Physics C: Mechanics

Units of Instruction	Weighting
Unit 1: Kinematics	**10–15%**
Unit 2: Force and Translational Dynamics	**20–25%**
Unit 3: Work, Energy and Power	**15–25%**
Unit 4: Linear Momentum	**10–20%**
Unit 5: Torque and Rotational Dynamics	**10–15%**
Unit 6: Energy and Momentum of Rotating Systems	**10–15%**
Unit 7: Oscillations	**10–15%**



AP Physics C: Electricity & Magnetism Course Overview

C: E&M Units: May 2025

Calculus Based course meant to replicate 2nd Semester University Physics.

Can be taught as a semester long course or a year long course.

Unit Number	Unit Title
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

AP Physics C: E&M

Units of Instruction	Exam Weighting
Unit 8: Electric Charges, Fields, and Gauss's Law	**15–25%**
Unit 9: Electric Potential	**10–20%**
Unit 10: Conductors and Capacitors	**10–15%**
Unit 11: Electric Circuits	**15–25%**
Unit 12: Magnetic Fields and Electromagnetism	**10–20%**
Unit 13: Electromagnetic Induction	**10–20%**

Redesign Committee

- Hamza Balci, *Kent State University*
- Suzanne Brahmia, *University of Washington*
- Eric Burkholder, *Stanford University*
- Robert Davis, *Brigham Young University*
- Veronica Ellingson, *Hudson Senior High School*
- Kristin Glover, *Prairie Ridge High School*
- Kathy Harper, *The Ohio State University*
- Mark Hossler, *Landmark Christian School*
- Stefan Jeglinski, *University of North Carolina*
- Kathy Koenig, *University of Cincinnati*
- Kristine Lang, *Colorado College*
- Samuel Lofland, *Rowan University*
- Joe Mancino, *Glastonbury High School*
- Ricardo Markland, *Miami Coral Park Senior High School*
- Dee Dee Messer, *William Mason High School*
- Holley Mosley, *Liberty High School*
- Matt Sckalor, *Great Neck South High School*
- Peter Sheldon, *Randolph College*
- Gay Stewart, *West Virginia University*
- Shelly Strand, *West Fargo High School*
- Oather Strawderman, *Lawrence Free State High School*
- Brian Utter, *University of California Merced*
- Matt Vonk, *University of Wisconsin*

College Board Consultants

- Brian Brown
- Anders Gardestig
- Ann Marie Zolandz
- Angela Jensvold
- Mark Widmer

AP Physics Course and Exam Description

Course and Exam Description : ‘CED’

The Course and Exam Description aligns course skills with course content.

Content Instruction

- Instruction should help develop and reinforce long-term takeaways for students, not just mastery of or familiarity with specific concepts or vocabulary definitions.
- Consider what students should remember beyond the completion of the course – that is, what students should *understand* vs. *know.*

Skill Instruction

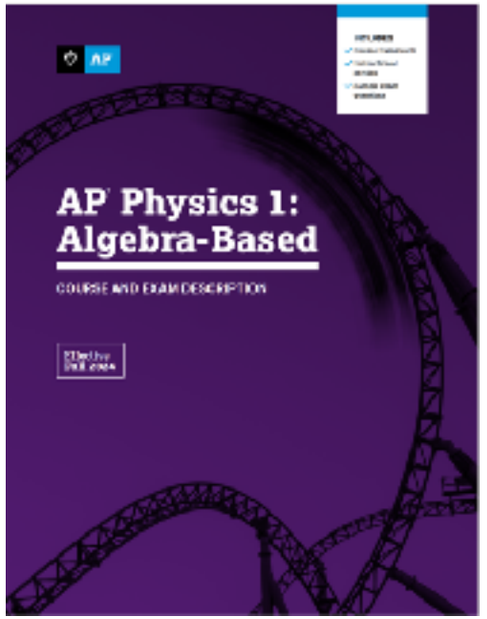
- Students need explicit instruction and repeated opportunities to practice course skills in different contexts throughout the school year – just because students can apply a skill in Unit 1 doesn't always mean they'll be able to apply it in Unit 3.
- Course skills help students make sense of new situations, giving them the tools they need to be successful on the AP Exam and in sequent courses.

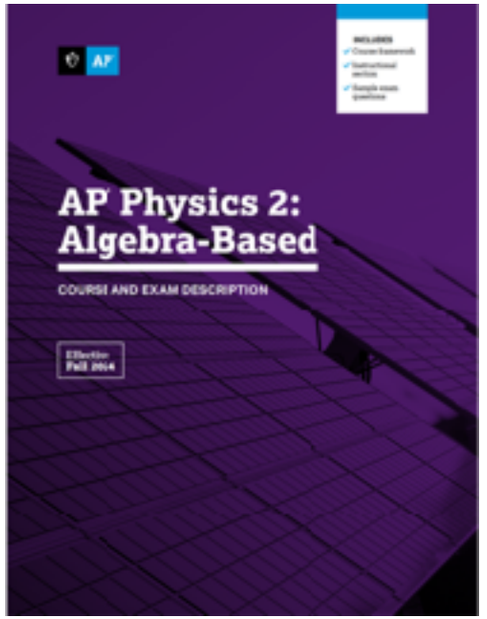
AP Physics Course and Exam Descriptions

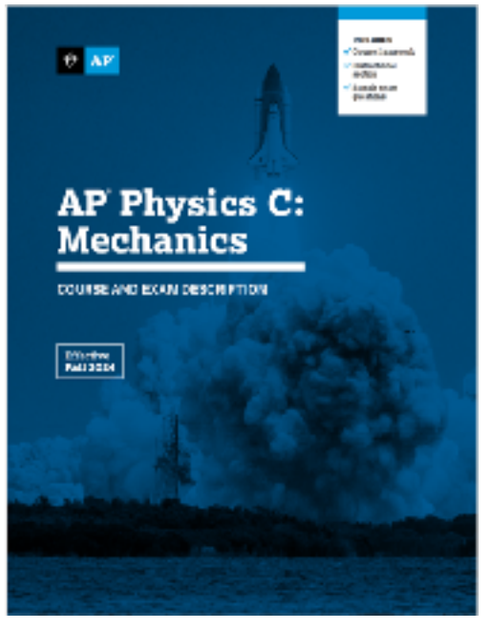
A “one-stop shop” for teachers!!

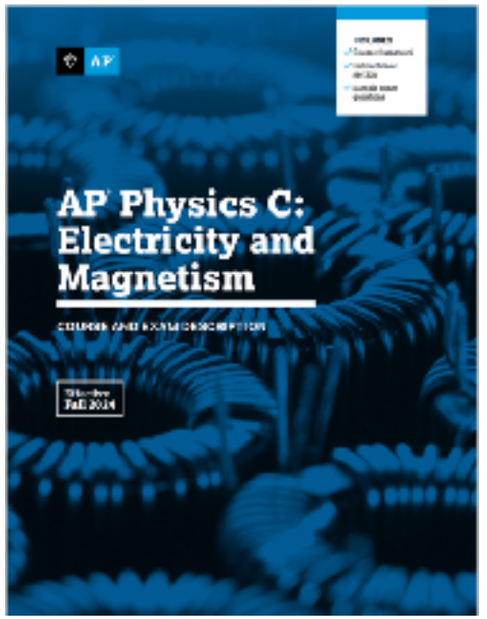
Major Sections:

- Front Section
- Course Framework
- Laboratory Investigations
- Instructional Approaches
- Exam Information
- Scoring Guides
- Appendix









The Course and Exam Description has **six** main sections.

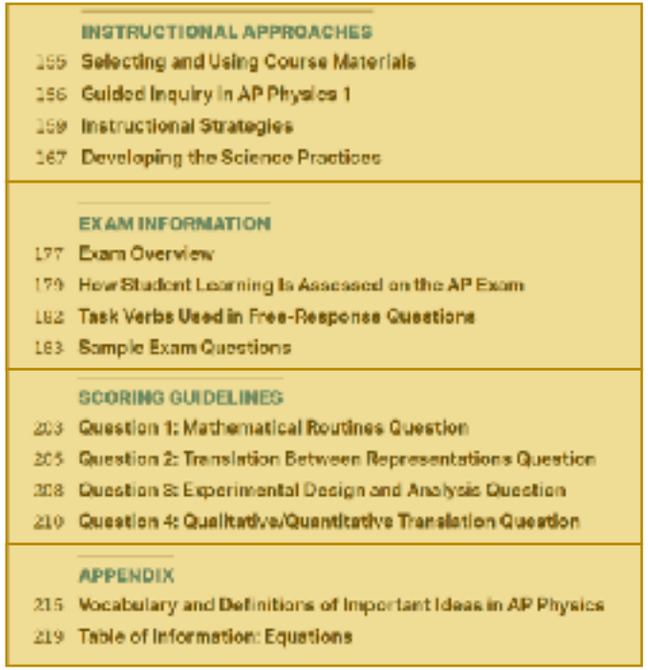


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1. **Front Matter**: All about AP, including resources and supports, as well as course prerequisites and laboratory requirements.

2. **Course Framework**: All course content and skills, with both high-level and detailed views.

3. **Laboratory Investigations**: Information on lab experiments and materials, lab manuals and notebooks, lab time, how to set up a lab program, lab equipment, group collaboration, lab safety, what “counts” as a lab, types and formats of labs, and lab skills.

4. **Instructional Approaches**: Selecting and using course materials, scaffolding scientific inquiry, strategies for constructing learning activities that develop course content and skills, and a case study for practicing apply course skills within the context of a single scenario.

5. **Exam Information**: Overview of the structure and contents of the AP Exam, plus sample exam questions.

6. **Scoring Guidelines**: Explanation of how points are awarded for each FRQ type on the AP Exam

7. **Appendix**: Vocabulary and definitions of important course/discipline ideas, and the reference sheet with equations

Checkpoint 1
What are the three Science Practices and the ten Skills? What do you notice about the skills as you go down the column of a practice?

Checkpoint 2
How many units are there in the AP Physics course? Which unit has the greatest number of topics? How many topics does that unit have?

Checkpoint 3
In the Course at a Glance, what do the percentage ranges under each unit header represent? Why are they given as ranges? Which unit has the greatest percentage listed?

Checkpoint 4
What information is provided at the beginning of every Unit?

Checkpoint 5
Put these terms in order from most general to most specific content knowledge:
Topic
Learning Objective
Unit
Essential Knowledge.

Checkpoint 6
AP Physics courses require that 25% of instruction time is spent in hans-on laboratory work. How does AP define *Labs* and *Lab Time*?

Checkpoint 7
What are the Generic Lab Equipment items and Physics-Specific Optional Lab Equipment items listed in the Course and Exam Description?

Checkpoint 8
Where can you find more detailed information about teaching and developing the Science Practices?

Checkpoint 9
Which skills are assessed on the MCQ section of the exam and which skills are assessed on the FRQ section of the exam?

Checkpoint 10
Where can you find the Equation Sheets in the Course and Exam Description? What information are students provided in them?

Textbooks, Syllabus Development Guides, Sample Syllabi And Yearlong Pacing

2026-2027 Plan

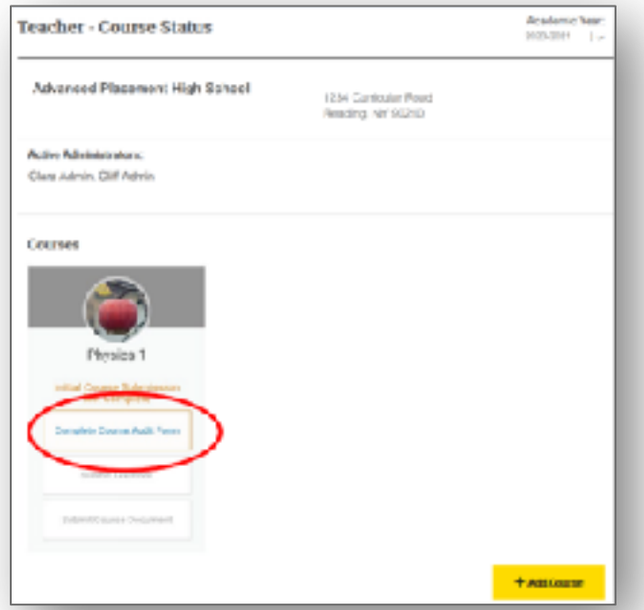
2026-27 AP Course Audit Process: AP Physics

Submission Options

1. Adopt the Unit Guides or a Sample Syllabus
2. Claim identical to an approved syllabus (i.e., from a colleague)
3. Submit an original course document

All AP Physics teachers **returning from before 2024** will have to:

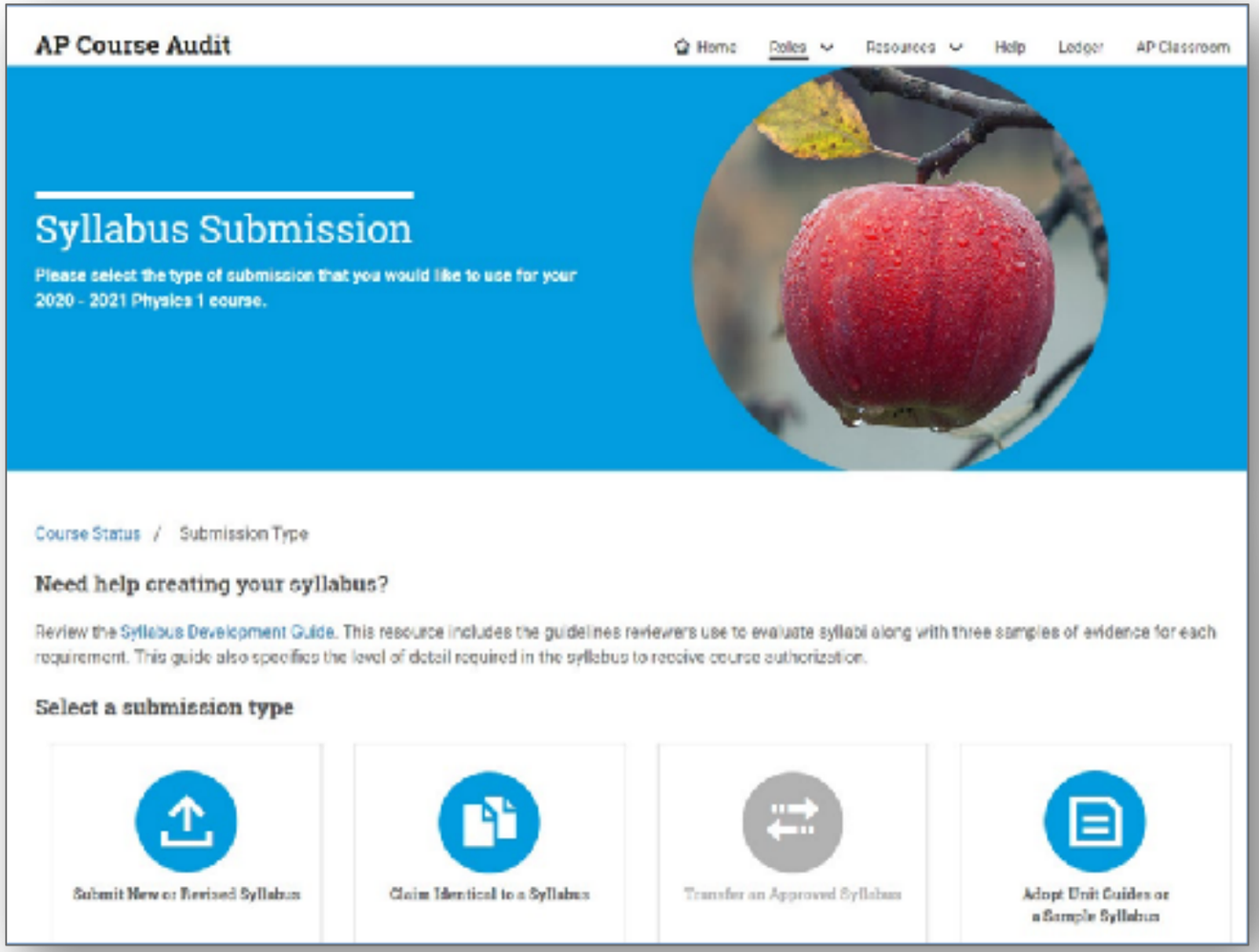
1. Complete the AP Course Audit Form attestation; and
2. Select one of the three submission options for authorization.

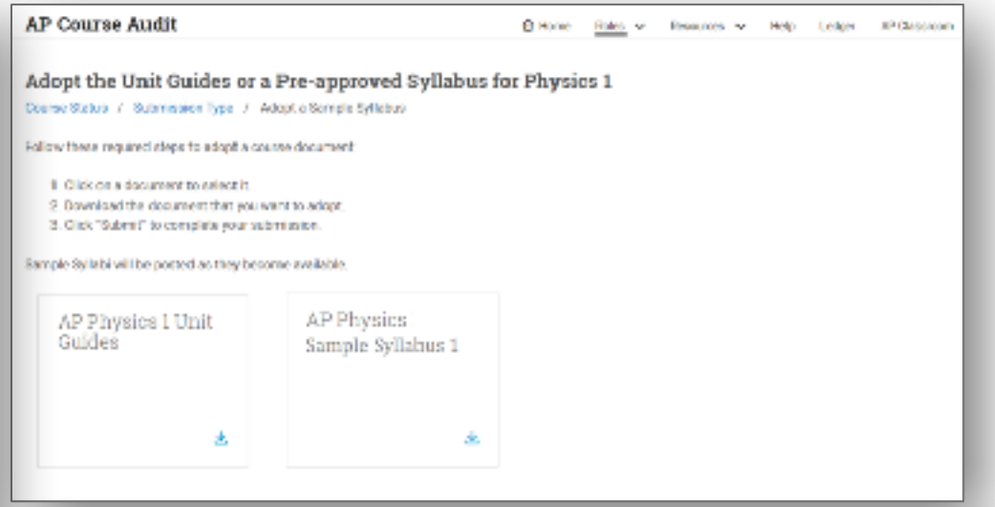


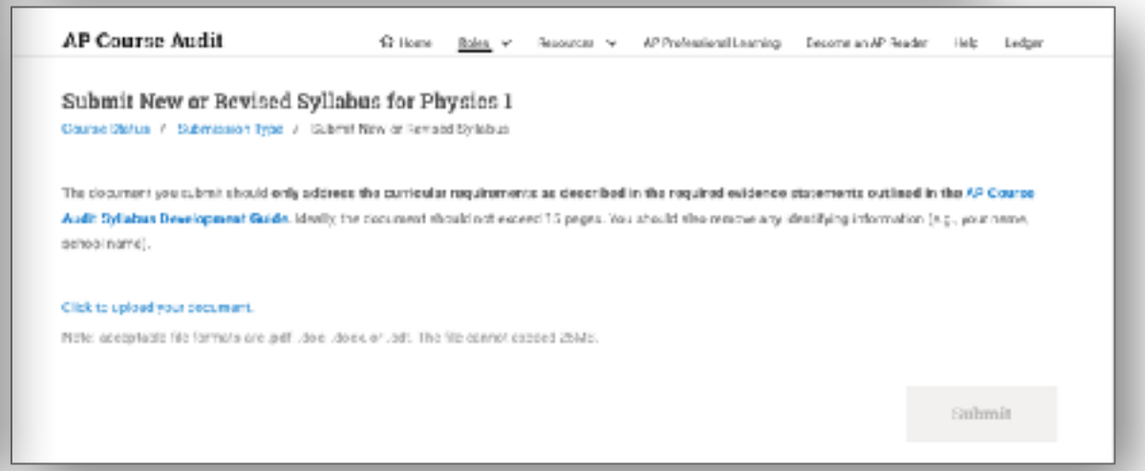
Note: An original course document does not have to be what is used in the classroom. The document submitted needs only address the curricular requirements as described in the required evidence statements outlined in the **AP Course Audit Syllabus Development Guide**.

2026-27 AP Course Audit Process: AP Physics

Submission Options

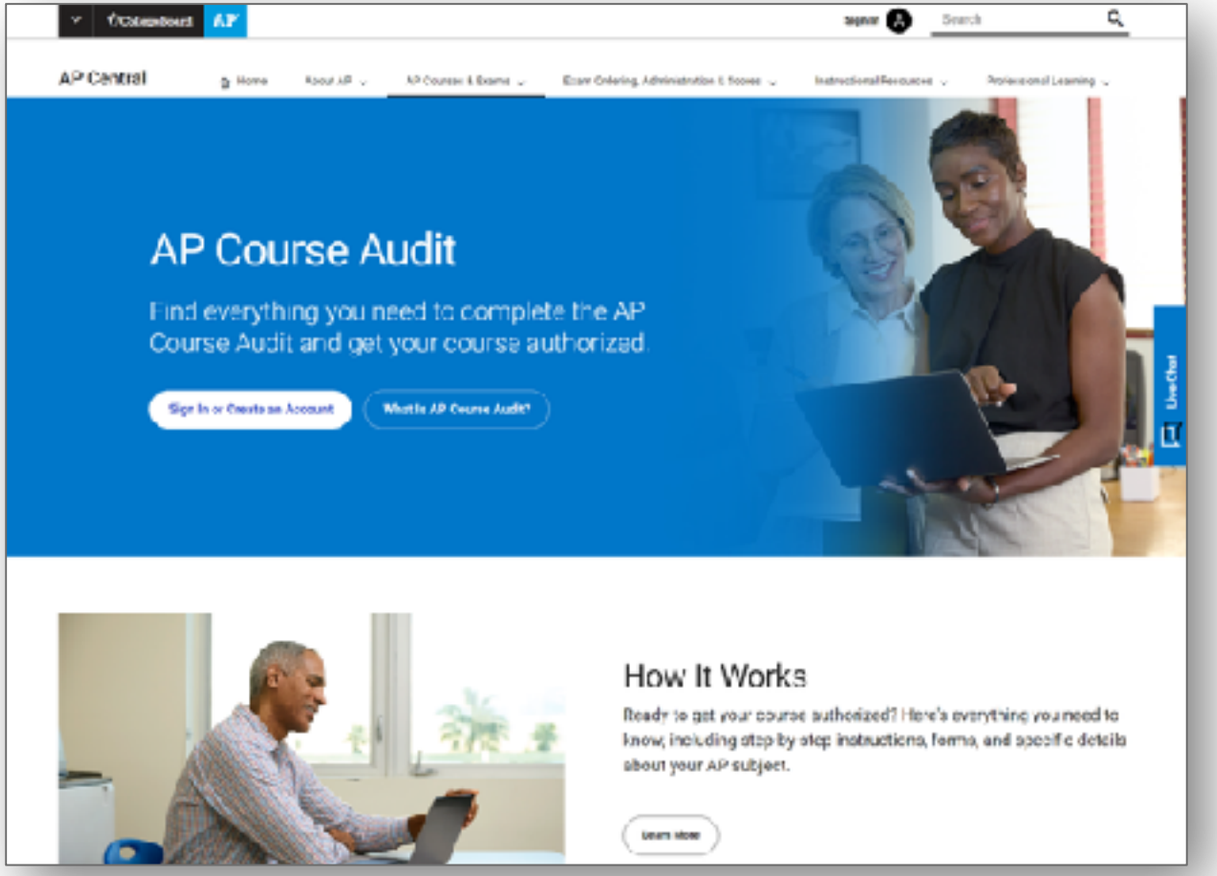






https://apcentral.collegeboard.org/media/pdf/ap-course-audit-user-guide.pdf

AP Teacher Access to AP Classroom



- For AP Physics teachers to be able to access AP Classroom AND to be able to create class sections for the 2025-26 school year, **only two actions are necessary.**
  - The AP teacher must complete and submit the AP Course Audit form.
  - The AP Course Audit Administrator must approve the form.
- **Important:** Selecting and completing one of the syllabus submission options is **not** required for access to AP Classroom or to create class sections.
- Teachers can access AP Classroom at **https://myap.collegeboard.org**. Bookmark this website!!!

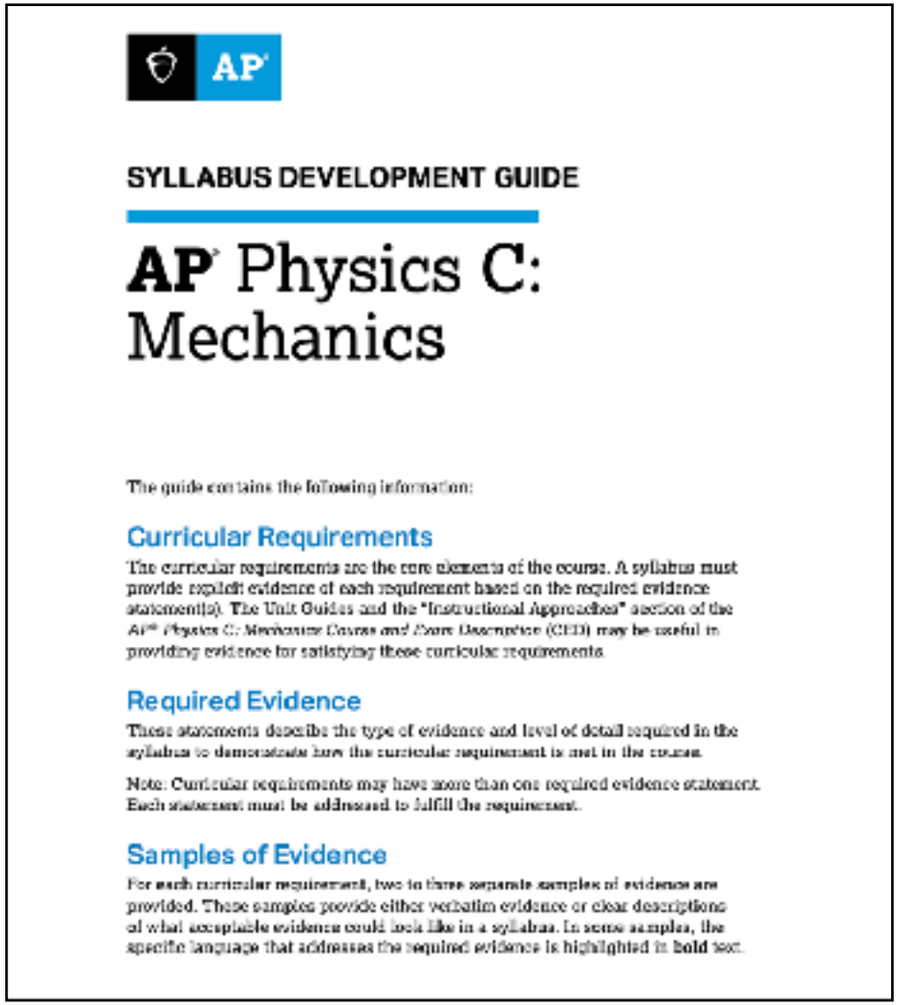
Example AP Physics C Textbook List

- Bauer, Wolfgang, and Gary Westfall. University Physics, McGraw Hill.
- Chabay, Ruth W., and Bruce A. Sherwood. Matter and Interactions. New York: John Wiley & Sons.
- Fishbane, Paul M., Stephen Gasiorowicz, and Stephen M. Thornton. Physics for Scientists and Engineers. Upper Saddle River, NJ: Prentice Hall.
- Giancoli, Douglas C. Physics for Scientists and Engineers. Upper Saddle River, NJ: Prentice Hall.
- Halliday, David, Robert Resnick, and Jearl Walker. Fundamentals of Physics. New York: John Wiley & Sons. (or any variation on the Halliday text)
- Hecht, Eugene. Physics: Calculus. New York: Brooks/Cole.
- Knight, Randall D. Physics for Scientists and Engineers: A Strategic Approach with Modern Physics. Boston, MA: Addison-Wesley.
- Knight, Randall D. Physics for Scientists and Engineers: A Strategic Approach with Modern Physics, AP Edition. Pearson.
- Moebs, William, Samuel Ling, and Jeff Sanny. University Physics Volume 1. OpenStax.
- Sanny, Jeff, and William Moebs. University Physics. Fort Worth, TX: Saunders.
- Serway, Raymond A. Principles of Physics. 1st Edition. Fort Worth, TX: Saunders, 2012.
- Serway, Raymond A. and John W. Jewett, Physics for Scientists and Engineers with PhysicsNow and InfoTrac. 5th edition. National Geographic Learning/Cengage Learning.
- Tipler, Paul A. Physics for Scientists and Engineers. New York, NY: W. H. Freeman.
- Wolfson, Richard, and Jay M. Pasachoff. Physics for Scientists and Engineers. Reading, MA: Addison Wesley Longman.
- Young, Hugh D., and Roger A. Freedman. University Physics. 14th Edition. Addison Wesley.
- Young, Hugh D., Roger A. Freedman, T.R. Sandin, and A. Lewis Ford. Sears and Semansky's University Physics. Reading, MA: Addison-Wesley.

AP Physics Online Textbook

Openstax.org

Curricular Requirements: Syllabus Development Guide Mech



AP

SYLLABUS DEVELOPMENT GUIDE

AP® Physics C: Mechanics

The guide contains the following information:

Curricular Requirements

The curricular requirements are the core elements of the course. A syllabus must provide explicit evidence of each requirement based on the required evidence statement(s). The Unit Guides and the "Instructional Approaches" section of the *AP® Physics C: Mechanics Course and Exam Description* (CED) may be useful in providing evidence for satisfying these curricular requirements.

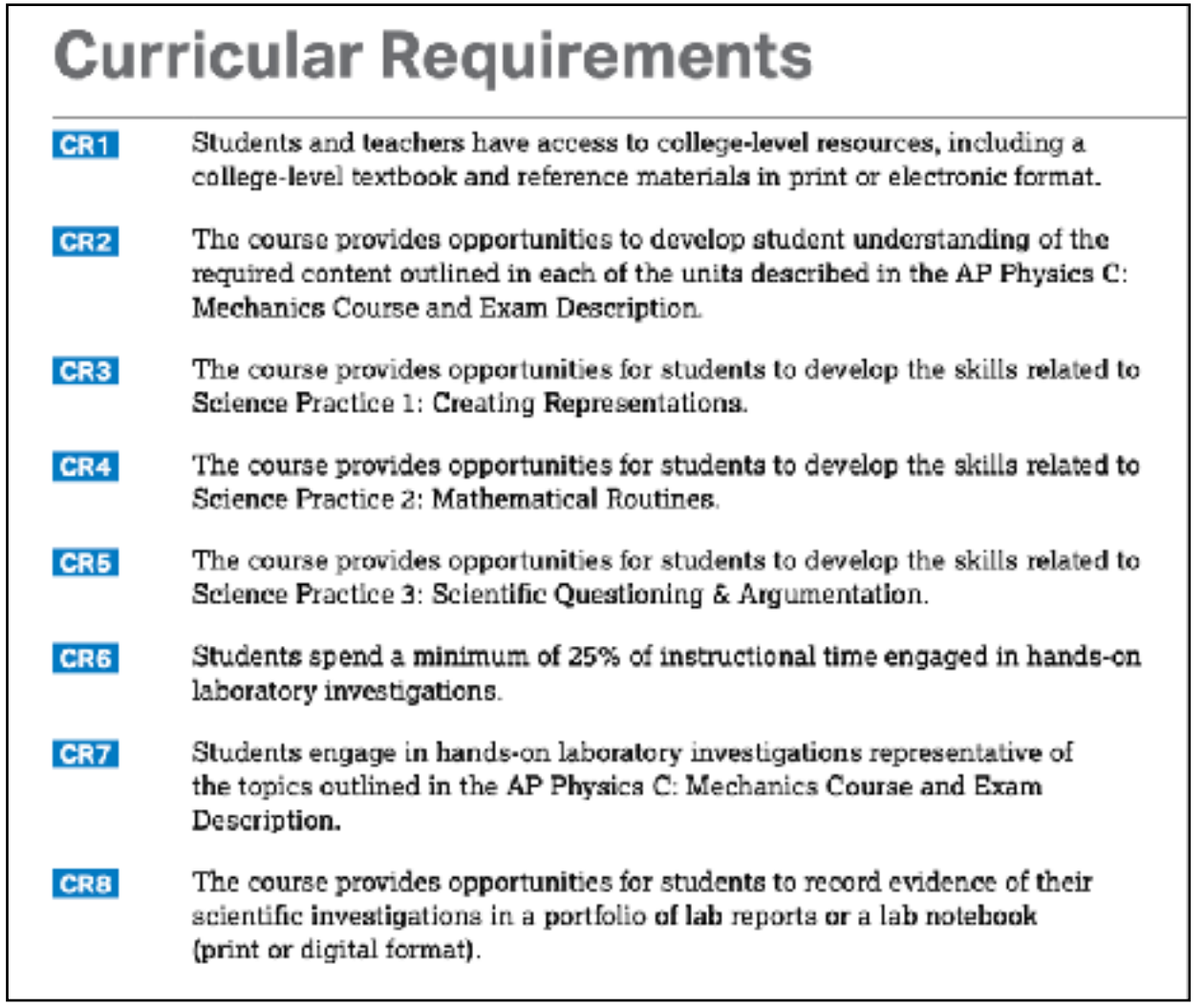
Required Evidence

These statements describe the type of evidence and level of detail required in the syllabus to demonstrate how the curricular requirement is met in the course.

Note: Curricular requirements may have more than one required evidence statement. Each statement must be addressed to fulfill the requirement.

Samples of Evidence

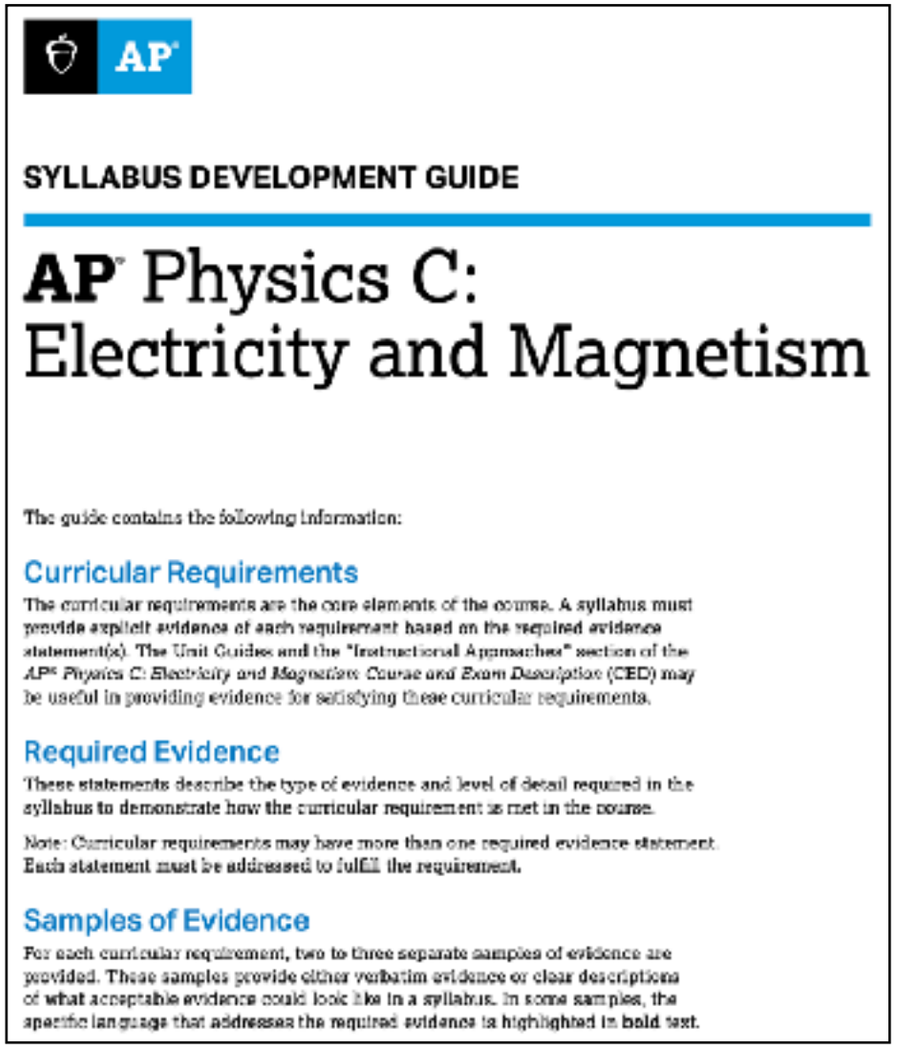
For each curricular requirement, two to three separate samples of evidence are provided. These samples provide either verbatim evidence or clear descriptions of what acceptable evidence could look like in a syllabus. In some samples, the specific language that addresses the required evidence is highlighted in **bold** text.



Curricular Requirements

CR1	Students and teachers have access to college-level resources, including a college-level textbook and reference materials in print or electronic format.
CR2	The course provides opportunities to develop student understanding of the required content outlined in each of the units described in the AP Physics C: Mechanics Course and Exam Description.
CR3	The course provides opportunities for students to develop the skills related to Science Practice 1: Creating Representations.
CR4	The course provides opportunities for students to develop the skills related to Science Practice 2: Mathematical Routines.
CR5	The course provides opportunities for students to develop the skills related to Science Practice 3: Scientific Questioning & Argumentation.
CR6	Students spend a minimum of 25% of instructional time engaged in hands-on laboratory investigations.
CR7	Students engage in hands-on laboratory investigations representative of the topics outlined in the AP Physics C: Mechanics Course and Exam Description.
CR8	The course provides opportunities for students to record evidence of their scientific investigations in a portfolio of lab reports or a lab notebook (print or digital format).

Curricular Requirements: Syllabus Development Guide E&M



AP

SYLLABUS DEVELOPMENT GUIDE

AP® Physics C: Electricity and Magnetism

The guide contains the following information:

Curricular Requirements

The curricular requirements are the core elements of the course. A syllabus must provide explicit evidence of each requirement based on the required evidence statement(s). The Unit Guides and the "Instructional Approaches" section of the *AP® Physics C: Electricity and Magnetism Course and Exam Description* (CED) may be useful in providing evidence for satisfying these curricular requirements.

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CR8	The course provides opportunities for students to record evidence of their scientific investigations in a portfolio of lab reports or a lab notebook (print or digital format).

Year Long Pacing Activity C:Mech and C:E&M

- In your group, break up the content into a year long list of units, that doesn't have to match the Course and Exam Description.
- Assign numbers of days/weeks to each unit, include location of breaks.
- Include time for review (hopefully!!).
- List the major content covered in each unit.
- **For each unit list one lab/activity you do during the unit.**

- Exam Dates 2027
  - Mechanics: Monday May 3 - Session 1 (9:00am)
  - E&M: Wednesday May 5 - Session 2 (1:00pm)

Angular Acceleration of Spinning Phone And Rotational Collisions

Oather Strawderman



Angular Acceleration of Rotating Phone Lab

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What ages are these for?

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Quantity: 1

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Buy Now

Ships from	Amazon
Sold by	Wsslon-85
Returns	30-day refund/replacement

Angular Acceleration of Rotating Phone Lab

- Put your phone on top of a fidget spinner
- Start the stopwatch on the phone and spin the phone
- Video the phone spinning with another phone until it stops
- Record the time when the phone is orientated upright
- Record the time after one rotation
- Calculate average angular velocity which is equal to the instantaneous angular velocity at the middle of those two times
- Repeat this calculation several times over a range of spins
- Plot instantaneous angular velocity vs time;
  the slope is the angular acceleration



Angular Acceleration of Rotating Phone Lab

Initial Time (s)	Time after 1 rotation (s)	Middle Time (s)	$\omega=2\pi/(\Delta t)$ (rad/s)

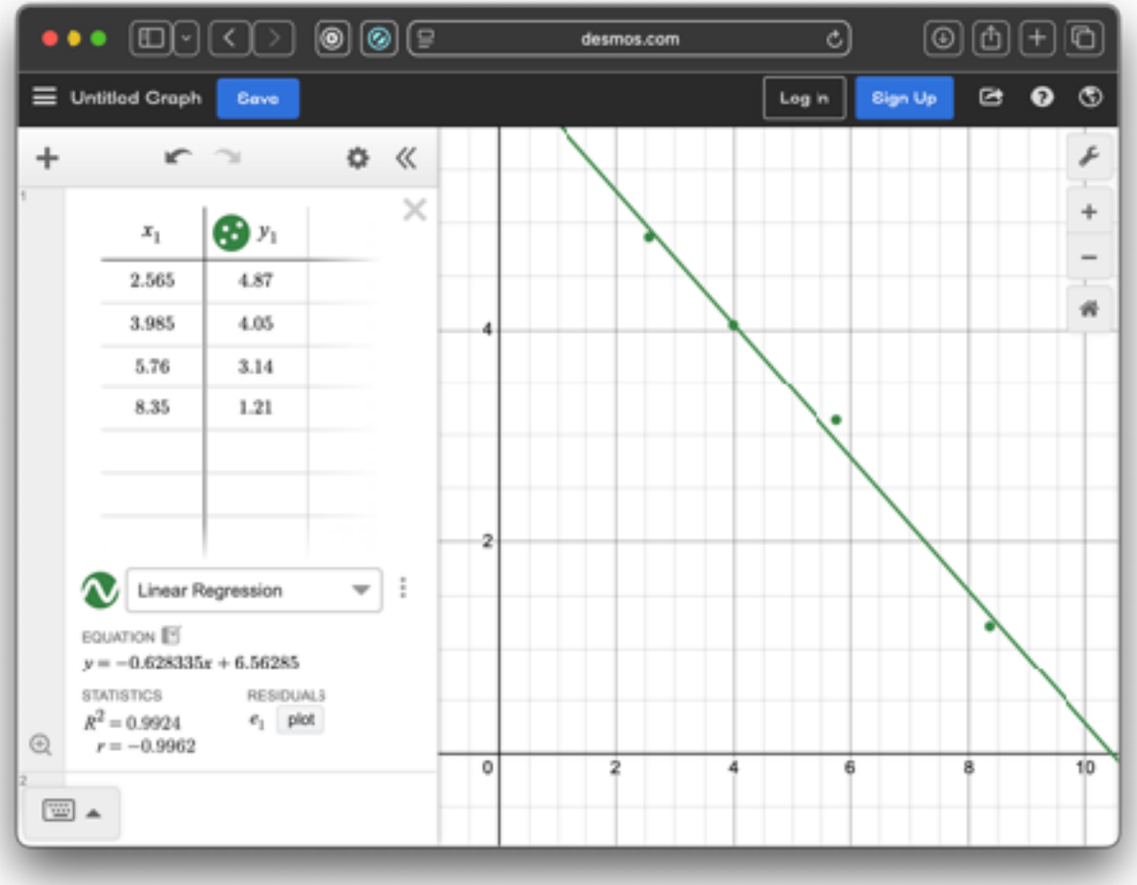
Angular Acceleration of Rotating Phone Lab



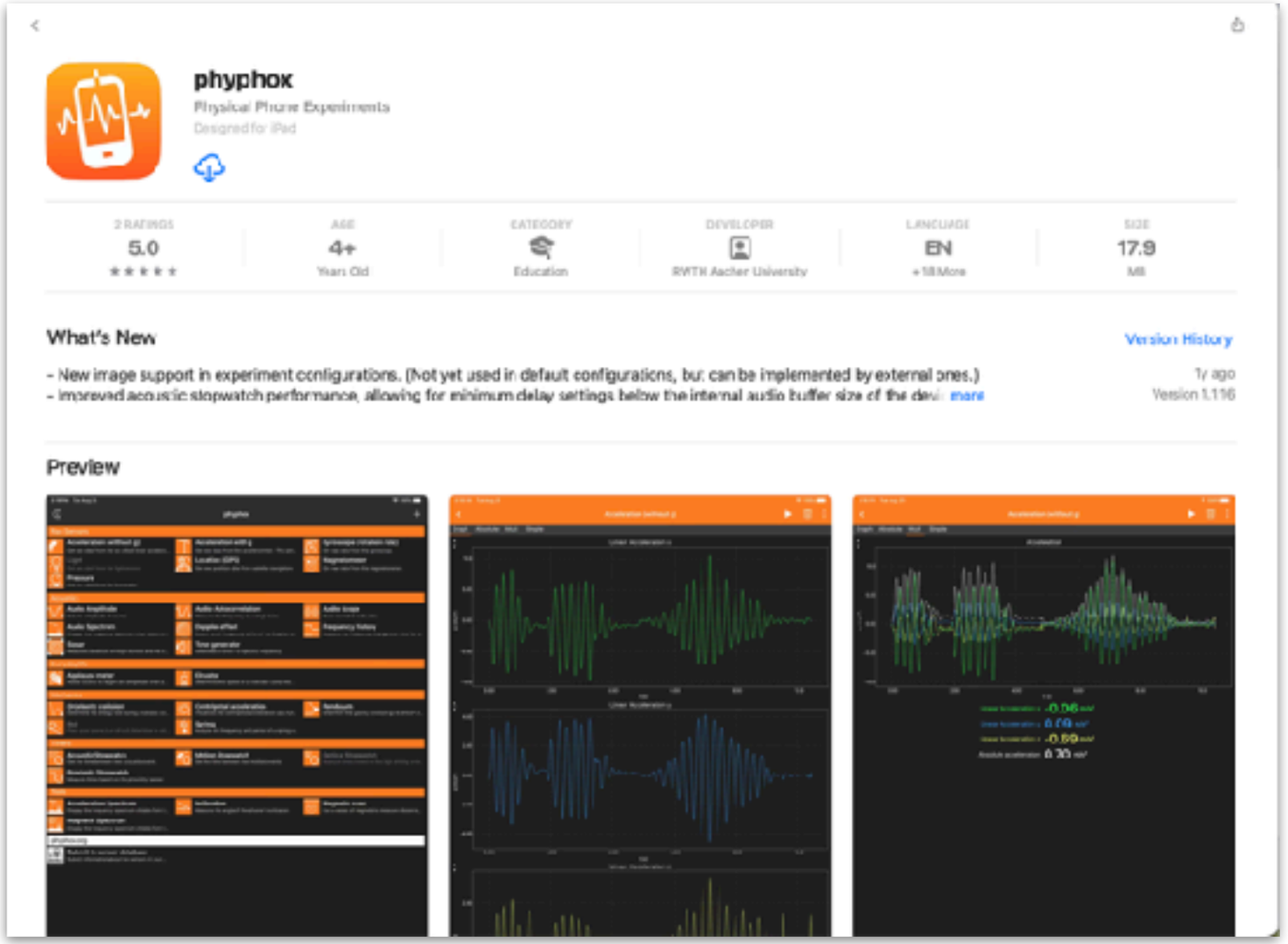
Initial Time (s)	Time after 1 rotation (s)	Middle Time (s)	ω=2π/(Δt) (rad/s)
1.92	3.21	2.565	4.87
6.76	9.93	8.35	1.21

Angular Acceleration of Rotating Phone Lab

Middle Time (s)	ω=2π/(Δt) (rad/s)
2.565	4.87
3.985	4.05
5.76	3.14
8.35	1.21



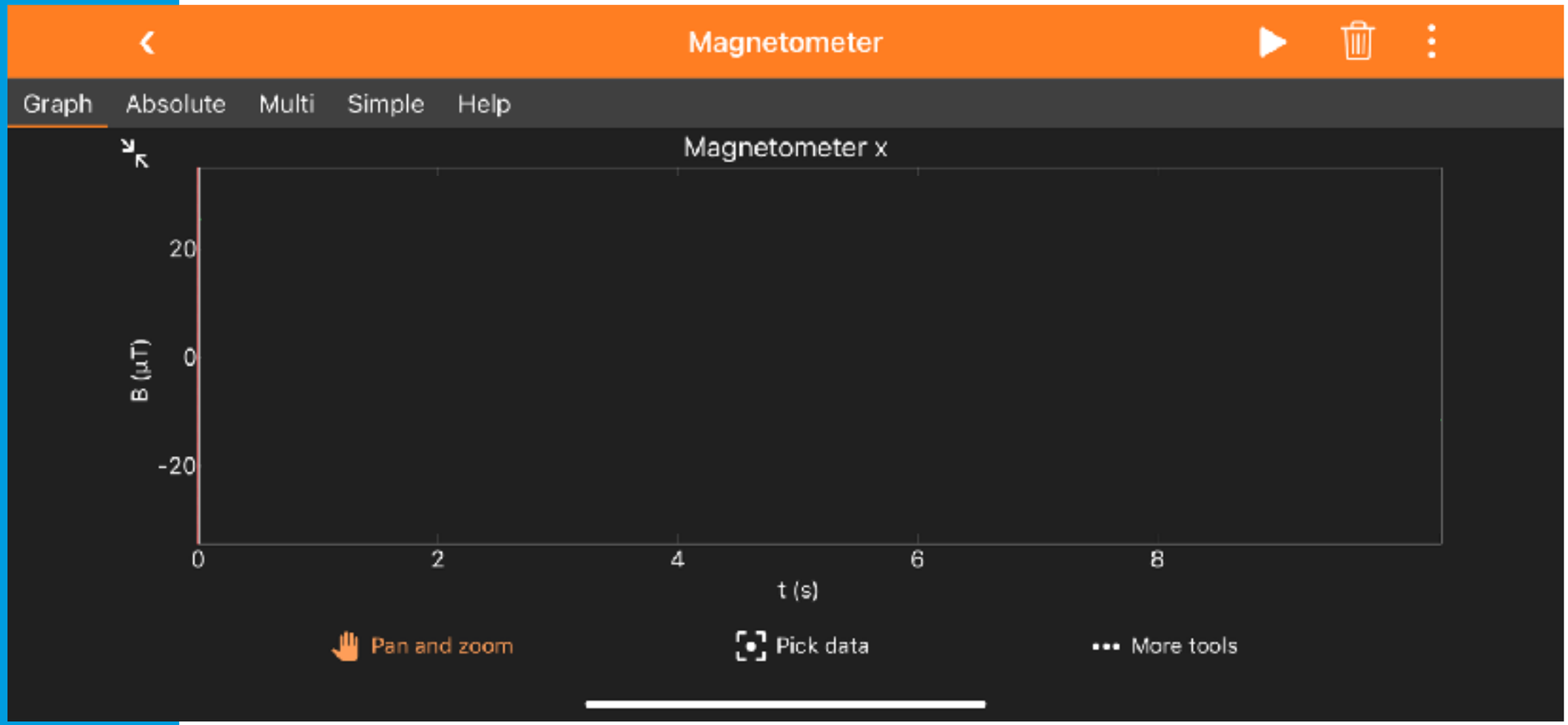
PhyPhox App


phyphox
Physical Phone Experiments
Designed for iPad
2 RATINGS
5.0
AGE
4+
Years Old
CATEGORY
Education
DEVELOPER
RWTH Aachen University
LANGUAGE
EN
+18 More
SIZE
17.9
MB
What's New
Version History
- New image support in experiment configurations. (Not yet used in default configurations, but can be implemented by external ones.)
- Improved acoustic stopwatch performance, allowing for minimum delay settings below the internal audio buffer size of the dev
more
1y ago
Version 1.1.16
Preview

Angular Acceleration of Rotating Phone Lab

- Use PhyPhox app on a smart phone or tablet
- Put your phone on top of a fidget spinner
- Open up the Magnetometer in PhyPhox
- Select the x graph and hit play
- Spin the phone and record until the phone stops spinning
- Record the time at the top of a peek
- Record the time at the next peek
- Calculate average angular velocity which is equal to the instantaneous angular velocity at the middle of those two times
- Repeat this calculation several times
- Plot instantaneous angular velocity vs time and the slope is the angular acceleration

Angular Acceleration of Rotating Phone Lab



Angular Acceleration of Rotating Phone Lab

- Use PhyPhox app on a smart phone or tablet
- Put your phone on top of a fidget spinner
- Open up the Gyroscope in PhyPhox and select z graph
- Hit play
- Spin the phone
- Once the phone stops spinning stop PhyPhox
- Select Pick Data
- Tap and drag along the line to determine angular acceleration

Density of Air Lab

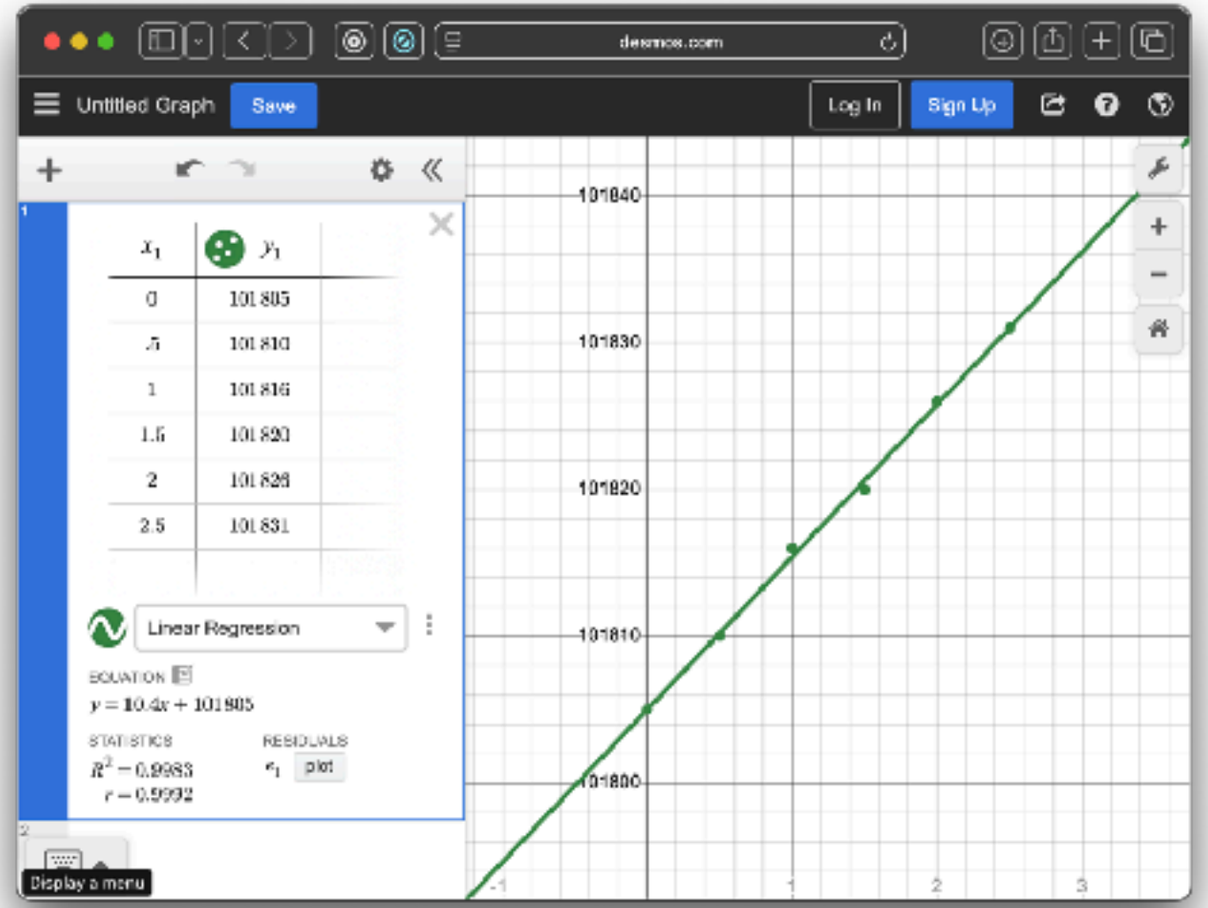
- Use PhyPhox app on a smart phone or tablet
- Raise your phone as high as possible, and measure pressure at this h = 0
- Vary ‘depth’ from this highest point
- Plot Pressure vs Depth
- Slope is ρg

Density of Air Lab

Depth (m)	Pressure (Pa)
0.0	101,805
0.5	101,810
1.0	101,816
1.5	101,820
2.0	101,826
2.5	101,831

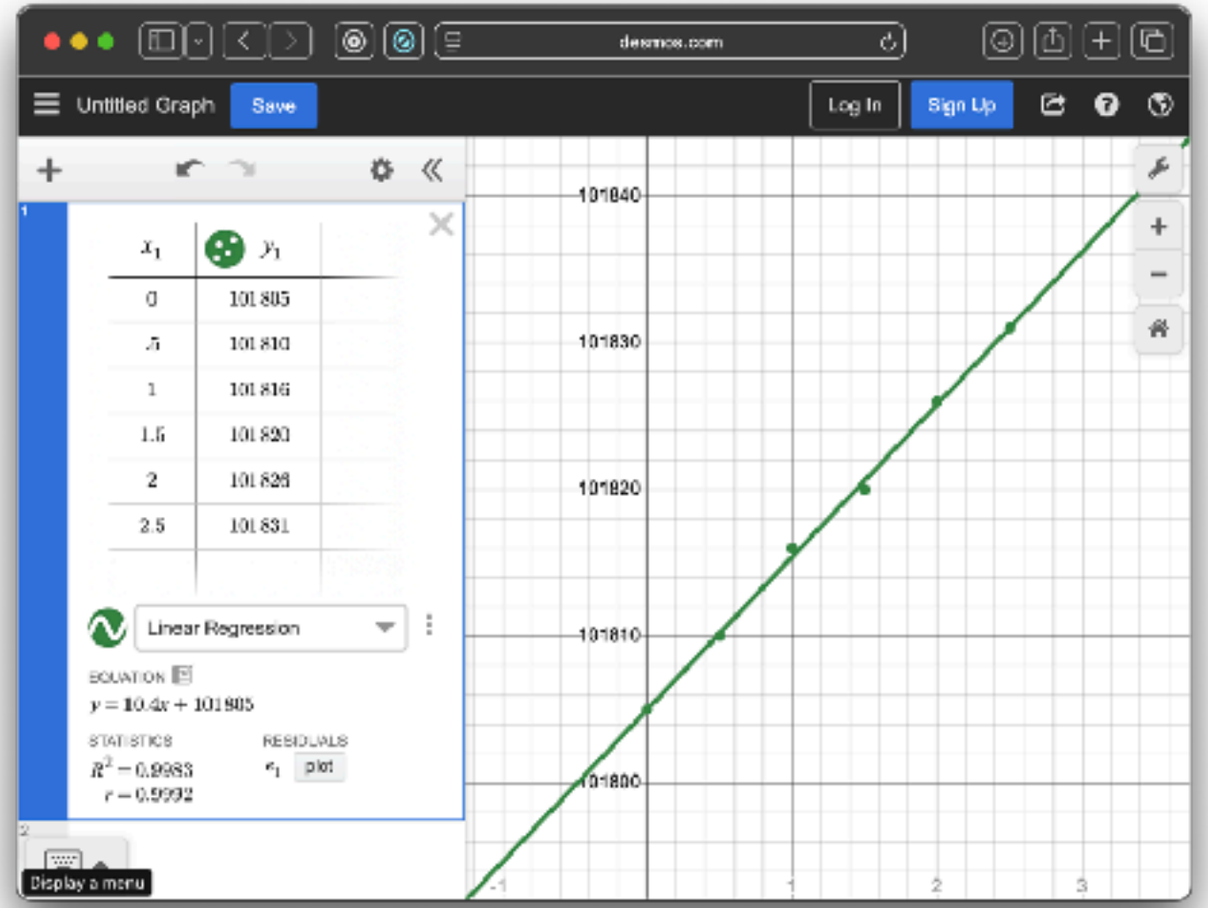
Density of Air Lab

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1.5	101,820
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Density of Air Lab

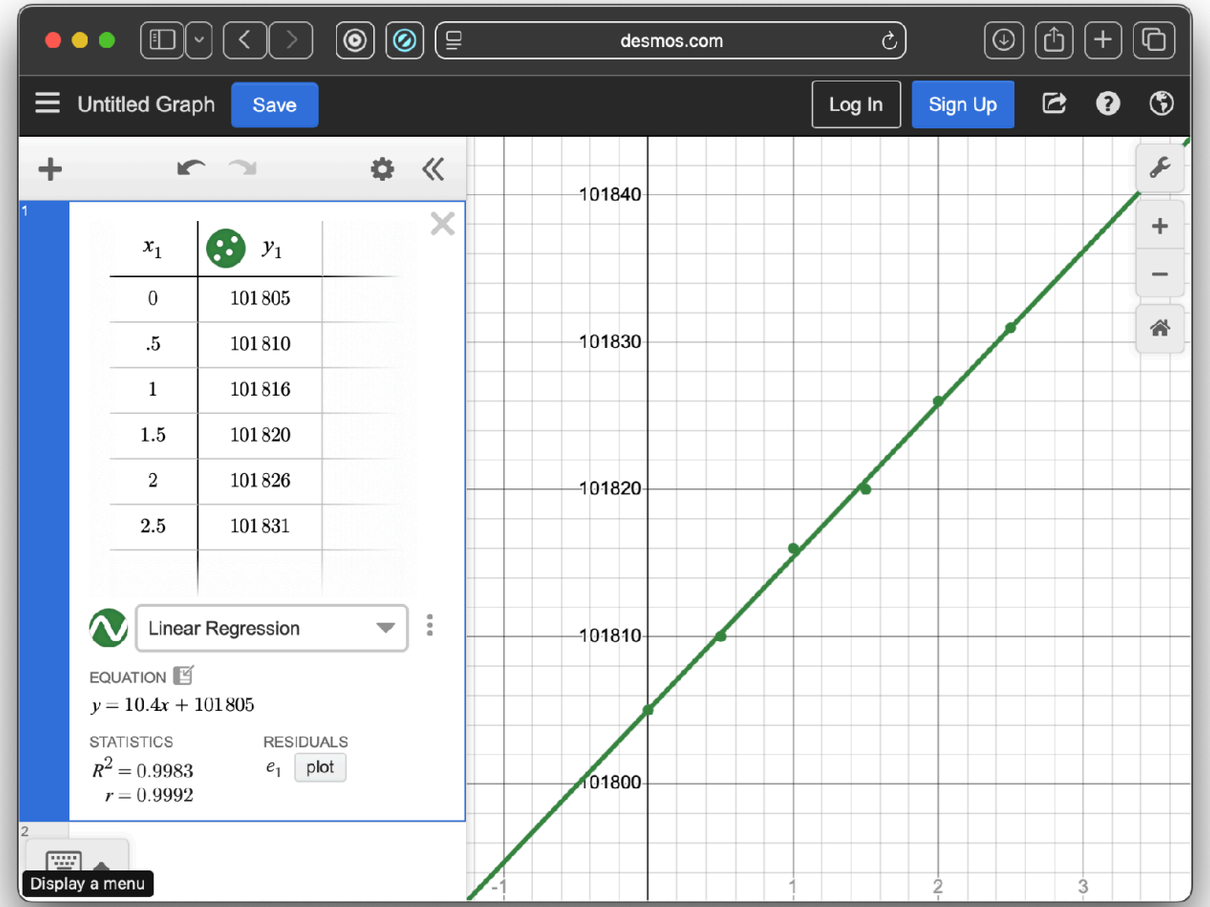
$P = \rho gh + P_0$



Density of Air Lab

$P = \rho gh + P_0$

$$y = 10.4x + 101805$$

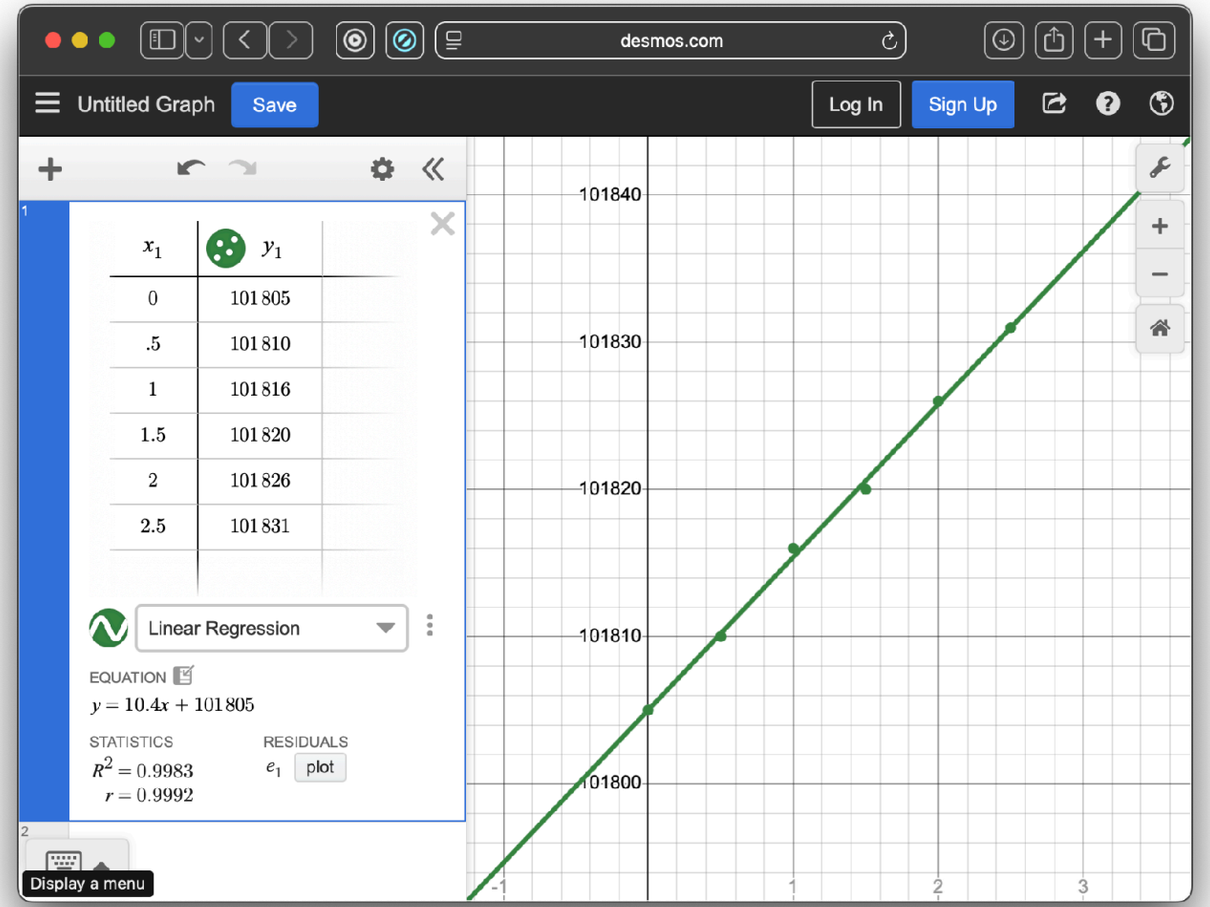


Density of Air Lab

$$P = \rho g h + P_0$$

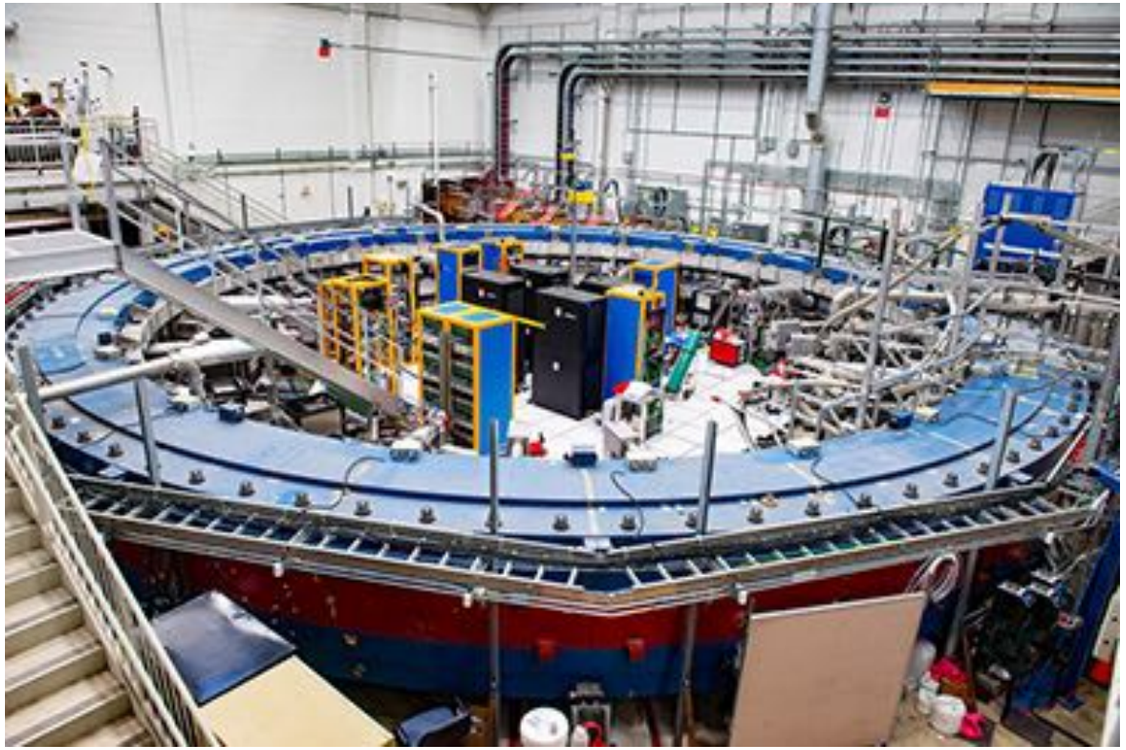
$$y = 10.4x + 101805$$

$$\rho_{AIR} \approx 1.06 \frac{kg}{m^3}$$



Lunch

Experimental Design and Analysis FRQ



FRQ #3 - 10 points

LAB FRQ

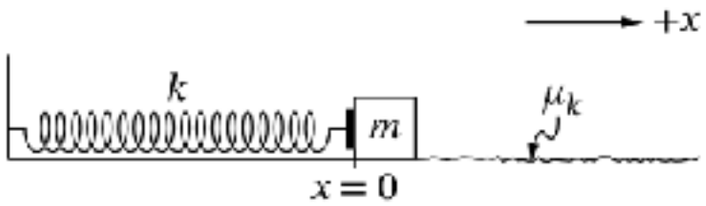
Mechanics LAB FRQ 2026

Question 3

The following information applies to parts A and B.

3. A horizontal spring of known spring constant k is attached to a wall. A block of known mass m is placed on a horizontal surface next to but not attached to the spring. The spring is at its relaxed length when the block is at position $x = 0$, as shown in Figure 1. There is friction between the block and the surface only for positions $x > 0$.

Figure 1



A student is asked to experimentally determine the coefficient of kinetic friction μ_k between the block and the surface using a graph. The student is permitted to use only measurements from a meterstick.

Mechanics LAB FRQ 2025

Question 3

3. A box is connected to one end of a rigid rod. Both the box and the rod have negligible mass. The other end of the rod is connected to a pivot. The box is open on one side, and a block is placed inside the box.

The center of mass of the block is displaced a vertical distance h, as shown in Figure 1. The block-box system is then released from rest and swings downward. There is negligible friction about the pivot. When the system is at the lowest point of its swing, the rod collides with a rigid stopper, as shown in Figure 2. The box comes to rest, and the block is launched horizontally out of the box. The block moves across a horizontal surface toward a motion sensor that measures the speed of the block. All frictional forces are negligible.

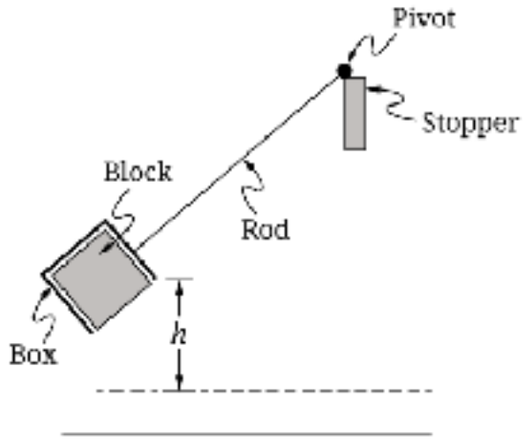


Figure 1

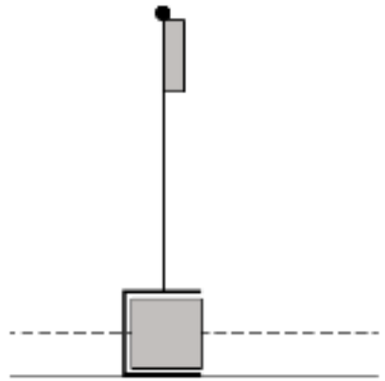


Figure 2

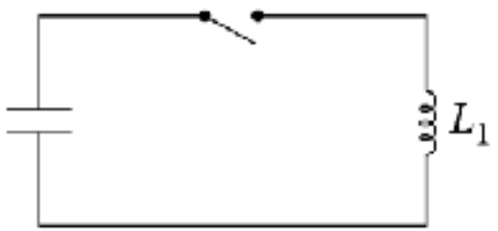
E&M LAB FRQ 2026

Question 3

The following information applies to parts A and B.

3. In Experiment 1, students are asked to collect data that can be graphed to determine the inductance L_1 of an inductor. The students have access to multiple charged capacitors, each of a different known capacitance, and a voltmeter that measures potential difference as a function of time. In each trial, the inductor is connected to a charged capacitor and an initially open switch, as shown in Figure 1.

Figure 1

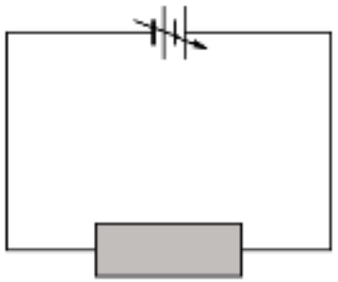


E&M LAB FRQ 2025

Question 3

3. In Experiment 1, students are asked to use a graph to determine the resistivity ρ_1 of a circuit element that is connected to a variable power supply, as shown in Figure 1. The circuit element is cylindrical and has uniform resistivity. The students have access to a voltmeter, an ammeter, and a ruler.

Figure 1



Circuit Element

Experimental Design and Analysis FRQ

- Find Question #3 the LAB FRQ
- Look at either the Mechanics or the E&M Student Samples packet
- Read through and determine the tasks that the student have to do for each part
- Record how many points per part

LAB FRQ Practice

- Work through the LAB FRQ for the exam of your choosing
- As you work the FRQ think about how you can help prepare you students for this item type
- How could you adjust how you structure labs?
- How could you adjust what you require in lab reports?

Experimental Design & Analysis FRQ

Tasks

Experiment 1

- **Part A**
- **Indicate** quantities that could be measured to create a linear graph (Part i-1pt)
- **Describe** a method to reduce experimental uncertainty (Part ii-1pt)

- **Part B**
- **Indicate** what quantities could be graphed on the axes to create a linear graph (Part i-1pt)
- **Describe** the relationship between the unknown quantity and one feature of the graph (Part ii-1pt)

Experimental Design & Analysis FRQ

Tasks

Experiment 2

- **Part C**
- **Label** the axes with quantities & units that could be measured to create a linear graph (Part i-1pt)
- **Label** the axes with linear scales (Part ii-1pt)
- **Plot** the corresponding data points on the grid (Part ii-1pt)
- **Draw** a best fit line (Part ii-1pt)

- **Part D**
- **Calculate** the unknown quantity (2pts)
  - 1pt for indicating what the slope represents
  - 1pt for stating the unknown quantity within a range

Experimental Design and Analysis (LAB)

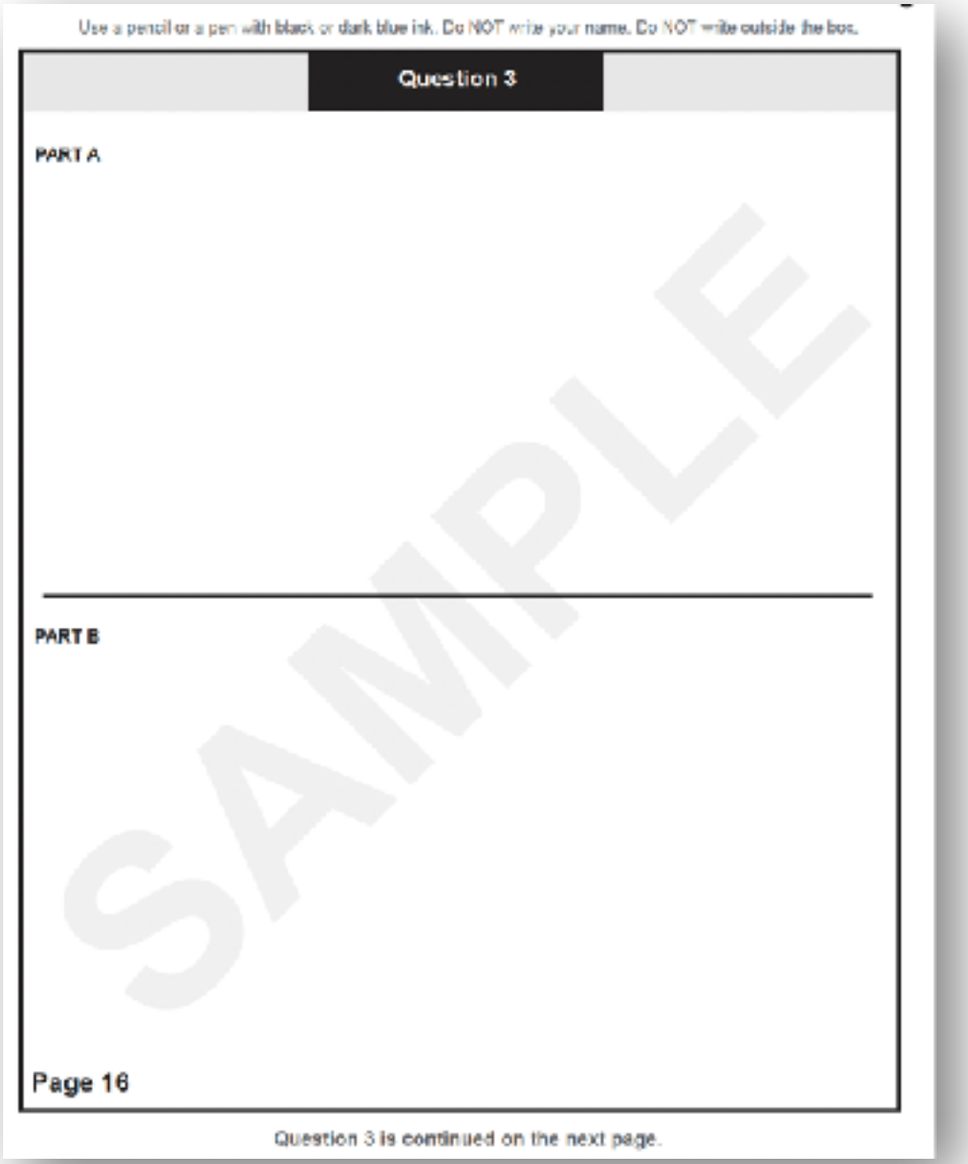
Skills: 1.B 2.B 2.D 3.A 3.B 3.C

10 points; suggested time: 25-30 minutes

The Experimental Design and Analysis (LAB) question assesses students' ability to create scientific procedures that can be used with appropriate data analysis techniques to determine the answer to given questions. The LAB question can roughly be divided into two sections: Design and Analysis. In the Design portion of the LAB question, students will be asked to develop a method by which a question about a given physical scenario could be answered. The experimental procedure is expected to be scientifically sound: vary a single parameter, and measure how that change affects a single characteristic. Methods must be able to be performed in a typical high school laboratory. Measurements must be made with realistically obtainable equipment or sensors. Students will be expected to describe a method by which the collected data could be analyzed in order to answer the posed question, by either graphical or comparative analyses.

Students will then be given experimental data collected in order to answer a similar, but not identical, question to what was asked in the Design portion of the question. Students will be asked to use the data provided to create and plot a graph that can be analyzed to determine the answer to the given question. For instance, the slope or intercepts of the line may be used to determine a physical quantity or perhaps the nature of the slope would answer the posed question.

FRQ Booklet Structure: Question #3 LAB: P1



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

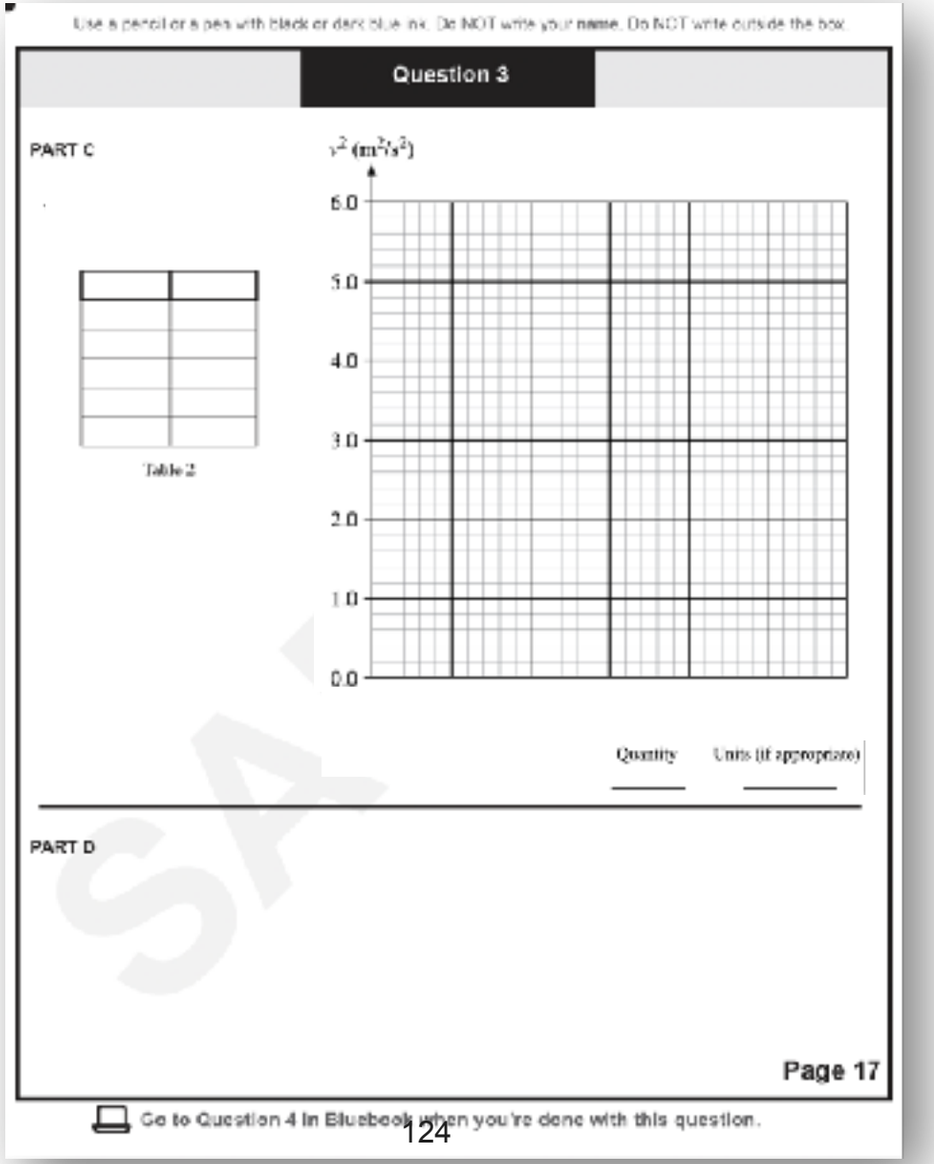
Question 3

PART A

PART B

SAMPLE

Question 3 is continued on the next page.



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

Question 3

PART C

v^2 (m^2/s^2)

6.0
5.0
4.0
3.0
2.0
1.0
0.0

Table 2

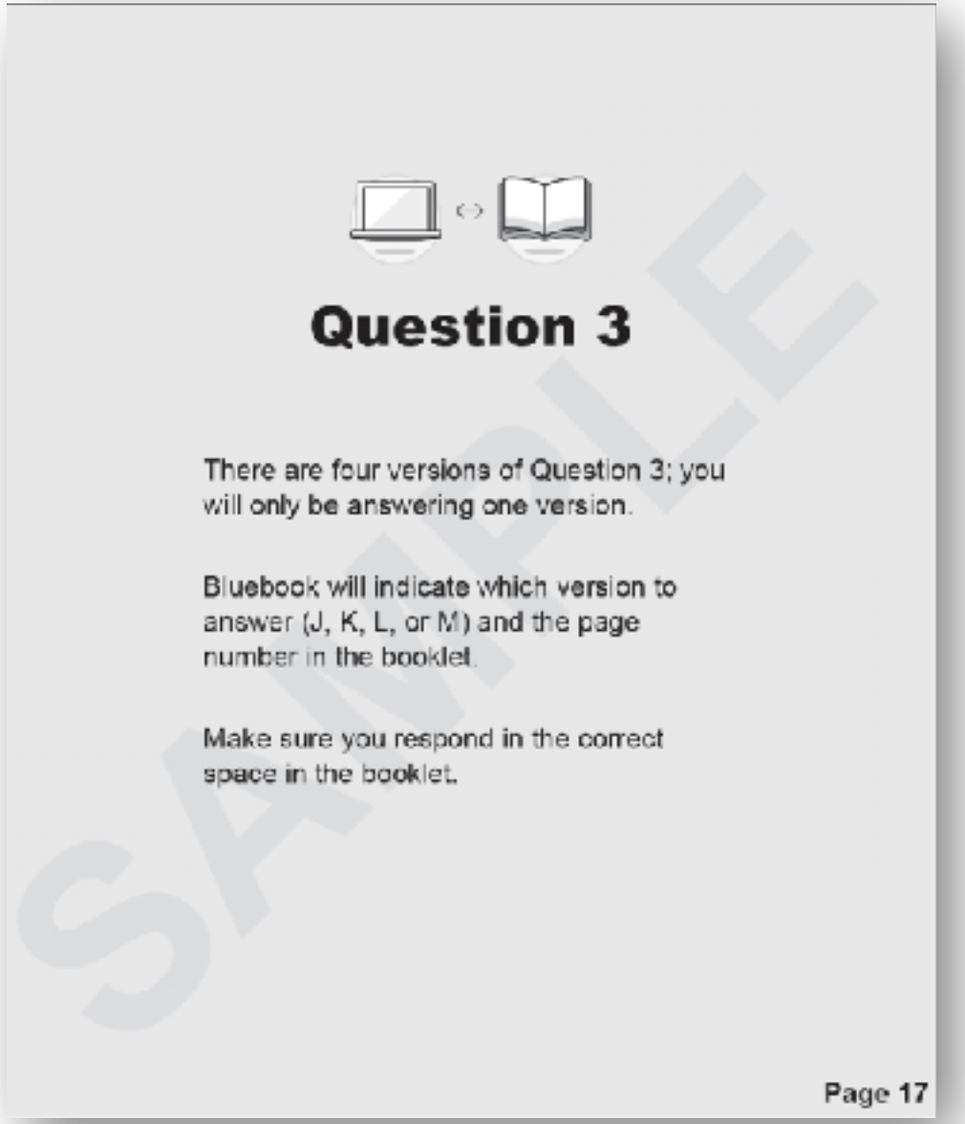
Quantity _____ Units (if appropriate) _____

PART D

SAMPLE

Go to Question 4 in Bluebook when you're done with this question.

FRQ Booklet: Which Version? P1



Question 3

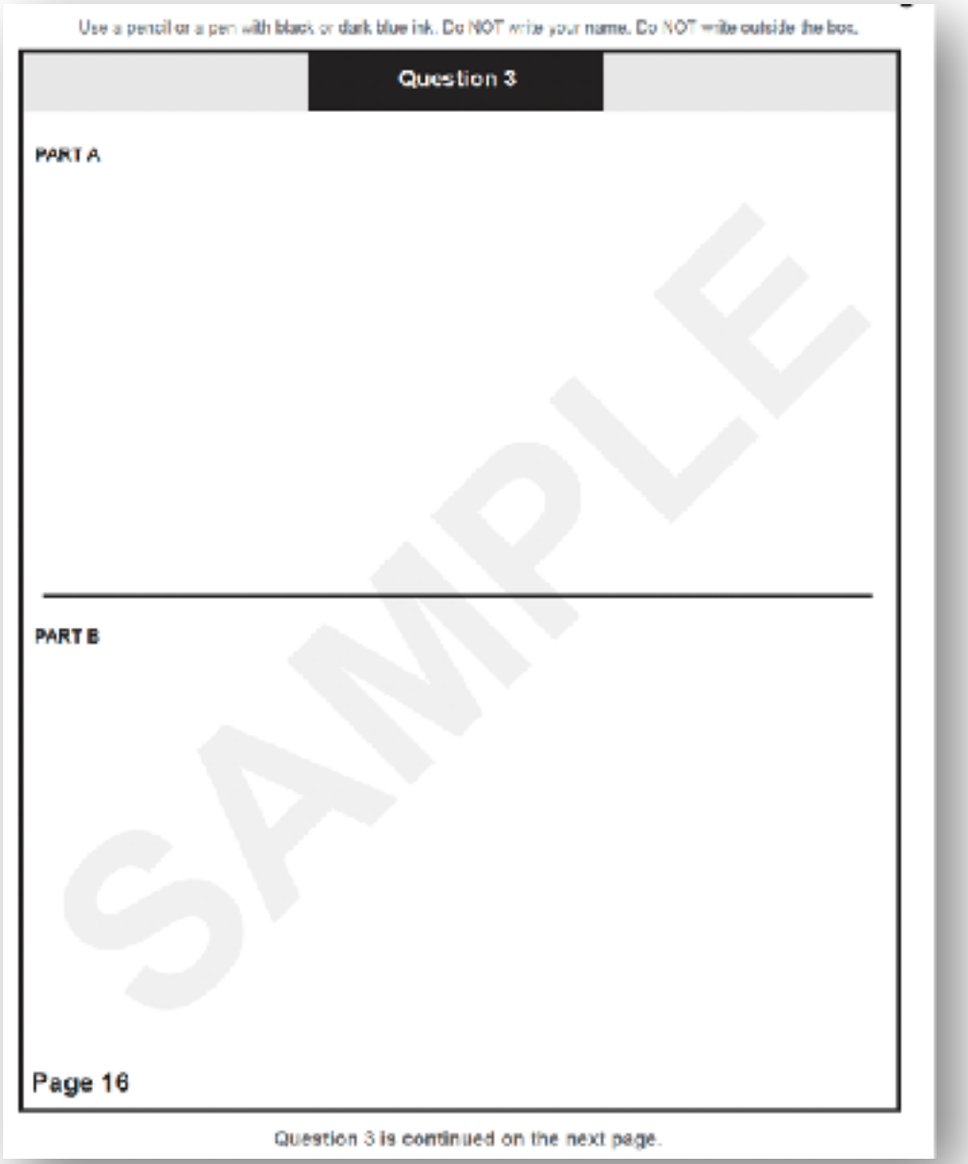
There are four versions of Question 3; you will only be answering one version.

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.

SAMPLE

FRQ Booklet Structure: Question #3 LAB - P2 & Cs



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

Question 3

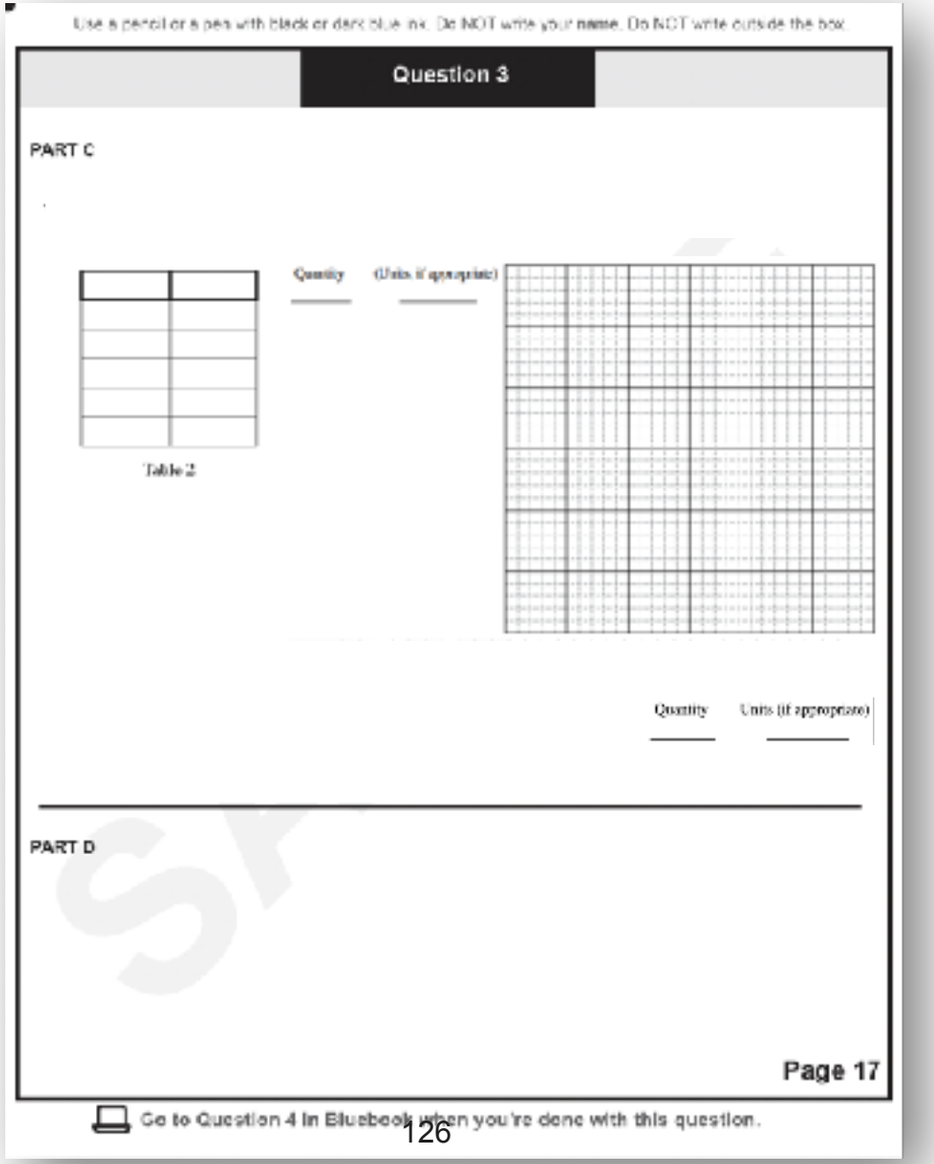
PART A

PART B

SAMPLE

Page 16

Question 3 is continued on the next page.



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

Question 3

PART C

Quantity (Units if appropriate)

Table 2

Quantity Units (if appropriate)

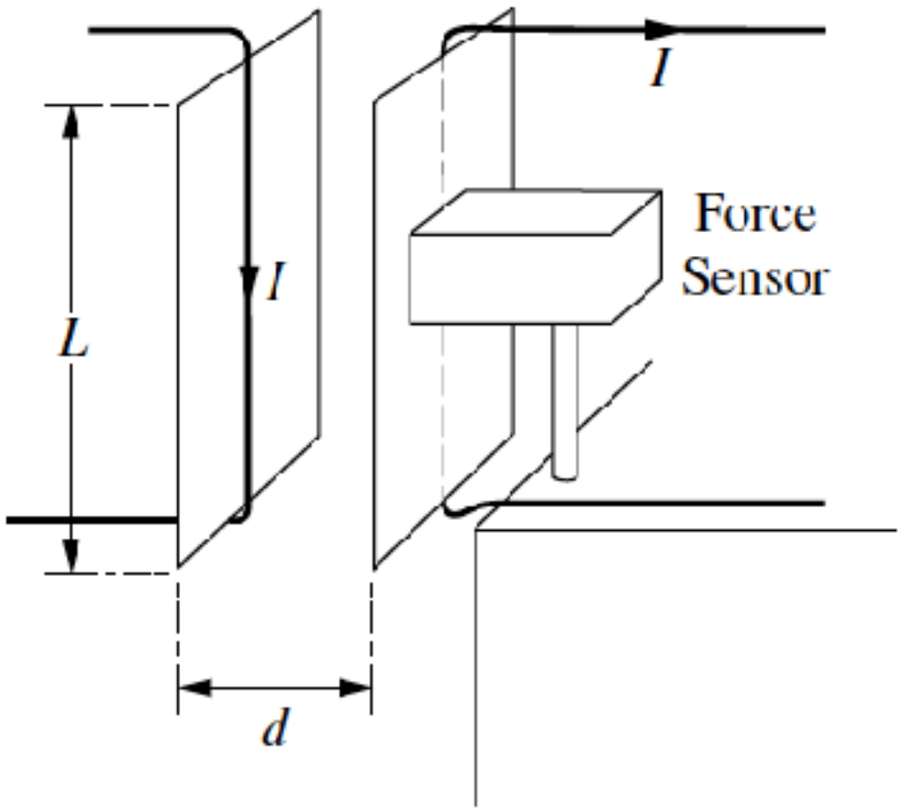
PART D

SAMPLE

Page 17

Go to Question 4 in Bluebook when you're done with this question.

Question #3: Experimental Design and *Analysis*: P2&Cs



The students want to determine an experimental value for the magnetic permeability of free space, μ_0. The same experimental setup is used and the current I is the same for both wires, as shown in Figure 2. The length L of the wire segments fixed to the boards is measured. In this experiment the distance d between the wires is held fixed and the force is measured while the current I is then varied. Using measured values of $L = 1.4$ m and $d = 0.005$ m, the students collect the data shown in Table 1.

Table 1

I (A)	F (mN)
2.8	0.35
3.2	0.60
3.6	0.65
4.0	1.00
4.4	1.10

Question #3: Experimental Design and *Analysis*: P2&Cs

(c) i. **Label** the axes of the grid provided with measured or calculated quantities. Include units, as appropriate. The graphed quantities should yield a linear graph that can be used to determine μ_0.

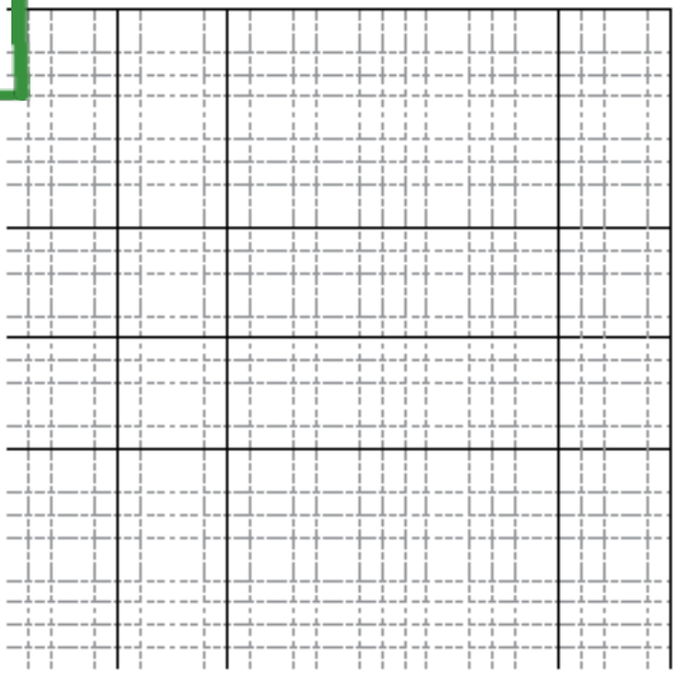
ii. On the grid provided, create a graph of the quantities indicated in part (c)i.

- Clearly **label** the axes with a numerical scale.
- **Plot** the corresponding data points on the grid.
- Table 2 is provided in your booklet for scratch work and will not be scored.

iii. **Draw** a best-fit line for the data plotted in part (c)(ii).

(d) Using the line drawn in part (c)(iii) and the measured values $L = 1.4$ m and $d = 0.005$ m as needed, **calculate** the magnetic permeability of free space, μ_0.

Quantity _____ (Units, if appropriate) _____

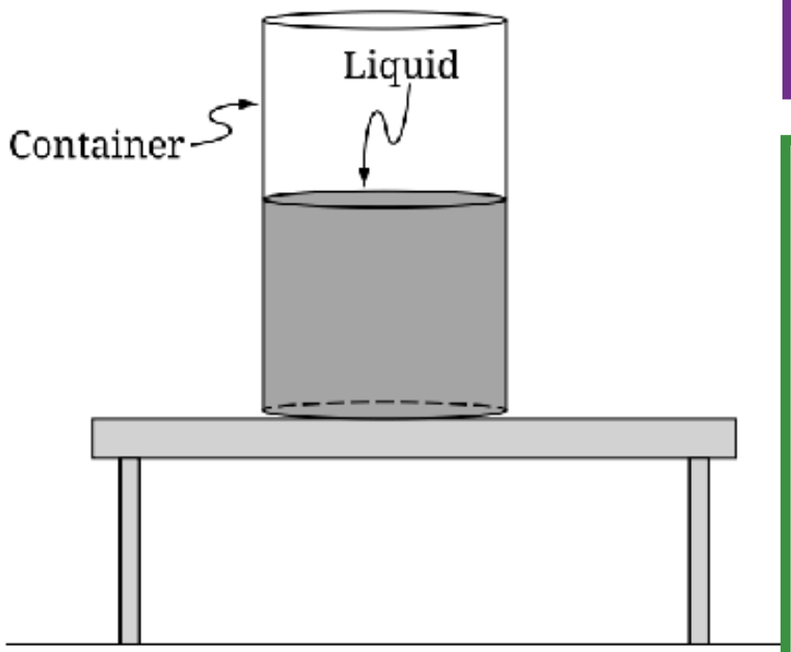


Quantity _____ Units (if appropriate) _____

Question #3: Experimental *Design* and Analysis

A group of students are given a cylindrical container half filled with a liquid of unknown density ρ as shown in Figure 1. The students have access to an additional container with more of the same liquid, meter sticks, and a pressure sensor. They do not have access to a scale.

Figure 1



A. i. **Indicate** quantities that could be measured by the students that would allow them to determine the density of the liquid using a linear graph.

ii. Briefly **describe** a method to reduce experimental uncertainty for the measured quantities.

B. i. **Indicate** what quantities students could graph on the horizontal and vertical axes to create a linear graph that can be used to determine the density of the liquid.

ii. Briefly **describe** the relationship between the density of the liquid and a feature of the graph from Part B (i). Your answer may include an equation that relates the density of the liquid and the chosen feature of the graph.

Question #3: Experimental Design and *Analysis*: P1

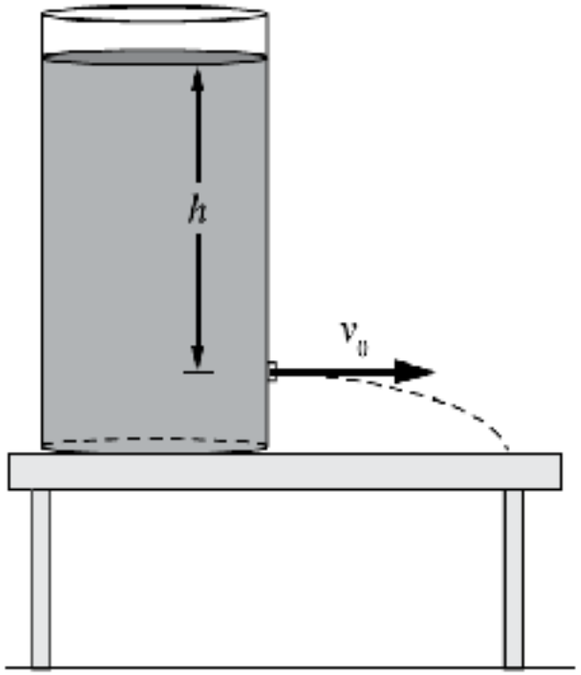


Figure 2

The students perform another experiment with another cylindrical container which is filled with water, as shown in Figure 2. The students make a small hole in the side of the cylinder and measure the speed v at which water exits the hole. The students plug the first hole, make another one at a different height, and repeat this procedure. Table 1 shows the height h of each hole relative to the top of the water, and the corresponding water speed v.

Question #3: Experimental Design and *Analysis*: P1

Table 1

Height h (m)	Speed v (m/s)
0.25	2.2
0.20	2.0
0.15	1.8
0.10	1.4
0.05	1.1

C. The students correctly determine that the relationship between h and v is given by

$$v = \sqrt{2gh}$$

The students want to determine an experimental value for the acceleration due to gravity. The students create a graph with v^2 plotted on the vertical axis.

i. **Label** the horizontal axis of Figure 3 with a measured or calculated quantity. Include units, as appropriate. The graphed quantities should yield a linear graph that can be used to determine the acceleration due to gravity.

Question #3: Experimental Design and *Analysis*: P1

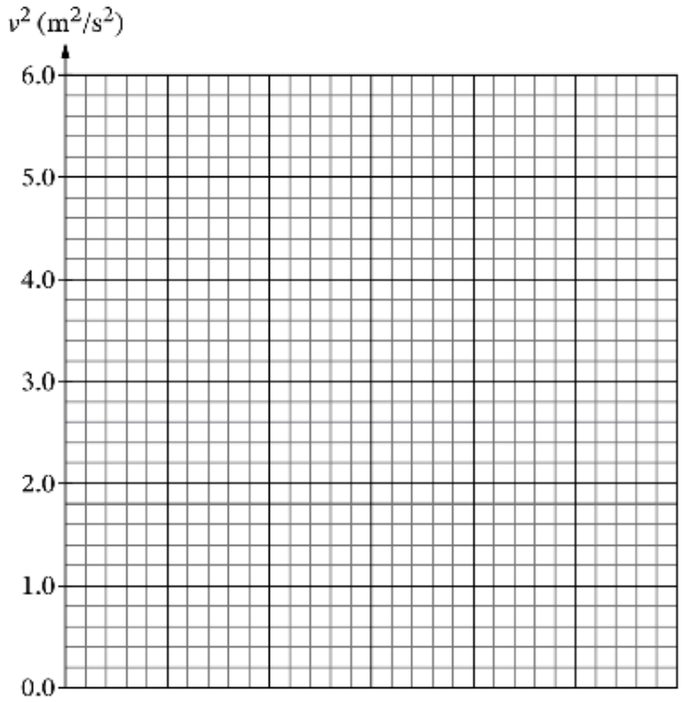
ii. On the grid provided in Figure 3, create a graph of the quantities indicated in part C (i).

- Clearly **label** the horizontal axis with a numerical scale.
- **Plot** the corresponding data points on the grid.
- Table 2 is provided in your booklet for scratch work and will not be scored.

iii. **Draw** a best fit line for the data graphed in part C (ii).

D. **Calculate** an experimental value for the acceleration due to gravity using the best-fit line that you drew in part C (iii).

Figure 3



Quantity	Units (if appropriate)
_____	_____

Experimental Design Part: Tips

- Use the Reference Table equations to guide your thinking to decide what quantity you will vary and what quantity will vary as a result
- Make sure and mention that you will vary the independent variable many times (10 times for example) to reduce experimental uncertainty
- Be very clear which axis which quantity will be graphed on in Part B.
- Show the equation you are using and how the slope of the graph will give you the unknown quantity, write derivation in $y=mx+b$ format

Experimental Analysis Part: Tips

- Use the Reference Table equations to guide your thinking to decide what quantity you will vary and what quantity will vary as a result
- **Tip:** Use the space in Part D to do your derivations to determine what you are going to graph, write derivation in $y=mx+b$ format
- Fill out the data table to help the Reader know what values you are plotting but it will not be scored

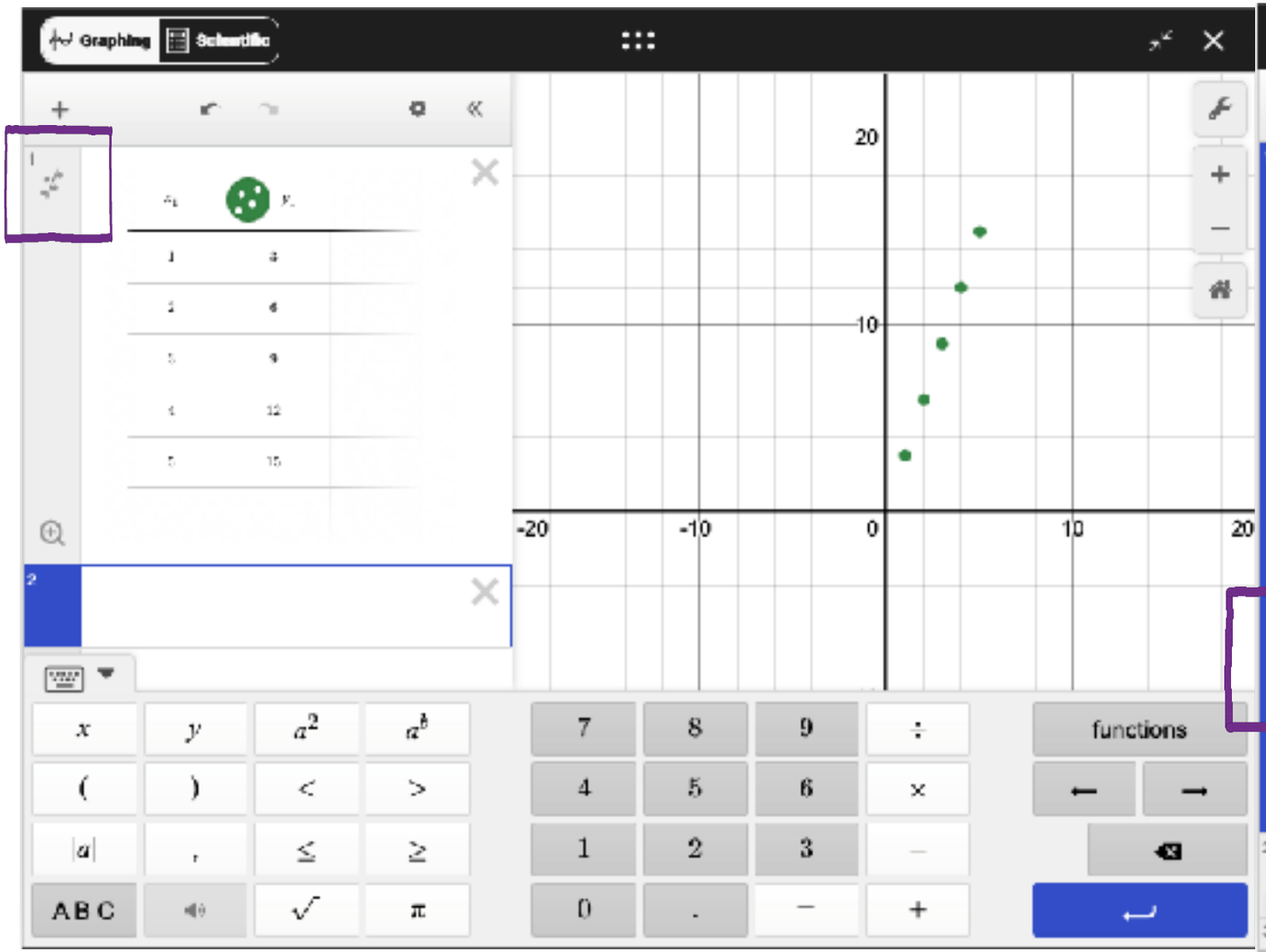
Experimental Analysis Part: Tips

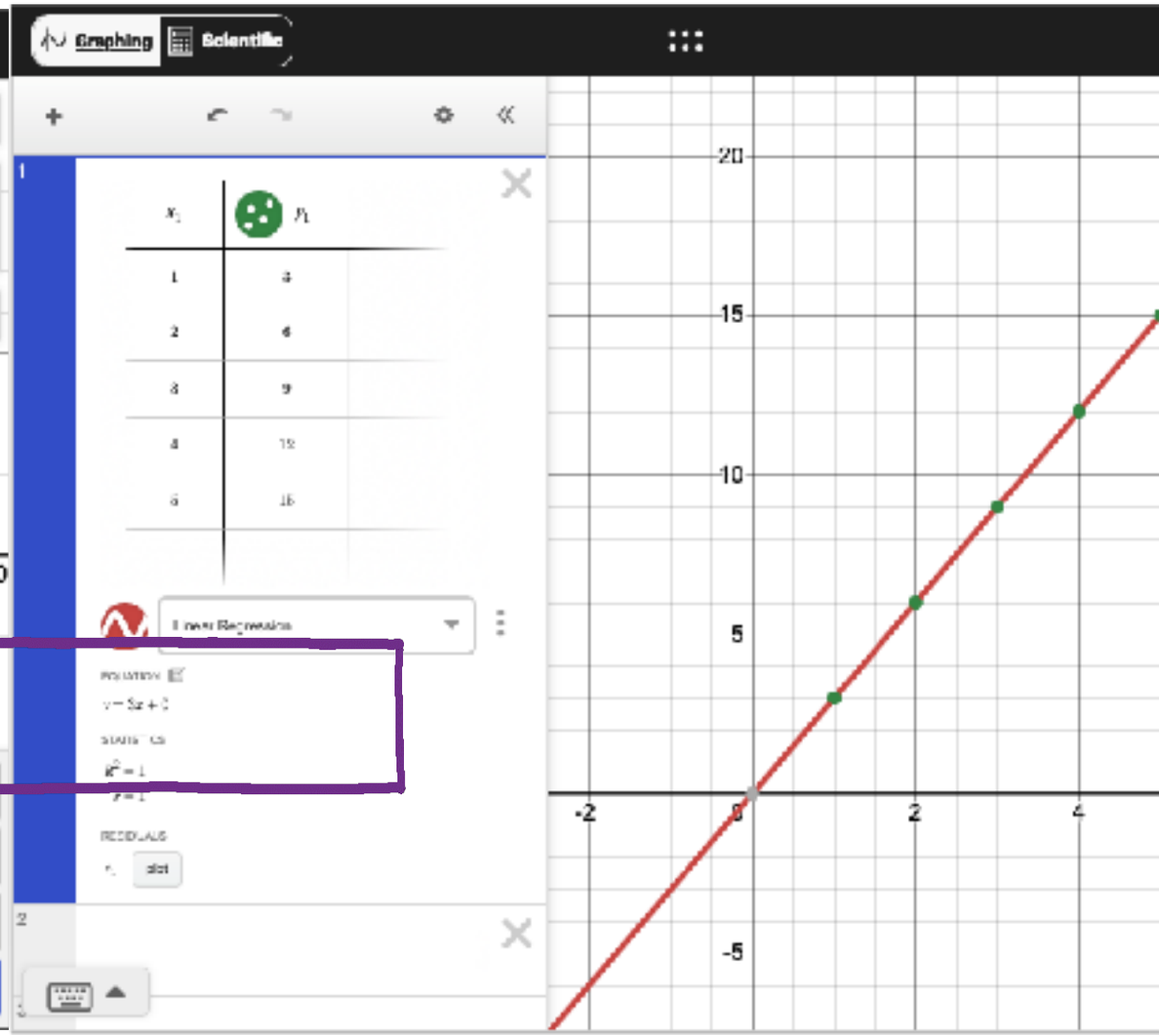
- Label both axes with the Quantity and the Units, i.e,. length (m) or time (s) or t^2 (s^2)
- Make sure if a quantity is squared in your equation, you plot that quantity squared
- Label each axis with a linear scale of values
- Use as much of your graph as possible, don't have all the dots in the bottom left-hand corner because it makes it difficult to determine if the data points are correctly plotted
- Good rule of thumb is to have an equal number data points above and below the best fit line

Experimental Analysis Part: Tips

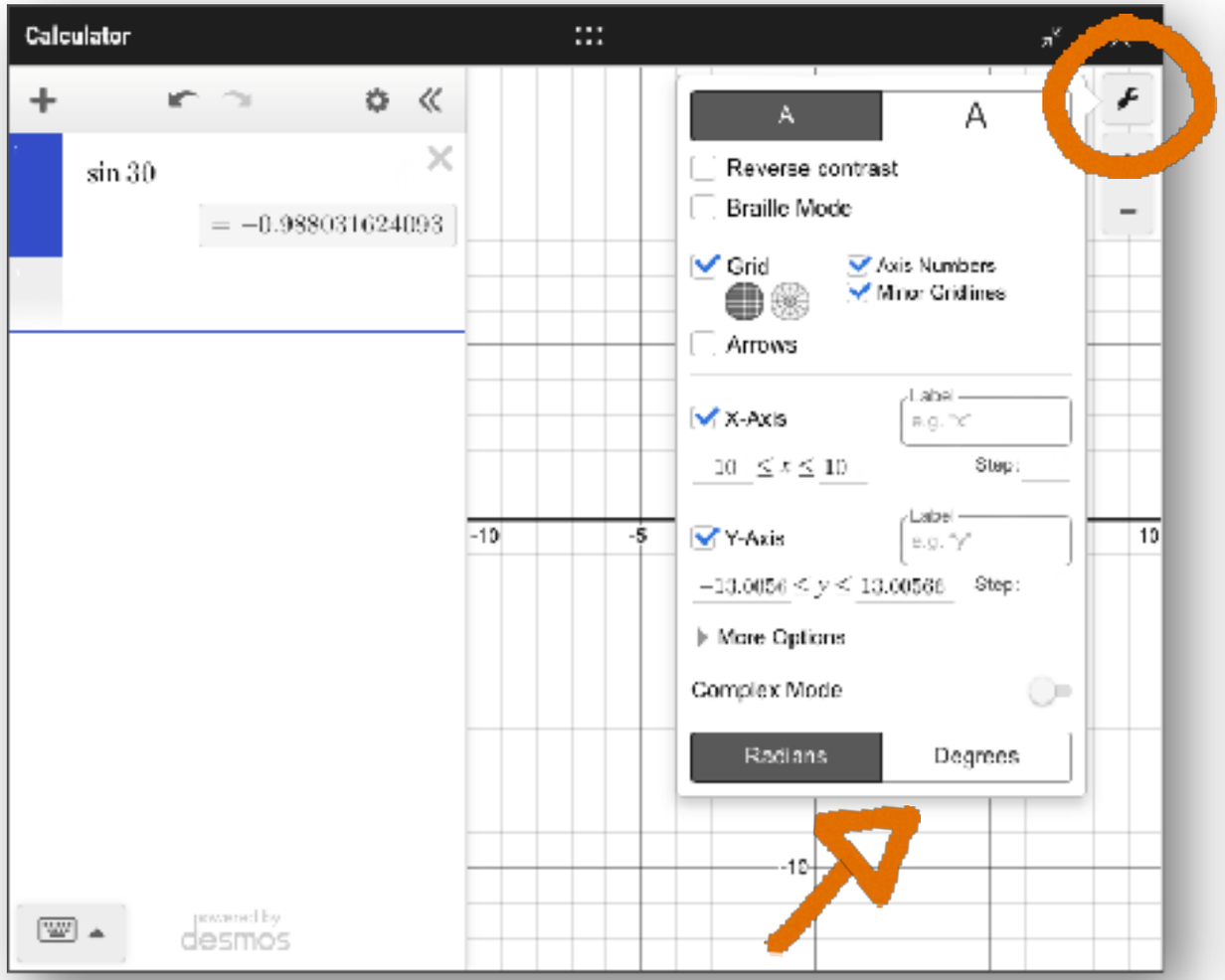
- Make it clear how the graph/equation will be used to determine the unknown quantity
- ~~When calculating the slope of the line show your work and make sure to use points on the line~~
- **Use Desmos to determine the slope of your line**
- ~~Make sure your answer to Part D includes the correct units~~

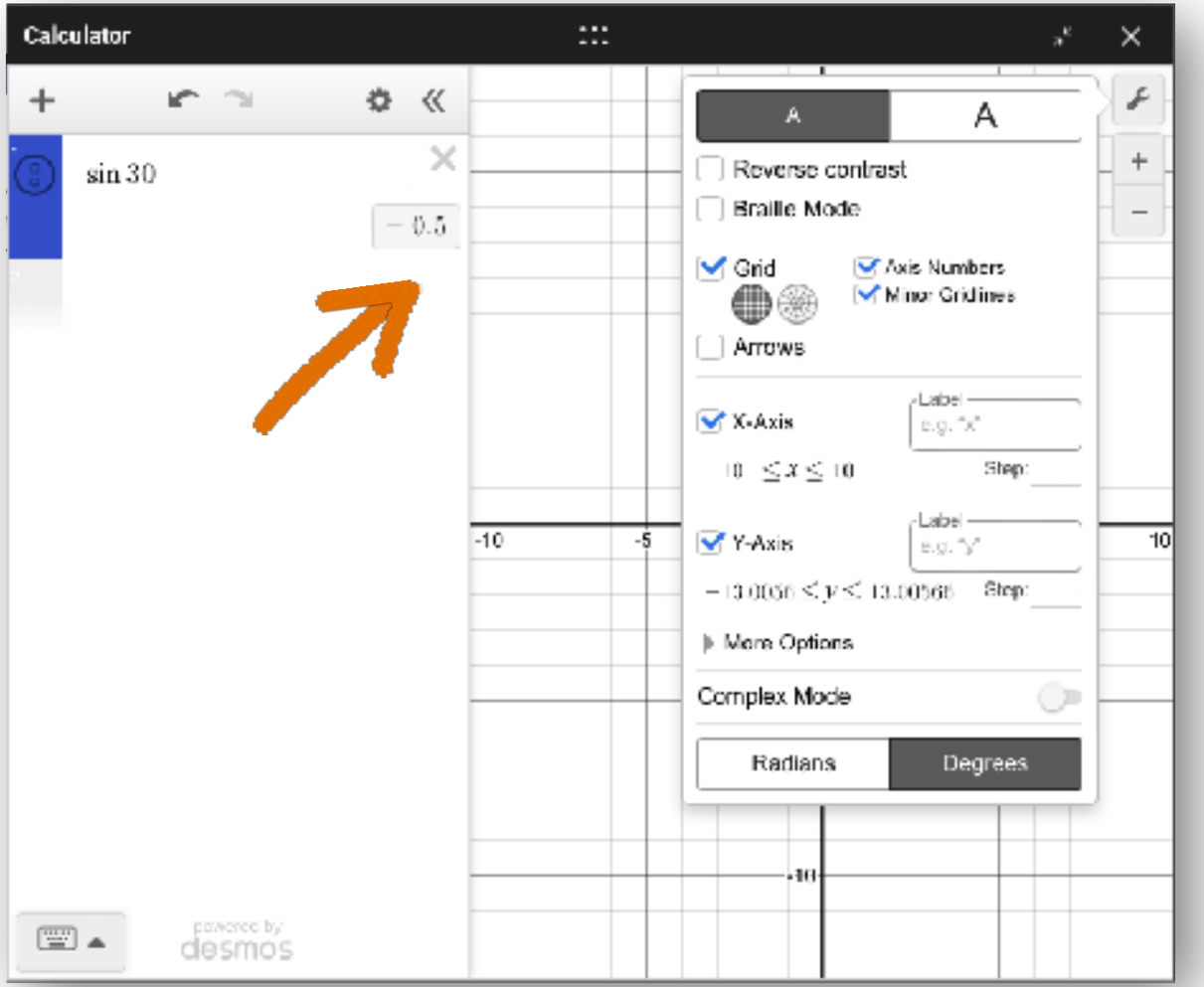
Using Desmos to Determine Slope of a Graph





Switching Modes in Desmos!!





Developing the Science Practices

How your students will be asked to demonstrate **what** they know

LAB Skills: 1.B 2.B 2.D 3.A

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.	

Instructional Planning Report Data

Mech 2026

QUESTION 3 EXPERIMENTAL DESIGN AND ANALYSIS (LAB)	10		5.9
LAB PART A POINT 1	1		0.6
LAB PART A POINT 2	1		0.8
LAB PART B POINT 1	1		0.4
LAB PART B POINT 2	1		0.3
LAB PART C POINT 1	1		0.5
LAB PART C POINT 2	1		0.8
LAB PART C POINT 3	1		0.8
LAB PART C POINT 4	1		0.8
LAB PART D POINT 1	1		0.5
LAB PART D POINT 2	1		0.4

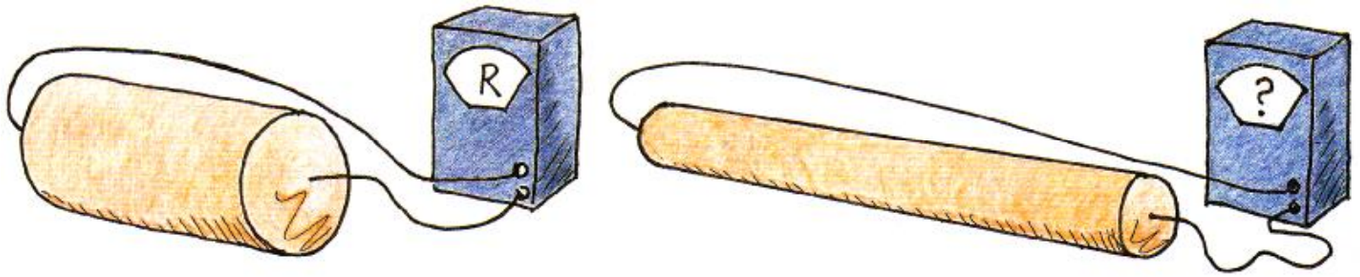
E&M 2026

QUESTION 3 EXPERIMENTAL DESIGN AND ANALYSIS (LAB)	10		6.6
LAB PART A POINT 1	1		0.8
LAB PART A POINT 2	1		0.8
LAB PART B POINT 1	1		0.3
LAB PART B POINT 2	1		0.2
LAB PART C POINT 1	1		0.8
LAB PART C POINT 2	1		0.8
LAB PART C POINT 3	1		0.8
LAB PART C POINT 4	1		0.8
LAB PART D POINT 1	1		0.6
LAB PART D POINT 2	1		0.5

Next Time Questions: Arbor Scientific

NEXT-TIME QUESTION

Roll a piece of modeling clay into a cylinder and use an ohmmeter to measure its resistance.



Now roll it out until it's twice as long, and measure the resistance again. Compared with the initial resistance, the new resistance is

a) unchanged.
b) twice as much.
c) four times as much.
d) eight times as much.
e) actually less.

Defend your answer!

thanx to Peter Hopkinson

CONCEPTUAL Physics

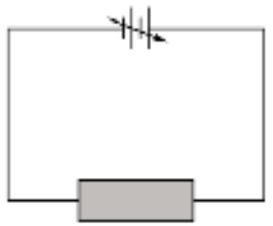
ARBOR SCIENTIFIC
TOOLS THAT TEACH.

E&M LAB FRQ 2025: Nichrome Wire Experiments

Question 3

3. In Experiment 1, students are asked to use a graph to determine the resistivity ρ_1 of a circuit element that is connected to a variable power supply, as shown in Figure 1. The circuit element is cylindrical and has uniform resistivity. The students have access to a voltmeter, an ammeter, and a ruler.

Figure 1



Circuit Element

A. Describe a procedure for collecting data that would allow the students to use a graph to determine ρ_1, including any steps necessary to reduce experimental uncertainty.

B. Describe how the collected data could be graphed and how that graph would be analyzed to determine ρ_1.

In Experiment 2, the students are asked to use a graph to determine the resistivity ρ_2 of solid, cylindrical resistors made of the same material but of different lengths L. The cross-sectional area of each resistor is 5.0×10^{-6} m^2. The students directly measure the resistance R between the ends of each resistor. Table 1 provides L and R for each resistor.

Mathematical Routines

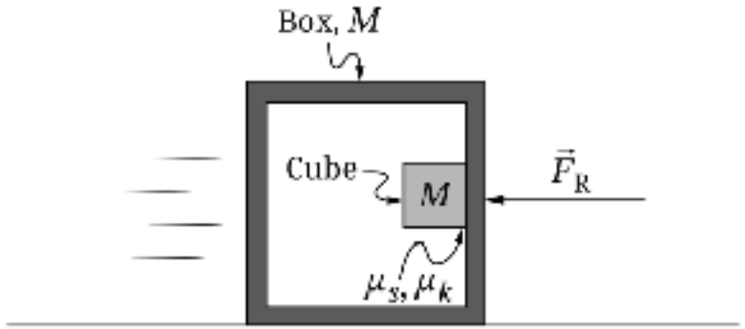
FRQ #1 - 10 points

Mathematical Routines Mechanics FRQ 2026

Question 1: Version J

1. A box of mass M slides to the right on a horizontal surface. A small cube, also of mass M, is inside the box. The cube is against the right wall of the box and above the bottom of the box, as shown in Figure 1. The coefficients of static and kinetic friction between the cube and the wall of the box are μ_s and μ_k, respectively, where $\mu_s > \mu_k$.

Figure 1



The speed of the box is decreasing as a result of a resistive force that is exerted on the box. The resistive force $\vec{F}_R$ is modeled by $\vec{F}_R = -b\vec{v}$, where b is a positive constant and $\vec{v}$ is the velocity of the box. Friction between the box and horizontal surface is negligible.

Mathematical Routines Mechanics FRQ 2025

Question 1: Version J

1. Two blocks, 1 and 2, slide toward each other on a horizontal surface. Block 1 has mass m and slides in the $+x$-direction with constant speed $2v_0$. Block 2 has mass $6m$ and slides in the $-x$-direction with constant speed v_0, as shown in Figure 1. The blocks then collide and stick together. The collision occurs from time $t = 0$ to $t = t_c$. After the collision, where $t > t_c$, the blocks move together with the same constant speed.

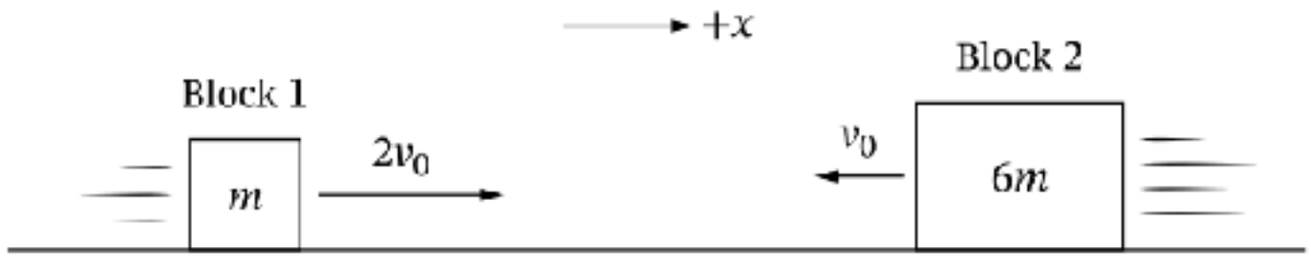


Figure 1

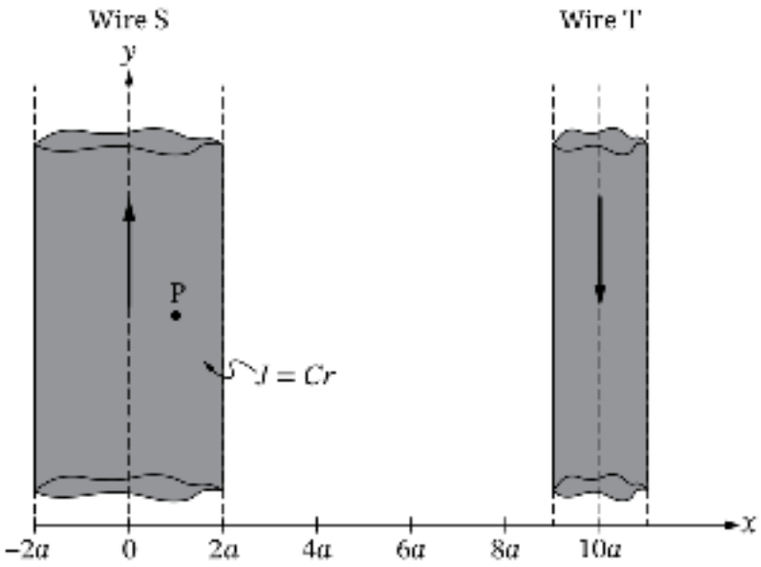
Mathematical Routines E&M FRQ 2026

Question 1: Version J

1. Two very long, cylindrical, current-carrying Wires S and T are oriented parallel to the y-axis, as shown in Figure 1. The centers of the wires are in the xy-plane. The wires are described as follows.

- Wire S has radius $2a$ and is centered at $x = 0$. Wire S has nonuniform current density and carries total current I_0 in the $+y$-direction. The magnitude of the current density in Wire S as a function of the radial distance r from the center of the wire is described by $J = Cr$, where C is a positive constant.
- Wire T has radius a and is centered at $x = 10a$. Wire T has uniform current density and carries total current I_0 in the $-y$-direction.

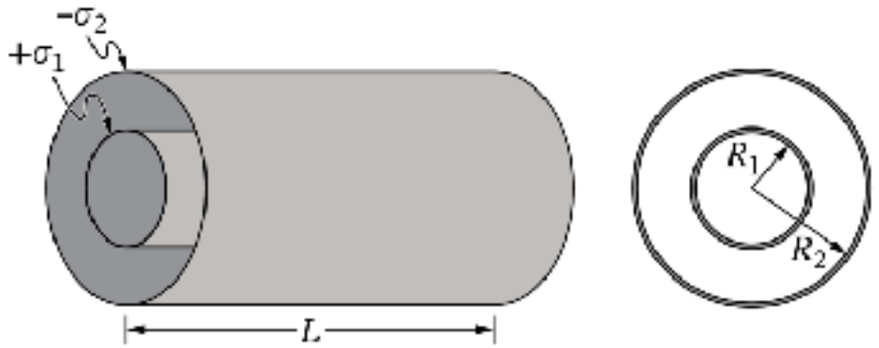
Figure 1



Mathematical Routines E&M FRQ 2025

Question 1: Version J

1. An isolated, air-filled, charged capacitor consists of two conducting, coaxial, cylindrical shells that each have length L. The inner shell has radius R_1 and the outer shell has radius R_2, as shown in Figure 1, where $R_1 < R_2 \ll L$. The surface charge densities (amounts of charge per unit area) of the inner and outer shells are $+\sigma_1$ and $-\sigma_2$, respectively. The absolute values of the total charges on the shells are equal.



Side View

Cross-Sectional View

Note: Figures not drawn to scale.

Figure 1

Mathematical Routines FRQ

- Find Question #1 the MR FRQ
- Look at either the Mechanics or the E&M Student Samples packet
- Read through and determine the tasks that the student have to do for each part
- Record how many points per part

MR FRQ Practice

- Work through the MR FRQ for the exam of your choosing
- As you work the FRQ think about how you can help prepare you students for this item type.
- How could you adjust your problem sets to match this derivation focused format?
- How could you adjust what you require when you score derivation FRQs?

NEW Item Type

Mathematical Routines

FRQ #1

Mathematical Routines FRQ Mech and E&M

The Mathematical Routines question assesses students' ability to use mathematics to analyze a scenario and make predictions about that scenario.

(a) Students will be expected to **symbolically derive relationships between variables, as well as calculate numerical values**. (5pts)

(a) Students will be expected to **create and use representations that describe the scenario**, either to help guide the mathematical analysis (such as drawing a free-body diagram) or that are applicable to the scenario (such as sketching velocity as a function of time). (2pts)

(b) Students will be expected to **symbolically derive relationships between variables, as well as calculate numerical values**. (3pts)

NEW Item Type

Mathematical Routines

FRQ #1

Mathematical Routines FRQ P1 & P2

The Mathematical Routines question assesses students' ability to use mathematics to analyze a scenario and make predictions about that scenario.

(a) Students will be expected to **symbolically derive relationships between variables, as well as calculate numerical values**. (5pts)

(a) Students will be expected to **create and use representations that describe the scenario**, either to help guide the mathematical analysis (such as drawing a free-body diagram) or that are applicable to the scenario (such as sketching velocity as a function of time). (2pts)

(b) For AP Physics 1 and AP Physics 2, the Mathematical Routines question will ask students to ***make a claim or prediction about the scenario and use appropriate physics concepts and principles to support and justify that claim***. The justification is expected to be a logical and sequential application of physics concepts that demonstrates a student's ability to connect multiple concepts to each other. (3pts)

Tips for Derivations and Calculations

- Start with a fundamental Physics Law or Principle
- Show all your Physics work, it is OK to not show every Algebra step
- Try to be as organized as possible and follow a clear path
- For answers to derivations, only use the given variables using the same letters/symbols and physical constants as appropriate
- Circle or box your answer so it is clear to the Reader

FRQ Booklet: Which Version?



Question 1

There are four versions of Question 1; 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.

Question #1: Mathematical Routines-PC

A.

i. **Derive** an expression for the speed of Object A at the instant Object A is passing through position x_0. Express your answer in terms of m_A, U_0, x_0, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

ii. On the grid shown in Figure 2, **draw** a graph of the force exerted on Object A by Object B.

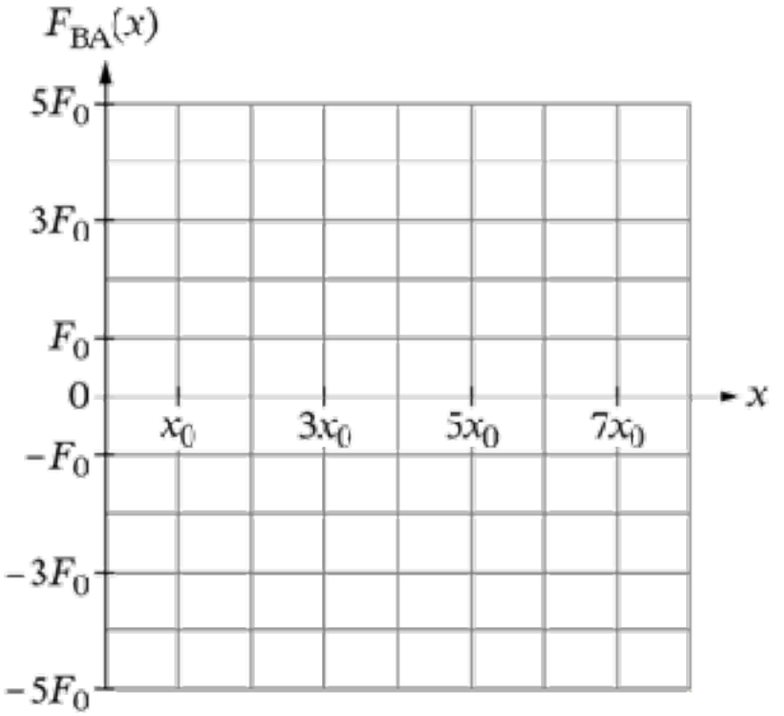
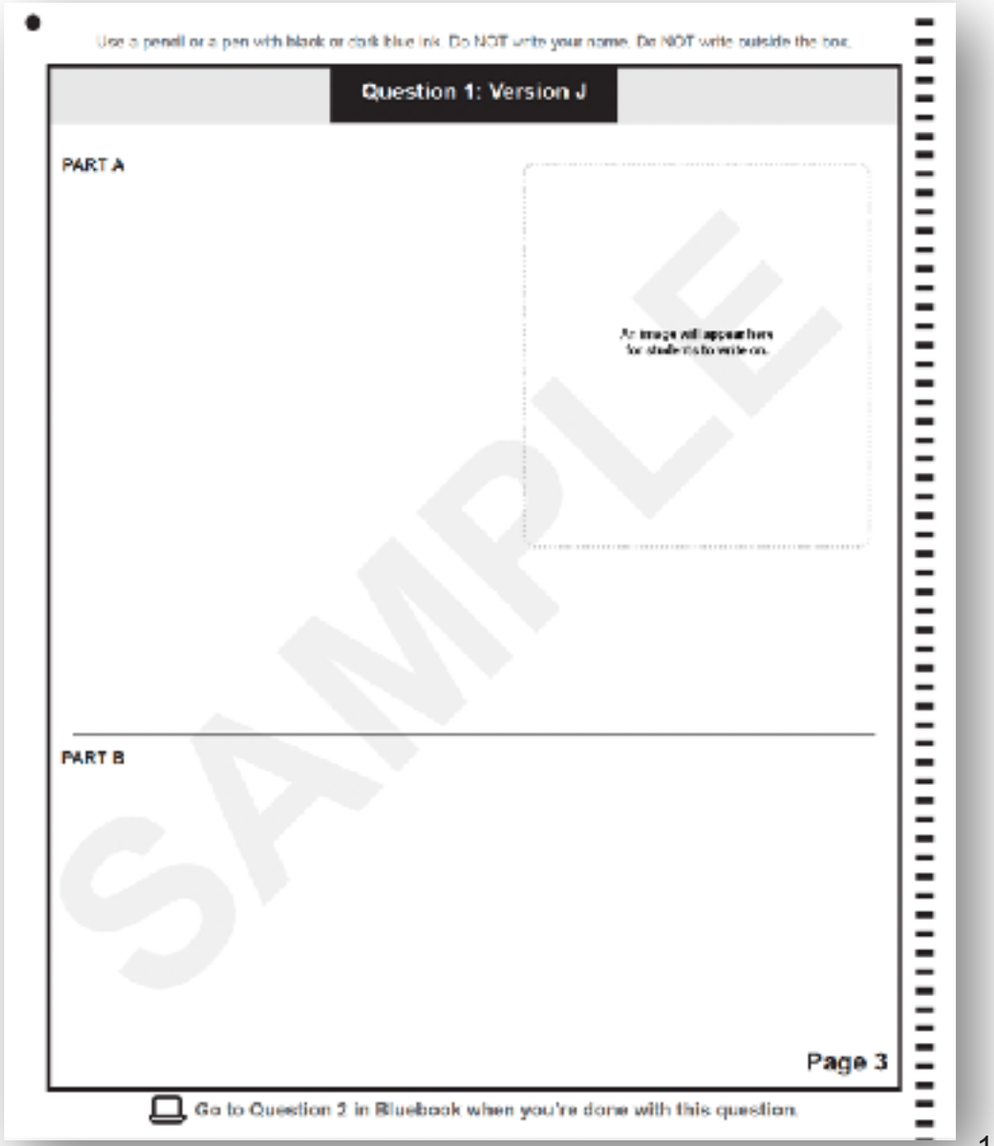


Figure 2

In another scenario, Object A is replaced by Object C. Objects C and B interact with each other through a conservative force $F_{BC}(x) = -\beta x^2$, where $\beta = \frac{3}{8}\ \frac{\text{kg}}{\text{s}^2\text{m}}$. The potential energy $U_{BC}(x)$ of the Object C–Object B system is defined to be zero when Object C is at position $x = -2$ m. No external forces are exerted on the two-object system.

B. **Derive** an equation for $U_{BC}(x)$. Express your answer only in terms of x. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

FRQ Booklet Structure: Which Version??


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

Question 1: Version J

PART A

An image will appear here for students to write on.

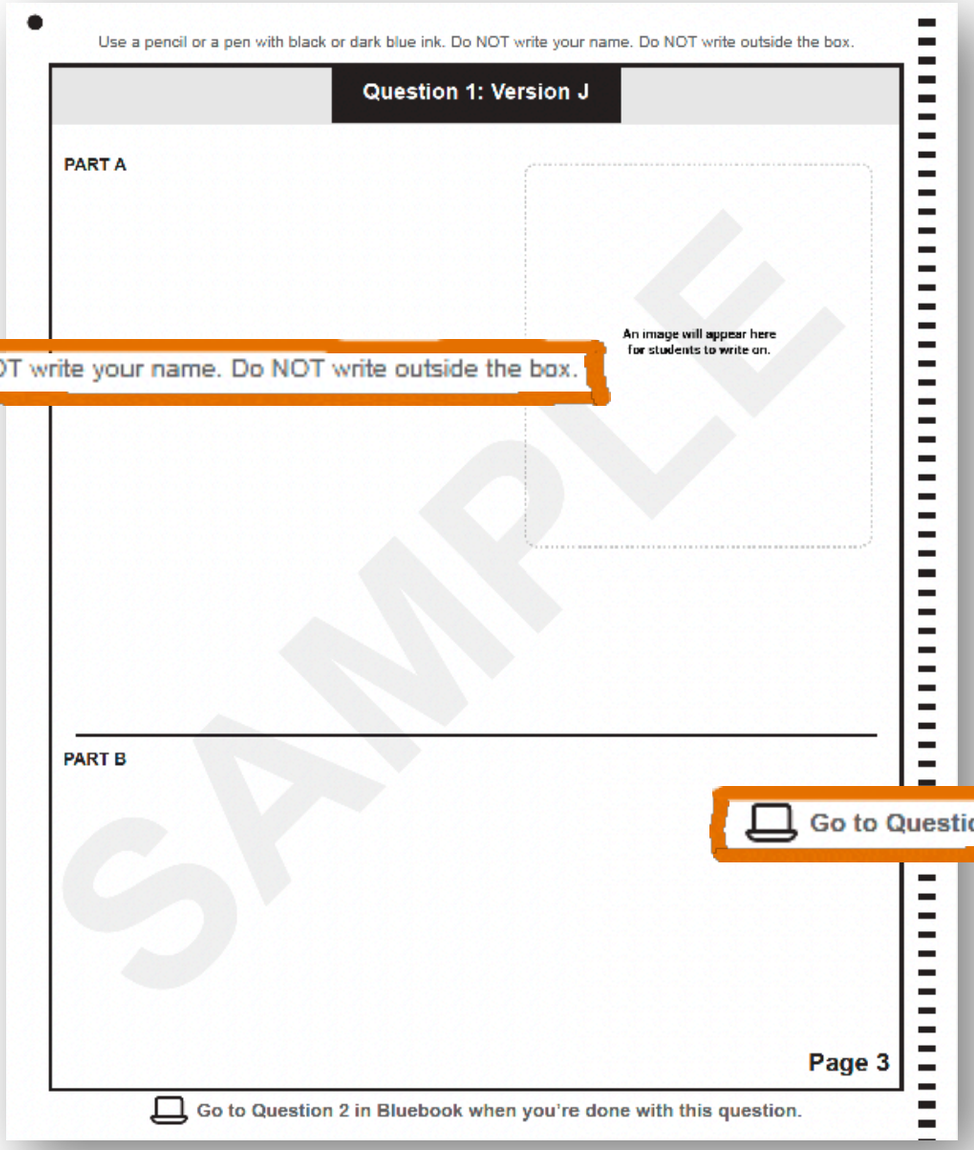
PART B

SAMPLE

Page 3

Go to Question 2 in Bluebook when you're done with this question.

FRQ Booklet Structure: Label Sub-parts



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

Go to Question 2 in Bluebook when you're done with this question.

Developing the Science Practices

How your students will be asked to demonstrate **what** they know

Mathematical Routines Skills: 1.A 1.C 2.A 2.B 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.	

Instructional Planning Report Data

Mech 2026

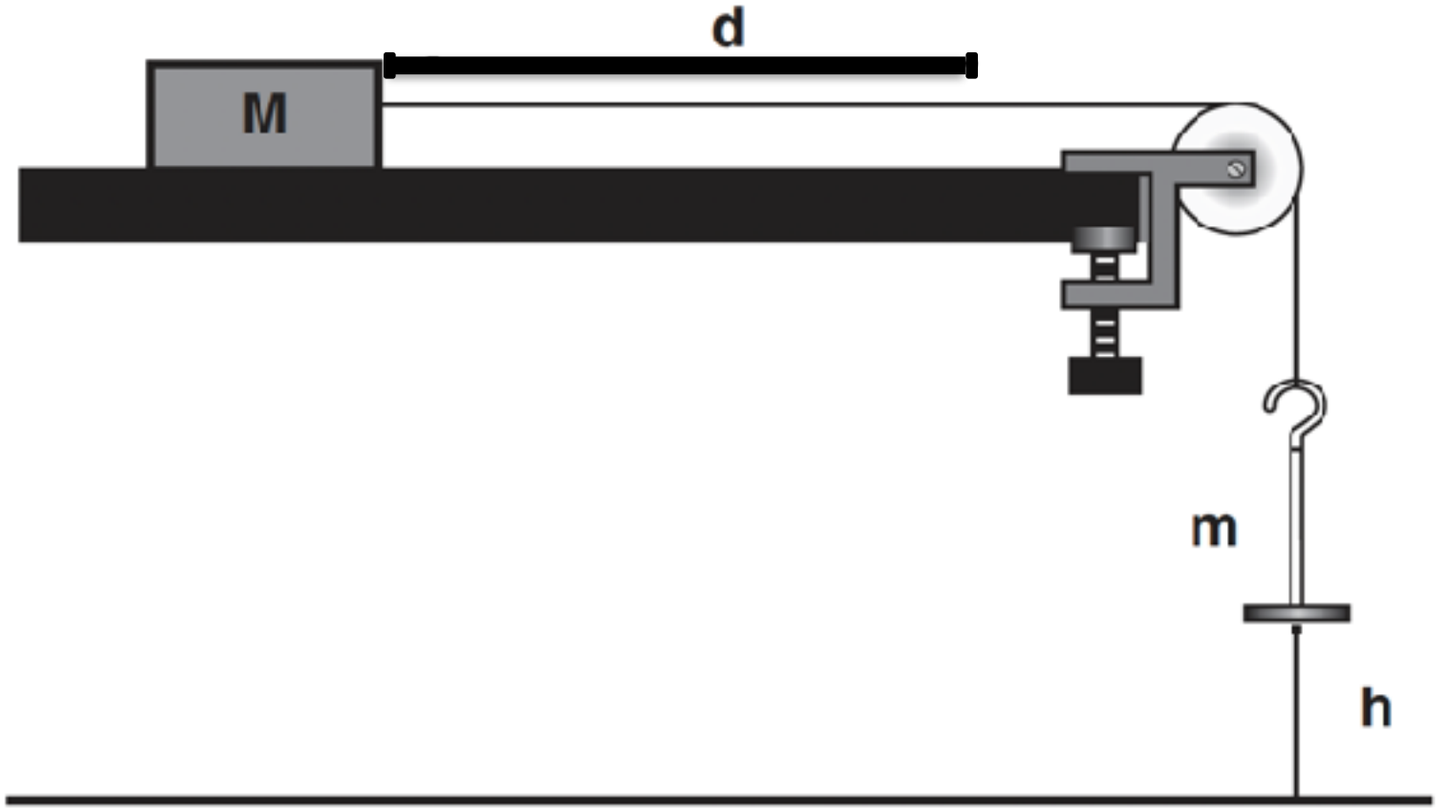
QUESTION 1 MATHEMATICAL ROUTINES (MR)	**10**		**3.5**
MR PART A POINT 1	1		**0.4**
MR PART A POINT 2	1		**0.9**
MR PART A POINT 3	1		**0.1**
MR PART A POINT 4	1		**0.2**
MR PART A POINT 5	1		**0.1**
MR PART A POINT 6	1		**0.5**
MR PART A POINT 7	1		**0.2**
MR PART B POINT 1	1		**0.5**
MR PART B POINT 2	1		**0.3**
MR PART B POINT 3	1		**0.3**

E&M 2026

Question	Max Score	Mean	
			Global
QUESTION 1 MATHEMATICAL ROUTINES (MR)	10		4.5
MR PART A POINT 1	1		0.8
MR PART A POINT 2	1		0.4
MR PART A POINT 3	1		0.3
MR PART A POINT 4	1		0.5
MR PART A POINT 5	1		0.2
MR PART A POINT 6	1		0.5
MR PART A POINT 7	1		0.2
MR PART B POINT 1	1		0.8
MR PART B POINT 2	1		0.6
MR PART B POINT 3	1		0.3

Derive an equation for μ_K between the block and table in terms of the given variables and fundamental constants.

Note: Massless/Frictionless Pulley & d>>h



CollegeBoard

Calculus on the AP Physics C Practice Exam #1

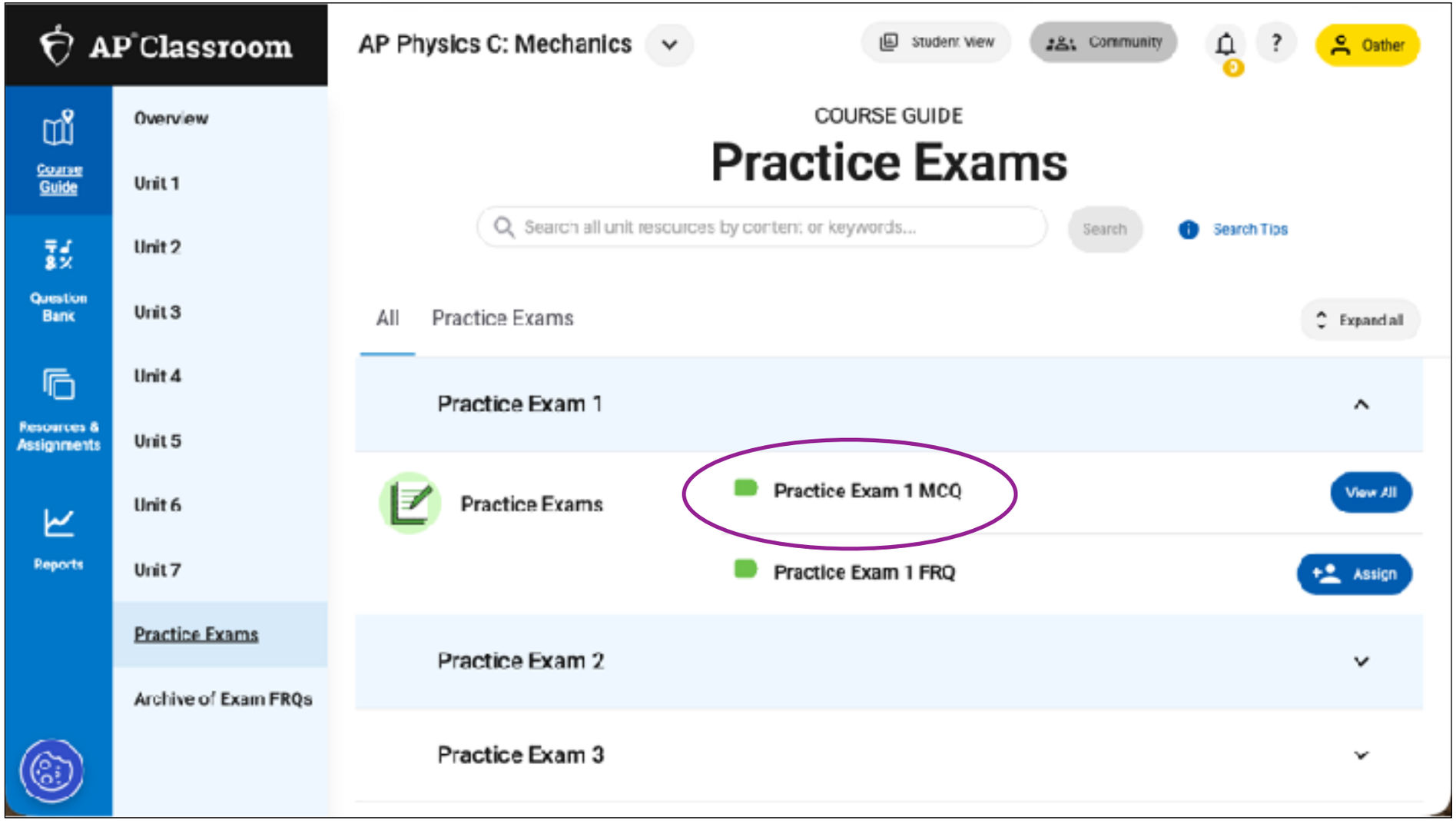
Mechanics and E&M

2024-2025

Calculus MCQs

- Open AP Classroom
  - *Either Mechanics or E&M*
- Access Practice Exam #1
- Look through all of the questions and identify the ones that require the students to use calculus
- Make a list of those questions

Calculus MCQs



Calculus MCQs

Mechanics	E&M
14	4
15	(5)
20	8
22	10
(23)	21
25	40
28	
33	
36	

Calculus on the AP Physics C Practice Exam #1

Mechanics

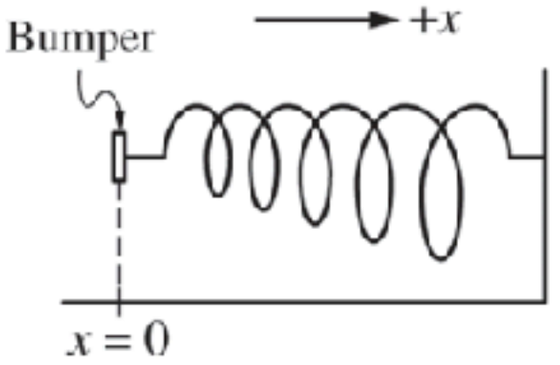
14. An object is moving along the y-axis. The object's position as a function of time is given by $y = \alpha t^3 - \beta t + \phi$, where $\alpha = 1\ \text{m/s}^3$, $\beta = 4\ \text{m/s}$, and $\phi = 5\ \text{m}$. What is the acceleration of the object at time $t = 3.0\ \text{s}$?

(A) $6\ \text{m/s}^2$

(B) $18\ \text{m/s}^2$

(C) $20\ \text{m/s}^2$

(D) $23\ \text{m/s}^2$



15. A nonideal spring is fixed to a wall. A small bumper on the end of the spring is initially at position $x = 0$ when the spring is at its equilibrium length, as shown. When the spring is compressed a distance x from equilibrium, the elastic potential energy U_s of the spring in joules is given by $U_s = 3x^3 - 4x^2 + 2x$. What is the spring force F_s as a function of x ?

(A) $F_s = 9x^2 - 8x + 2$

(B) $F_s = -9x^2 + 8x - 2$

(C) $F_s = \frac{3}{4}x^4 - \frac{4}{3}x^3 + x^2$

(D) $F_s = -\frac{3}{4}x^4 + \frac{4}{3}x^3 - x^2$

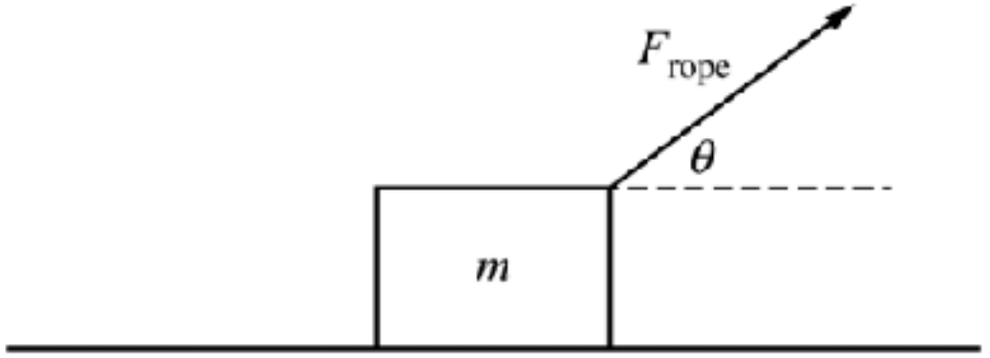
20. The work done on an object is described by the equation $W = 3t^2 + 5t - 1$, where W is in joules and t is in seconds. What is the power delivered to the object at $t = 2.0\,\text{s}$?

(A) 10.5 W

(B) 16.0 W

(C) 17.0 W

(D) 21.0 W



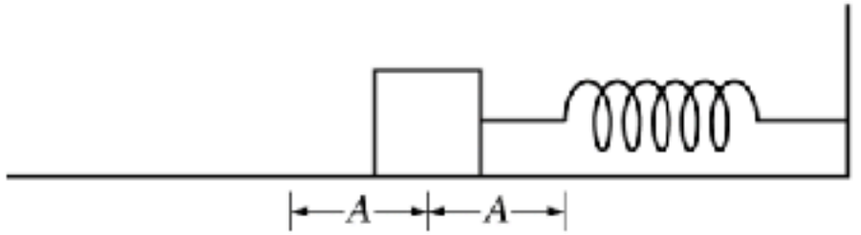
22. A box of mass m is pulled across a horizontal surface by a rope. The rope exerts a variable force F_{rope} directed at an angle θ from the horizontal that is described by the function $F_{\text{rope}} = \cos(\beta x)$, where β is a positive constant. The box is pulled from position $x = 0$ to $x = D$, where $F_{\text{rope}} < mg$. Which of the following is the work done on the box by the rope as it is pulled from $x = 0$ to $x = D$?

(A) $D\cos(\beta D)$

(B) $D\cos(\beta D)\cos\theta$

(C) $\beta\sin(\beta D)\cos\theta$

(D) $\frac{1}{\beta}\sin(\beta D)\cos\theta$



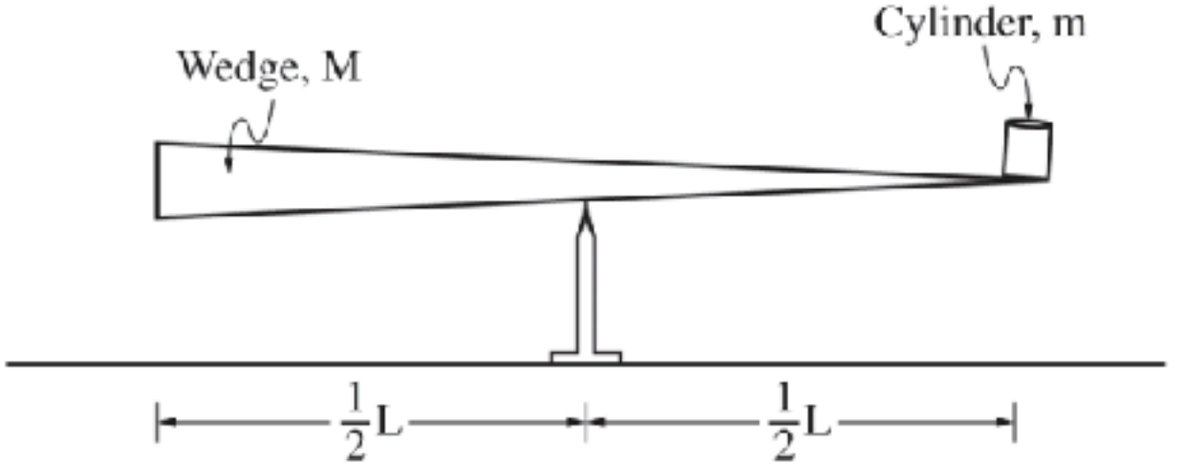
23. A block on a horizontal surface is attached to one end of a horizontal spring. The other end of the spring is attached to a wall. The block oscillates with amplitude A and period T, as shown. There is negligible friction between the block and surface. At time $t = 0$ the net force on the block is zero. Which of the following is an expression for the speed of the block at time $t = \frac{T}{6}$?

(A) $v = \frac{\pi A}{T}$

(B) $v = \frac{3\sqrt{3}A}{T}$

(C) $v = \frac{\pi\sqrt{3}A}{T}$

(D) $v = \frac{2\pi^2 A}{3T}$



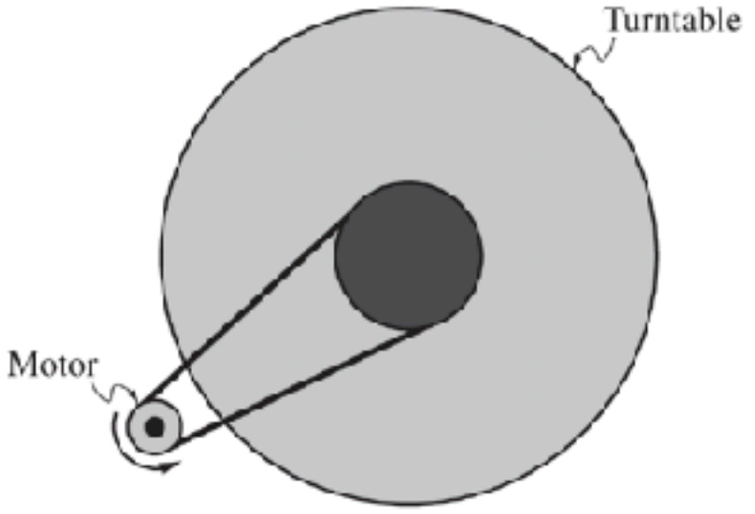
25. A wedge of mass M is balanced about its center with a small cylinder of mass m attached to its narrowest end, as shown. The linear mass per length of the wedge can be modeled by an equation of the form: $\lambda = bx^2$, where b is a constant with appropriate units and x is the distance from the narrowest end. What is the ratio $\frac{M}{m}$ of the masses of the two objects?

(A) $\frac{2}{3}$

(B) 1

(C) 2

(D) 3



Top View

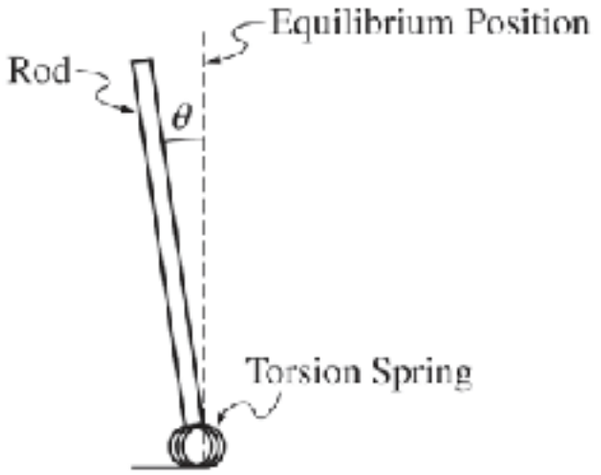
28. A motor is attached to a turntable by a belt, as shown in the Top View figure. When the motor is turned on, the angular displacement of the turntable is modeled by the equation $\theta(t) = 6t^{\frac{3}{2}} - 2t + 2\pi$, where θ is in radians and t is in seconds. What is the angular velocity ω of the turntable as a function of time?

(A) $\omega(t) = \frac{12}{5}t^{\frac{5}{2}} - t^2 + 2\pi t$

(B) $\omega(t) = 9t^{\frac{1}{2}} - 2$

(C) $\omega(t) = 6t^{\frac{1}{2}} - 2$

(D) $\omega(t) = \frac{9}{2}t^{-\frac{1}{2}}$



Top View

33. A torsion spring is fixed to the end of a rod of rotational inertia I_R. The torsion spring is fixed to a horizontal table with negligible friction, as shown in the Top View. When the rod is displaced an angle θ from equilibrium, the torsion spring exerts a restoring torque of magnitude $\tau = 2\kappa\theta^2$, where κ is a positive constant with appropriate units. After being displaced by an angle θ_0, the rod is released and rotates through its equilibrium position with angular speed ω_0. Which of the following is a correct expression for ω_0 ?

(A) Zero

(B) $\dfrac{2\kappa\theta_0^3}{3I_R}$

(C) $2\sqrt{\dfrac{\kappa\theta_0^2}{I_R}}$

(D) $2\sqrt{\dfrac{\kappa\theta_0^3}{3I_R}}$

36. The magnitude of the momentum of an object as a function of time, in seconds, is given by $p = (4\,\text{kg} \cdot \text{m/s}^3)\,t^2$. The magnitudes of the net force exerted on the object at times t_1 and $t_2 = 2t_1$ are F_1 and F_2, respectively. Which of the following correctly compares F_2 and F_1 ?

(A) $F_2 = 2F_1$

(B) $F_2 = 4F_1$

(C) $F_2 = 8F_1$

(D) $F_2 = 16F_1$

Calculus on the AP Physics C Practice Exam #1

E&M

4. The current in a resistor of resistance R_0 varies with time t. Starting at $t = 0$, the current in the resistor is $I(t) = \alpha t$, where α is a positive constant. How much energy is dissipated by the resistor during the time interval $0 \le t \le t_f$?

(A) $\alpha R_0 t_f$

(B) $\alpha^2 R_0 t_f^2$

(C) $2\alpha^2 R_0 t_f$

(D) $\frac{1}{3}\alpha^2 R_0 t_f^3$

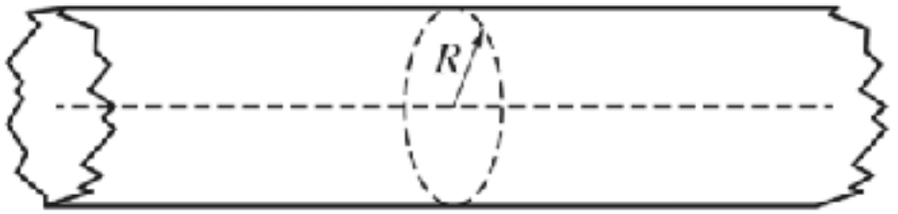
5. A square conducting loop of wire is initially in the xy-plane with its center located at the origin. There is a magnetic field that is uniform in space, but not necessarily constant in time, that is initially described by $\vec{B} = B_0\left(\hat{i} + \hat{k}\right)$ at time $t = 0$. Which of the following would cause an emf to be induced in the loop of wire?

(A) Varying the field in time as $\vec{B}(t) = B_0\left(\hat{i}\cos(\omega t) + \hat{k}\right)$ while keeping the loop stationary.

(B) Varying the field in time as $\vec{B}(t) = B_0\left(\hat{i} + \hat{k}\cos(\omega t)\right)$ while keeping the loop stationary.

(C) Rotating the loop about the z-axis while keeping the field constant in time.

(D) Moving the loop in the positive z-direction while keeping the field constant in time.



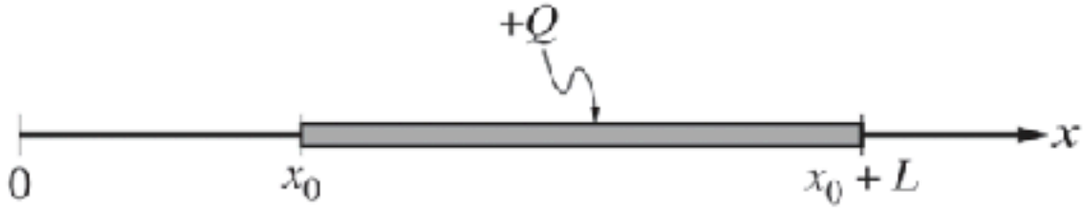
8. A long conducting cylinder has radius R, as shown in the figure, and carries a current to the left. The current density varies with distance r from the cylinder's central axis according to the equation $J = kr^2$, where $r \leq R$ and k is a positive constant. What is the total current in the cylinder?

(A) $\frac{1}{3}kR^3$

(B) $\frac{1}{4}kR^4$

(C) $\frac{\pi}{2}kR^4$

(D) $\frac{\pi}{5}kR^5$



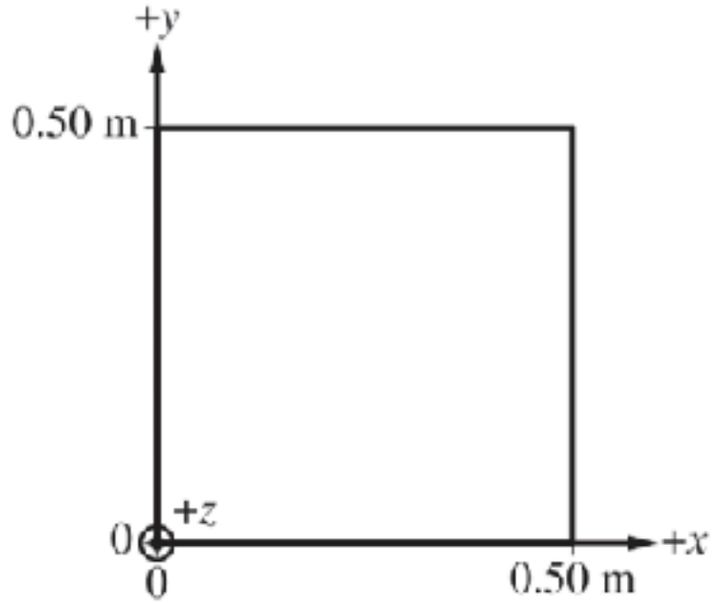
10. A positive charge $+Q$ is uniformly distributed within a very thin nonconducting cylinder of length L. The cylinder is placed along the x-axis in the region $x_0 < x < x_0 + L$, as shown in the figure. What is the electric potential at the origin?

(A) $k\frac{Q}{2}\left(\frac{1}{x_0} + \frac{1}{x_0 + L}\right)$

(B) $k\frac{Q}{L}\ln\left(\frac{x_0 + L}{x_0}\right)$

(C) $k\frac{Q}{L}\ln\left(\frac{L}{x_0}\right)$

(D) $k\frac{Q}{x_0}$



21. The figure shows a square in the xy-plane ($z = 0$) occupying the region defined by $0 < x < 0.50\ \text{m}$ and $0 < y < 0.50\ \text{m}$. The electric field at the surface of the square is in the z-direction. The magnitude of the electric field is given by $E_z(x) = bx$, where b is a positive constant. If the electric flux through the square is $3.0\ \text{N} \cdot \text{m}^2/\text{C}$, what is the value of the constant b ?

(A) $6\ \text{N/(C} \cdot \text{m)}$

(B) $12\ \text{N/(C} \cdot \text{m)}$

(C) $24\ \text{N/(C} \cdot \text{m)}$

(D) $48\ \text{N/(C} \cdot \text{m)}$

40. An inductor in a circuit has an inductance L and the current I in the inductor varies with time t according to the equation $I(t) = \alpha t^2$, where α is a constant. The induced emf of the inductor is zero at time $t = 0$. What is the magnitude of the induced emf of the inductor as a function of time?

(A) $2\alpha t$

(B) $2L\alpha t$

(C) $\frac{1}{3}\alpha t^3$

(D) $\frac{1}{3}L\alpha t^3$

DAY 2: October 18

Please Change Partners!
Thank You!!

CollegeBoard

AP Physics C Workshop

Shenzhen College of International Education

Shenzhen, China



Oather Strawderman

International Lead AP Physics Consultant

October 17-18, 2026

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 October 18

AM1

- *Meterstick Torque Lab Free Response Question*
- Reading / Mock Reading
- AP Classroom / Instructional Planning Reports

AM2

- Translation Between Representations Free Response Questions
- Types of Representation: Diagrams & Sketches
- *Toilet Paper Roll Free Response Question Activity*

PM1

- Qualitative/Quantitative Translation Free Response Questions
- Writing Strategies
- *Dielectric Constant of Paper Lab Free Response Question*

PM2

- TIPERs & Ranking Tasks
- P1 Workbook
- *Online Simulation Labs*

Contact Info:

www.PhluidPhysics.com

oather@PhluidPhysics.com

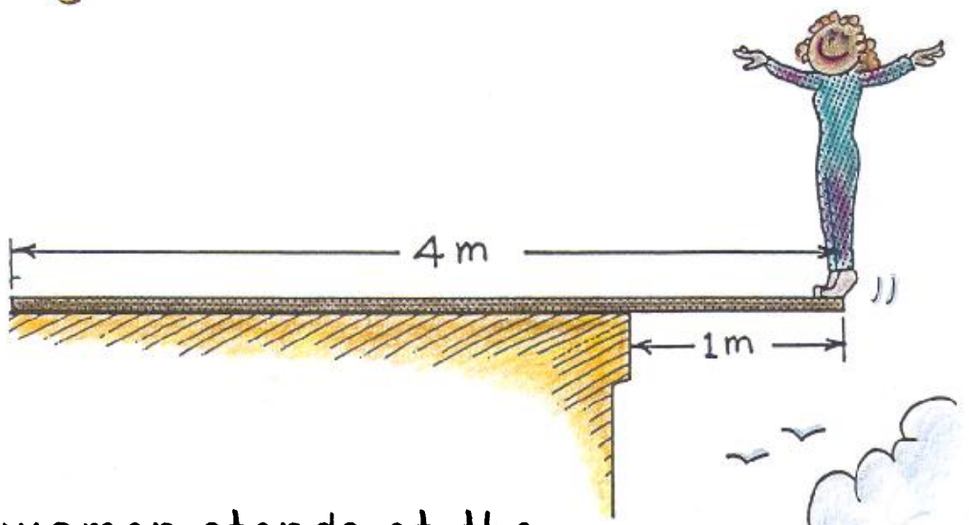
Workshop Links & Documents

www.PhluidPhysics.com/Resources

Next Time Questions: Arbor Scientific

NEXT-TIME QUESTION

CONCEPTUAL Physics



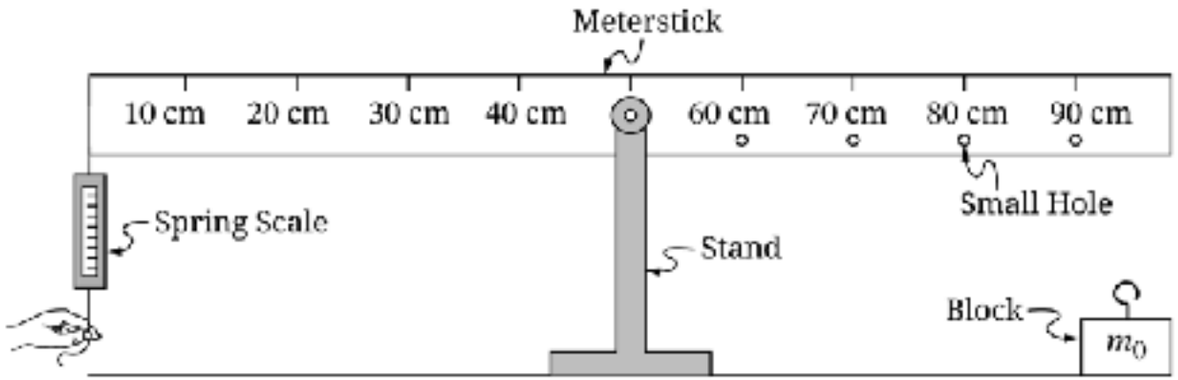
The 40-kg woman stands at the end of a 4-meter-long uniform plank. If the maximum overhang for balance is 1 meter, estimate the mass of the plank.

Hewitt Drew-it!

Experimental Design and Analysis: P1 2025 Torque FRQ Lab

3. Students are investigating balancing systems using the following setup. The students have a spring scale of negligible mass that is fixed to one end of a uniform meterstick. The center of the meterstick is attached to a stand on which the meterstick can pivot. There is a hook of negligible mass fixed to the top of a block of mass m_0. The hook can be attached to the meterstick through one of the small holes in the meterstick, as shown in Figure 1. The students do not have a direct way to measure the mass of the block. The block cannot be attached to the spring scale.

Figure 1

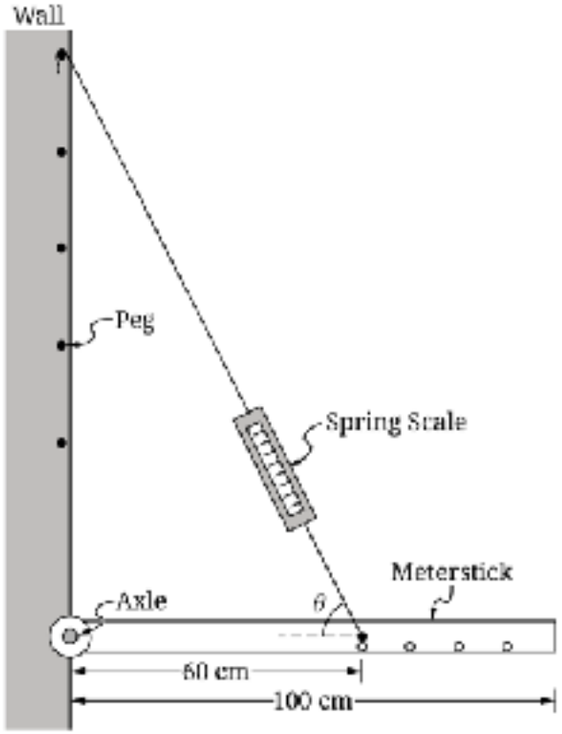


The students are asked to take measurements that will allow the students to create a linear graph whose slope could be used to determine the mass m_0 of the block.

A. Describe an experimental procedure to collect data that would allow the students to determine m_0. Include any steps necessary to reduce experimental uncertainty.

B. Describe how the data collected in part A could be graphed and how that graph would be analyzed to determine m_0.

Figure 2



The angle θ that the string makes with the meterstick can be varied by attaching the string to one of the pegs located along the wall. The students use the spring scale to measure the tension F_T required to hold the meterstick horizontal. Table 1 shows the measured values of θ and F_T.

AP Reading

Scoring the Free Response Questions

AP Reading

- 7 (12) Days long
- First Week: June 3-9, 2027
- Cincinnati, OH
- 2026 (2025 / 2024) Exam Volumes
- **P1 Exams** 183,400 (174,506 / 164,950)
- **P2 Exams** 25,012 (23,650 / 22,831)
- **C:Mech Exams** 70,672 (66,238 / 61,606)
- **C:E&M Exams** 32,309 (29,946 / 28,238)
- 563 Onsite Readers and 485 At-Home Readers
- Mix of HS teachers & college professors



Scoring Guides

- Rubric points are now uniform across exams.
- Item writers put the Physics into the uniform rubric.
- Test Development Committee has the final say before going to the Reading.
- Leaders ‘clarify’ the rubric after looking at hundreds of student samples.
- 5 days of Leader meetings
- 7 days of Reading

Reading Positions

- Reader
- Table Leader
- Question Leader
- Exam Leader
- Chief Reader

Reading Process

- Image projected on a laptop
- Readers grade just one question, not the whole exam.
- Readers decide if a response gets each individual point by clicking a radial button for each rubric point.
- Make sure they use a sharpened pencil or pen
- Focus your students on having good handwriting that is not miniscule.


AP







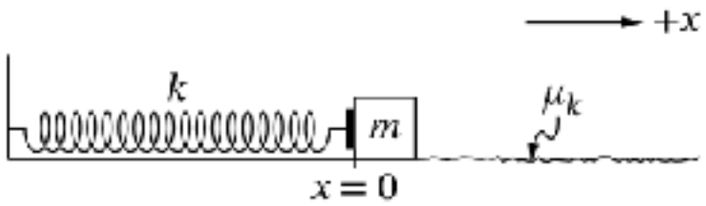
Mock Reading Activity

Question 3

The following information applies to parts A and B.

3. A horizontal spring of known spring constant k is attached to a wall. A block of known mass m is placed on a horizontal surface next to but not attached to the spring. The spring is at its relaxed length when the block is at position $x = 0$, as shown in Figure 1. There is friction between the block and the surface only for positions $x > 0$.

Figure 1



A student is asked to experimentally determine the coefficient of kinetic friction μ_k between the block and the surface using a graph. The student is permitted to use only measurements from a meterstick.

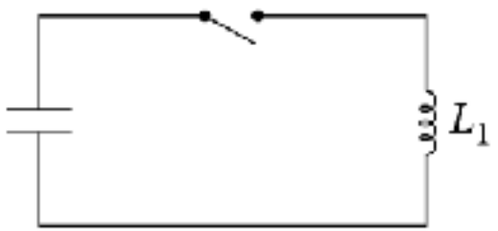
Mock Reading Activity

Question 3

The following information applies to parts A and B.

3. In Experiment 1, students are asked to collect data that can be graphed to determine the inductance L_1 of an inductor. The students have access to multiple charged capacitors, each of a different known capacitance, and a voltmeter that measures potential difference as a function of time. In each trial, the inductor is connected to a charged capacitor and an initially open switch, as shown in Figure 1.

Figure 1



Mock Reading Activity: Lab FRQ

- Find FRQ#3 in the Student Sample Packet
- Practice using the rubric to score several student samples.
- The purpose of this activity is to give you an idea of what the Reading is like and practice applying a rubric.
- You will NOT agree with every decision made about how the rubric is applied, this activity is just to get a feel for the Reading.

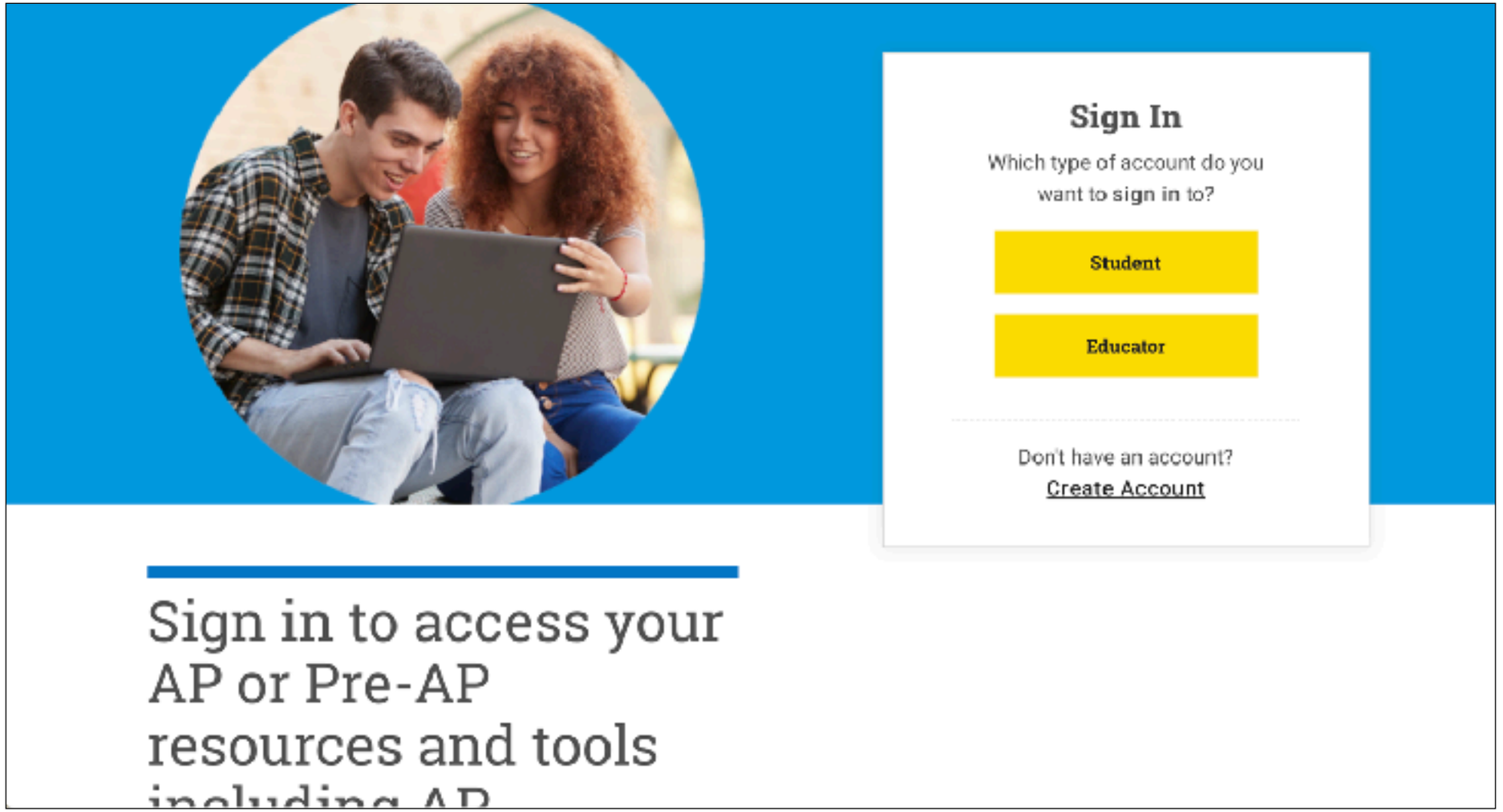
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AP Classroom

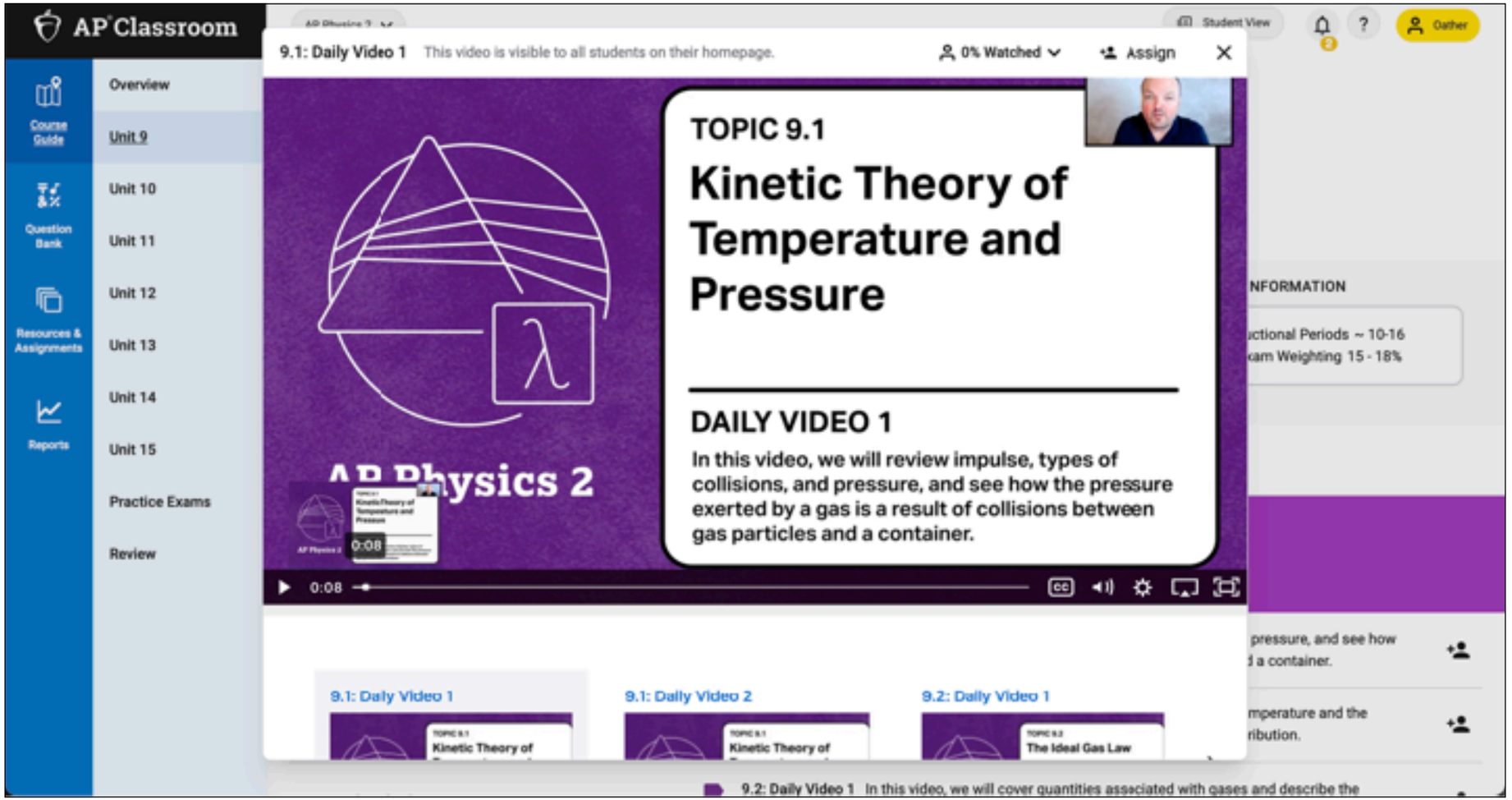
Consistent use increases AP score by 1 full point!!!



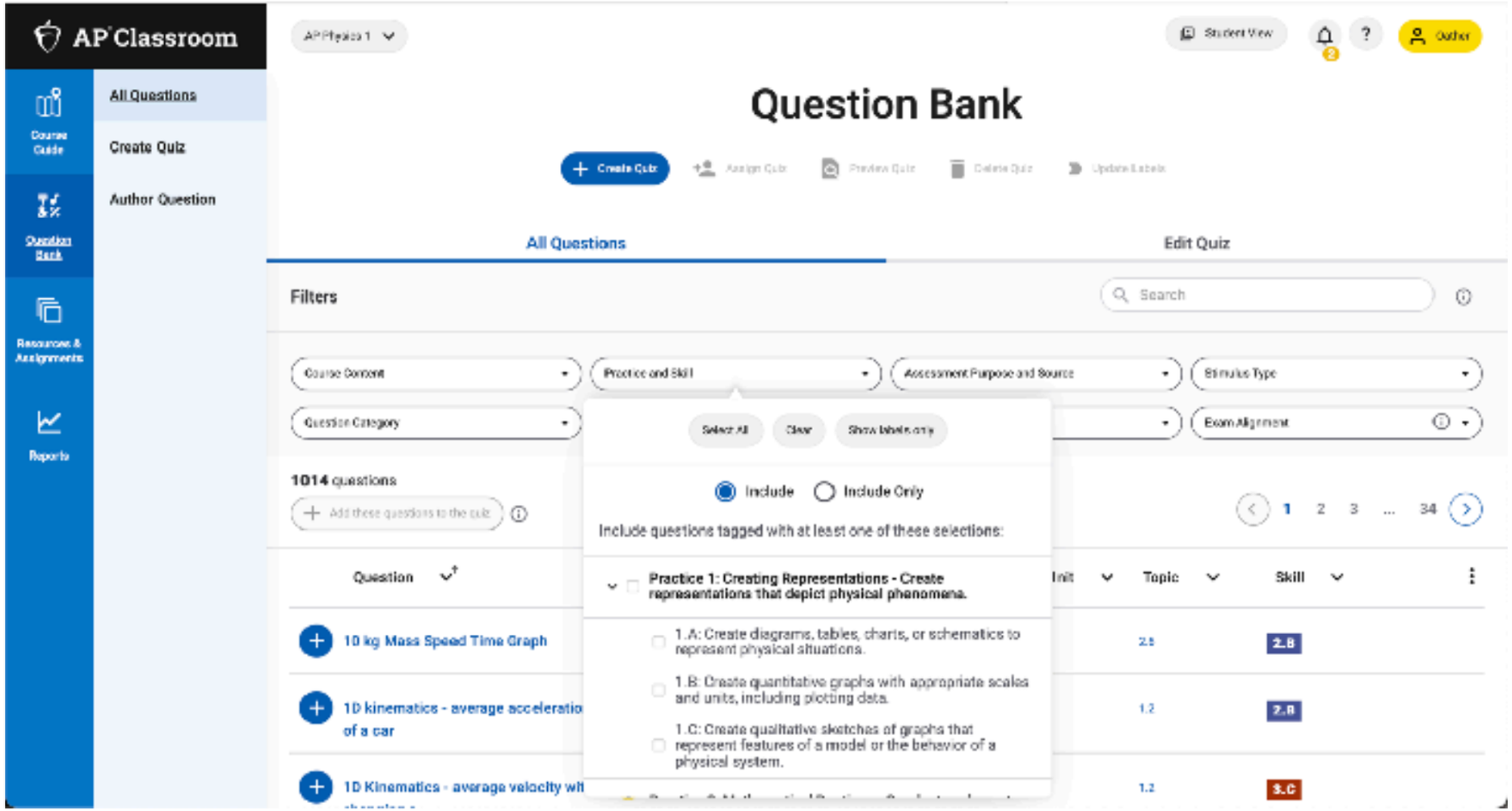
MyAP.CollegeBoard.org



AP Classroom - AP Daily Videos



AP Classroom - Question Bank



Questions in AP Classroom

Formative	**Summative**

Questions in AP Classroom

Formative	**Summative**
Topic Questions MCQ Only Yellow Light Bulb	

Questions in AP Classroom

Formative	**Summative**
Topic Questions MCQ Only Yellow Light Bulb	
Progress Check MCQ & FRQ Blue Desk Lamp	

Questions in AP Classroom

Formative	**Summative**
Topic Questions MCQ Only Yellow Light Bulb	**Practice Exams** MCQ & FRQ Green Question Mark
Progress Check MCQ & FRQ Blue Desk Lamp	

Questions in AP Classroom

Formative	**Summative**
Topic Questions MCQ Only Yellow Light Bulb	**Practice Exams** MCQ & FRQ Green Question Mark
Progress Check MCQ & FRQ Blue Desk Lamp	**Old AP Exams** MCQ & FRQ No Icon

Translation Between Representations Free Response Question

FRQ #2
12 Points

TBR

Translation Between Representations Mech FRQ 2026

AP PHYSICS C: MECHANICS 2026 - **FREE-RESPONSE QUESTIONS**

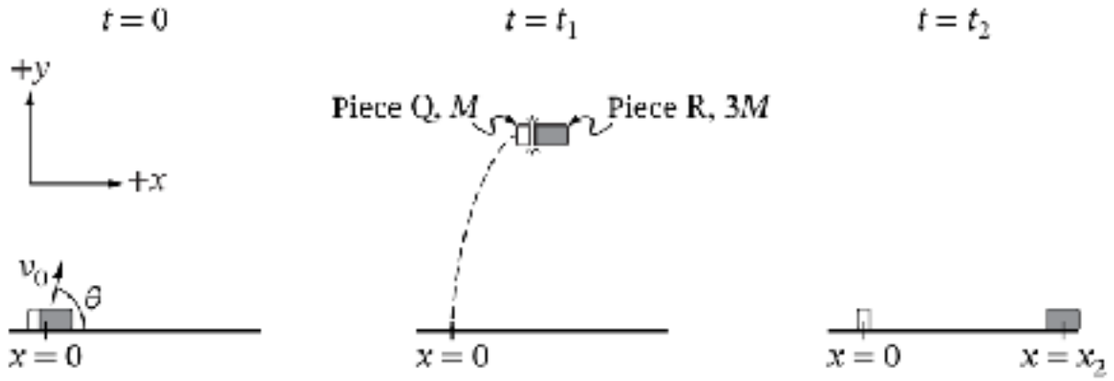
Question 2: Version J

2. A projectile of total mass $4M$ is launched from the ground at position $x = 0$ and time $t = 0$. The projectile is launched with an initial speed v_0 at an angle θ above the horizontal. When the projectile is at the highest point in its trajectory, it breaks into Pieces Q and R of masses M and $3M$, respectively.

The motion of the projectile is described for the following times.

- At $t = t_1$, immediately after the projectile breaks apart, the two pieces are moving away from each other horizontally.
- At $t = t_2$, Piece Q reaches the ground at $x = 0$ and Piece R reaches the ground at $x = x_2$, as shown in Figure 1.

Figure 1



Note: Figure not drawn to scale.

Translation Between Representations Mech FRQ 2025

Question 2: Version J

2. In Scenario 1, a system composed of two springs, A and B, and a block of mass m is at rest on a horizontal surface. Friction between the block and the surface is negligible. Each spring is attached to a fixed wall and the block, as shown in Figure 1. Spring A has a spring constant k and Spring B has a spring constant $2k$. Each spring is at its relaxed length when the block is at position $x = 0$, as shown.

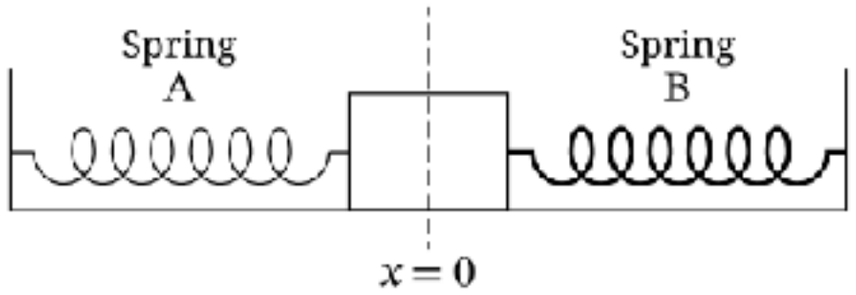


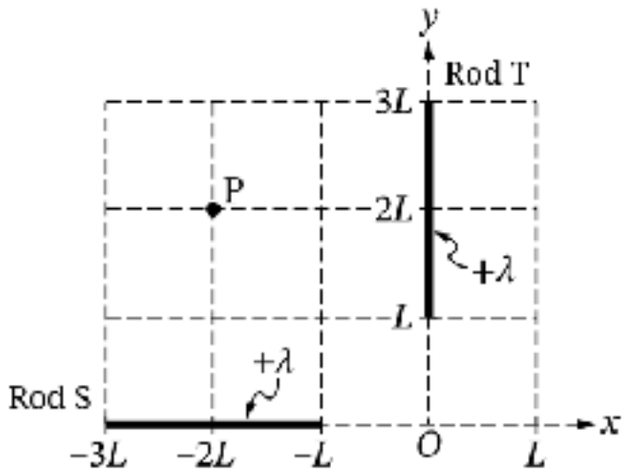
Figure 1

Translation Between Representations E&M FRQ 2026

Question 2: Version J

2. Thin, nonconducting, charged Rods S and T are held fixed in the xy-plane, as shown in Figure 1. Rod S is oriented along the x-axis in the region $-3L \le x \le -L$. Rod T is oriented along the y-axis in the region $L \le y \le 3L$. Each rod has uniform, positive linear charge density $+\lambda$. Point P is located at $(-2L, 2L)$.

Figure 1



Translation Between Representations E&M FRQ 2025

Question 2: Version J

2. A rotating, circular, conducting loop of area A and resistance R is in an external uniform magnetic field of magnitude B that is directed in the $-z$-direction. At time $t = 0$, the magnetic field is perpendicular to the plane of the loop, as shown in Figure 1. The loop is rotating with constant angular speed ω and period T about the dashed line that is along the diameter of the loop. The value of the magnetic flux through the loop as a function of time t is $\Phi = BA\cos(\omega t)$.

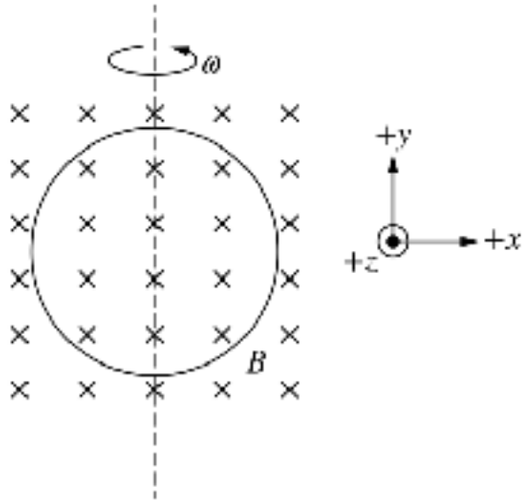


Figure 1

Translation Between Representations FRQ

- Find Question #2 which is the TBR FRQ
- Look at either the Mechanics or the E&M Student Samples packet
- Read through and determine the tasks that the student have to do for each part
- Record how many points per part

TBR FRQ Practice

- Work through the TBR FRQ for the exam of your choosing
- As you work the FRQ think about how you can help prepare you students for this item type.
- How could you adjust your problem sets to include multiple representations?
- How could you adjust what you require when you score FRQs with diagrams and sketches?

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

SAMPLE

Question 2: Version J continues on the next page.

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

SAMPLE

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

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?

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

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

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

Developing the Science Practices

How your students will be asked to demonstrate **what** they know

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.

Instructional Planning Report Data

CollegeBoard

Mech 2026

QUESTION 2 TRANSLATION BETWEEN REPRESENTATIONS (TBR)	12	5.1
TBR PART A POINT 1	1	0.6
TBR PART A POINT 2	1	0.5
TBR PART A POINT 3	1	0.5
TBR PART B POINT 1	1	0.7
TBR PART B POINT 2	1	0.4
TBR PART B POINT 3	1	0.2
TBR PART B POINT 4	1	0.1
TBR PART C POINT 1	1	0.5
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	0.3

E&M 2026

QUESTION 2 TRANSLATION BETWEEN REPRESENTATIONS (TBR)	12		7.4
TBR PART A POINT 1	1		0.9
TBR PART A POINT 2	1		0.9
TBR PART A POINT 3	1		0.8
TBR PART B POINT 1	1		0.7
TBR PART B POINT 2	1		0.6
TBR PART B POINT 3	1		0.5
TBR PART B POINT 4	1		0.5
TBR PART C POINT 1	1		0.8
TBR PART C POINT 2	1		0.8
TBR PART C POINT 3	1		0.5
TBR PART D POINT 1	1		0.4
TBR PART D POINT 2	1		0.2

Question #2: Translation Between Representations

Section II

Directions

0:00

Hide

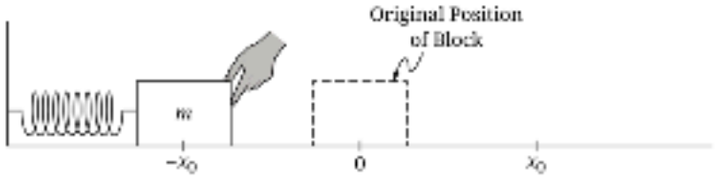
Highlights & Notes | Calculator | Reference | More

THIS IS A TEST PREVIEW

On exam day, you'll write your answer in the free-response booklet.

A block of mass m is attached to an ideal spring, whose other end is fixed to a wall. The block is displaced a distance x_0 to the left of the spring's equilibrium position, as shown in Figure 1. The block is then released from rest and oscillates with negligible friction along the horizontal surface. While the block is oscillating, it has a maximum speed v_{max}.

Figure 1



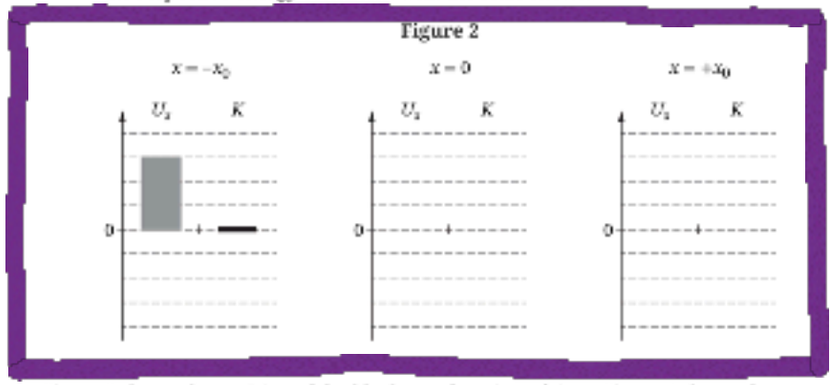
2 Mark for Review

A. The energy bar charts in Figure 2 represent the spring potential energy U_s of the block-spring system and the kinetic energy K of the block, as the block passes through positions $x = -x_0$, $x = 0$, and $x = +x_0$, while the block oscillates. The [illegible] $x = -x_0$ is complete.

Draw shade[illegible]ectangles to complete the energy bar charts in Figure 2 for [illegible]0 and $x = +x_0$.

- Positive energy values are above the zero-energy line ("0"), and negative energy values are below the zero-energy line.
- Shaded regions should start at the dashed line representing zero energy.
- Represent any energy that is equal to zero with a distinct line on the zero-energy line.
- The relative height of each shaded region should reflect the magnitude of the respective energy consistent with the scale shown.

Figure 2



B. Figure 3 shows the position of the block as a function of time. Figure 4 shows the force exerted by the spring on the block as a function of time.

Oather Strawderman

Question 2 of 4

Back | Next

Question #2: Translation Between Representations

Section II

Directions

0:00

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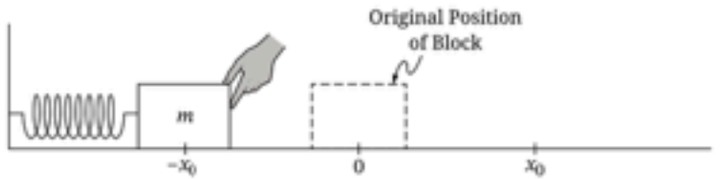
Highlights & Notes | Calculator | Reference | More

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Figure 1



B. Figure 3 shows the position of the block as a function of time. Figure 4 shows the force exerted by the spring on the block as a function of time.

Figure 3

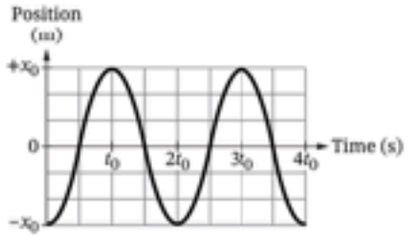
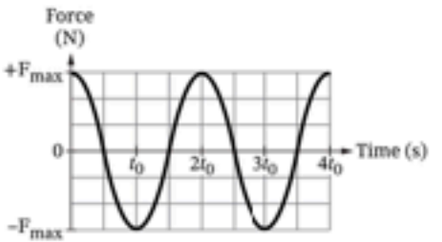


Figure 4



i. Using figures 3 a[illegible]4, **determine** an [illegible]pression for the spring constant of the spring in terms of [illegible]sical constants as appro[illegible]

ii. Starting with the equation for the period of a mass on a s[illegible]ng, **derive** an expression for the mass of the block. Express your answer [illegible], $F_{\_\_\_}$, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference

Oather Strawderman

Question 2 of 4

Back | Next

Question #2: Translation Between Representations

Section II

Directions

0:00

Hide

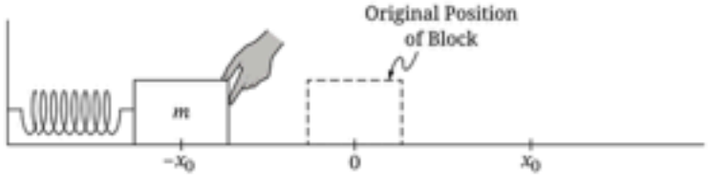
Highlights & Notes | Calculator | Reference | More

THIS IS A TEST PREVIEW

On exam day, you'll write your answer in the free-response booklet.

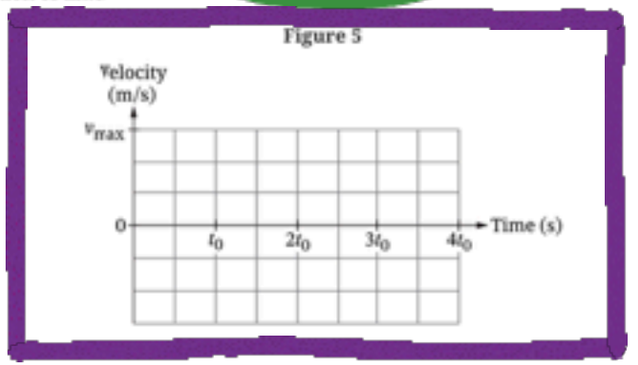
A block of mass m is attached to an ideal spring, whose other end is fixed to a wall. The block is displaced a distance x_0 to the left of the spring's equilibrium position, as shown in Figure 1. The block is then released from rest and oscillates with negligible friction along the horizontal surface. While the block is oscillating, it has a maximum speed v_{max}.

Figure 1



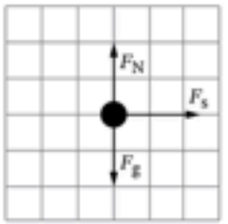
C. On the axes provided in Figu **sketch** a graph of velocity of the block as a function of time

Figure 5



D. A student sketches the free-body diagram in Figure 6, and makes the following claim: "The free-body diagram shows the forces exerted on the block at time $t = 1.5t_0$."

Figure 6



Justify wh he student's sketch (Figure 6) and claim are or are not consistent ph of velocity as a function of time you sketched in part C.

Oather Strawderman

Question 2 of 4

Back | Next

Question #2: Translation Between Representations

The Translation Between Representations 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 relevant to the scenario.
- Students will **sketch 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.
- 12 points, Suggested time 25-30 minutes

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

SAMPLE

Question 2: Version J continues on the next page.

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

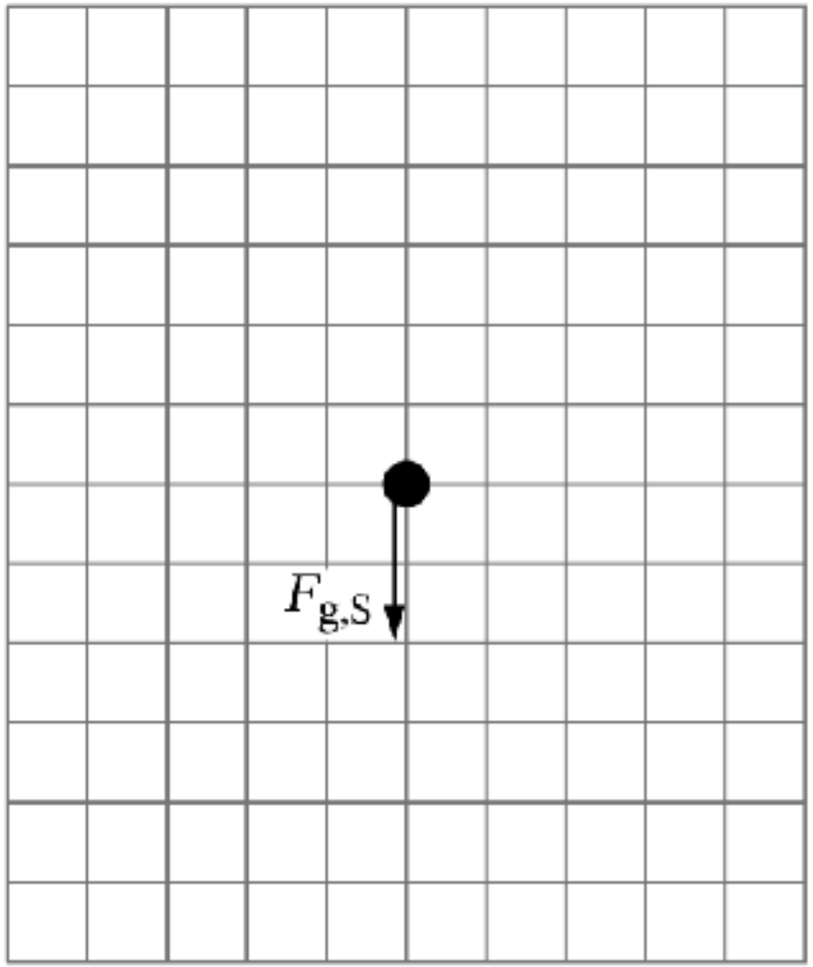
An image will appear here for students to write on.

PART D

SAMPLE

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

Free Body Diagrams



Car S, Back View

Figure 3

- Pointing away from the dot/box
- Touching the dot/box
- Same direction: side by side
- Labeled: Various conventions accepted
- Straight, use ruler
- Relative length on grid
- NO Components

Tips for Derivations and Calculations

- Start with a fundamental Physics Law or Principle
- Show all your work
- Try to be as organized as possible and follow a clear path
- For answers to derivations, only use the given variables using the same letters/symbols and physical constants as appropriate
- Make sure to include units in any numerical answer
- Circle your answer so it is clear to the Reader

Tips for Sketching Graphs

- You are not plotting data, do not make up data.
- Focus on the shape.
  - Straight
    - Slope
    - Vertical or Horizontal Intercept
  - Curved
    - What shape?
- If a grid is given, focus on relative location of lines (i.e., steeper, intersection of lines, axis intercept).

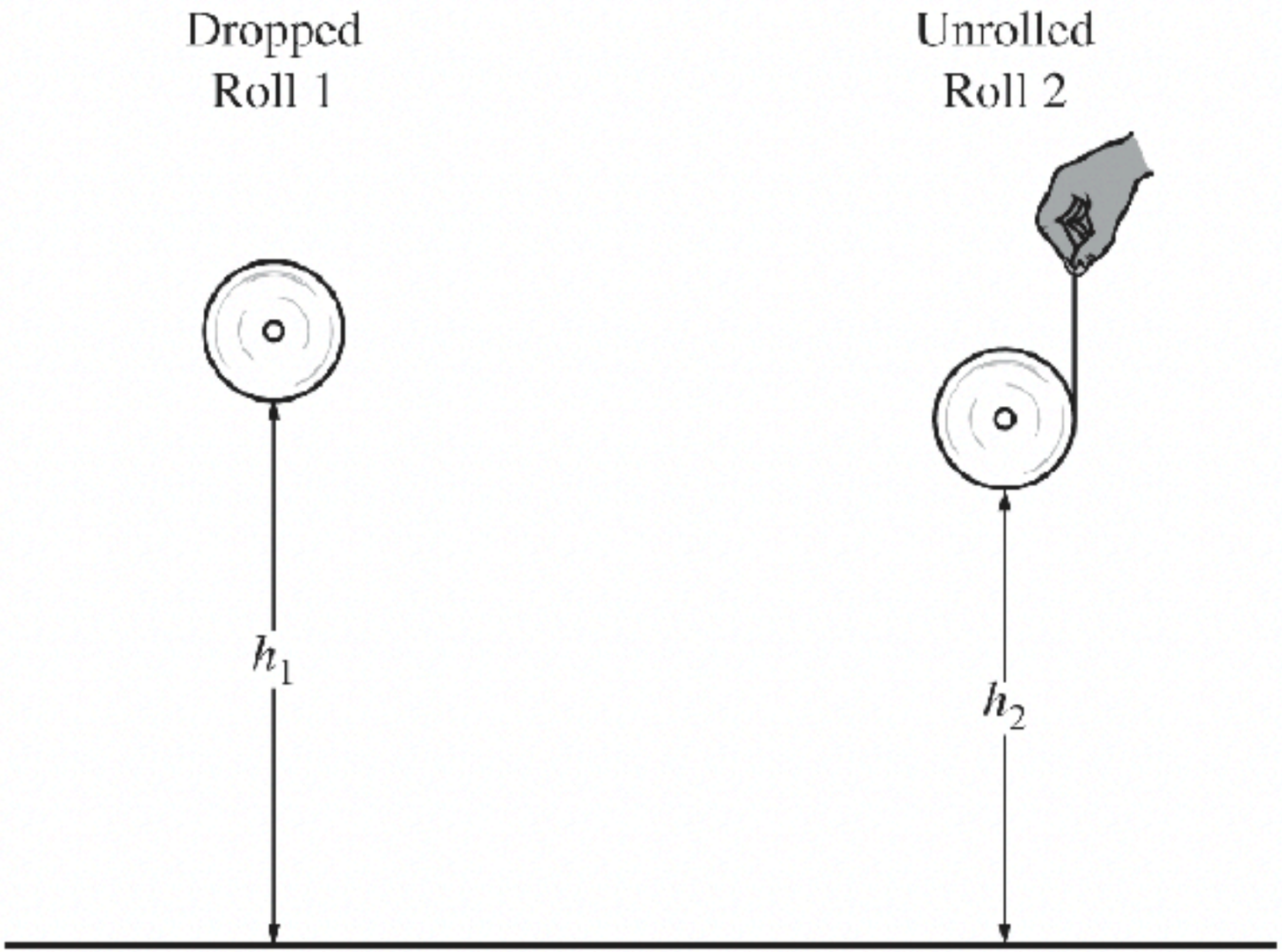
Do or Do Not Agree???

- One of the possible tasks for the written portion of this question:
  - *Justify why your answers to any two of the previous parts do/do not agree with each other.*

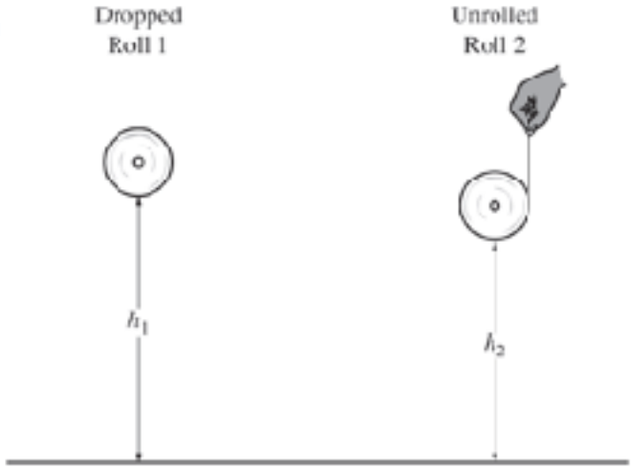
- If you are comparing two parts of your answers to each other, they must agree if you did both parts correctly! (**NOTE**: If a hypothetical student introduces a model/ claim, it may not necessarily match your answer(s).)

- What to do if you realize two of your parts do not agree??
  - Move on and come back to this part at the end
  - If you have enough time at the end, try and fix which part you realize is incorrect and then say how they agree
  - If not enough time, explain how the parts do not agree

Toilet Paper Roll TBR: P1 PE#1 FRQ #3

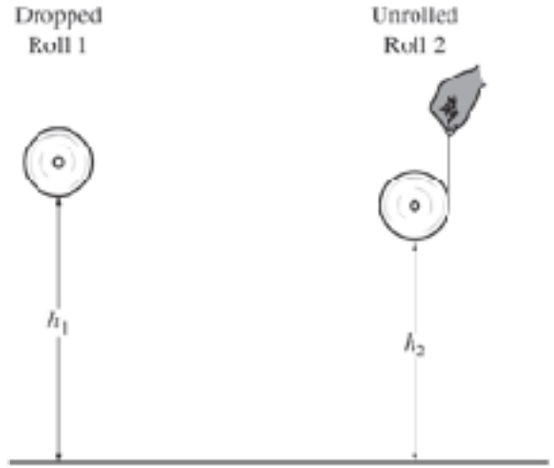


Toilet Paper Roll TBR: P1 PE#1 FRQ #3



Two identical rolls of paper have mass M and radius R. Roll 1 is held at a height h_1 above the ground and dropped from rest. Roll 1 falls to the ground without unrolling. Roll 2 is held a height h_2 above the ground, where $h_2 < h_1$. When Roll 2 is released from rest, the end of Roll 2 is held in place. Roll 2 unrolls and rotates while it falls, as shown in Figure 1. Both rolls are released from rest at time $t = 0$ and reach the ground at the same time $t = t_1$. The rotational inertia of both rolls of paper can be modeled as $I = \frac{1}{2}MR^2$.

Toilet Paper Roll TBR: P1 PE#1 FRQ #3



(a) **Draw** and **label** a force diagram of the forces (not components) exerted on each roll as they fall between $t = 0$ and $t = t_1$. Each force in your force diagram must be represented by a distinct arrow starting on, and pointing away from, the point at which the force is exerted on the roll.

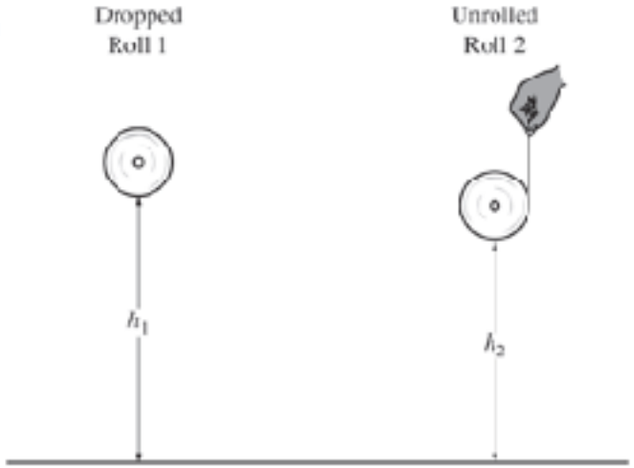


Dropped
Roll 1



Unrolled
Roll 2

Toilet Paper Roll TBR: P1 PE#1 FRQ #3

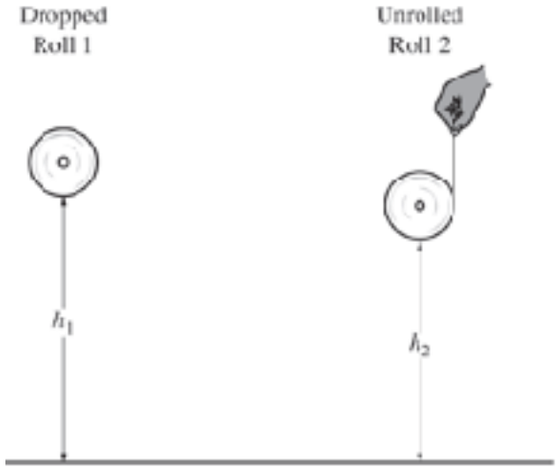


(b)

i. **Determine** an expression for the linear acceleration a_1 of Roll 1 as it falls in terms of h_1, h_2, M, R, and physical constants, as appropriate.

ii. Starting with Newton's second law in rotational or translational form, **derive** an expression for the linear acceleration a_2 of Roll 2 as it unrolls in terms of h_1, h_2, M, R, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference book.

Toilet Paper Roll TBR: P1 PE#1 FRQ #3



(c) Figure 2 shows a graph of the linear speed of Roll 1 as a function of time between $t = 0$ and $t = t_1$. The linear speed of Roll 1 just before it hits the ground is v_1. On the same grid, **sketch** the linear speed of Roll 2 as a function of time between $t = 0$ and $t = t_1$. Clearly **label** the final speed of Roll 2 as v_2.

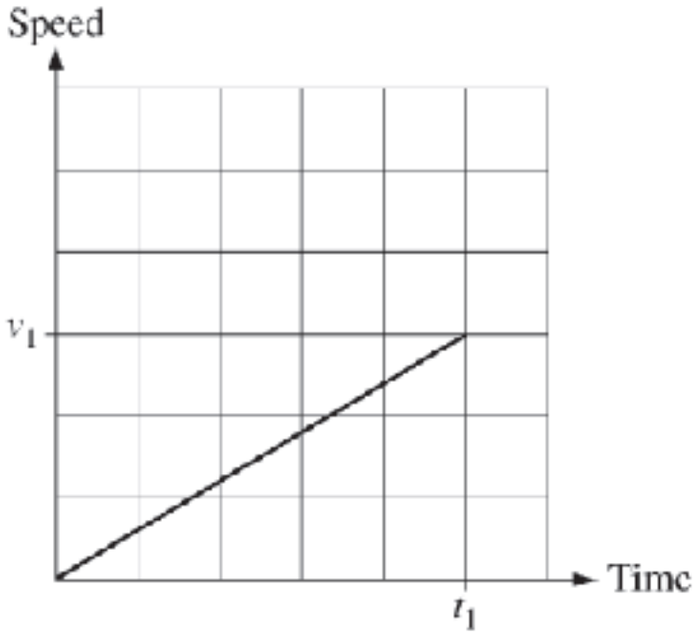
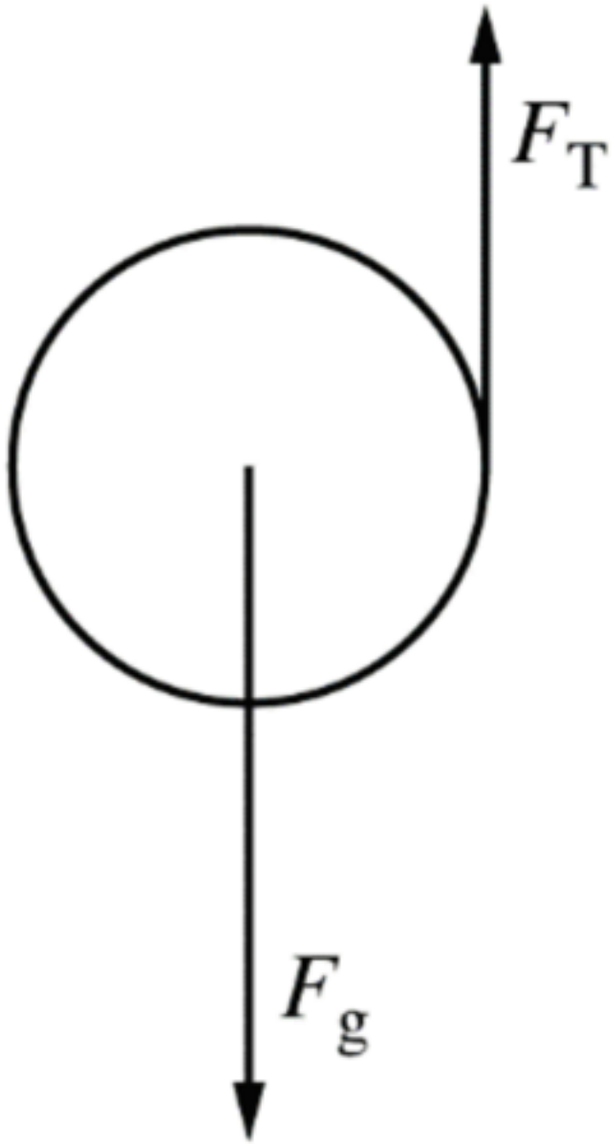


Figure 2

(d) **Justify** how the force diagram created in part (a) is or is not consistent with the graph drawn in part (c).


F_T
F_g

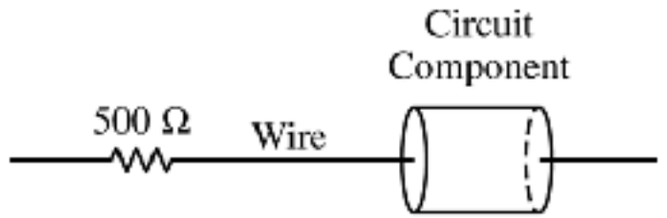
Electric Circuit Diagram

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.

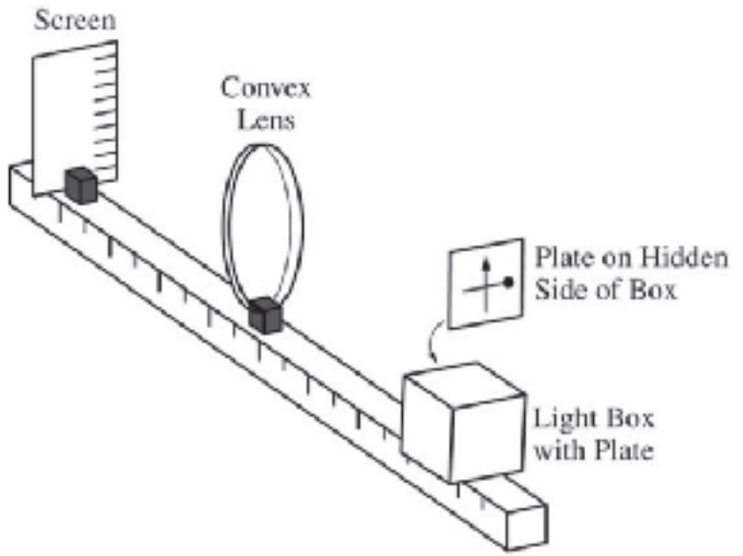
(a) The students are asked to experimentally determine whether the component is a resistor or an uncharged capacitor.

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.

Translation Between Representations FRQ

The Translation 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)

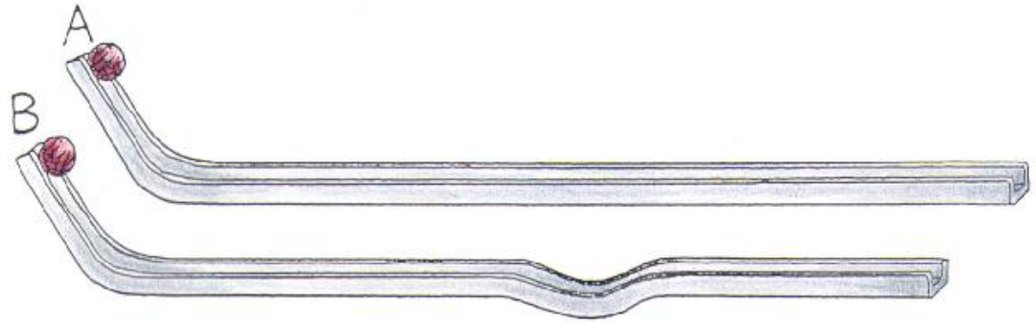
(d) Finally, students will be asked to do any **one of the following**: (2pts)

- 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.

TBR

Example of a Sketch

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

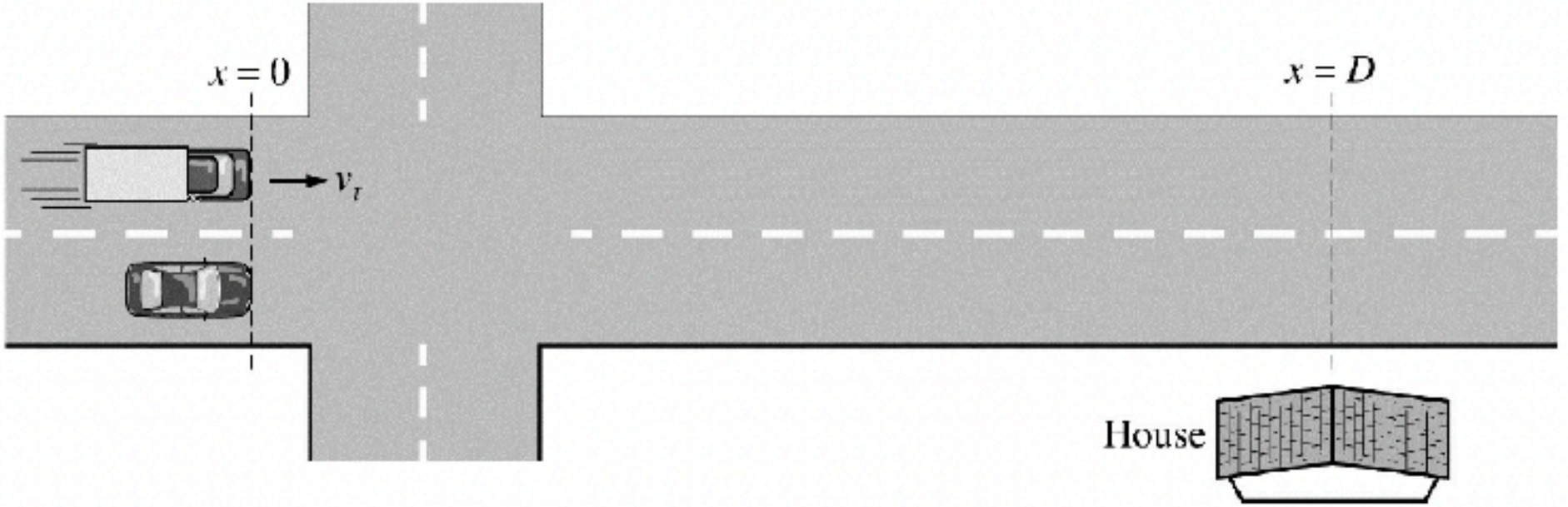
a) Track A.
b) Track B.
c)...Both reach the end at the same time.



CONCEPTUAL Physics

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Hewitt Drew It!



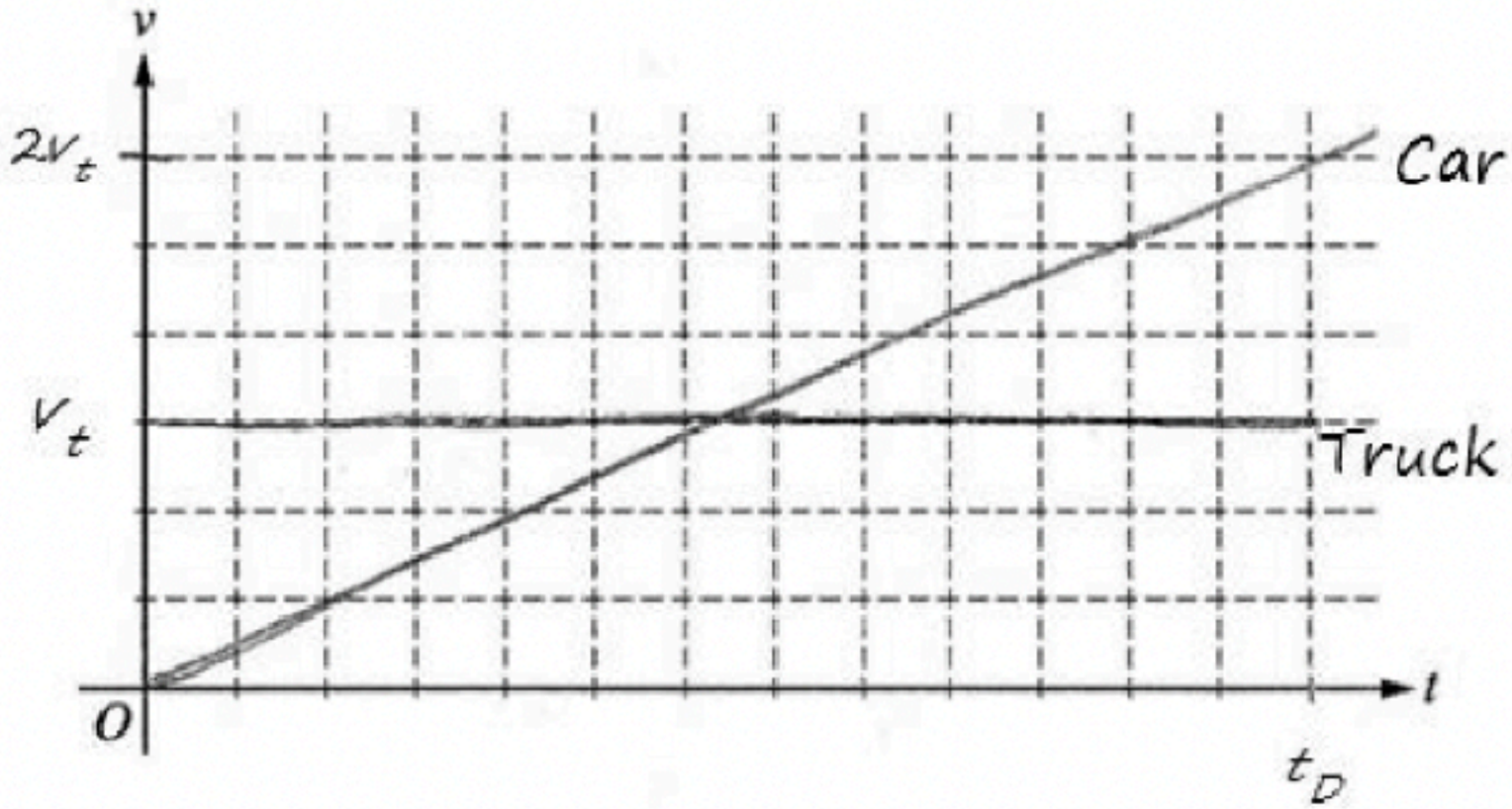
2. (12 points, suggested time 25 minutes)

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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NEXT-TIME QUESTION

CONCEPTUAL Physics



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

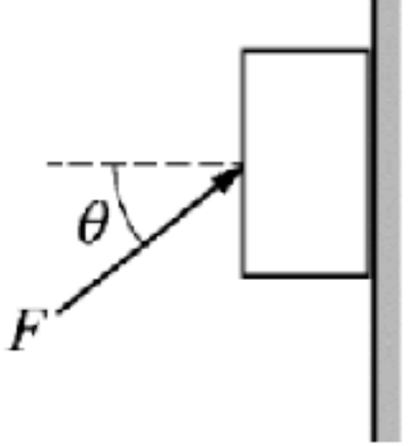
a) upward.
b) downward.
c) Can't say.

thanx to Arnold Arons

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AP Free Body Diagram Guidelines

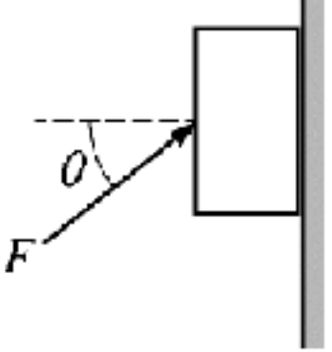
- Pointing away from the dot
- Touching the dot
- Labeled: Various conventions accepted
- Straight, use ruler
- Relative length on grid
- NO Components



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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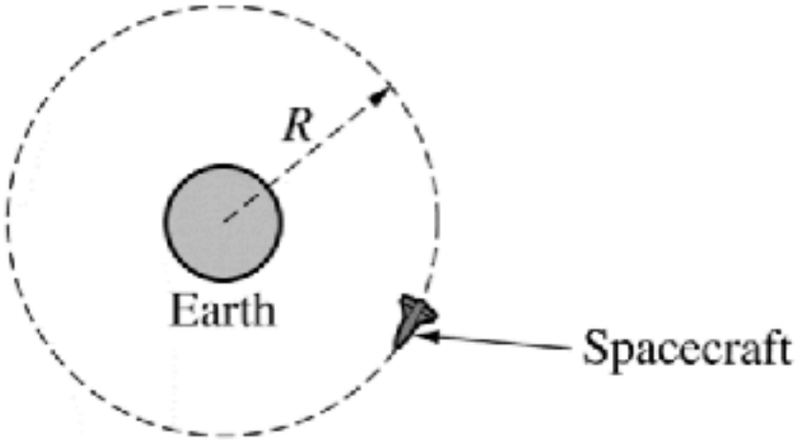
47. A block is held at rest against a wall by a force of magnitude F exerted at an angle θ from the horizontal, as shown in the figure above. Let $\vec{F}_g$ be the gravitational force exerted by Earth on the block, $\vec{F}_N$ be the normal force exerted by the wall on the block, and $\vec{F}_f$ be 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.

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

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

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

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

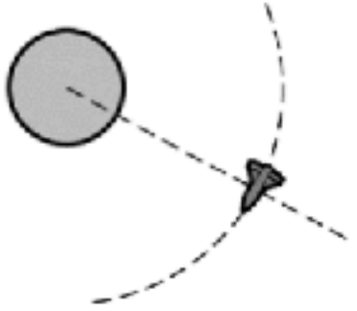


Note: Figure not drawn to scale.

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.

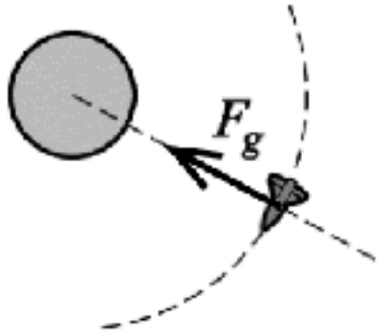
   (a) In the figure below, draw and label the forces (not components) that act on the spacecraft. Each force must be represented by a distinct arrow starting on, and pointing away from, the spacecraft.



Note: Figure not drawn to scale.

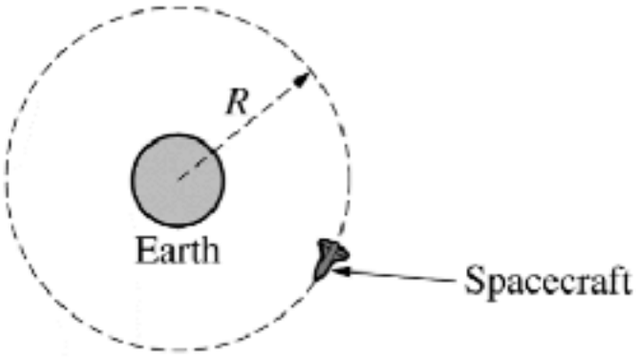
(a) LO / SP: 3.A.2.1 / 1.1; 3.B.2.1 / 1.1, 1.4
2 points

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.		

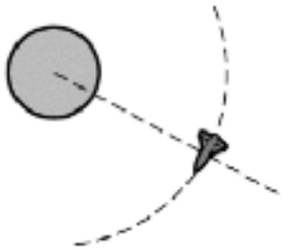


Note: Figure not drawn to scale.

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.

(b)

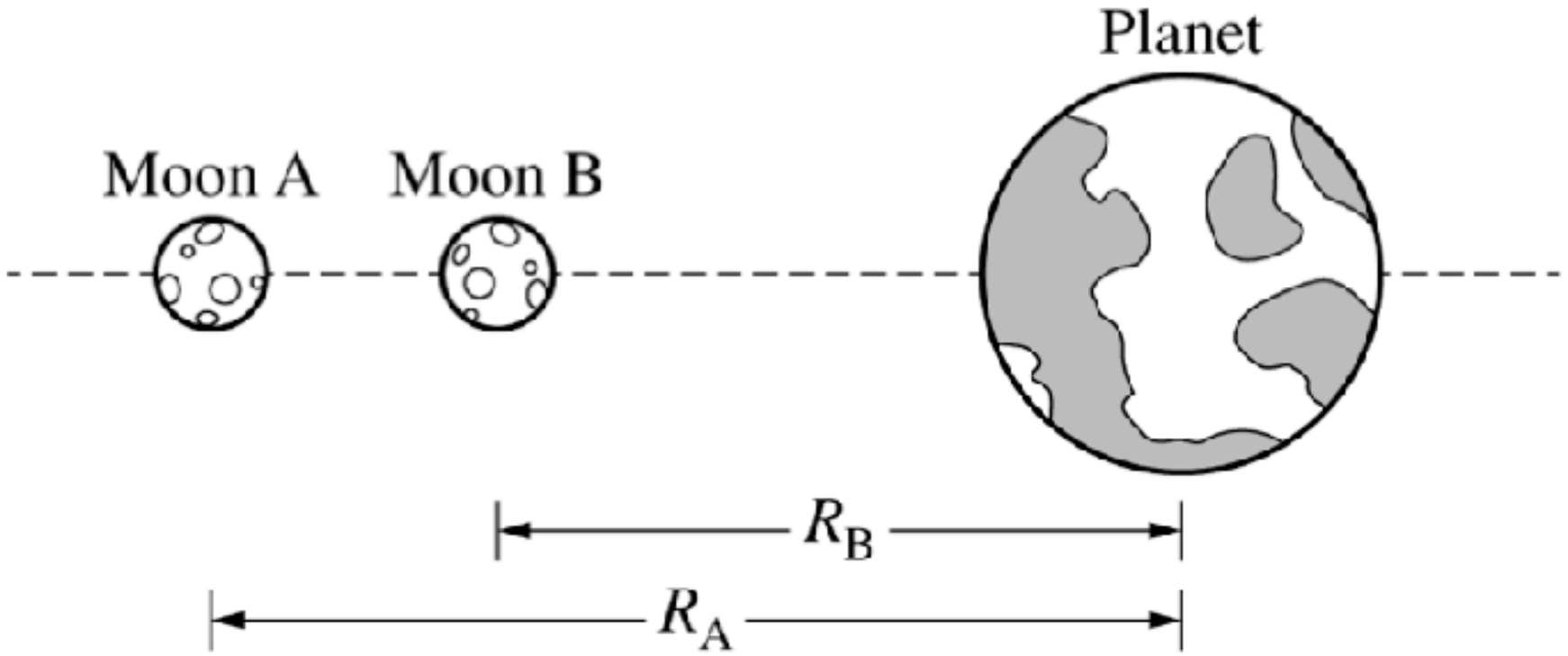
i. Derive an equation for the orbital period T of the spacecraft in terms of m, M_E, R, and physical constants, as appropriate. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

(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:

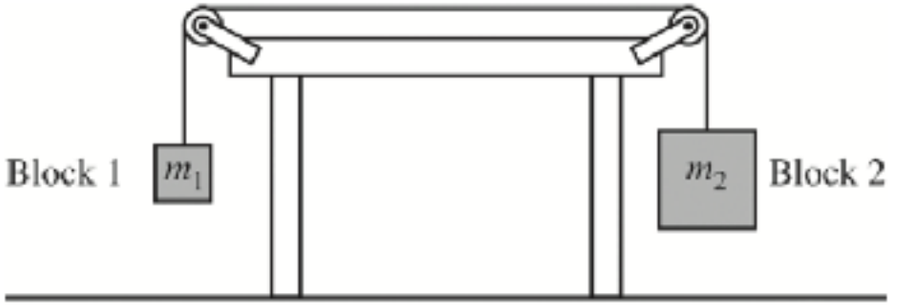
Acceptable labels for forces include: F_{AB}, $F_{A\text{ on }B}$, F_{planet}, F_{moon}, F_{0}, F_{p}, F_{gA}, etc.

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)

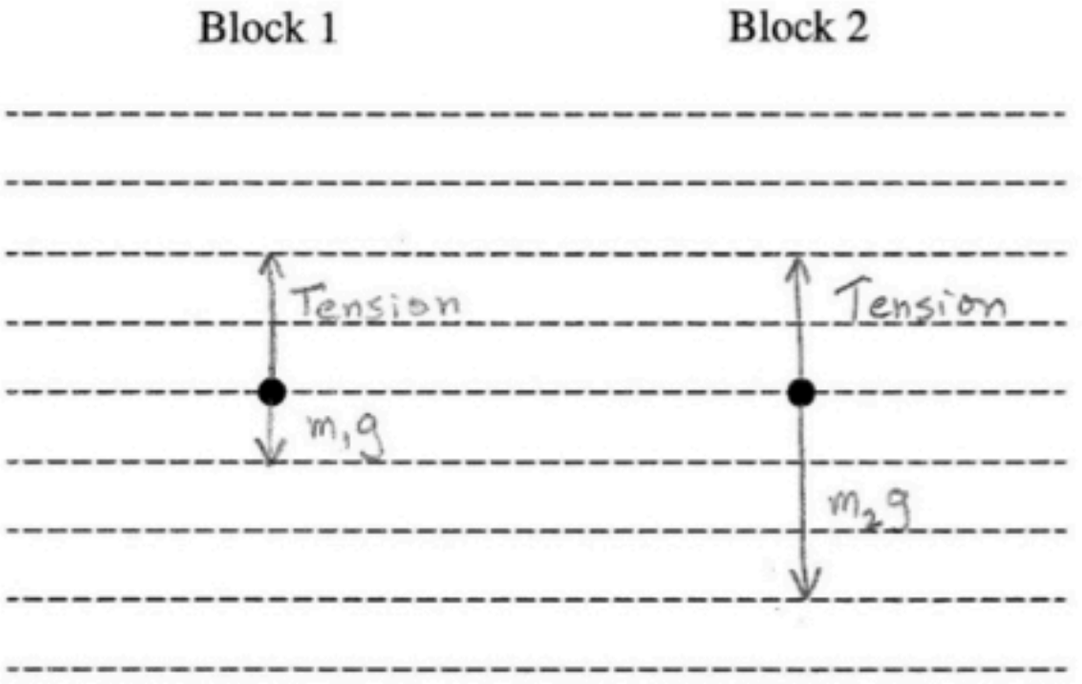
Two blocks are connected by a string of negligible mass that passes over massless pulleys that turn with negligible friction, as shown in the figure above. The mass m_2 of block 2 is greater than the mass m_1 of block 1. The blocks are released from rest.

(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.

Block 1 Block 2

of points

(a) 2 points

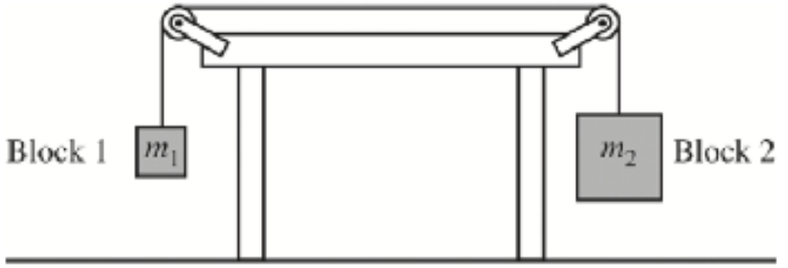


For drawing two vectors starting on the dots that point upward, have the same length and are labeled as the tension force — 1 point

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)

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.

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*

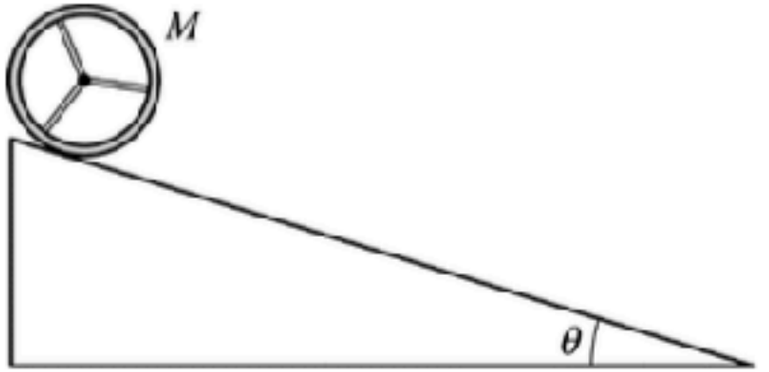
$F_{net} = (m_2 + m_1)a$

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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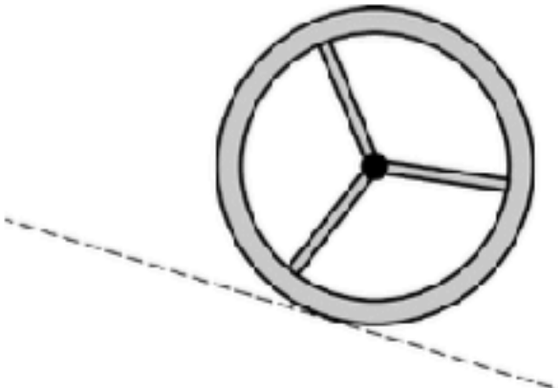


1. (7 points, suggested time 13 minutes)

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.

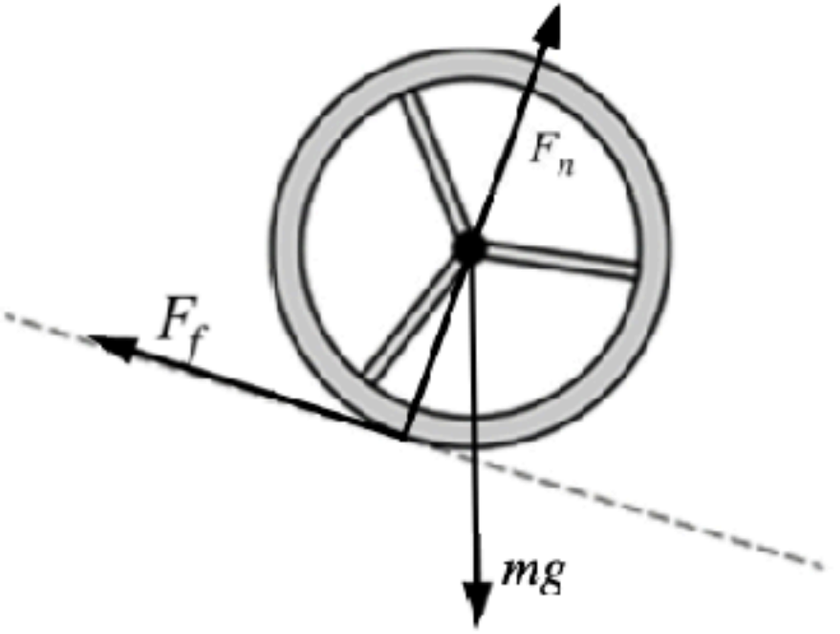
(a)

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

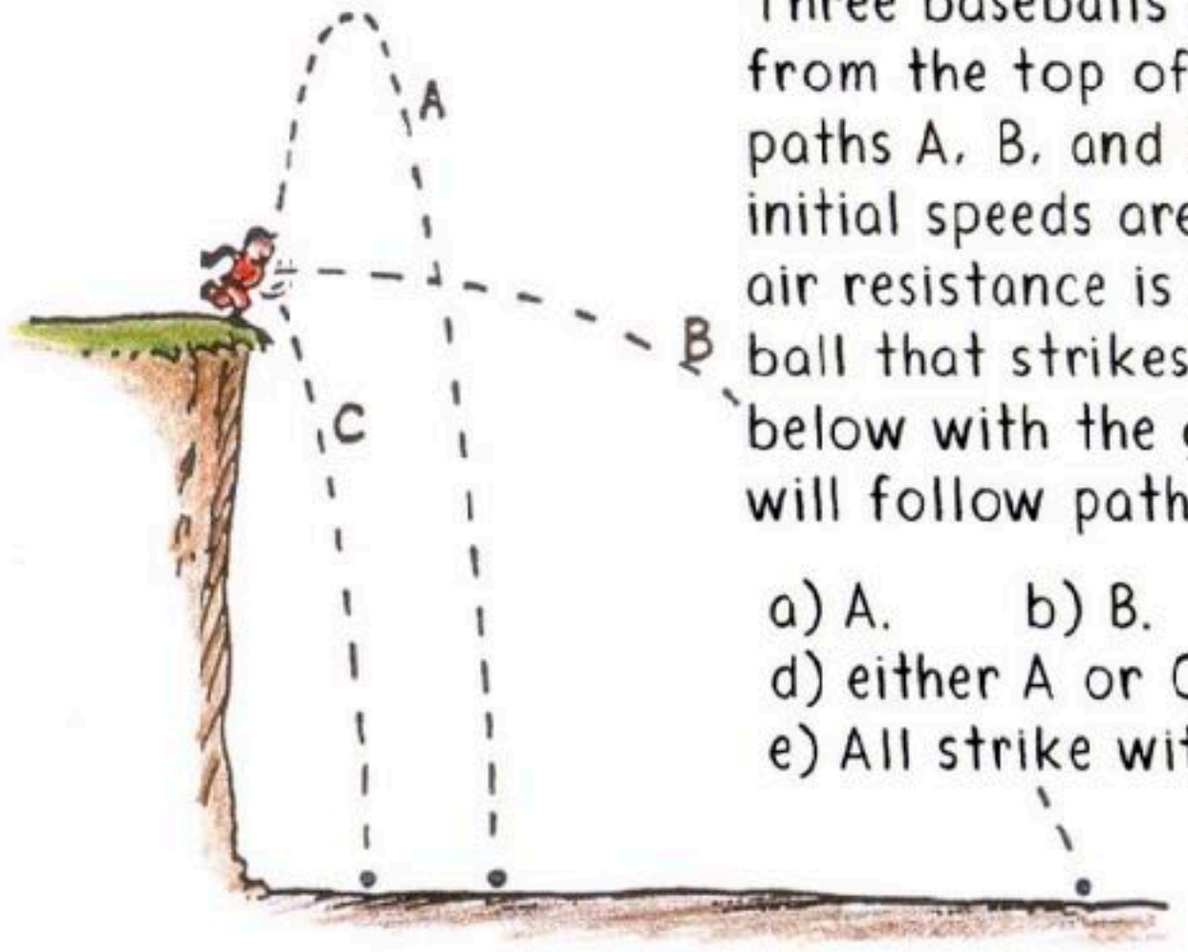
For labeled arrows representing the friction and normal forces or a single arrow representing the resultant of the friction and normal forces (i.e., the force exerted on the wheel by the surface), with no extraneous forces — 1 point

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.

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

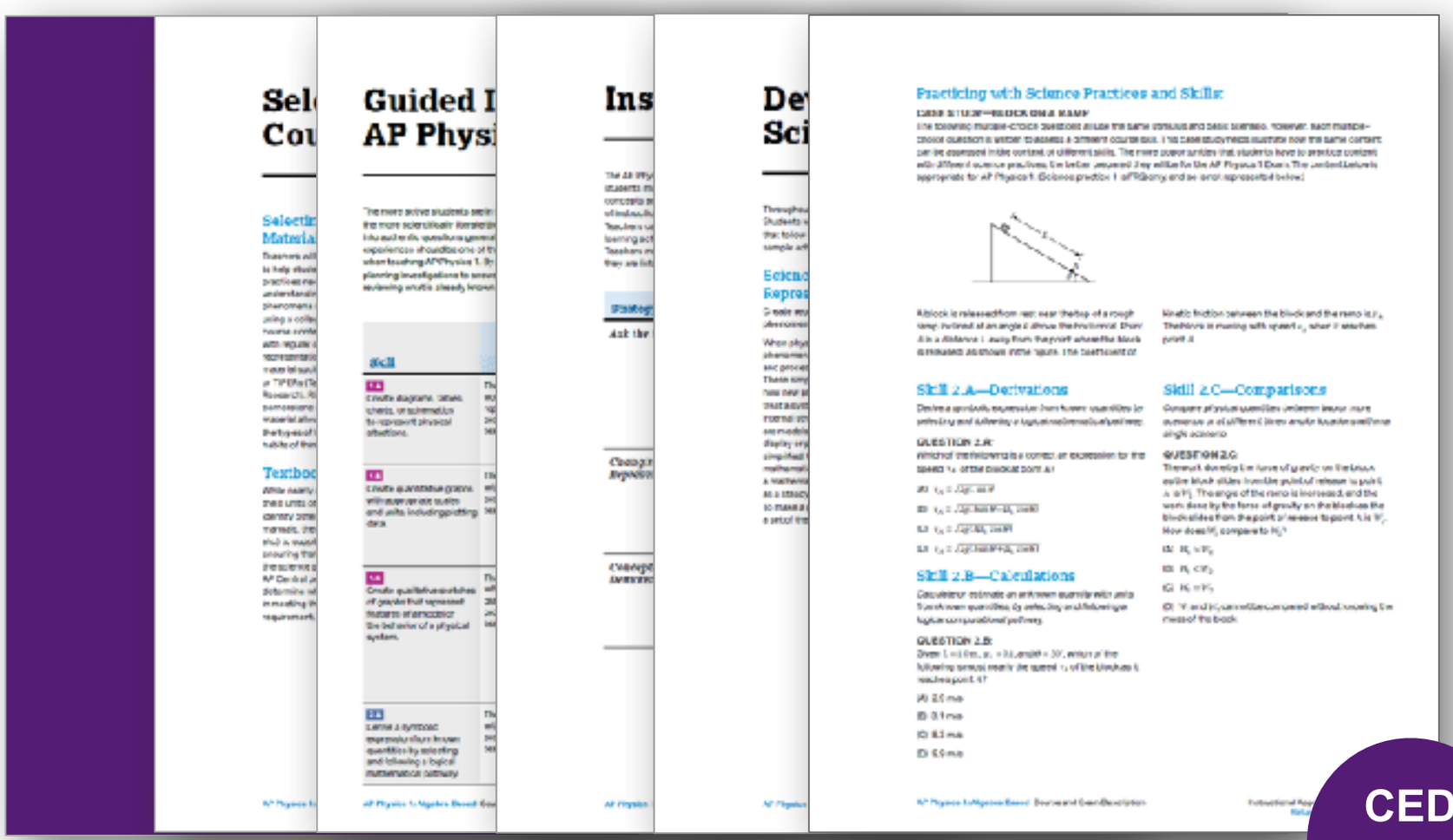
a) A. b) B. c) C.
d) either A or C.
e) All strike with the same speed.

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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



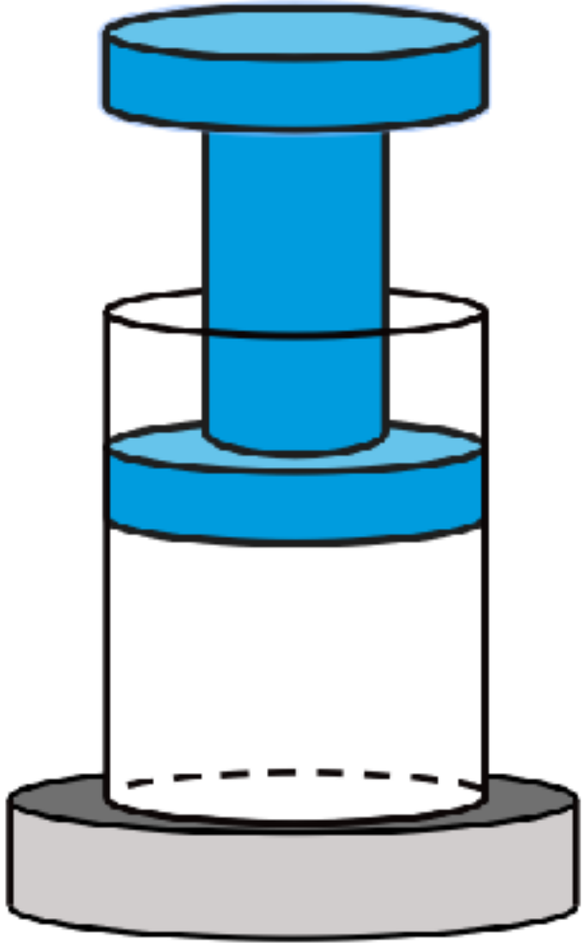
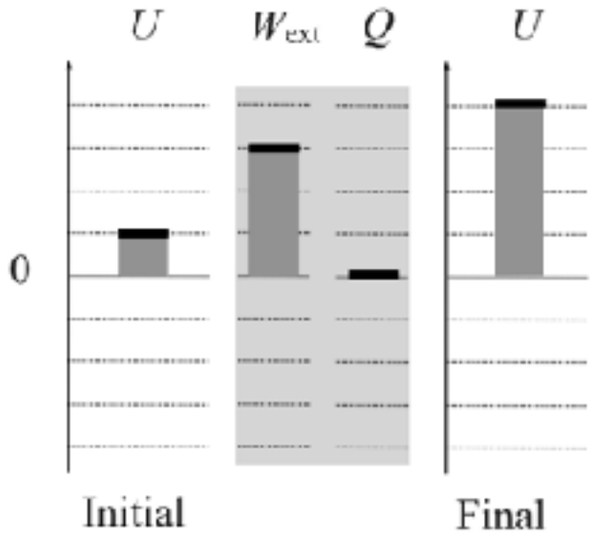
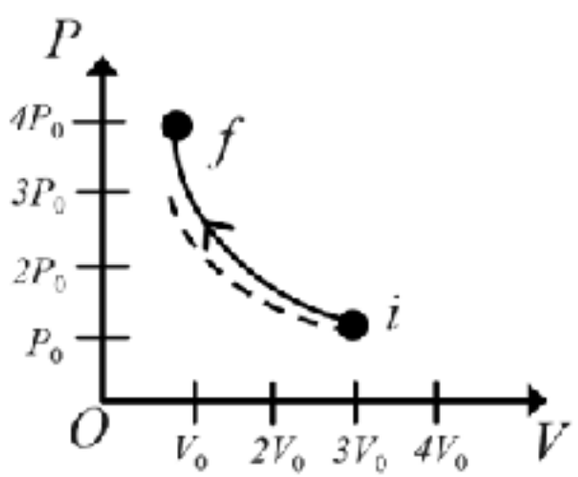


Diagram	**Graph**
Mathematical Representation	**Qualitative Analysis**

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.

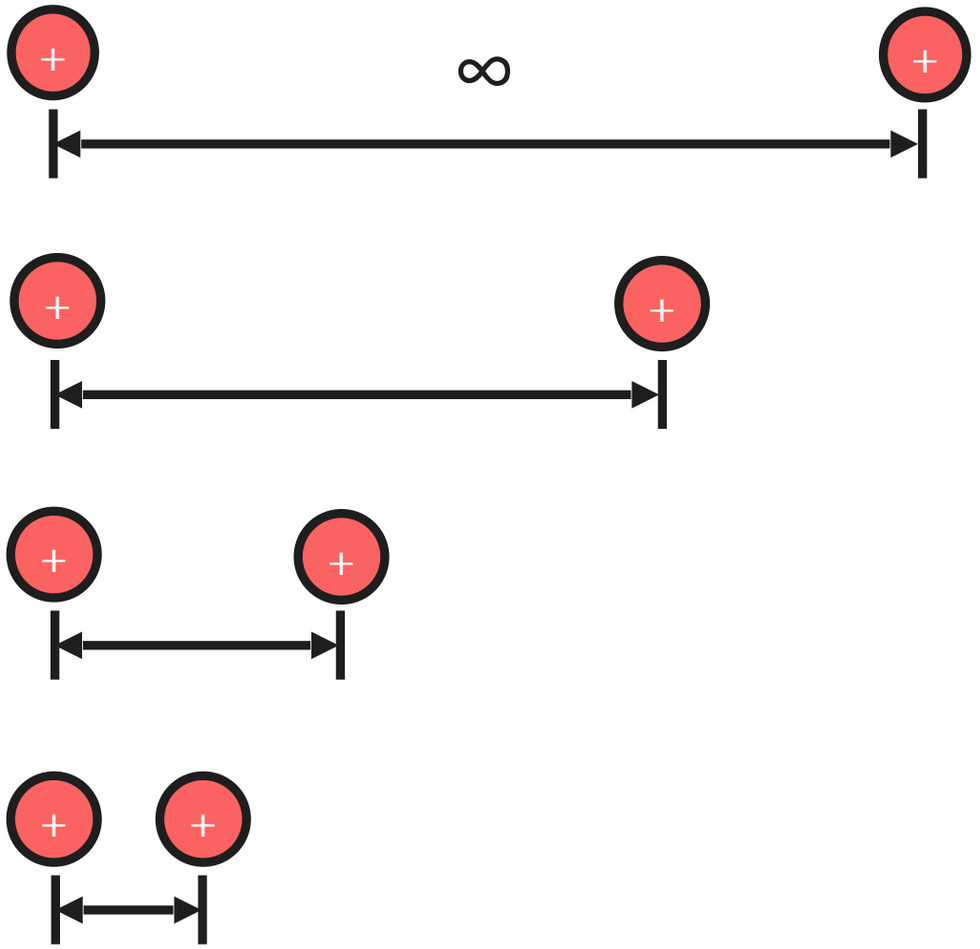
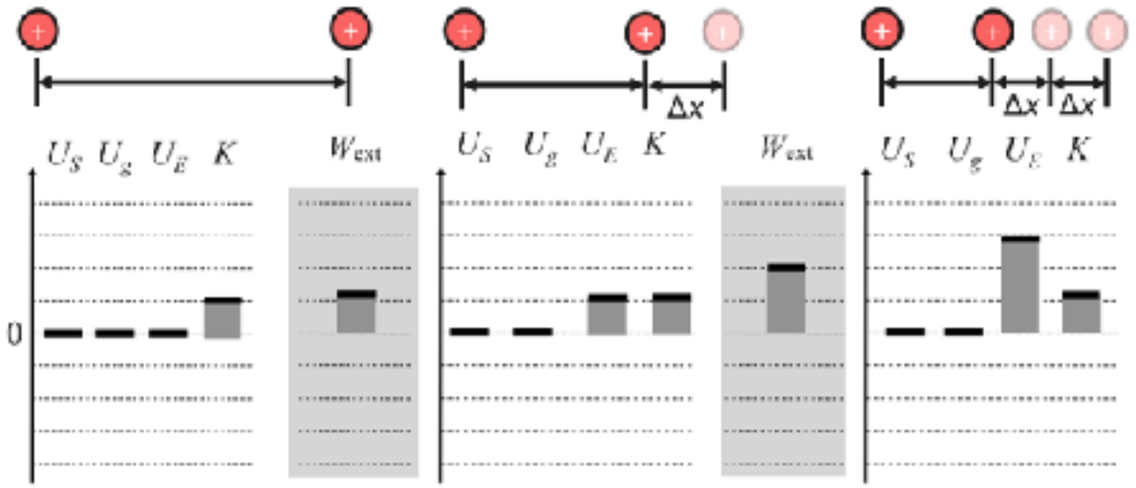
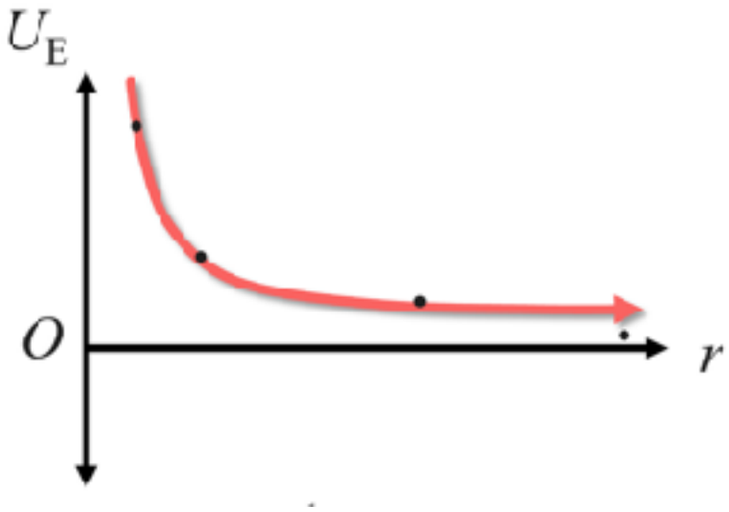


Diagram	**Graph**
Mathematical Representation	**Qualitative Analysis**

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 x 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.

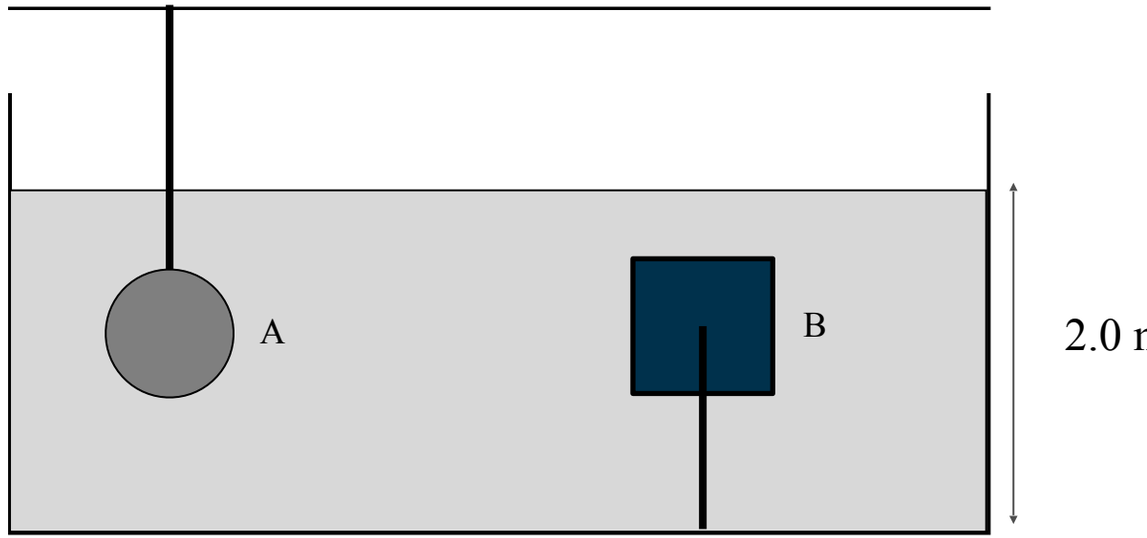


Diagram	**Graph**
Mathematical Representation	**Qualitative Analysis**

CollegeBoard

Systems and Energy

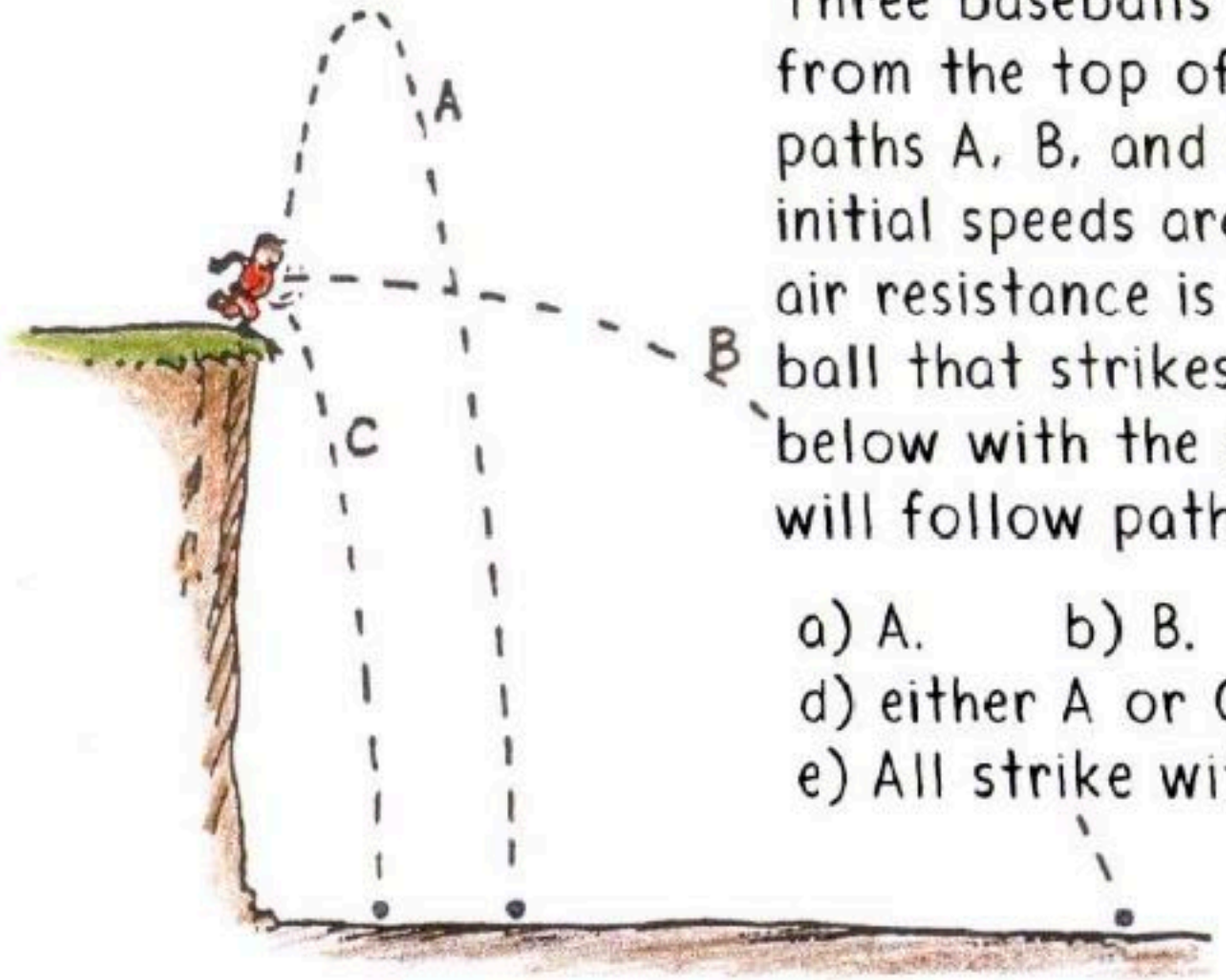


Oather Strawderman

International Lead AP Physics Consultant

NEXT-TIME QUESTION

CONCEPTUAL Physics

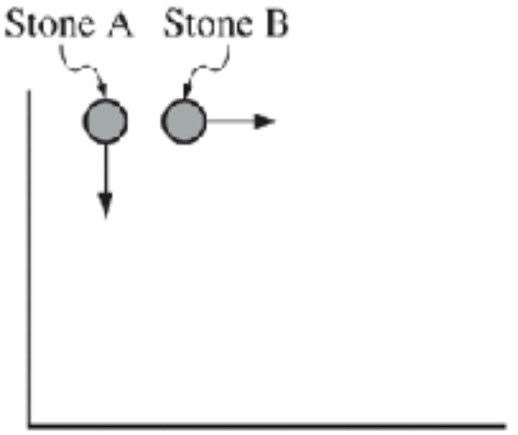


Three baseballs are thrown from the top of the cliff along paths A, B, and C. If their initial speeds are the same and air resistance is negligible. The ball that strikes the ground below with the greatest speed will follow path

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.

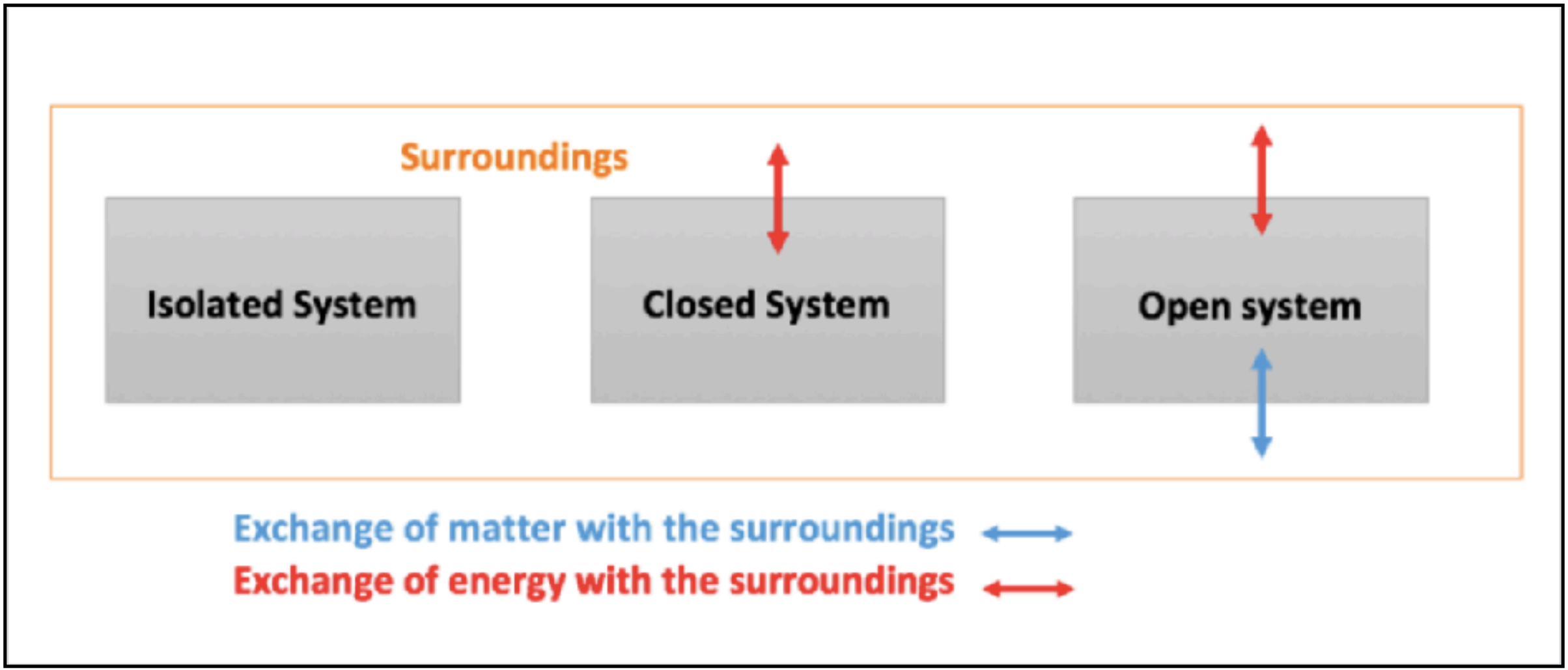
(D) Stone A reaches the ground first and has greater speed just before hitting the ground.

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

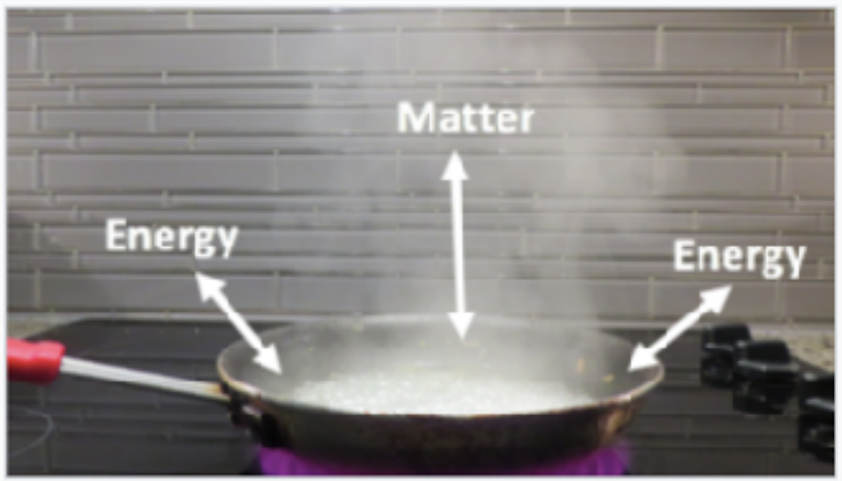


Figure 2. This is an open system. The system is the pan and the surrounding is the kitchen.[2]



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"), thinking it just served to emphasize how ridiculous the entire exercise was.

When I took them with my classes (silly 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 couldn't believe that we'd have ever taught energy without LOLs. 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 LOLs 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 update it like so:

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Energy Bar Charts (LOL Diagrams)

BLOGROLL

Action Reaction

Adventures with the Clever Carp

Always Humanize

Non-Verbal Thinking

Paper, Brain, Teeth

Play-Doh Universe

The Tetherball

Think Think Think

BLOG STATS

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ABOUT ME

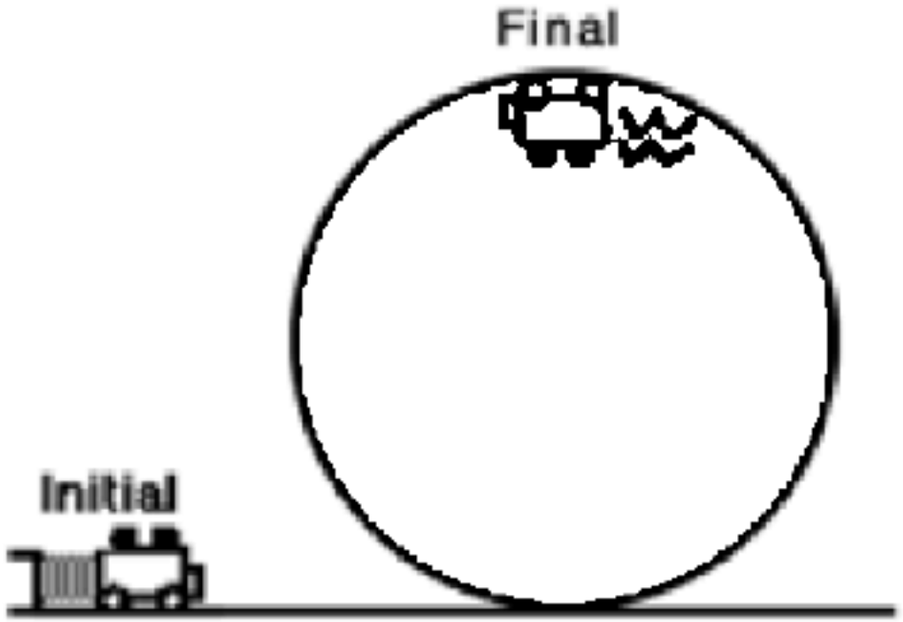
I teach high school kids physics in a progressive, independent day school in NYC. Thoughts and opinions expressed here are my own and not my school's. Let's humanize more thinking.

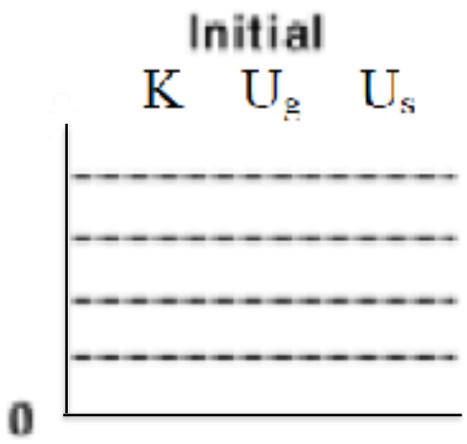
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Energy Bar Graphs

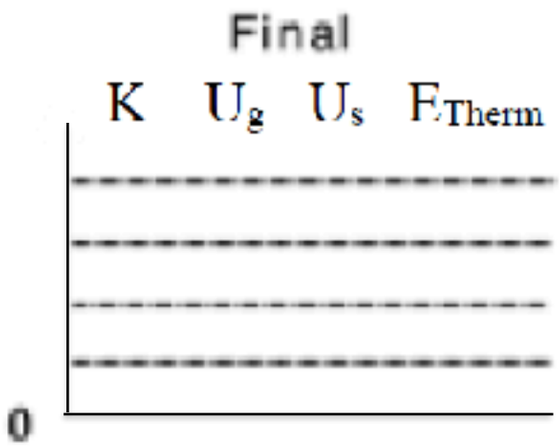
- The “Free Body Diagrams” of the Energy Unit
- Can be used during Fluids, Thermo and E&M in P2
- Three parts
  - First graph represents the energy in the system prior to the event
  - The Circle tells you the system you are analyzing and shows any work done on or by the system
  - Second graph represents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

Energy Bar Graphs WS

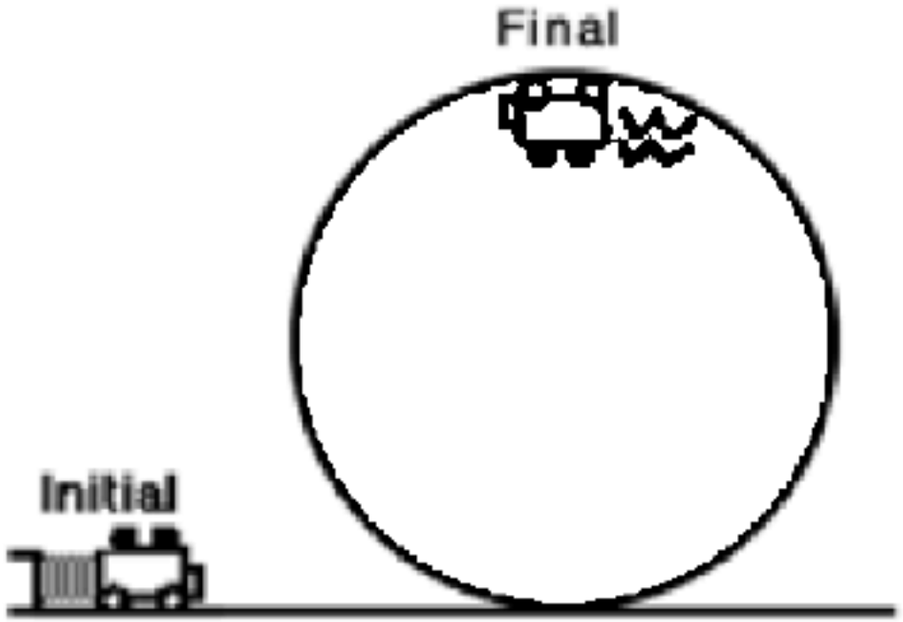


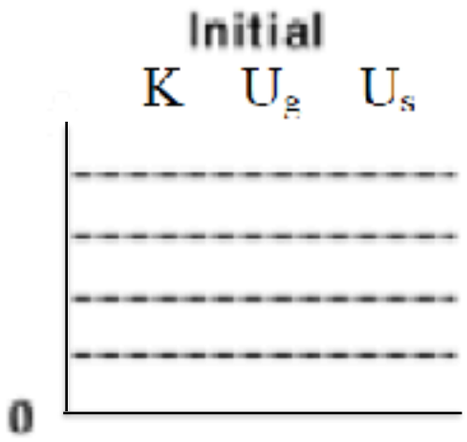


Energy Flow Diagram

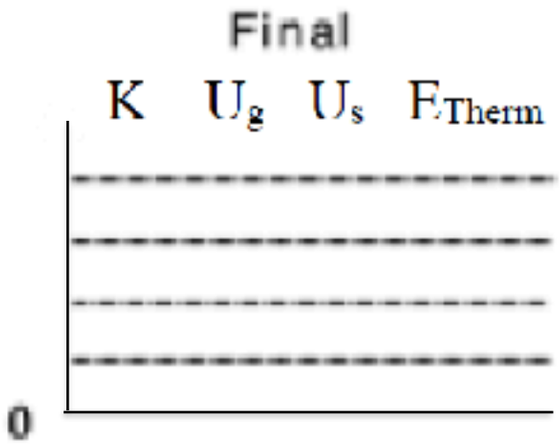


Energy Bar Graphs WS

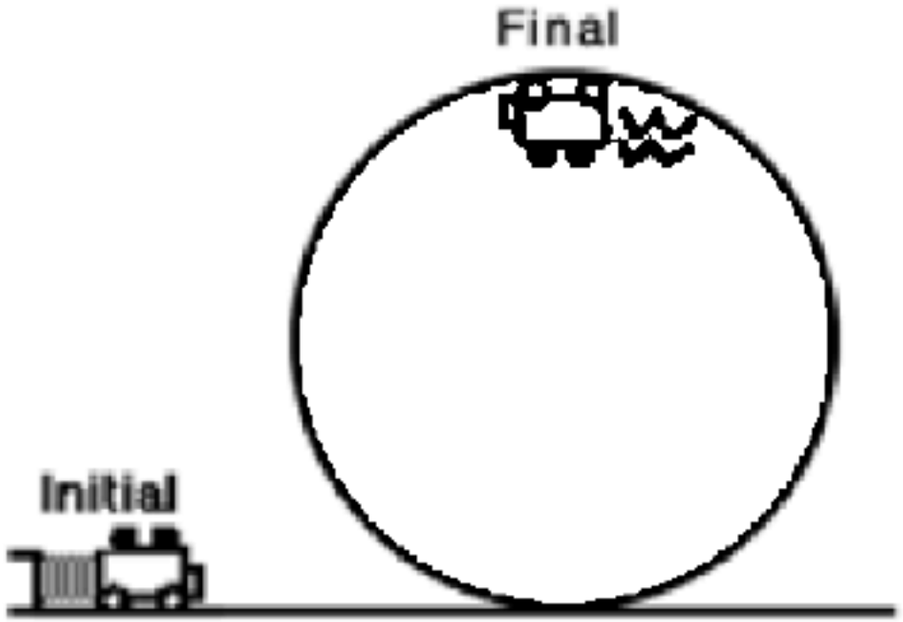


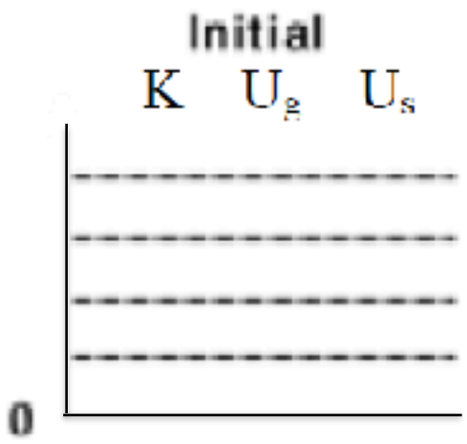


Energy Flow Diagram

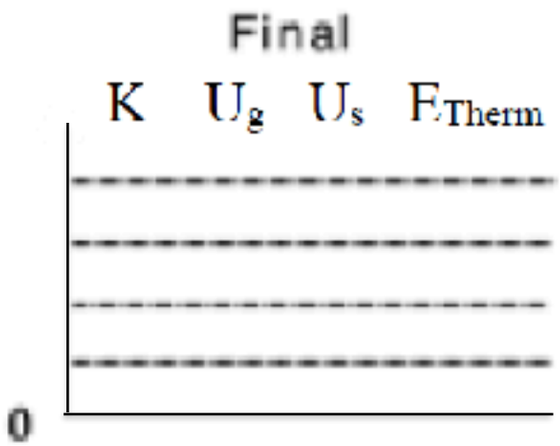


Energy Bar Graphs WS



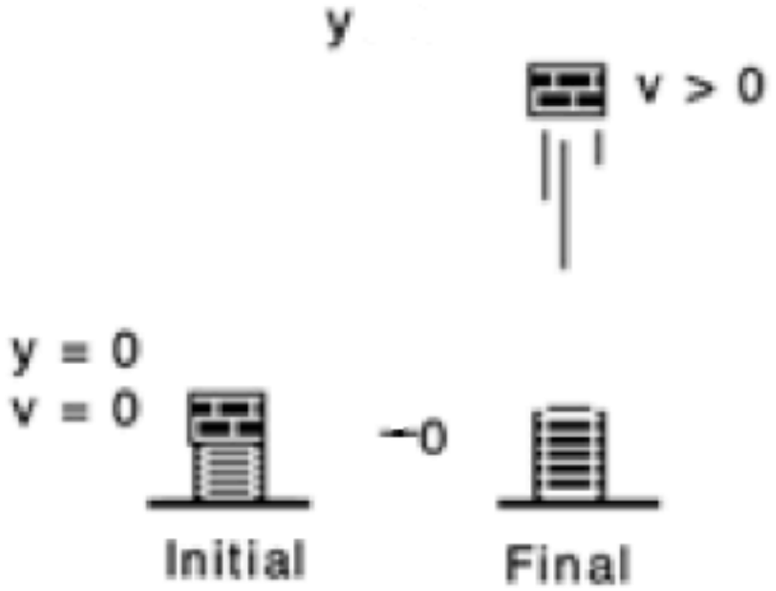


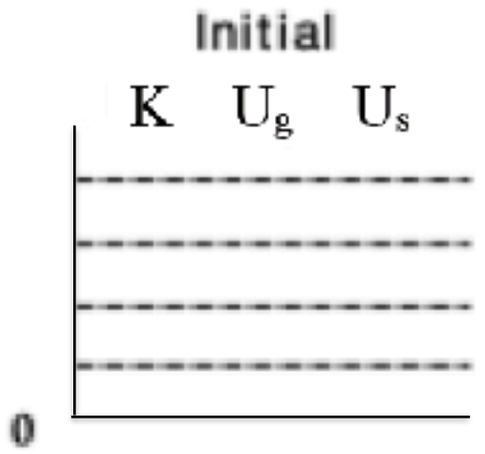
Energy Flow Diagram



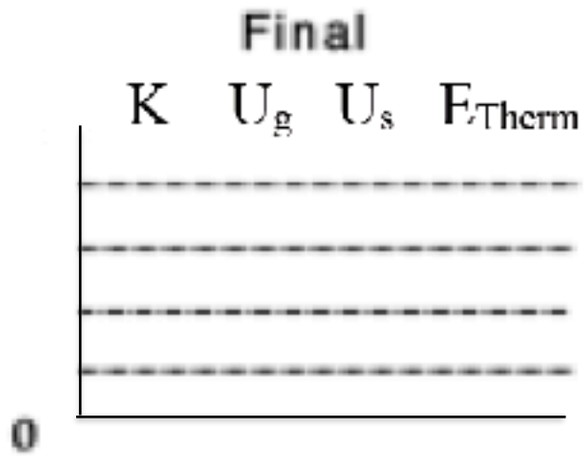
Energy Bar Graphs WS

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



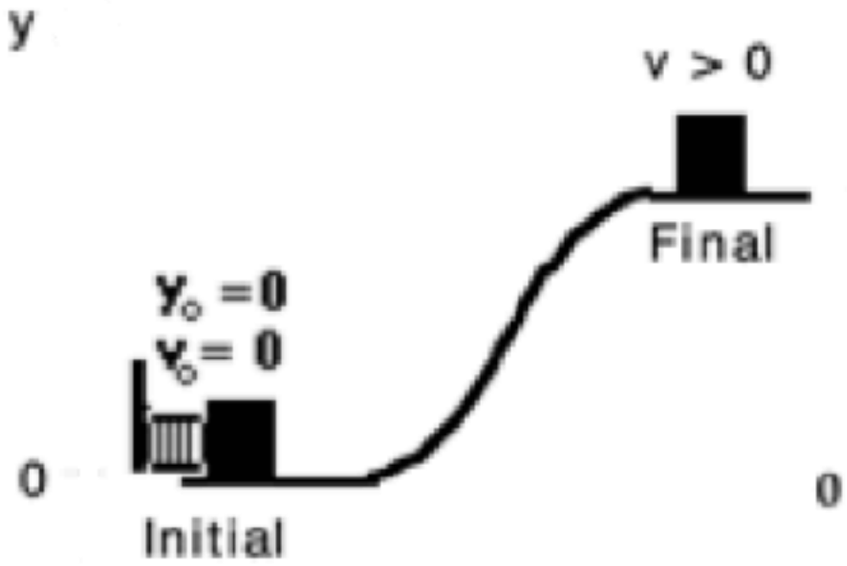


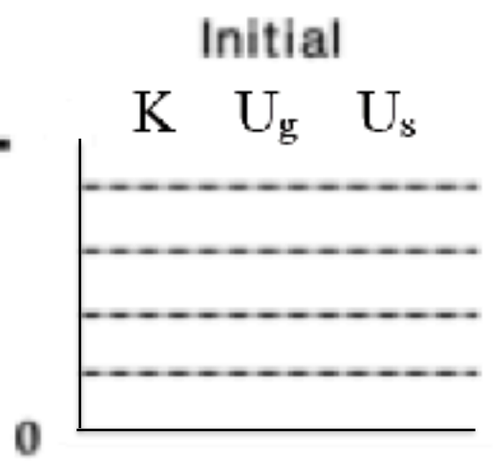
Energy Flow Diagram



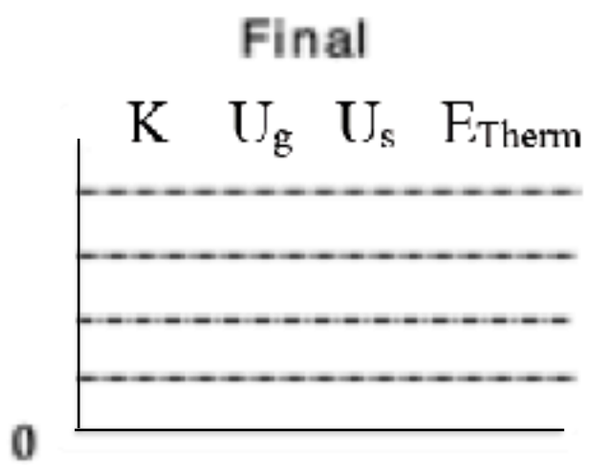
Energy Bar Graphs WS

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



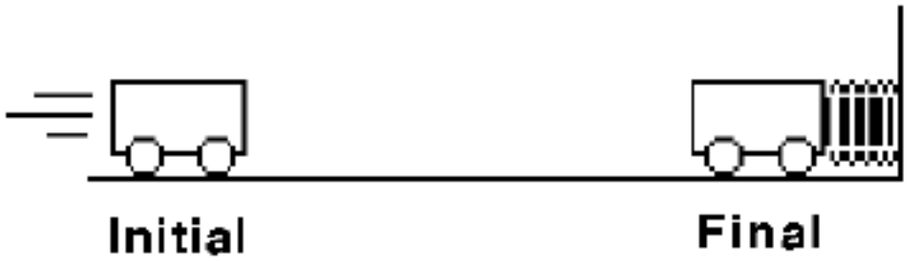


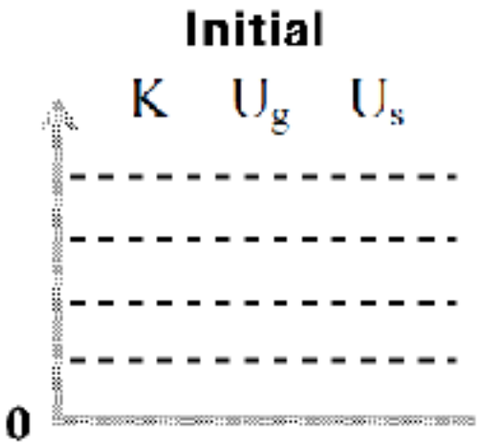
Energy Flow Diagram



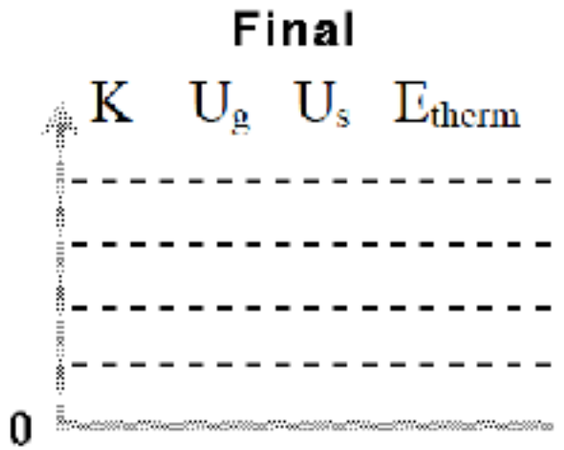
Energy Bar Graphs WS

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?



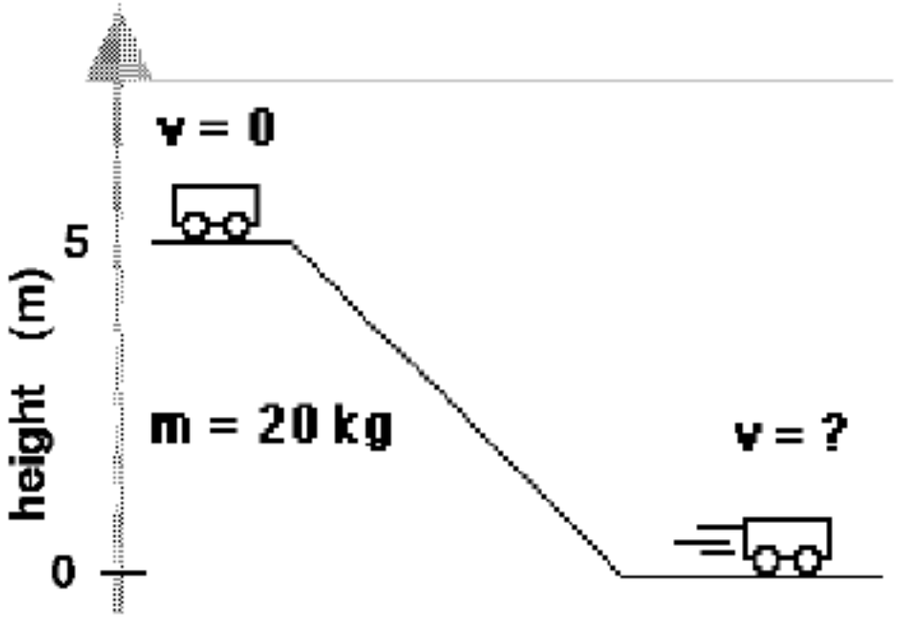


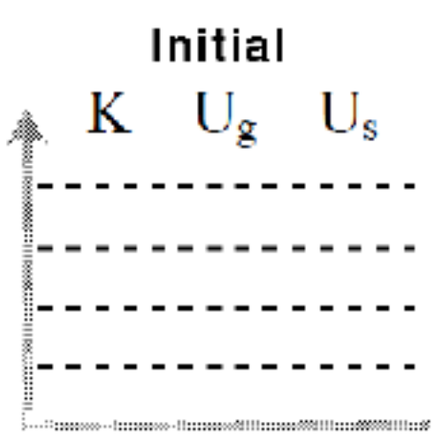
Energy Flow Diagram



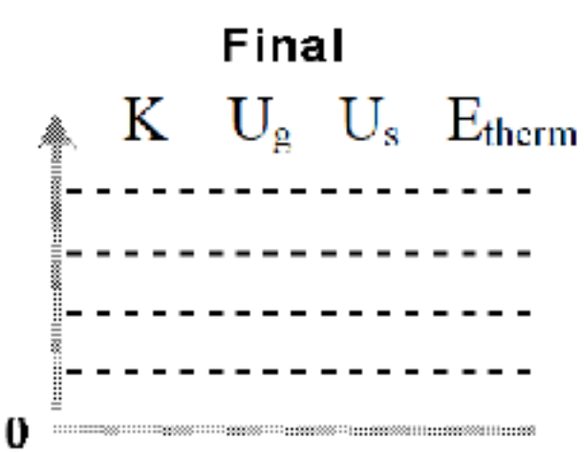
Day 2 Folder: Energy Bar Graphs WS

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





Energy Flow Diagram

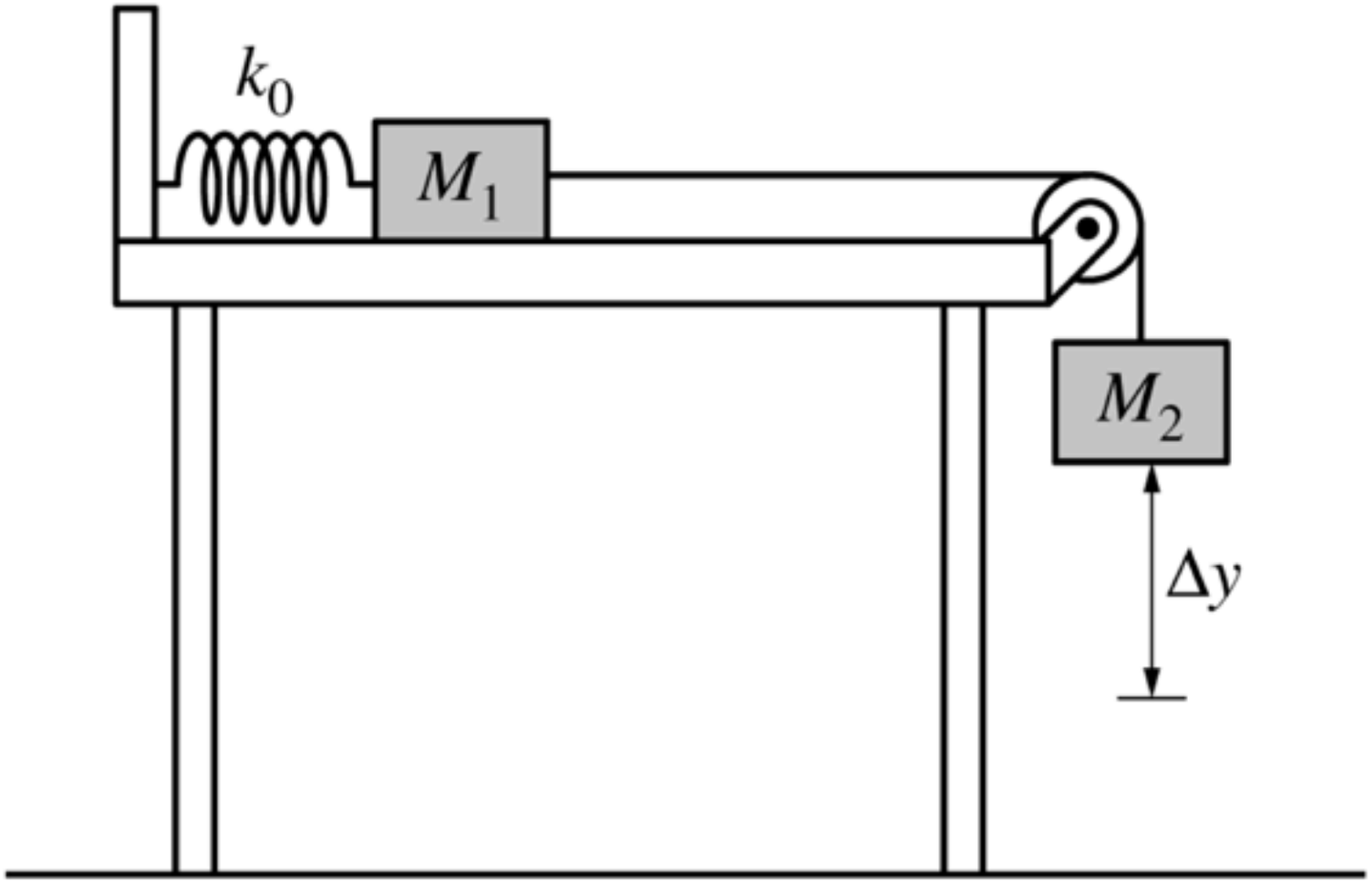


Energy Bar Graph MCQ: 2017 IPE

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

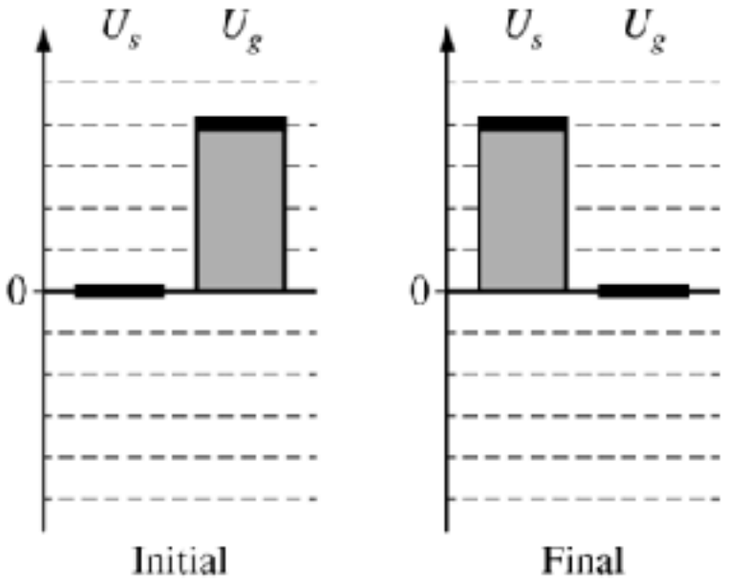
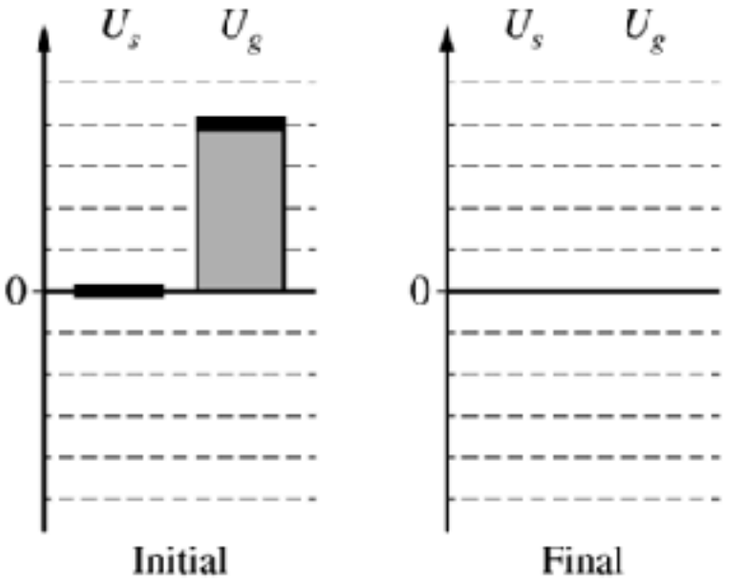


Diagram B: Nonnegligible Friction



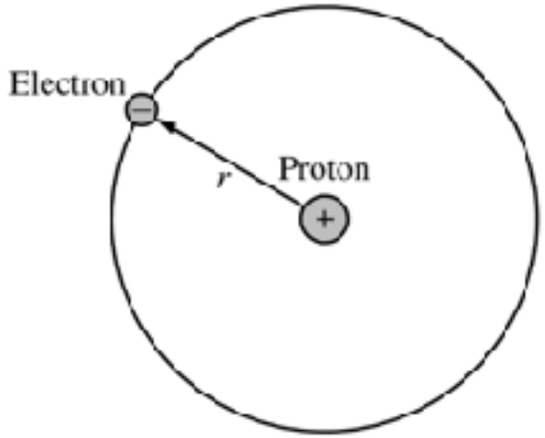
(c) Complete diagram B (at right above) for the scenario in which friction is nonnegligible. The energies for the initial state are already provided. Shade in the energies in the final state using the same scale as in diagram A.

- 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.



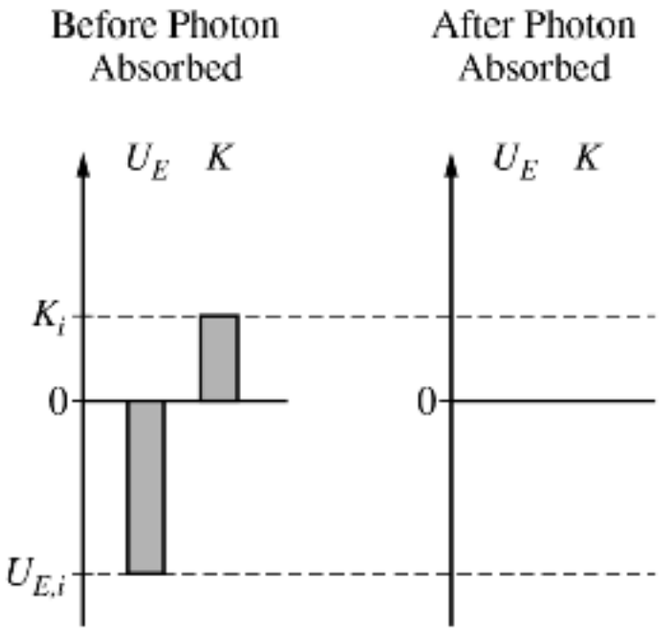
Note: Figure not drawn to scale.

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.

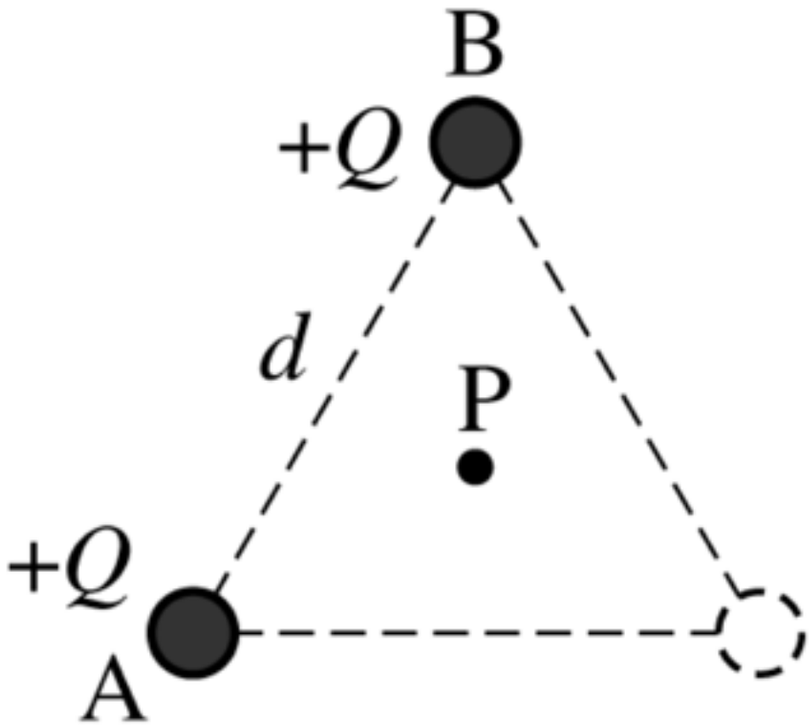
(a) Derive an equation for the speed v of the electron in terms of r and physical constants, as appropriate.

AP Physics 2 2022 Exam FRQ #3

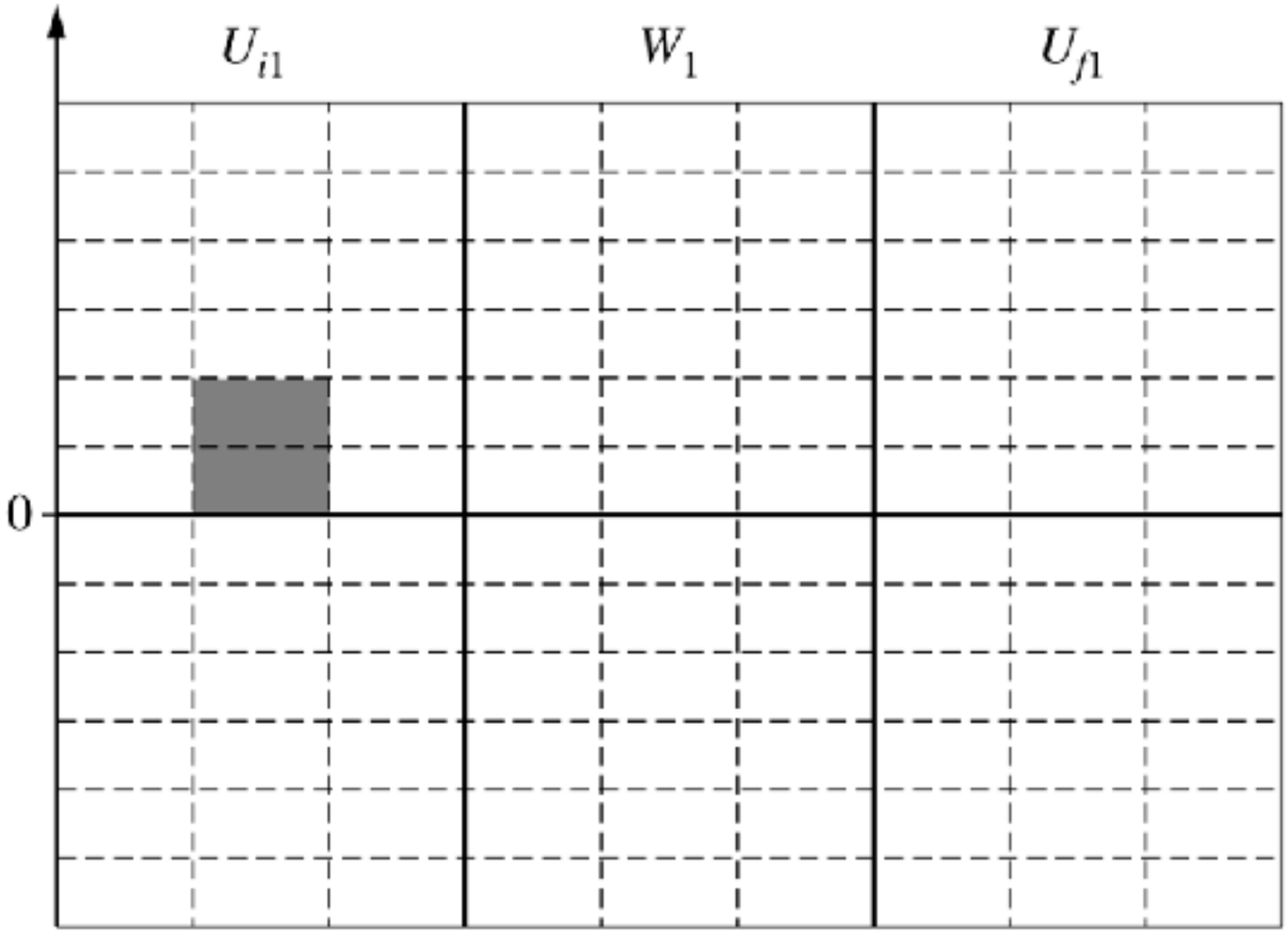


iii. The left bar chart in the figure above is complete and represents the initial electric potential energy $U_{E,i}$ of the atom and the initial kinetic energy K_i of the electron before the photon is absorbed. In the space provided on the right, draw a bar chart to represent a possible final electric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

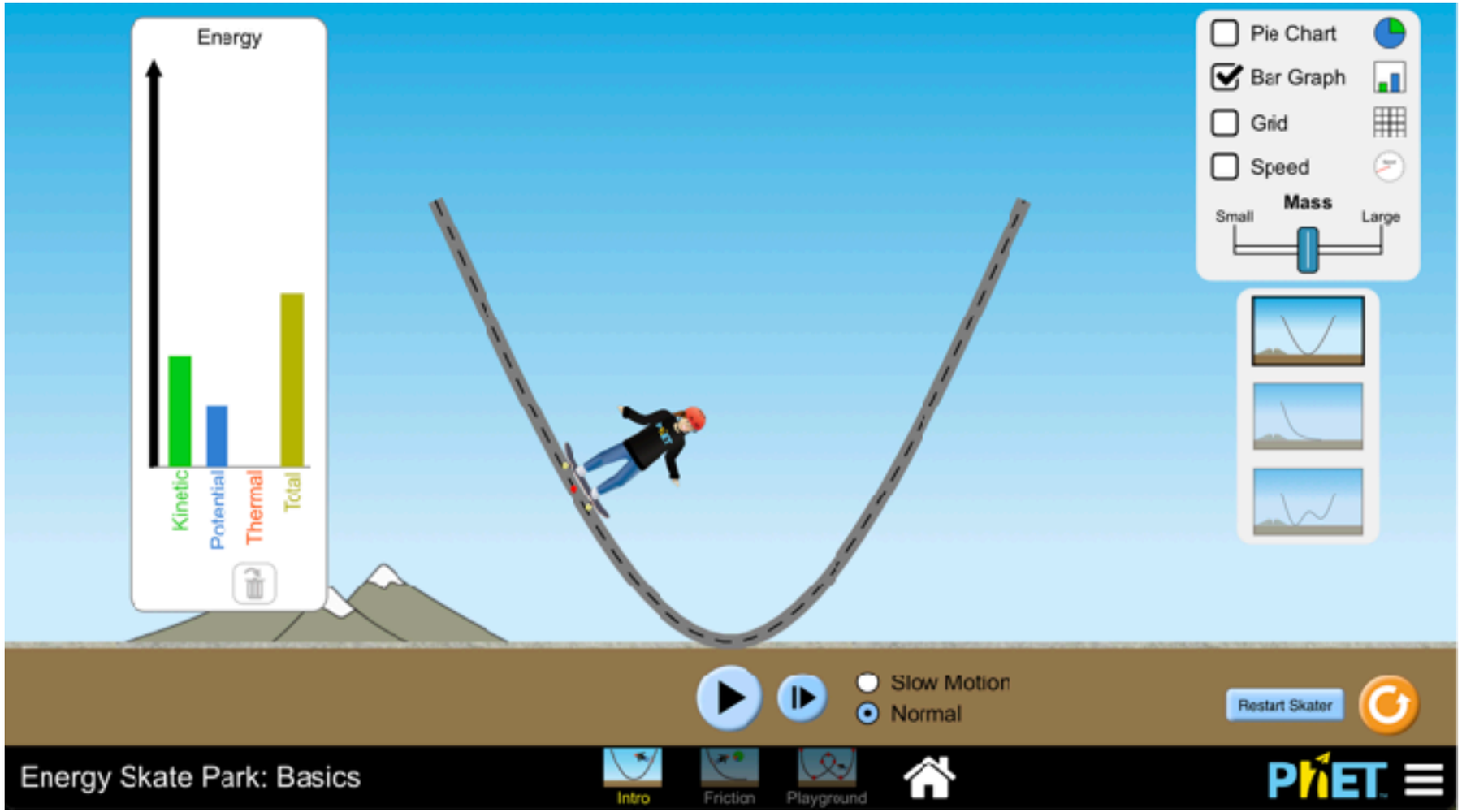
AP Physics 2 2023 Exam FRQ #4



AP Physics 2 2023 Exam FRQ #4

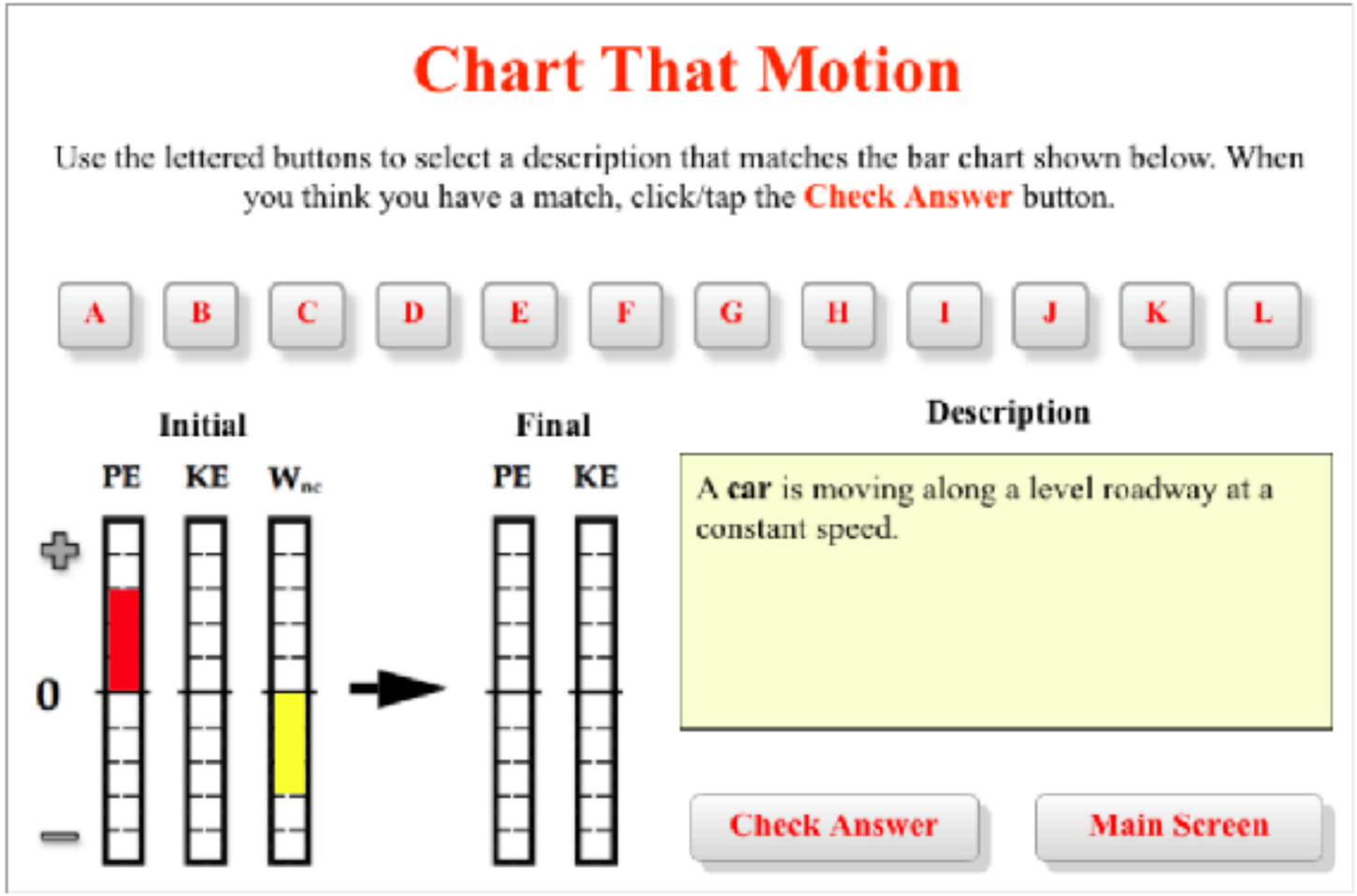


PhET: Energy Skate Park



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.

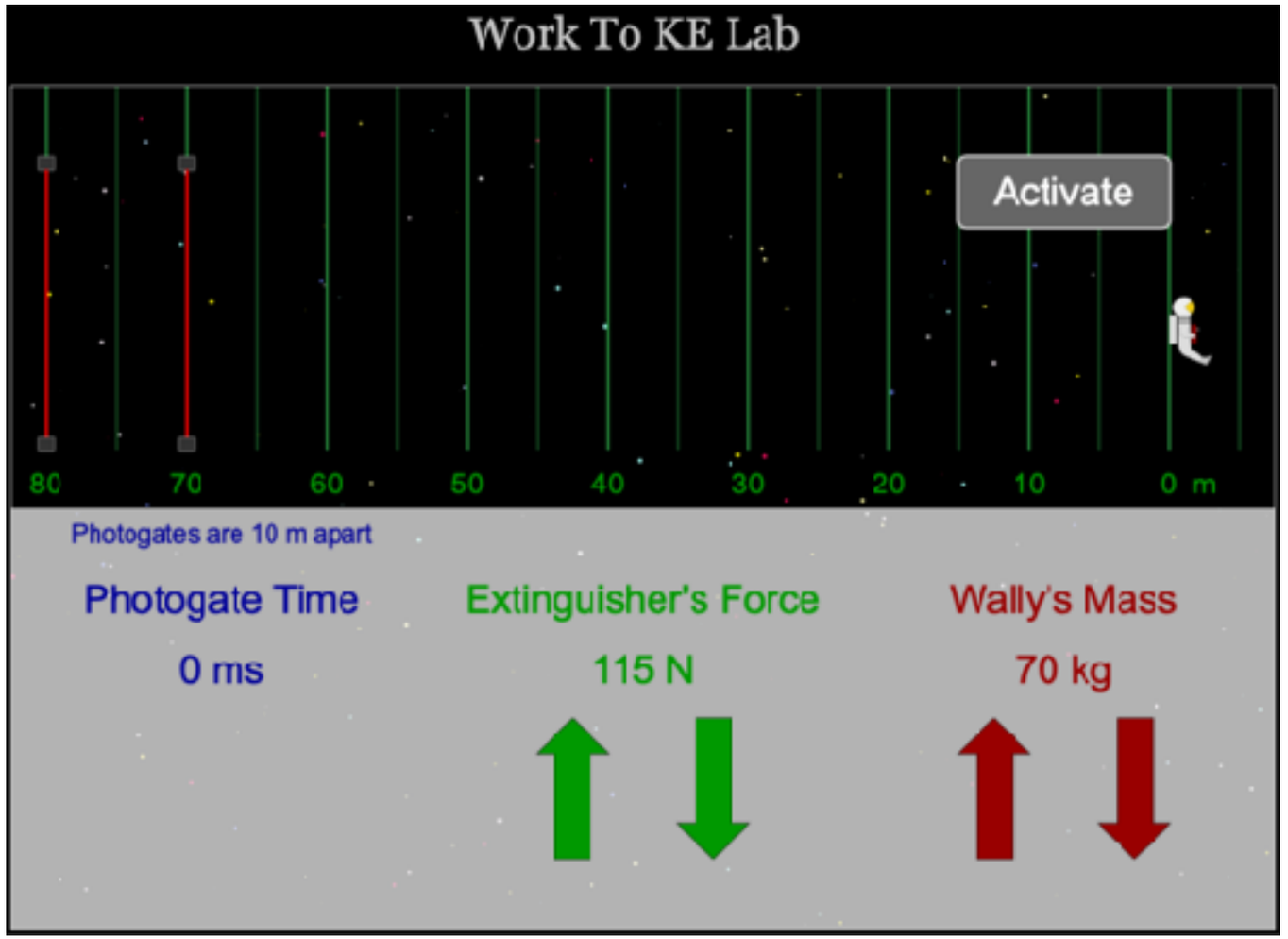
As the particles get closer to each other, each experiences an <u>increase</u> in

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

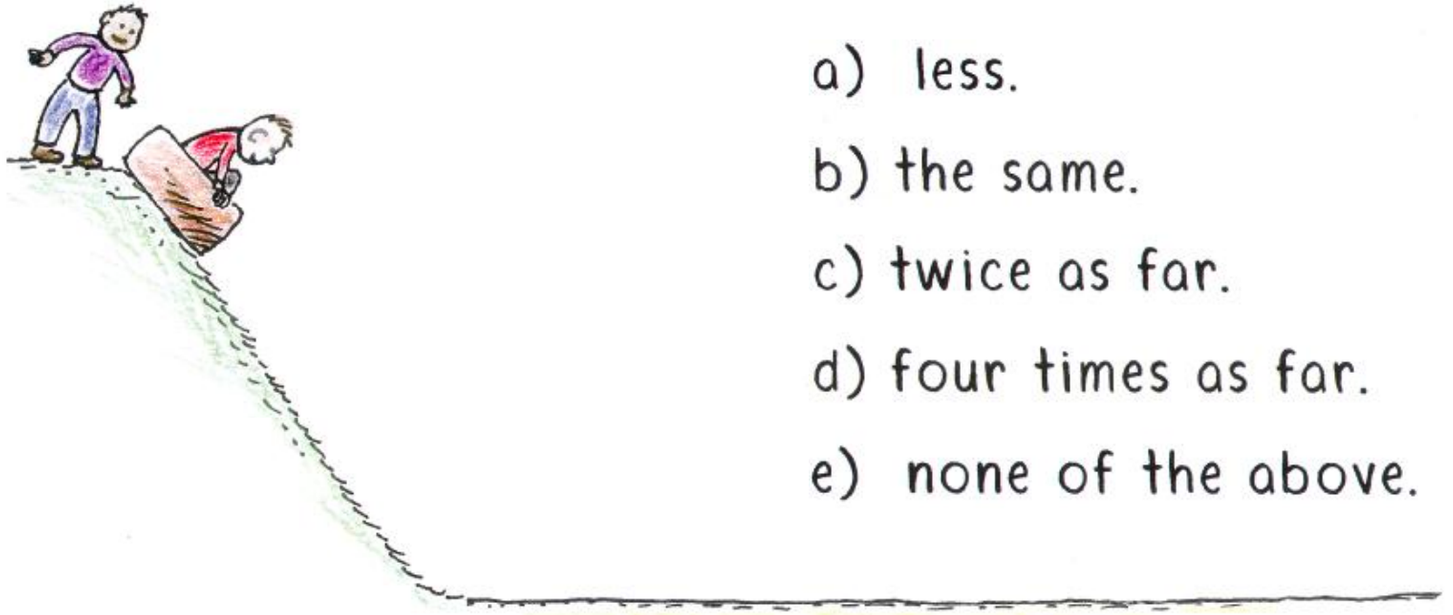


Access the Simulation at: https://www.thephysicsaviary.com/Physics/Programs/Labs/WorkToKELab/

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.

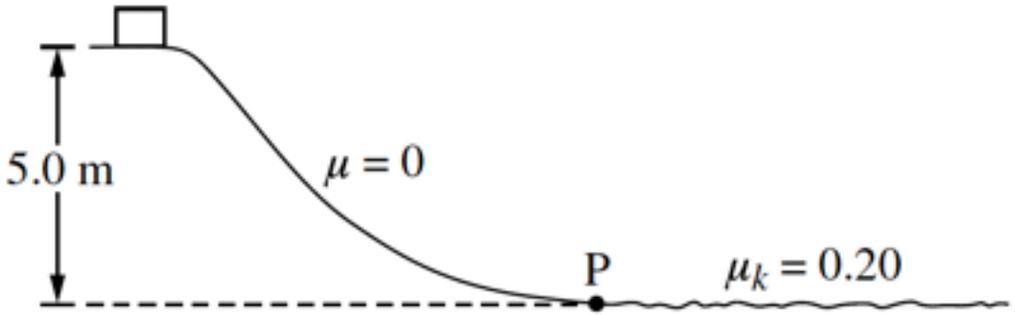
c) twice as far.

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

Lunch

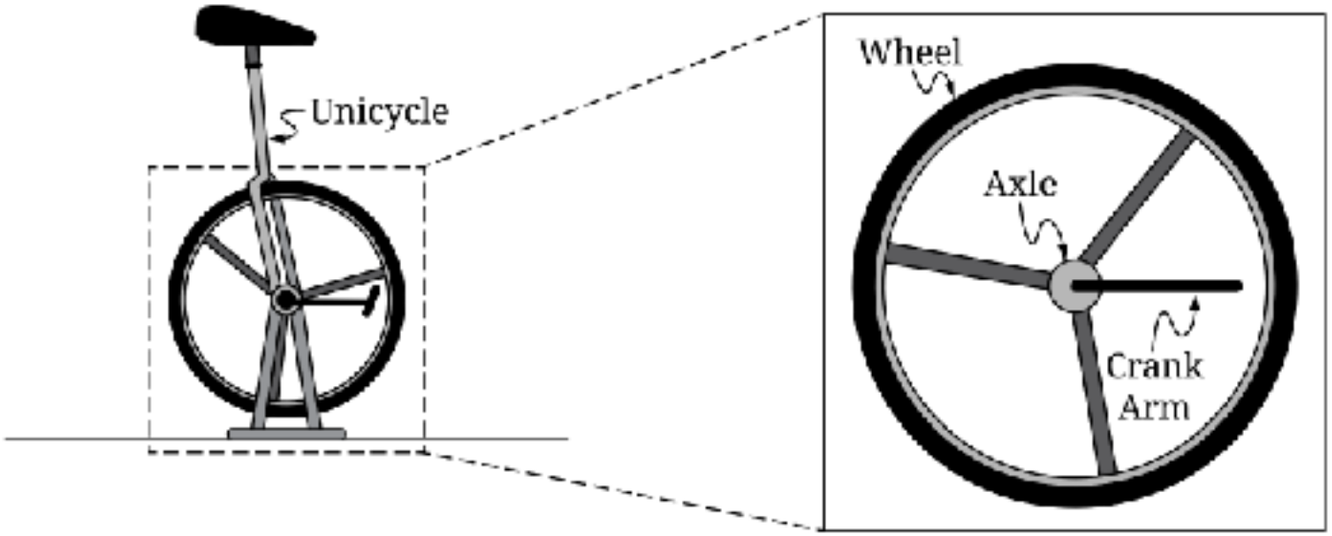
Qualitative / Quantitative Translation

FRQ #4 - 8 points

Qualitative/Quantitative Translation FRQ 2026

Question 4

4. A unicycle is placed on a stand such that the wheel does not touch the ground. The rotational inertia of the wheel about the axle is I_W. One end of a crank arm can be attached to the wheel, as shown in the side view.



Side View

Qualitative/Quantitative Translation FRQ 2025

Question 4

4. A uniform disk and ring, each of mass M and radius R, roll without slipping along a horizontal surface, as shown in Figure 1. The outer edges of the disk and ring are made of the same material. The center of mass of the disk and the center of mass of the ring each initially move with the same constant speed v.

The disk and the ring then smoothly transition to a ramp that is inclined at an angle θ above the horizontal. Both the disk and the ring continue to roll without slipping as they move up the ramp, as shown in Figure 2.

The ring travels a greater distance along the ramp than the disk travels before each momentarily comes to rest.

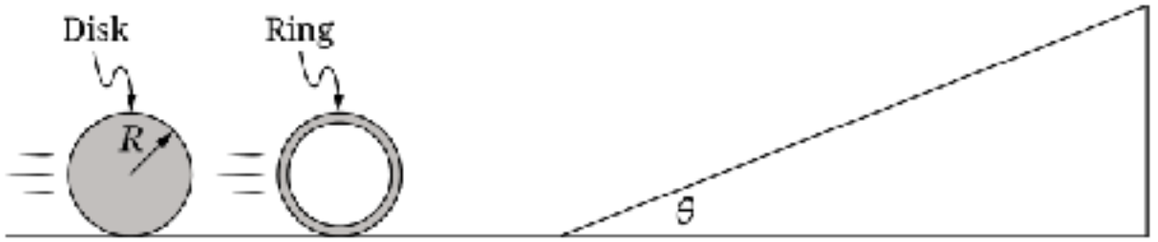
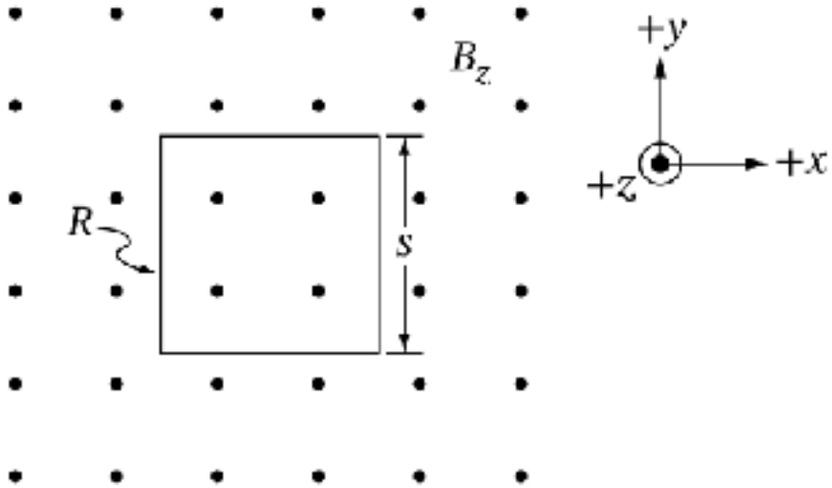


Figure 1

Qualitative/Quantitative Translation FRQ 2026

Question 4

4. In Scenario 1, a square conducting loop with side length s has total resistance R. The loop is held fixed in the xy-plane in an external, uniform, time-varying magnetic field that is initially directed in the +z-direction, as shown. The z-component of the magnetic field changes as a function of time t as described by $B_z = B_0 \cos\left(2\pi \frac{t}{t_1}\right)$, where B_0 and t_1 are positive constants.

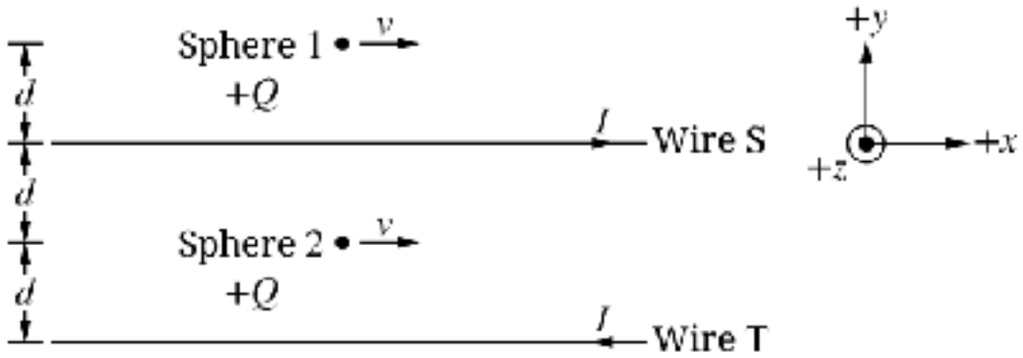


Qualitative/Quantitative Translation FRQ 2026

Question 4

4. Long, parallel wires S and T are a distance $2d$ apart. Both wires carry equal currents I, but the currents are in opposite directions. Both wires are parallel to the x-axis. At the instant shown in Figure 1, Sphere 1 is a distance d above Wire S, Sphere 2 is a distance d below Wire S, and both spheres are moving with speed v in the $+x$-direction. Each sphere has positive charge $+Q$. Gravitational effects are negligible.

Figure 1



Qualitative / Quantitative Translation FRQ

- Find Question #4 the QQT FRQ
- Look at either the Mechanics or the E&M Student Samples packet
- Read through and determine the tasks that the student have to do for each part
- Record how many points per part

QQT FRQ Practice

- Work through the QQT FRQ for the exam of your choosing
- As you work the FRQ think about how you can help prepare you students for this item type.
- How could you adjust your home work sets to match this derivation format?
- How could you adjust your home work sets to match this qualitative heavy question?

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

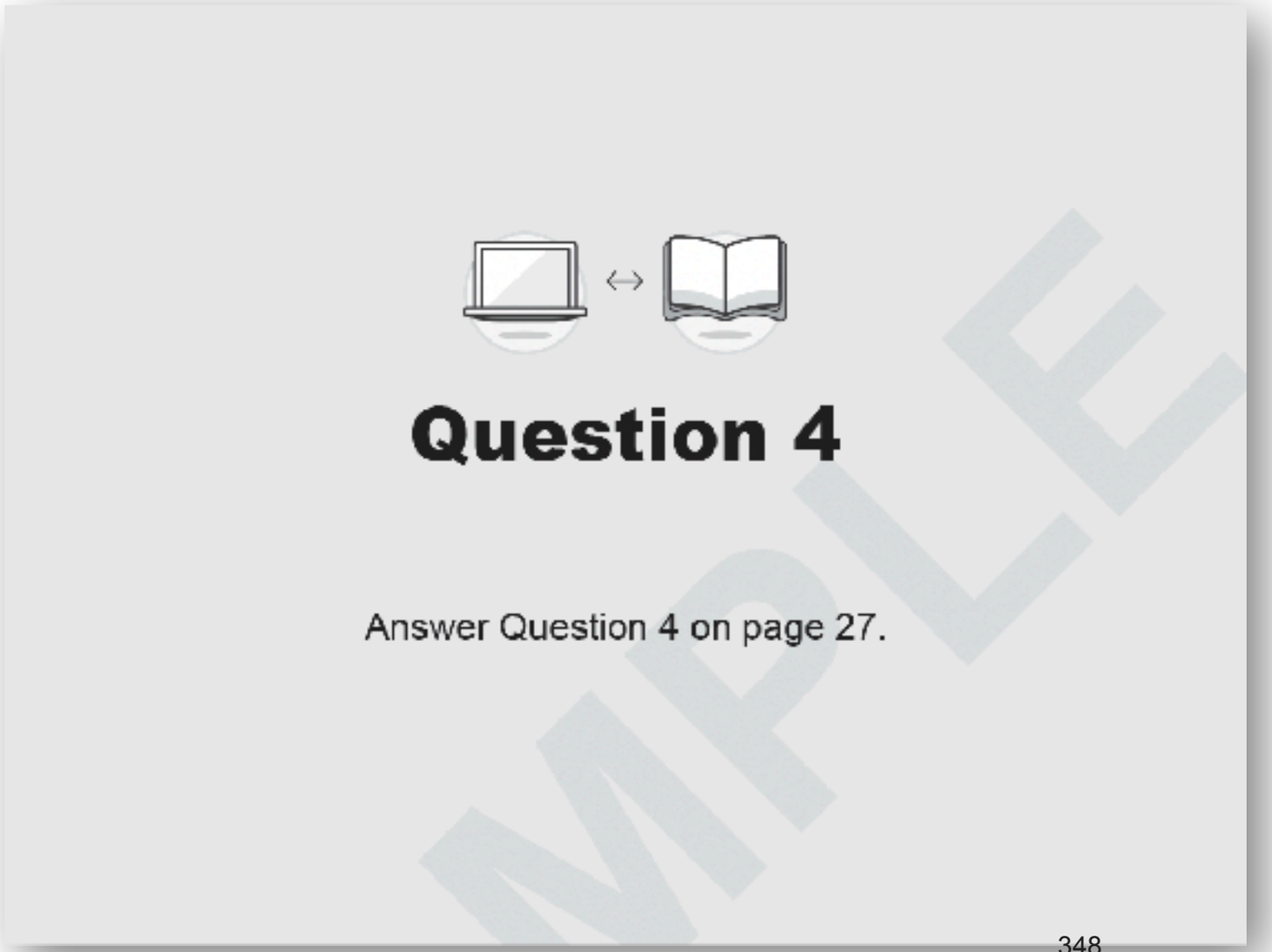
Evidence

Reasoning

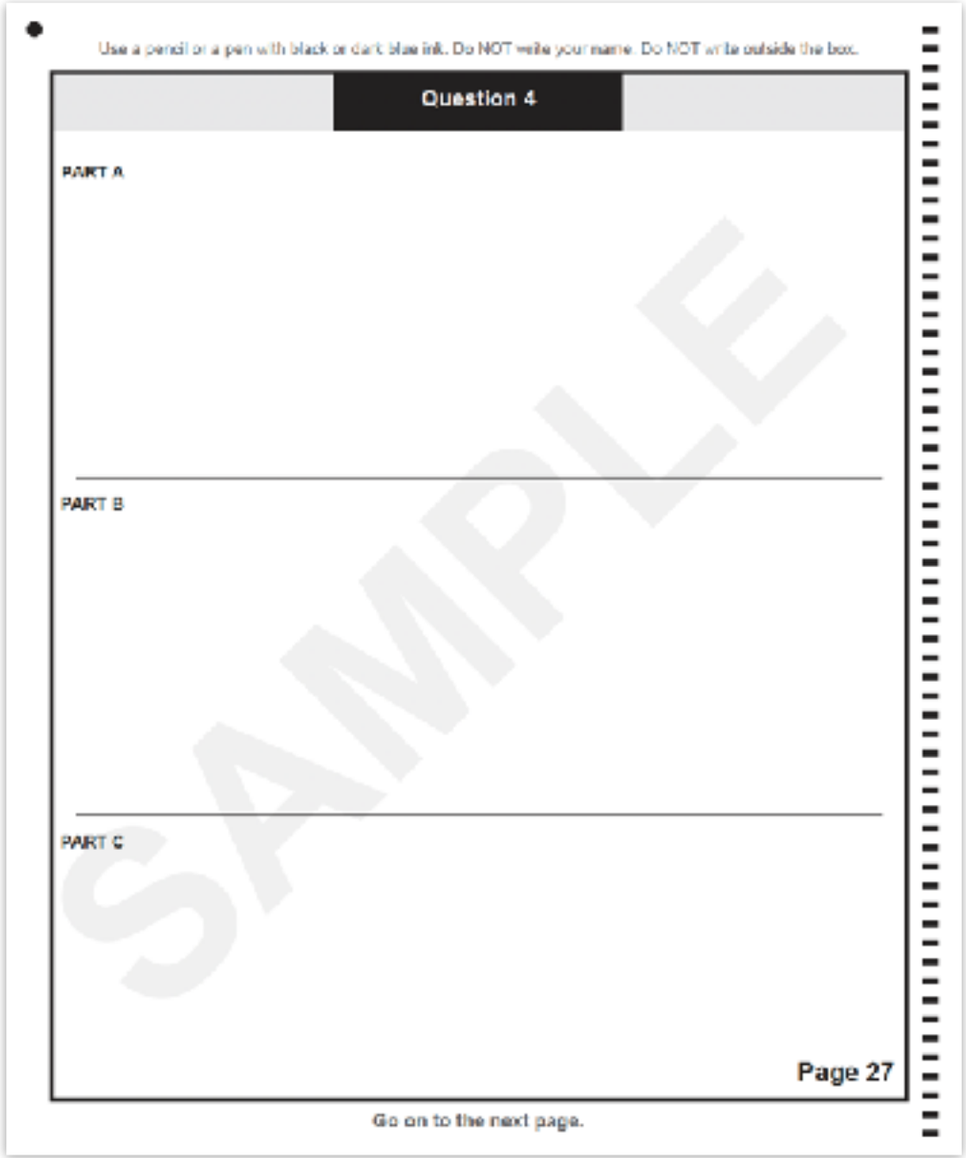
Claim

- **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

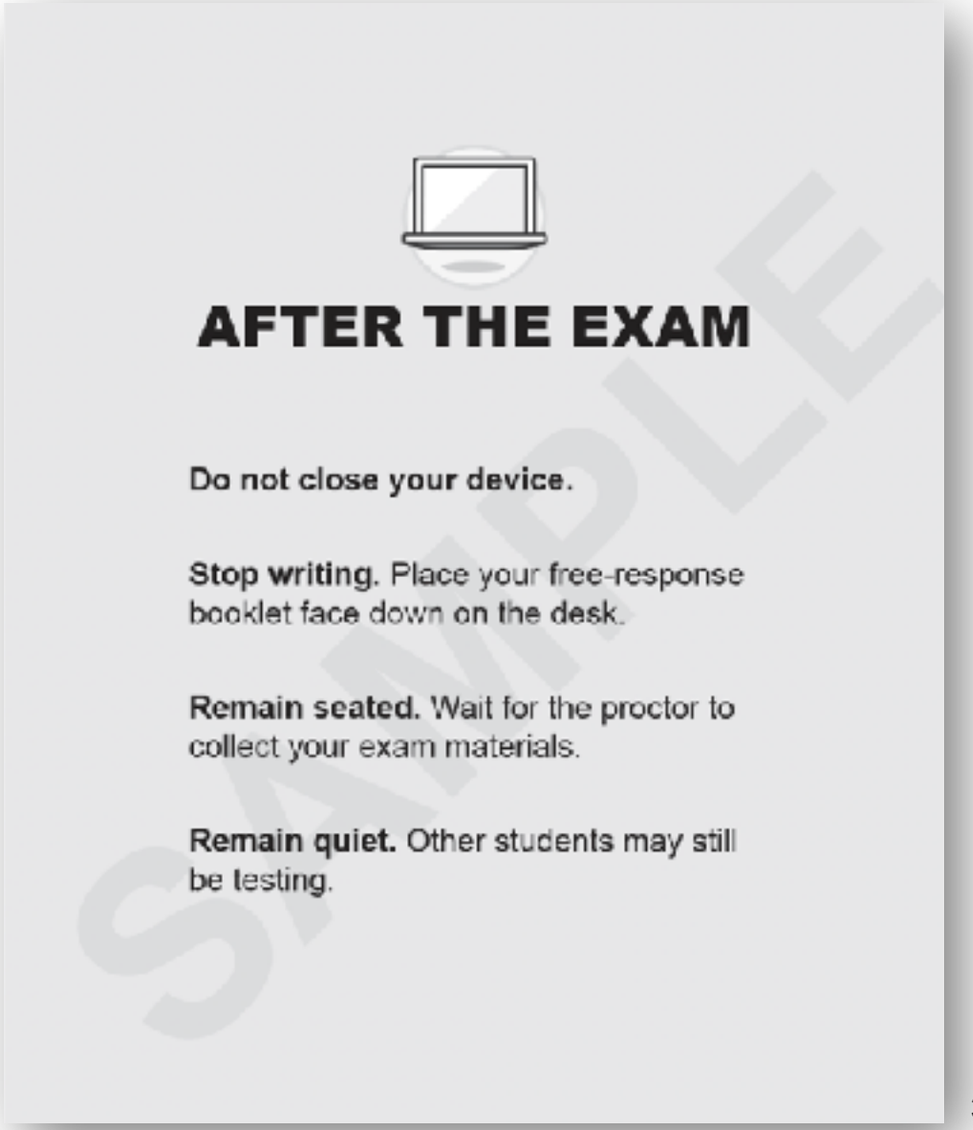
PART A

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

Developing the Science Practices

How your students will be asked to demonstrate **what** they know

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.	

Instructional Planning Report Data

CollegeBoard

Mech 2026

QUESTION 4 QUALITATIVE QUANTITATIVE TRANSLATION (QQT)	8		4.3
QQT PART A POINT 1	1		0.8
QQT PART A POINT 2	1		0.6
QQT PART A POINT 3	1		0.4
QQT PART B POINT 1	1		0.6
QQT PART B POINT 2	1		0.5
QQT PART B POINT 3	1		0.3
QQT PART C POINT 1	1		0.6
QQT PART C POINT 2	1		0.3

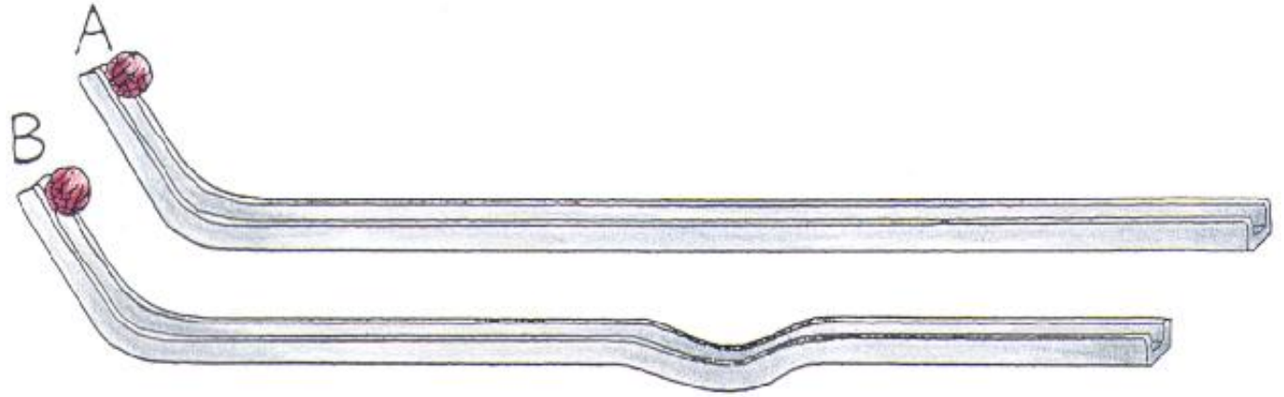
E&M 2026

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

Instructional Strategies for Effective Writing in AP Physics

Oather Strawderman

International Lead
AP Physics Consultant



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.



Scientific Writing

Strategies and Processes



CER

Claim

Evidence

Reasoning

- Framework for writing scientific arguments
- Tool students can use to answer “Justify your answer” questions
- Students may be familiar with this framework from other classes
- **Claim**: short statement that answers the question
- **Evidence**: information from the question or event description
- **Reasoning**: using Physics principles to synthesize your evidence into your Claim

Switch-it Up

Focus on the order

- CER is a great method, but…..
- Don’t start with answering the question!!
- Most of the time when students start with an answer it comes from their gut and not their brain, seen it thousands of times at the Reading
- Start with things they see and then tie them to Physics principles

ERC

Evidence

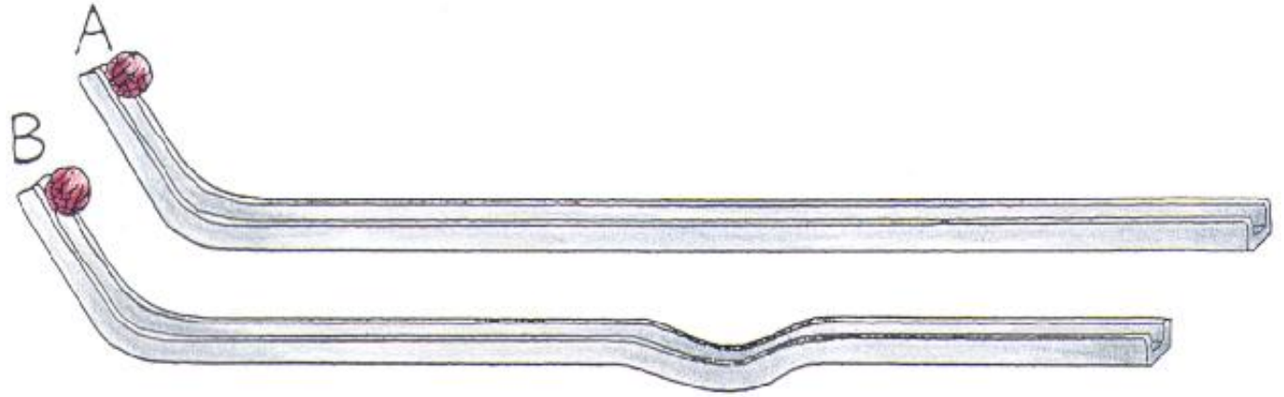
Reasoning

Claim

- NEW ORDER

- **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

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.



ERC

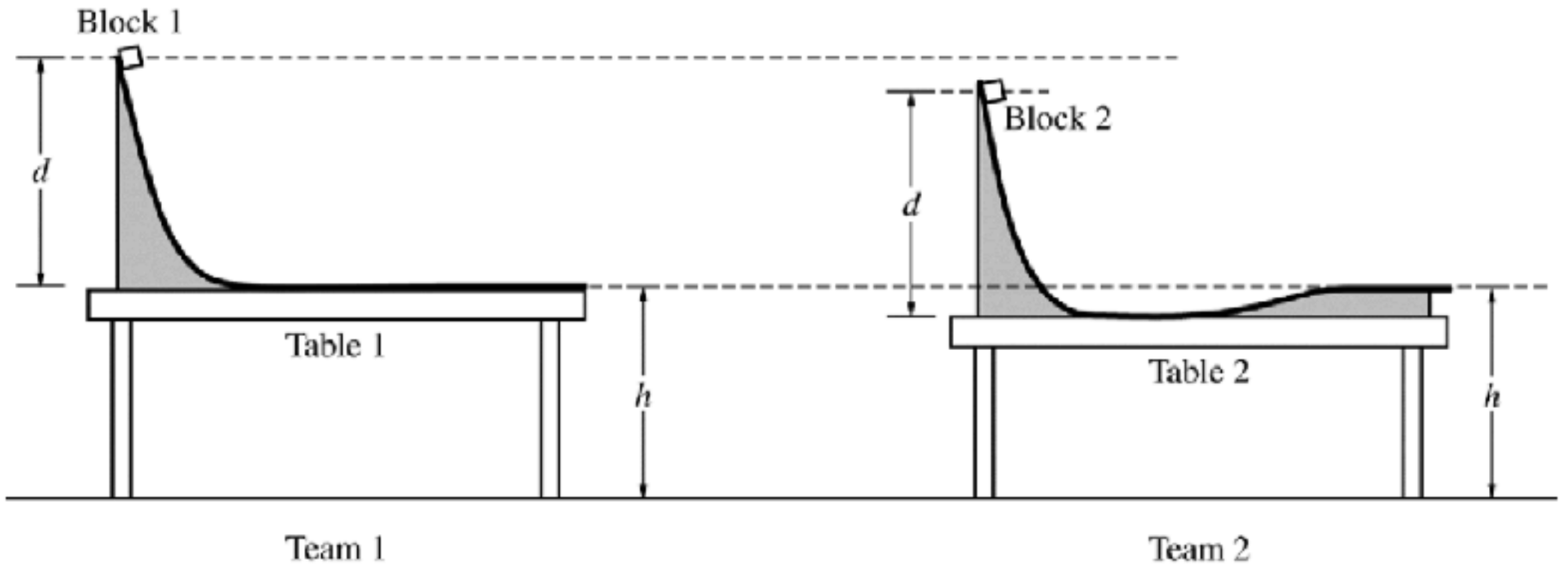
Evidence

Reasoning

Claim

- NEW ORDER

- **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



4. (7 points, suggested time 13 minutes)

A physics class is asked to design a low-friction slide that will launch a block horizontally from the top of a lab table. Teams 1 and 2 assemble the slides shown above and use identical blocks 1 and 2, respectively. Both slides start at the same height d above the tabletop. However, team 2's table is lower than team 1's table. To compensate for the lower table, team 2 constructs the right end of the slide to rise above the tabletop so that the block leaves the slide horizontally at the same height h above the floor as does team 1's block (see figure above).

(a) Both blocks are released from rest at the top of their respective slides. Do block 1 and block 2 land the same distance from their respective tables?

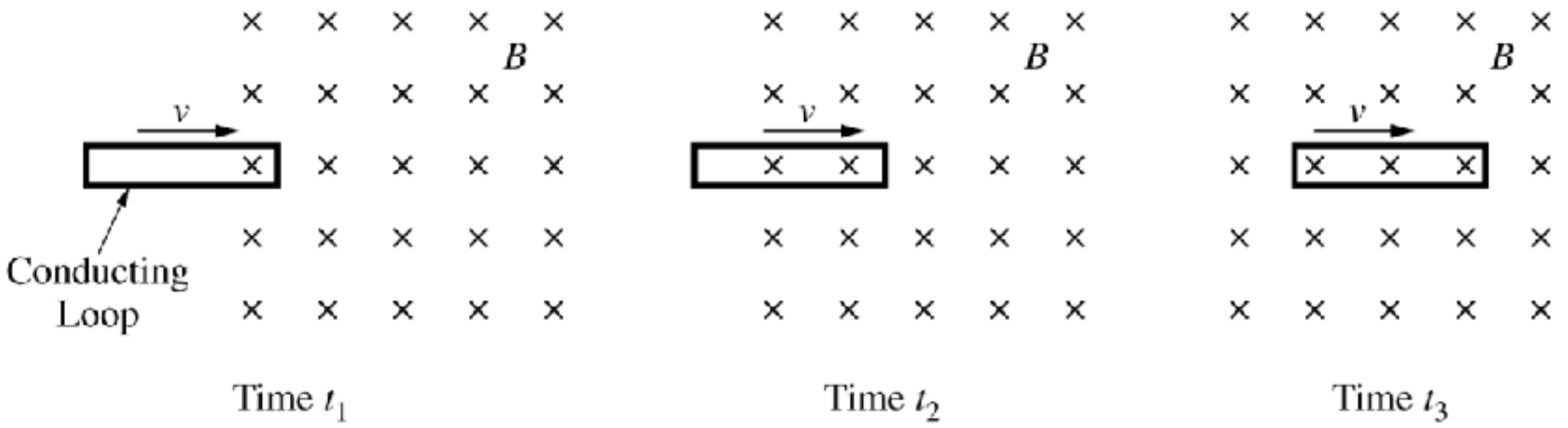
____ Yes ____ No

Justify your answer.

For attempting to use conservation of energy to compare the two blocks — 1 point
For explicitly or implicitly indicating that the launch velocities are different — 1 point
For stating or implying that the time to reach the ground is the same for both blocks — 1 point

Example: The amount of potential energy converted to kinetic energy is different for the two blocks. The potential energy is proportional to the change in height, which is smaller for block 2. Therefore, at the edge of the table, block 1 will have more kinetic energy than block 2, and hence a larger speed. The launches are both horizontal and from the same height, so the blocks will spend the same amount of time in the air. Because $d = vt$, the distances will be different for the two blocks (as the speeds are different).

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1. (10 points, suggested time 20 minutes)

The figures above show a rectangular conducting loop at three instants in time. The loop moves at a constant speed v into and through a region of constant, uniform magnetic field B directed into the page. The magnetic field is zero outside the region.

(a) In a coherent paragraph-length response, compare the magnitude and direction of the current at times t_1, t_2, and t_3. Include an explanation of why there is or is not a current and the direction of the current if one is present. Use fundamental physics concepts and principles in your explanation.

CollegeBoard

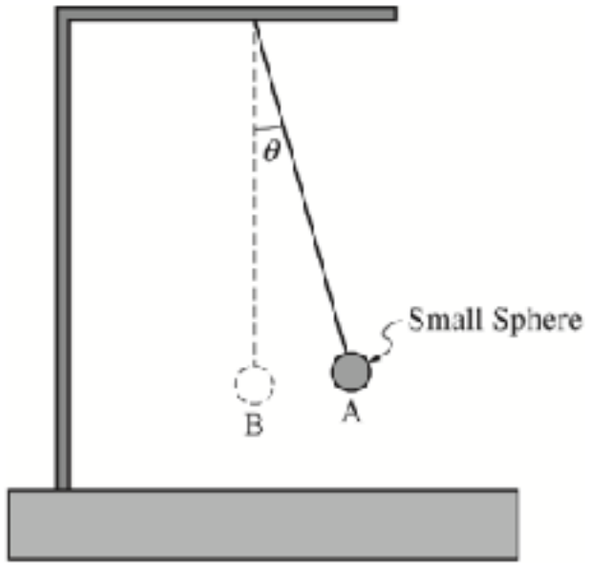
For indicating that the currents at t_1 and t_2 have equal nonzero magnitudes and are in the same direction		1 point
For indicating that there is no current at t_3		1 point
For correctly indicating that the currents depend on the change in flux through the loop or the forces on the charges moving in the field		1 point
For correctly identifying the direction of the current as counter-clockwise and either explaining that the direction of the current generates a magnetic field that opposes the change in flux or analyzing the force on the charge carriers in each segment of the loop		1 point
For an on-topic response that has sufficient paragraph structure, as described in the published requirements for the paragraph length response		1 point

CollegeBoard

A new pendulum is made by hanging the same small sphere from a different string with negligible mass. The new string is slightly elastic, and the length of the string may increase or decrease depending on the tension applied to the string. On Earth, when the sphere is again displaced θ from the vertical and released from rest, the new pendulum oscillates with period T_E.

The new pendulum is then taken to a different planet, Planet Y. The radius of Planet Y is the same as the radius of Earth, but the mass of Planet Y is larger than the mass of Earth. On Planet Y, when the sphere is again displaced from the vertical and released from rest, the new pendulum oscillates with period T_Y.

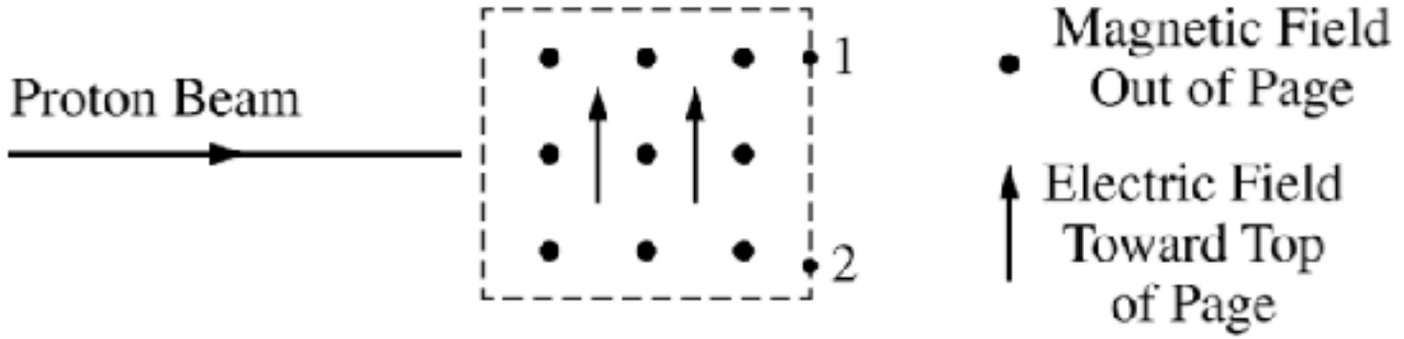
(b) In a clear, coherent paragraph-length response that may also contain drawings, **explain** how T_Y could be larger than T_E but also could be smaller than T_E.



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For relating a larger planetary mass to a **one** of the following: • A larger weight of the sphere • A larger acceleration due to gravity g • A larger gravitational field strength	**1 point**
For indicating that the period is inversely related to **one** of the following: • The acceleration due to gravity g • The gravitational field strength	**1 point**
For indicating that the amount of stretch is dependent on **one** of the following: • The weight of the sphere • The acceleration due to gravity g • The gravitational field strength	**1 point**
For relating the length of the string to the period of the pendulum	**1 point**

2019 AP® PHYSICS 2 FREE-RESPONSE QUESTIONS



Another region of space contains an electric field directed toward the top of the page and a magnetic field directed out of the page. Both fields are constant and uniform. A horizontal beam of protons with a variety of speeds enters the region, as shown above. Protons exit the region at a variety of locations, including points 1 and 2 shown on the figure. In a coherent, paragraph-length response, explain why some protons exit the region at point 1 and others exit at point 2. Use physics principles to explain your reasoning.

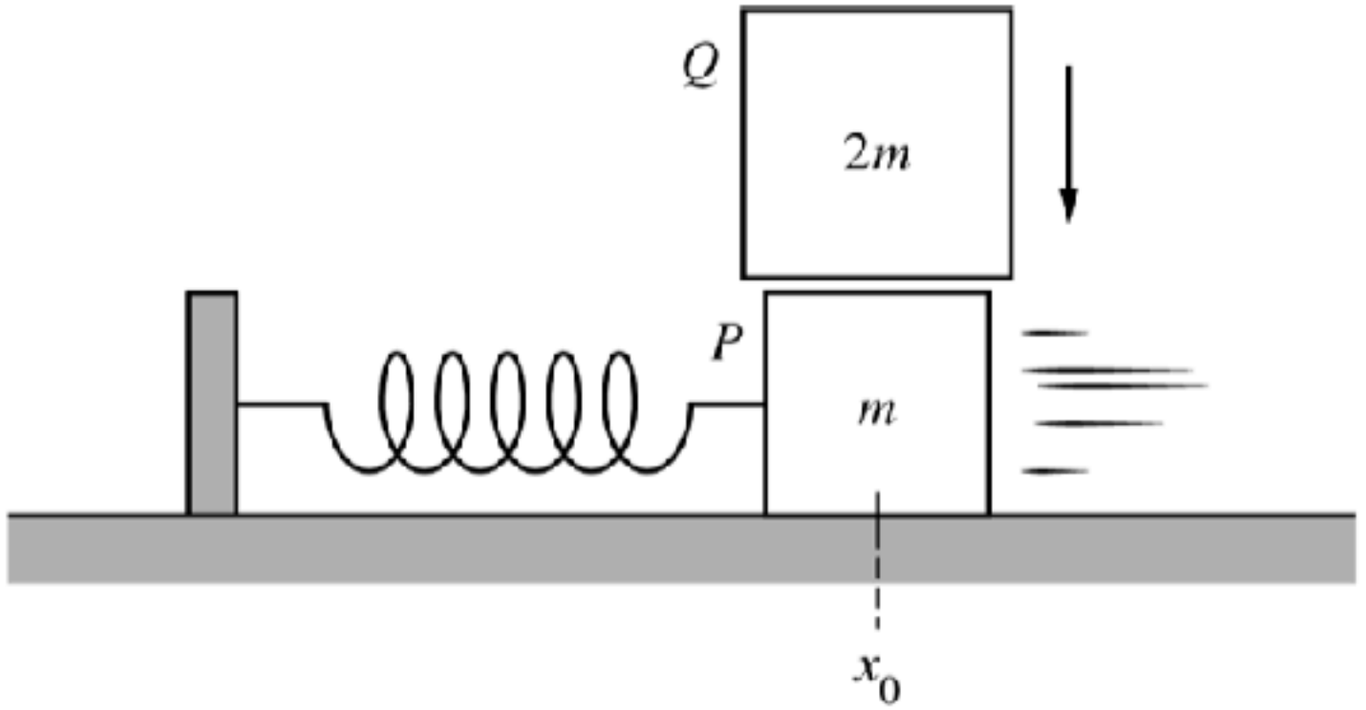
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For indicating that initially the electric and magnetic forces act in opposite directions		1 point
For indicating or implying that the magnetic force is affected by speed, but the electric force is not		1 point
For indicating that different paths occur as a result of the addition of forces		1 point
For indicating that slower protons exit higher than faster protons (i.e., slower protons exit at point 1 and faster protons exit at point 2)		1 point
For a logical, relevant, and internally consistent argument that addresses the question asked and follows the guidelines described in the published requirements for the paragraph-length response		1 point
Example: For a charged particle to travel through the region undeflected, the net force on it must be zero. This means that the upward electric force and the downward magnetic force must be equal and opposite to each other. This occurs for a particular speed. The electric force is independent of the particle's velocity, but the magnetic force will be larger for greater velocities and less for smaller velocities. If a particle is moving faster than the particular speed, it will experience a greater magnetic force and be deflected downward. If it is moving more slowly than the particular speed, it will be deflected upward.		

CollegeBoard

ERC

2018 P1 FRQ #5



(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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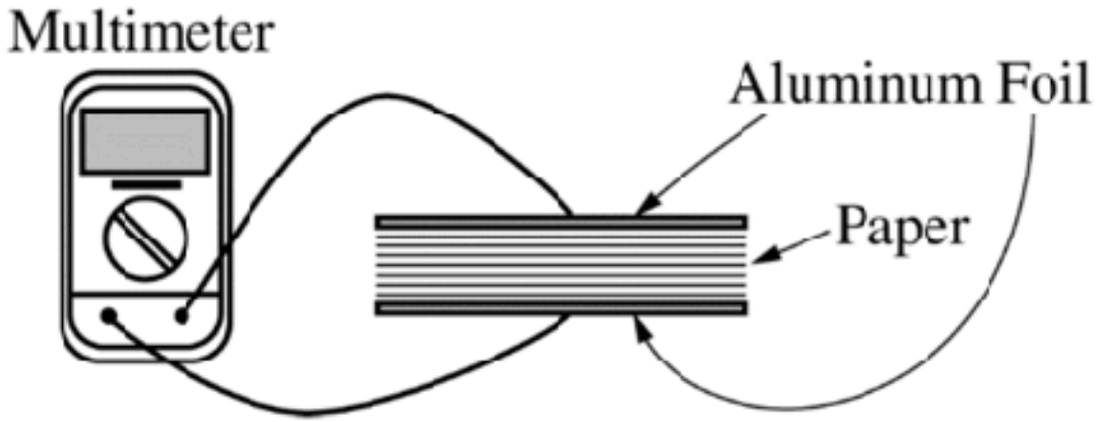
Correct answer: $A_{PQ} < A_P$. Note: The response is graded even if an incorrect selection is made.		
For applying conservation of momentum to the collision		1 point
For correctly finding that the post-collision speed has decreased (or, for determining that $v_f = \frac{1}{3}v_i$)		1 point
Note: The first 2 points can be earned for stating that the collision is inelastic		
For stating or implying that the system's kinetic energy has decreased (or, for calculating a lower final kinetic energy)		1 point
For stating or implying kinetic energy of blocks right after collision equals maximum potential energy of spring OR For stating or implying that the maximum potential energy equals the total mechanical energy just after the collision (Simply stating that $E_{\text{tot}} = \frac{1}{2}kA^2$ is sufficient.)		1 point
For stating or implying that maximum potential energy is reached when the displacement from equilibrium equals the amplitude of oscillation		1 point
Note: The previous 2 points can be earned in a single sentence in which one or both of the points is implicit.		

Tips

Just write it!

- Write every day!
- Start small, one sentence statements
- Start early!!
- Scaffold what you are asking them to do both Physics wise and writing wise….don't jump into lengthy responses in Unit 1
- Give them a framework to use that you teach and continually use…just like you do with Quantitative problems
- Present material in ways that foster writing vs just computation
- Show students the rubrics

2018 AP Physics C: E&M FRQ #2



A group of students are asked to take measurements that will allow the students to create a linear graph whose slope could be used to determine the dielectric constant of paper using the setup shown.

A. **Describe** an experimental procedure to collect data that would allow the students to determine the dielectric constant of paper. Include any steps necessary to reduce experimental uncertainty.

B. **Describe** how the data collected in part A could be graphed and how that graph would be analyzed to determine the dielectric constant of paper.

SHM LAB FRQ: Mech Unit 7 Progress Check FRQ#3

AP CollegeBoard

AP PHYSICS C: MECHANICS

Test Booklet

Unit 7 Progress Check: FRQ 3

1. Show all your work for each part of the question. The parts within the question may not have equal weight.

A scientist is on a space station orbiting another planet in an apparently weightless environment. The scientist is tasked with developing a method to measure the unknown mass of a rock sample that came from the planet's surface. The scientist has a collection of springs of different, known spring constants. The rock can be attached to each of the springs using a fastener of negligible mass.

(a) **Describe** an experimental procedure that (1) uses the springs with known spring constants and (2) would allow the scientist to determine the rock's mass by making a linear graph. Include steps necessary to reduce experimental uncertainty.

(b) For the data collected in the procedure from part (a), **describe** how the scientist could create a linear graph and how that graph would be analyzed to determine the rock's mass.

Pendulum LAB FRQ: Mech Unit 7 Progress Check FRQ#3



Figure 1

Down on the surface of the planet, an astronaut wishes to experimentally determine the planet's gravitational acceleration g_P. The astronaut grabs a small rock from the ground and attaches it to a string to make a simple pendulum, as shown in Figure 1. After measuring the string length L_S and the time t_{10} it takes the pendulum to make 10 small-angle oscillations, the string is cut to shorter and shorter lengths, with the procedure repeated for each length of string. The table shows the results of the astronaut's measurements.

Length of string L_S (m)	Time for 10 oscillations t_{10} (s)		
0.480	27.2		
0.350	24.1		
0.200	18.3		
0.100	13.3		
0.050	10.1		

Pendulum LAB FRQ: Mech Unit 7 Progress Check FRQ#3

AP CollegeBoard

Test Booklet

Unit 7 Progress Check: FRQ 3

(c)

i. **Indicate** what quantities could be graphed to yield a straight line that could be used to calculate an experimental value for g_P.

Horizontal axis: _____ Vertical axis: _____

Use the remaining columns in the table, as needed, to **record** any quantities indicated that are not already provided in the table. **Label** each column and include units.

ii. On the grid in Figure 2, **plot** the data points for the quantities indicated in part (c)(i). Clearly **scale** and **label** all axes, including units. On the same grid, **draw** a straight line that best represents the data.

(d) Using the line drawn in part (c)(ii), **calculate** an experimental value for g_P.

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TIPERs

Tasks Inspired by Physics Education Research

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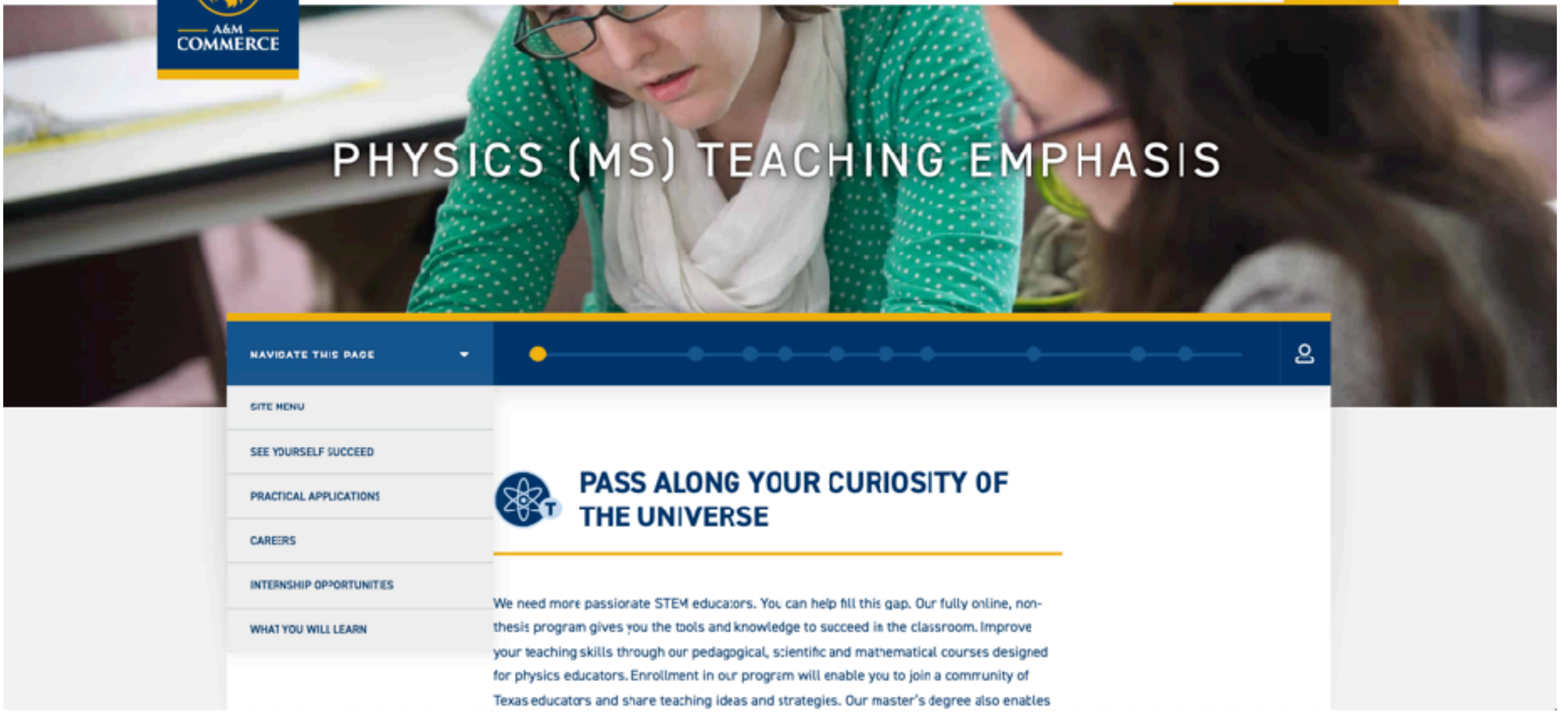
Physics Education Research

A field of research focused on understanding *how* students think about physics and how to teach physics more effectively.

"… focused inquiry into what happens as students struggle to grasp and use the concepts of physics."

How do students learn physics?

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SITE MENU
SEE YOURSELF SUCCEED
PRACTICAL APPLICATIONS
CAREERS
INTERNSHIP OPPORTUNITIES
WHAT YOU WILL LEARN
PASS ALONG YOUR CURIOSITY OF THE UNIVERSE
We need more passionate STEM educators. You can help fill this gap. Our fully online, non-thesis program gives you the tools and knowledge to succeed in the classroom. Improve your teaching skills through our pedagogical, scientific and mathematical courses designed for physics educators. Enrollment in our program will enable you to join a community of Texas educators and share teaching ideas and strategies. Our master's degree also enables

Using TIPERs

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

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

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PER Resources

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.

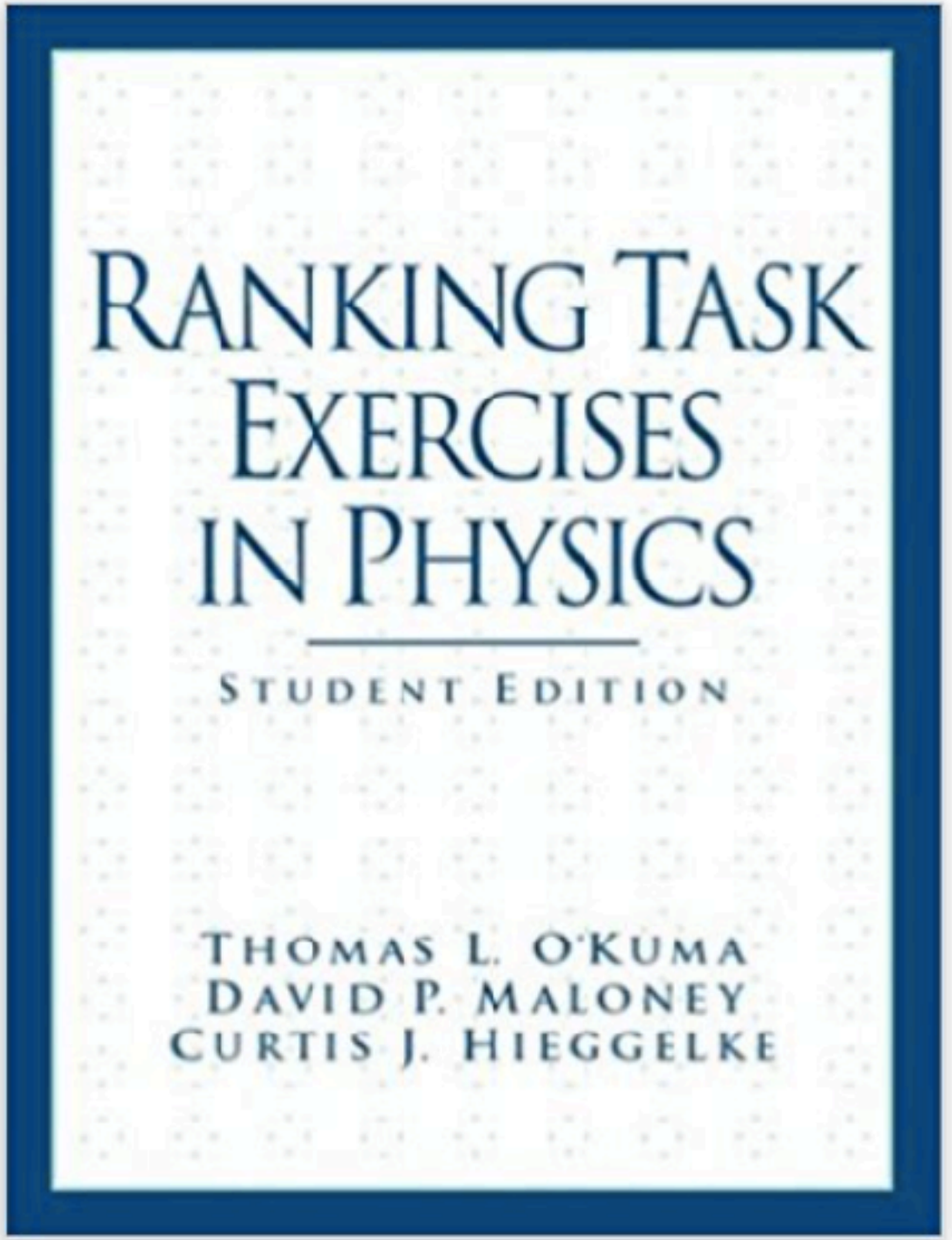
2.C Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.

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.


RANKING TASK
EXERCISES
IN PHYSICS
STUDENT EDITION
THOMAS L. O'KUMA
DAVID P. MALONEY
CURTIS J. HIEGGELKE

PEARSON SERIES IN EDUCATIONAL INNOVATION

TIPERs

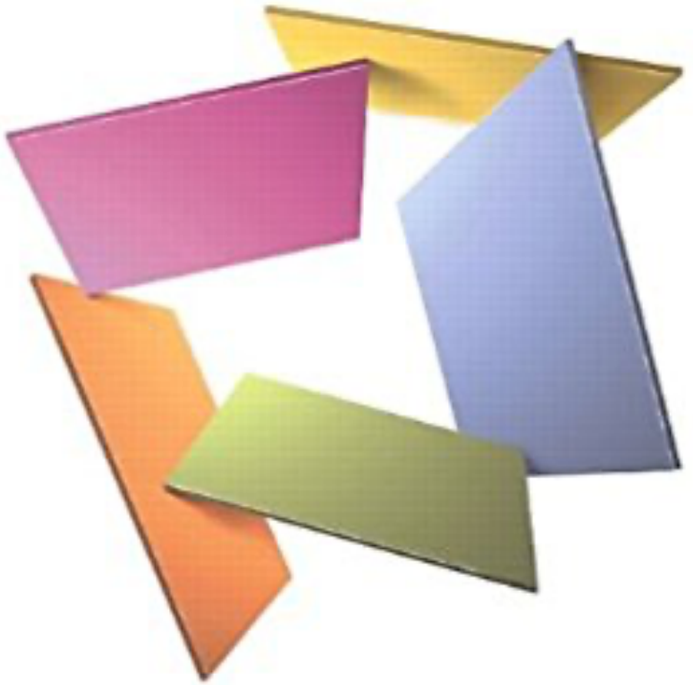
SENSEMAKING TASKS FOR INTRODUCTORY PHYSICS



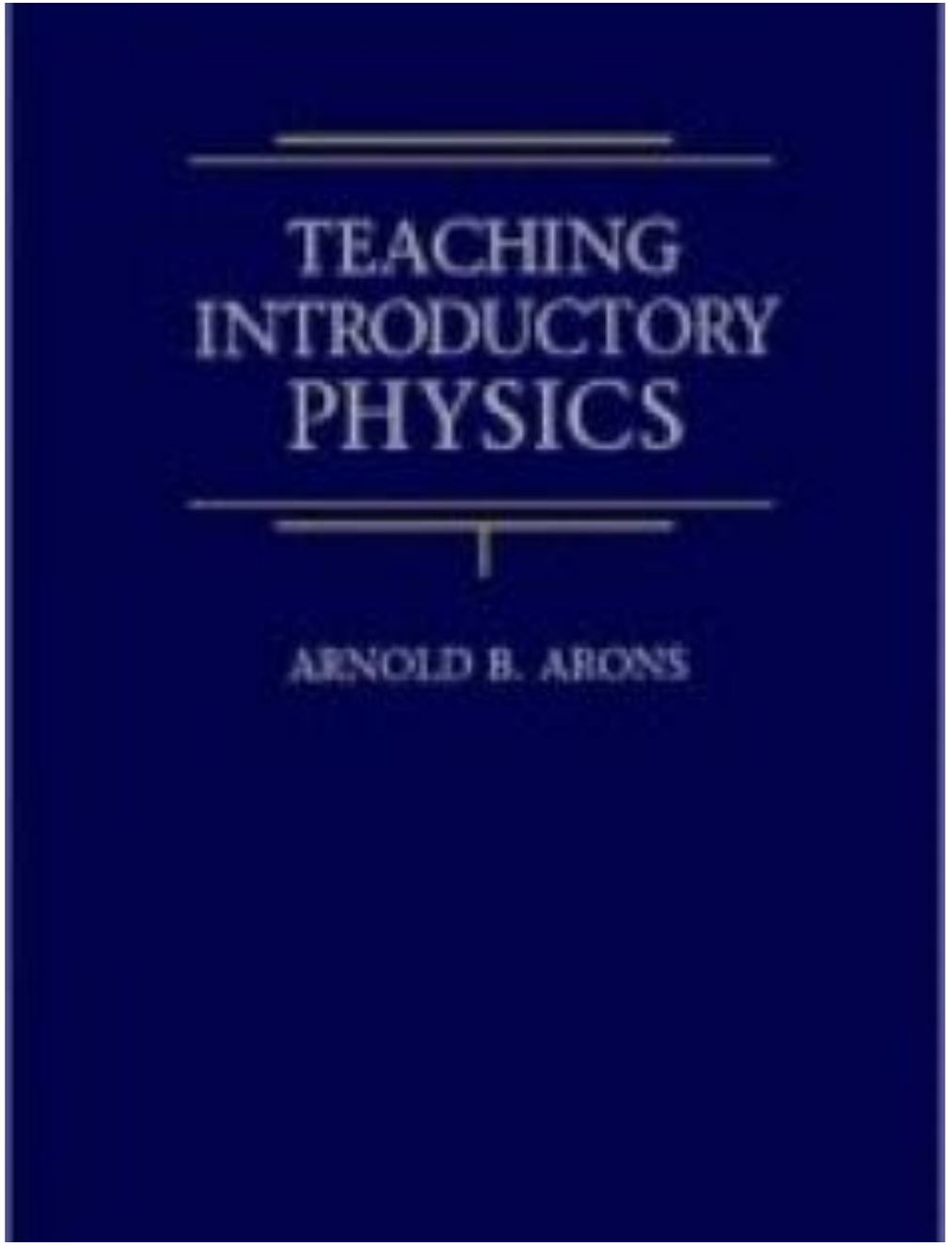
Hieggelke | Maloney | Kanim | O'Kuma

Five Easy Lessons

Strategies for Successful Physics Teaching



Randall D. Knight


TEACHING
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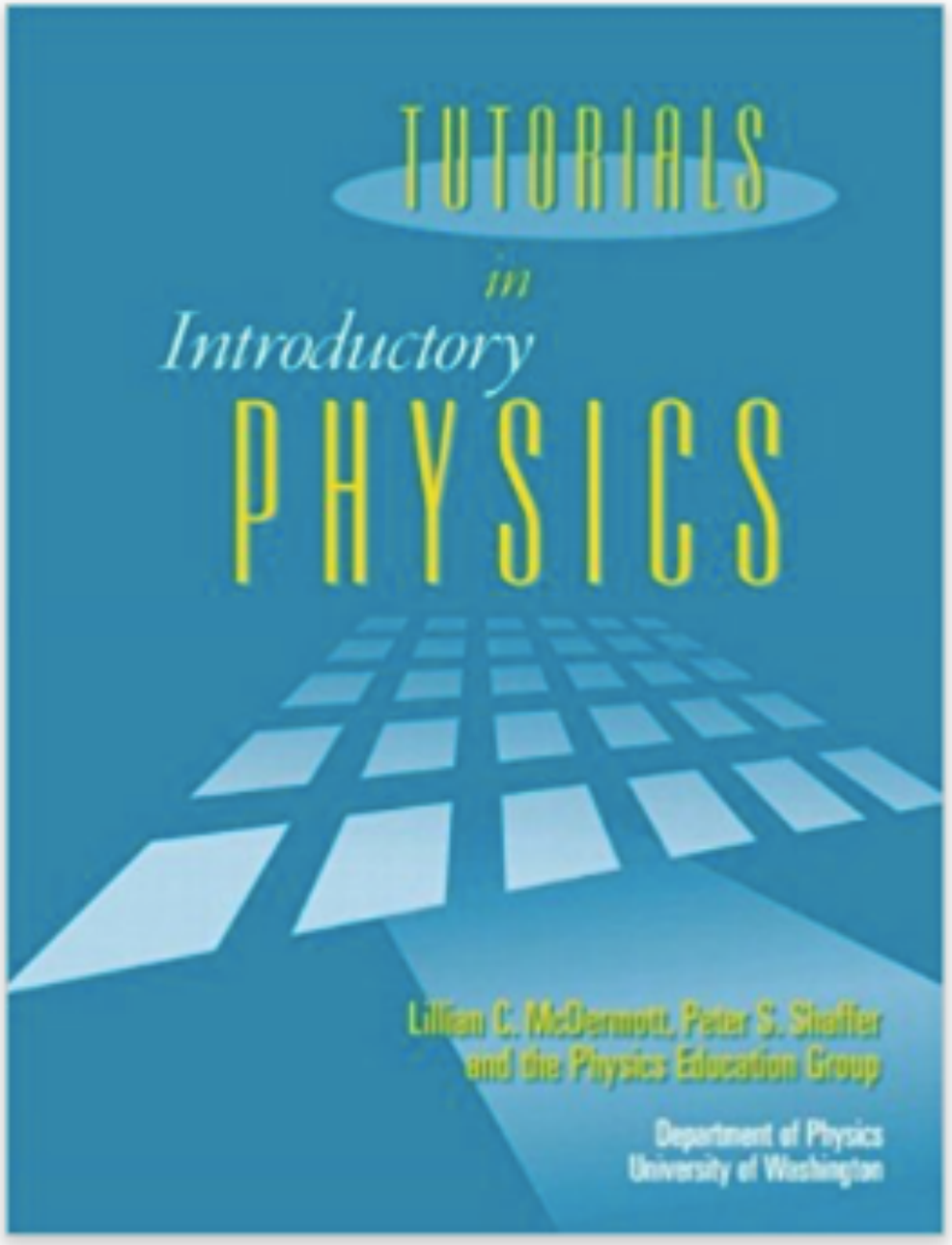
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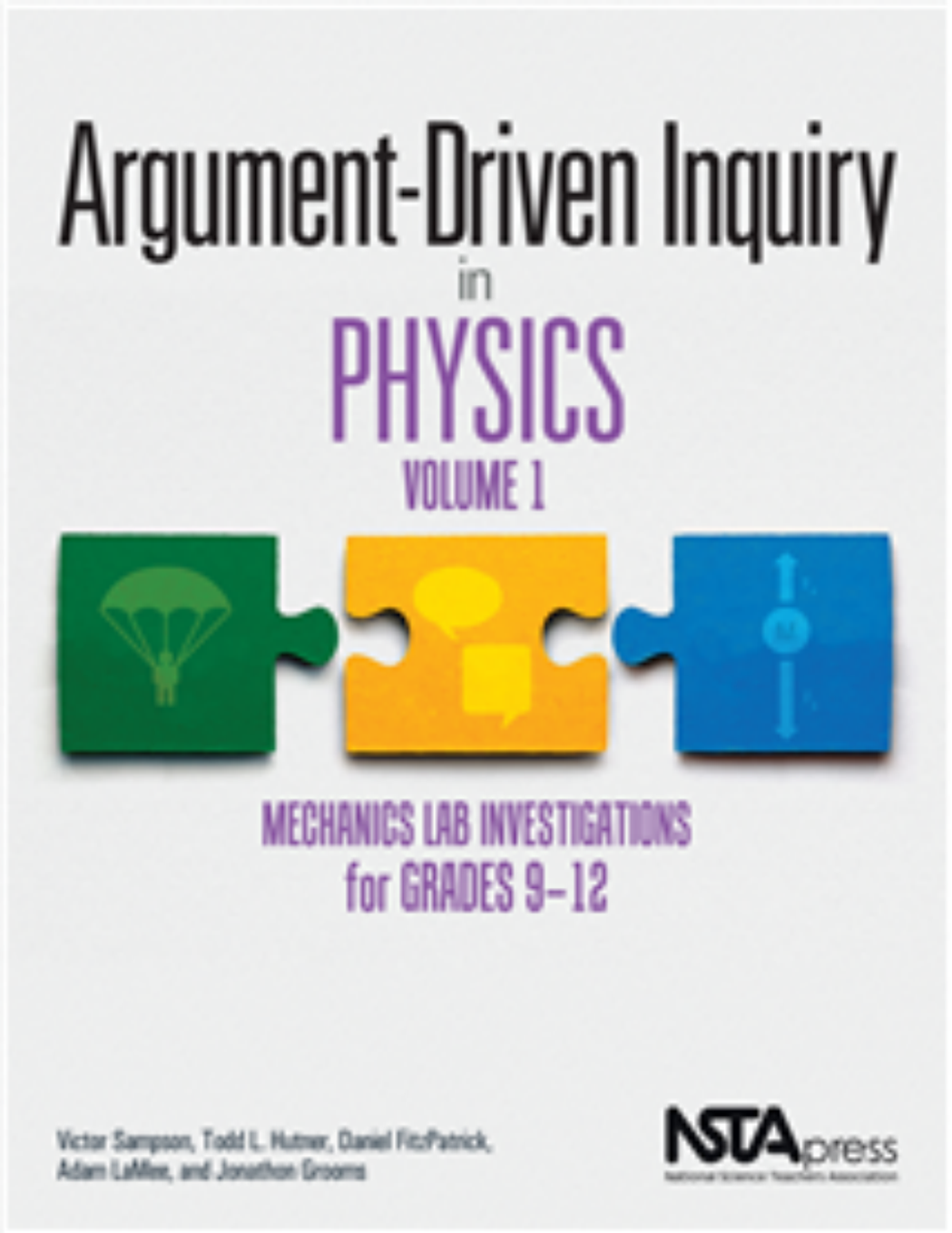
Cognitive Strategies for Improving Instruction

World Scientific

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May 2017
Volume 55 Number 5
The Physics Teacher
A publication of the American Association of Physics Teachers
AAPT


TUTORIALS
in
Introductory
PHYSICS
Lillian C. McDermott, Peter S. Shaffer
and the Physics Education Group
Department of Physics
University of Washington


Argument-Driven Inquiry
in
PHYSICS
VOLUME 1
MECHANICS LAB INVESTIGATIONS
for GRADES 9–12
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Conceptual Physics Volume 1

Designed to Support the NGSS*



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Mare Sullivan
Editor

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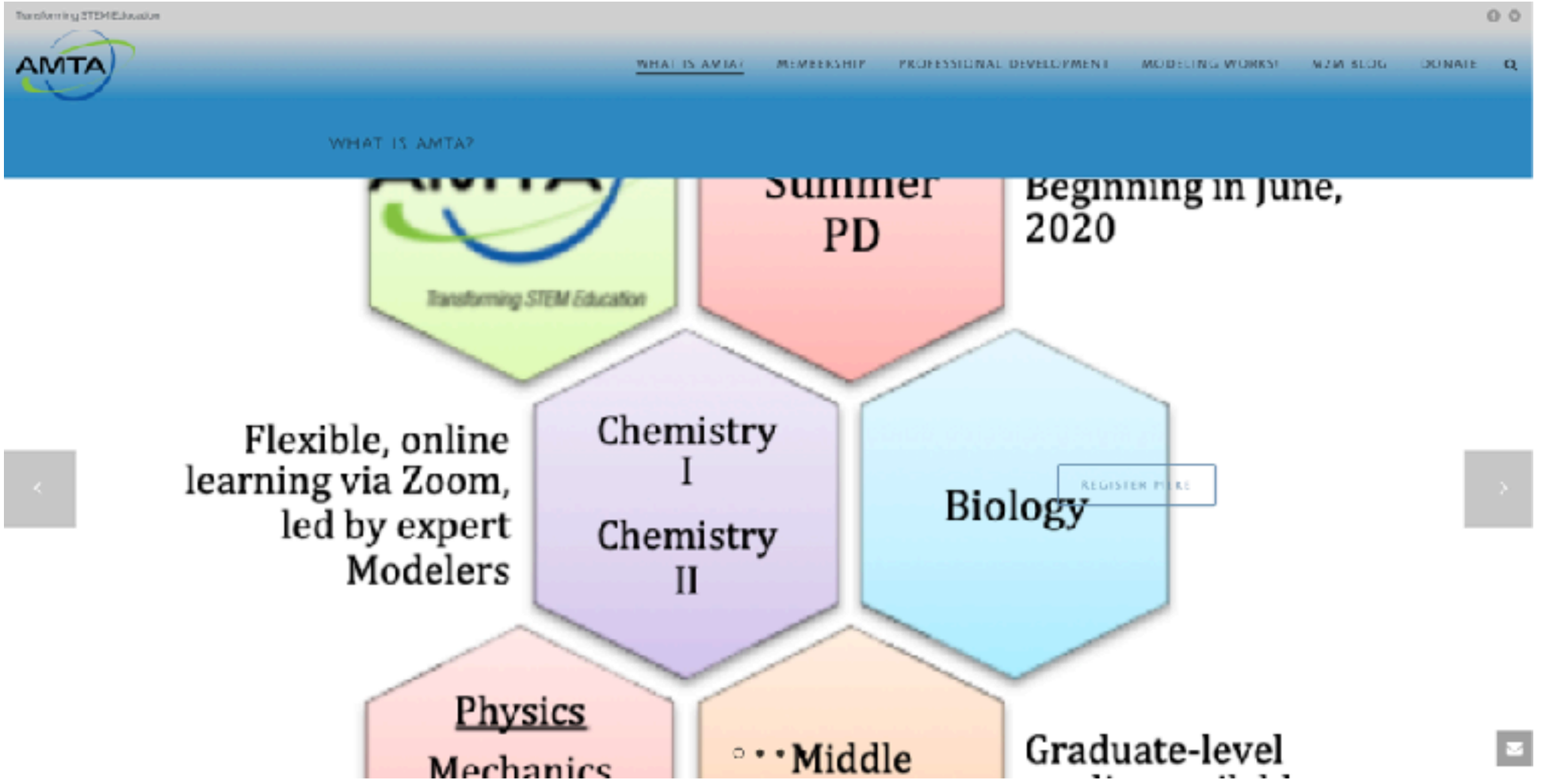
Conceptual Physics Volume 2

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Mare Sullivan
Editor


AMTA
WHAT IS AMTA?
Transforming STEM Education
Summer PD
Beginning in June, 2020
Flexible, online learning via Zoom, led by expert Modelers
Chemistry I
Chemistry II
Biology
Physics
Mechanics
Middle
Graduate-level

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

CollegeBoard

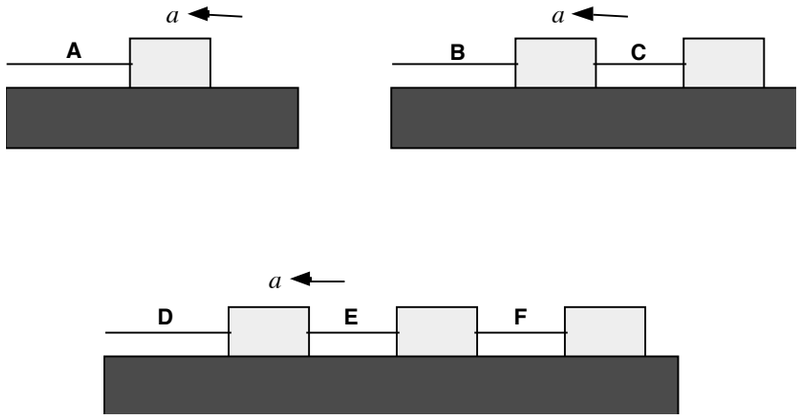
Ranking Task Exercises: Common Elements

- 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)

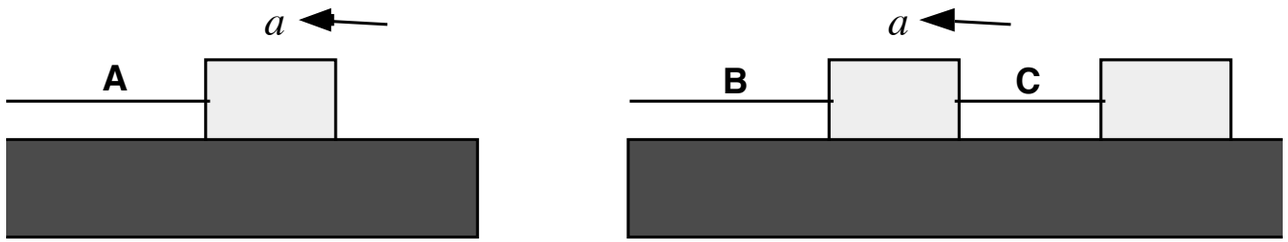
Basically Guessed				Sure				Very Sure	
1	2	3	4	5	6	7	8	9	10

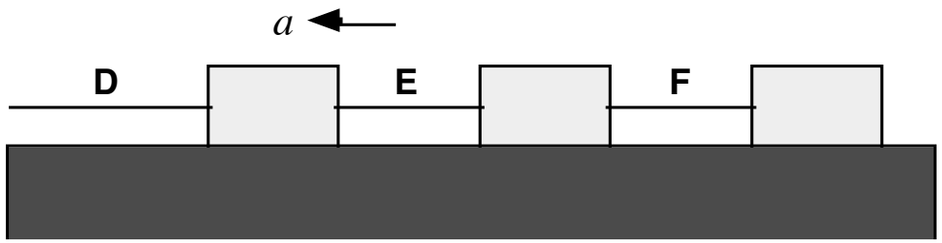
[27] S. Loucks

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.

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





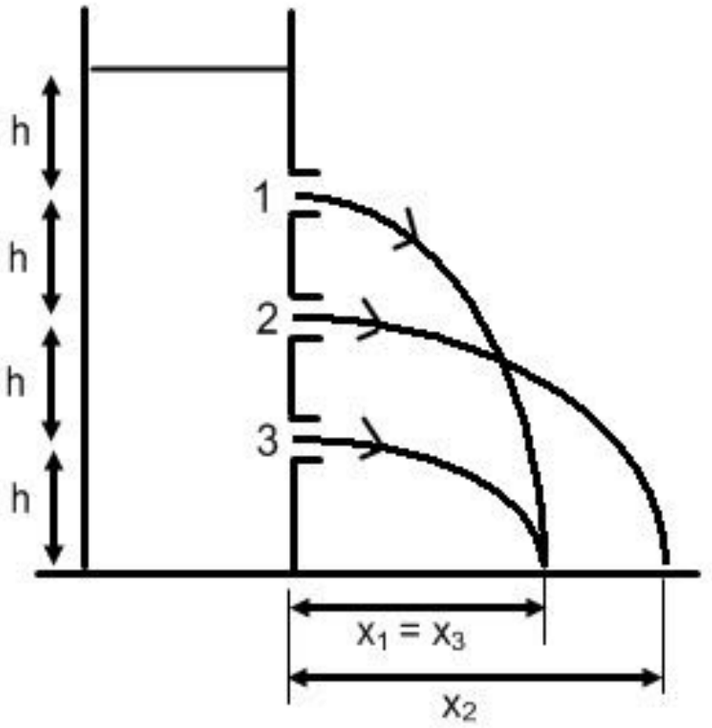
Greatest 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ Least

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

Please carefully explain your reasoning.

Ranking Task

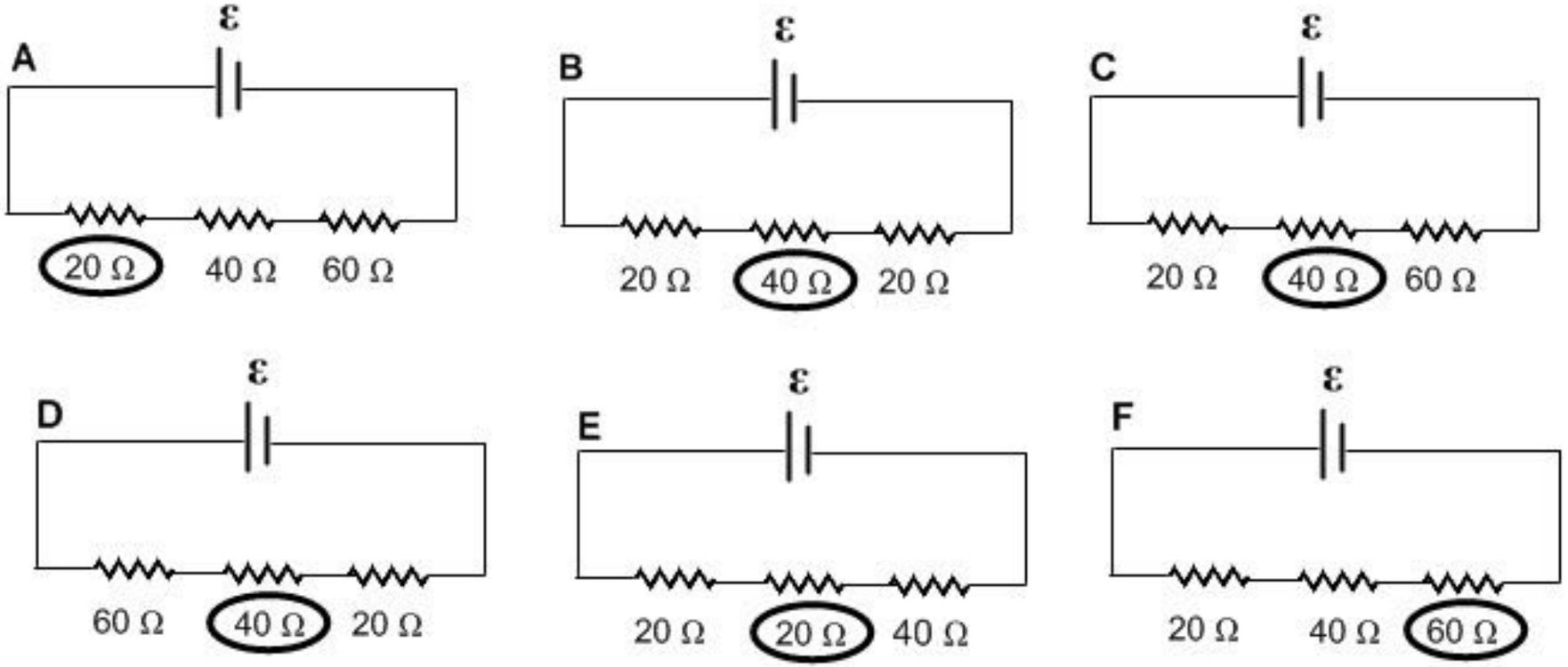
A physics experiment is performed with a can full of water that has three openings spaced at equal intervals **h** above the base of the can. The can is open to the atmosphere, and the speed of the water at the top of the can is approximately equal to zero. The result of the experiment is shown on the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

CollegeBoard

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.

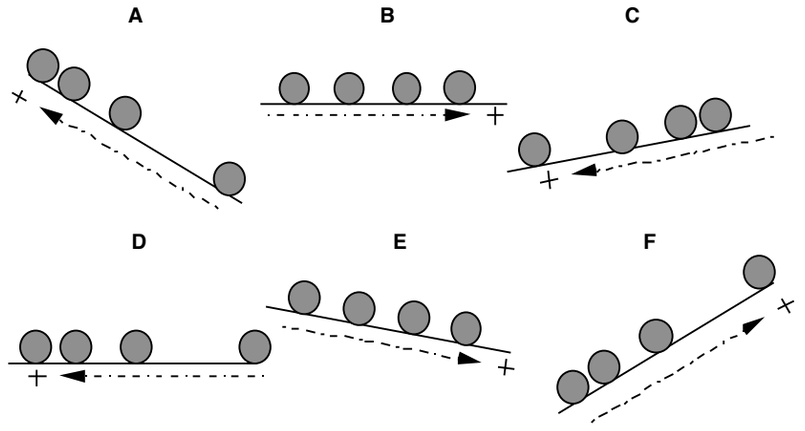


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Ball Motion Diagrams—Acceleration II [4]

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.

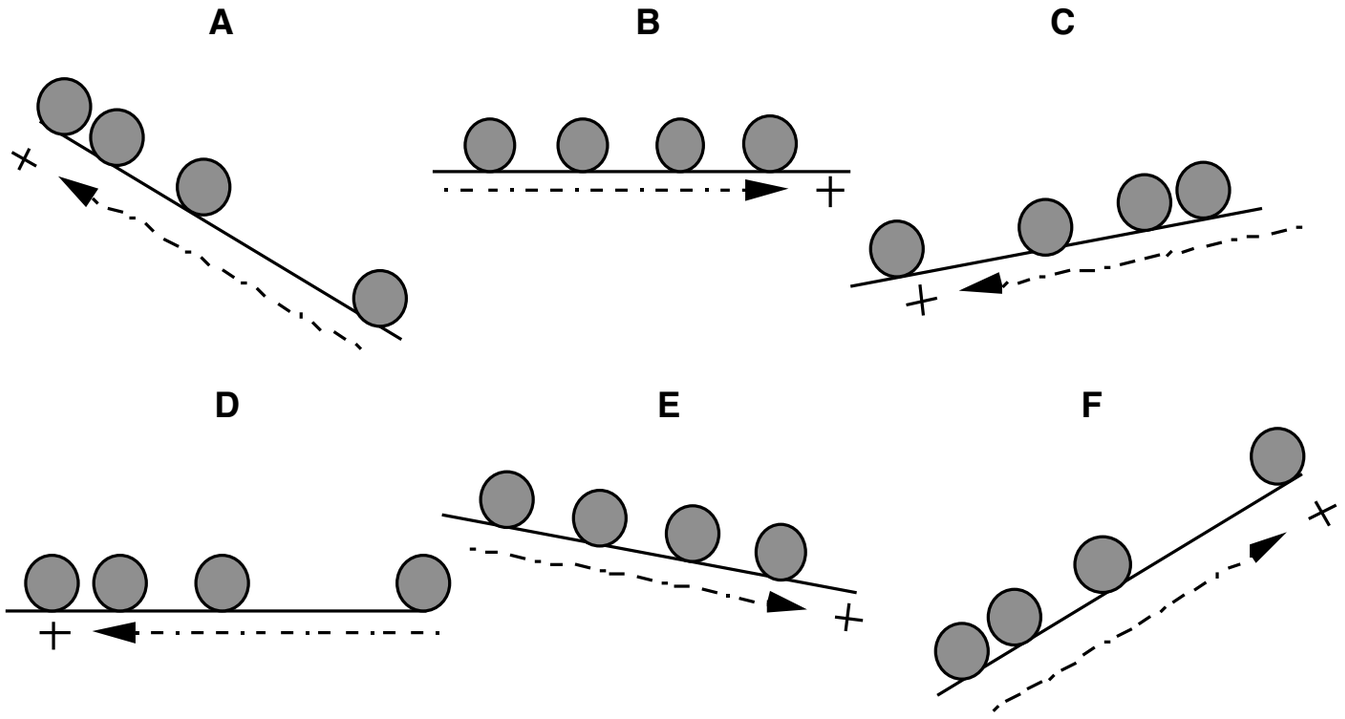
How sure were you of your ranking? (circle one)

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."

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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."

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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.

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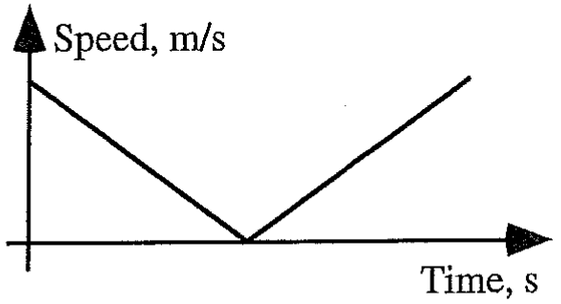
Conflicting Contentions Tasks

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

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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."*

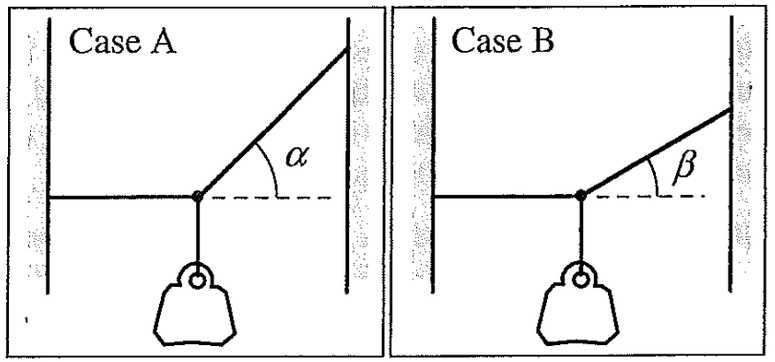
With which, if any, of these three students do you agree?

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."*

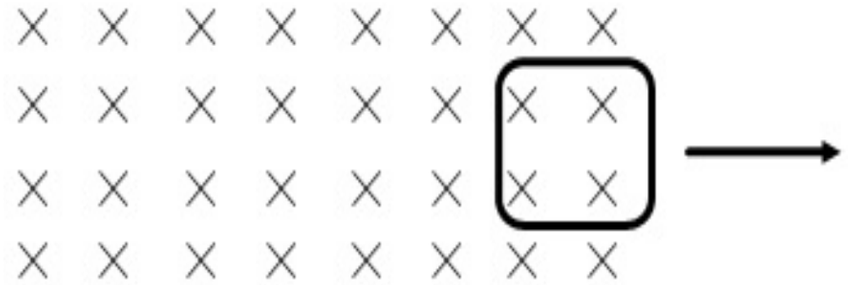
With which, if any, of these students do you agree?

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:

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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.*

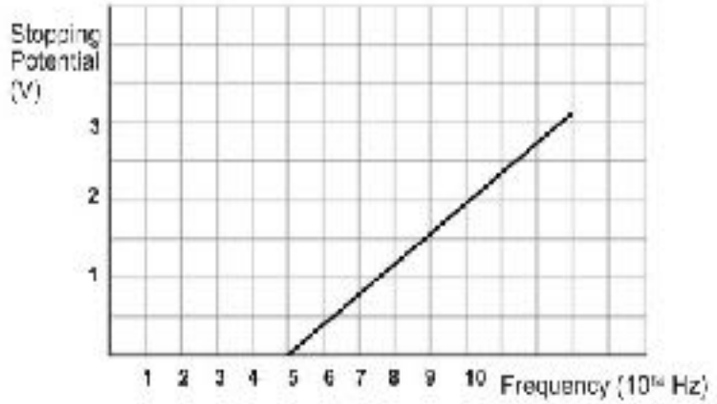
Student B: *There is no induced current since the loop is only halfway inside the magnetic field and does not receive the full effect of the magnetic field region.*

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.*

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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:

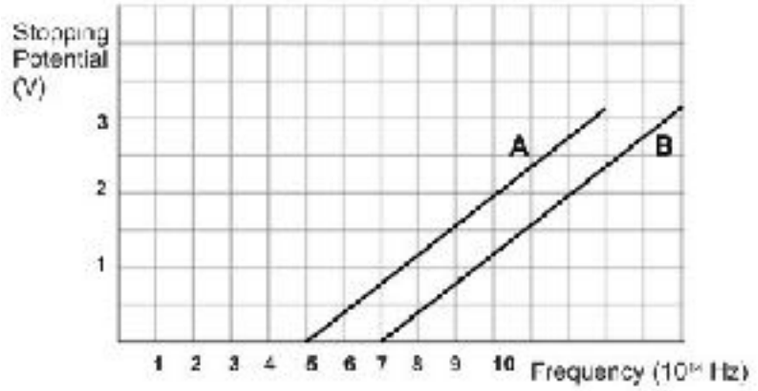


Students in a physics class were asked to draw an expected graph for a different metal surface with a threshold frequency of 7.0×10^{14} Hz. Three students' responses to this task are given.

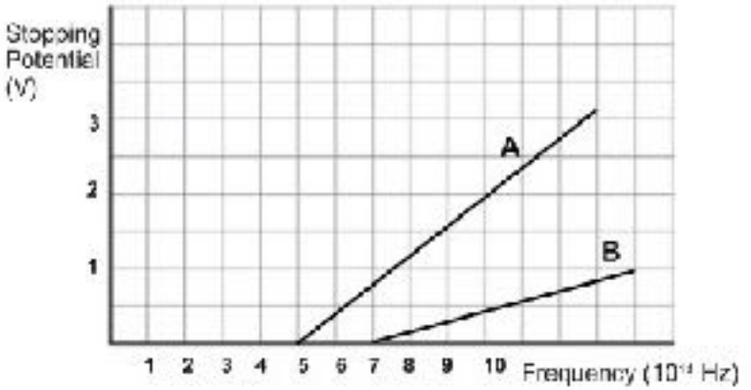
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Conflicting Contentions Task P2

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.

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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 ."

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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

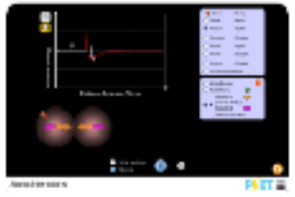
91 Results

A-Z

Physics × Java via CheerpJ × HTML5 ×



Alpha Decay



Atomic Interactions



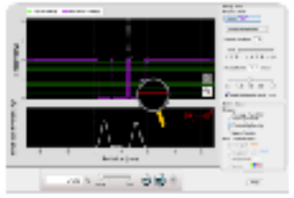
Balancing Act



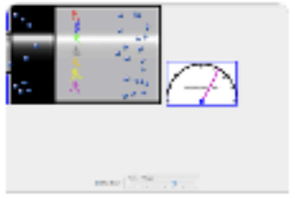
Balloons & Buoyancy



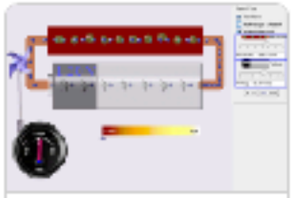
Balloons and Static Electricity



Band Structure



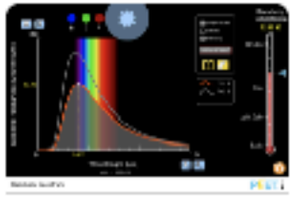
Battery Voltage



Battery-Resistor Circuit



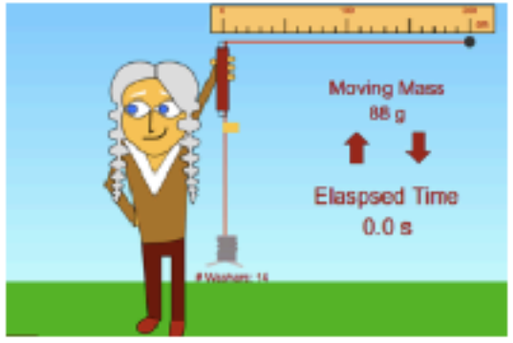






The Physics Aviary

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.

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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

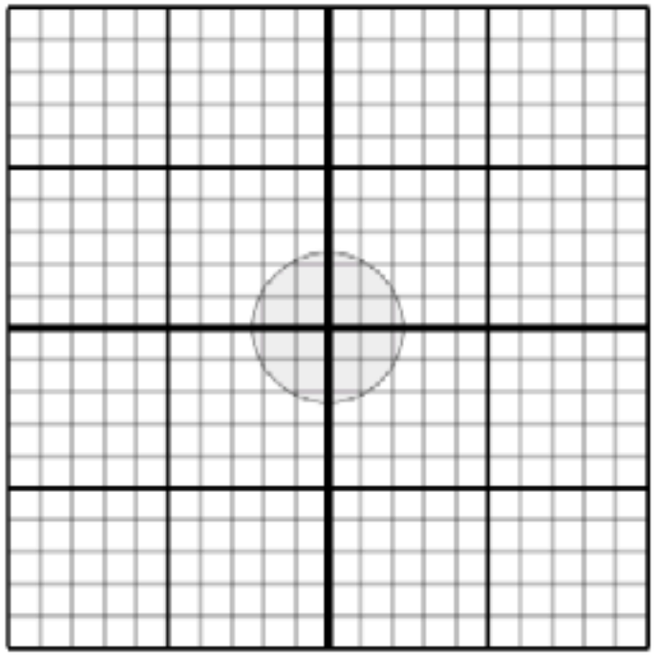
For graphing appropriate quantities whose slope can be used to calculate resistance directly or indirectly	1 point
For correctly stating how the slope relates to the resistivity	1 point

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)

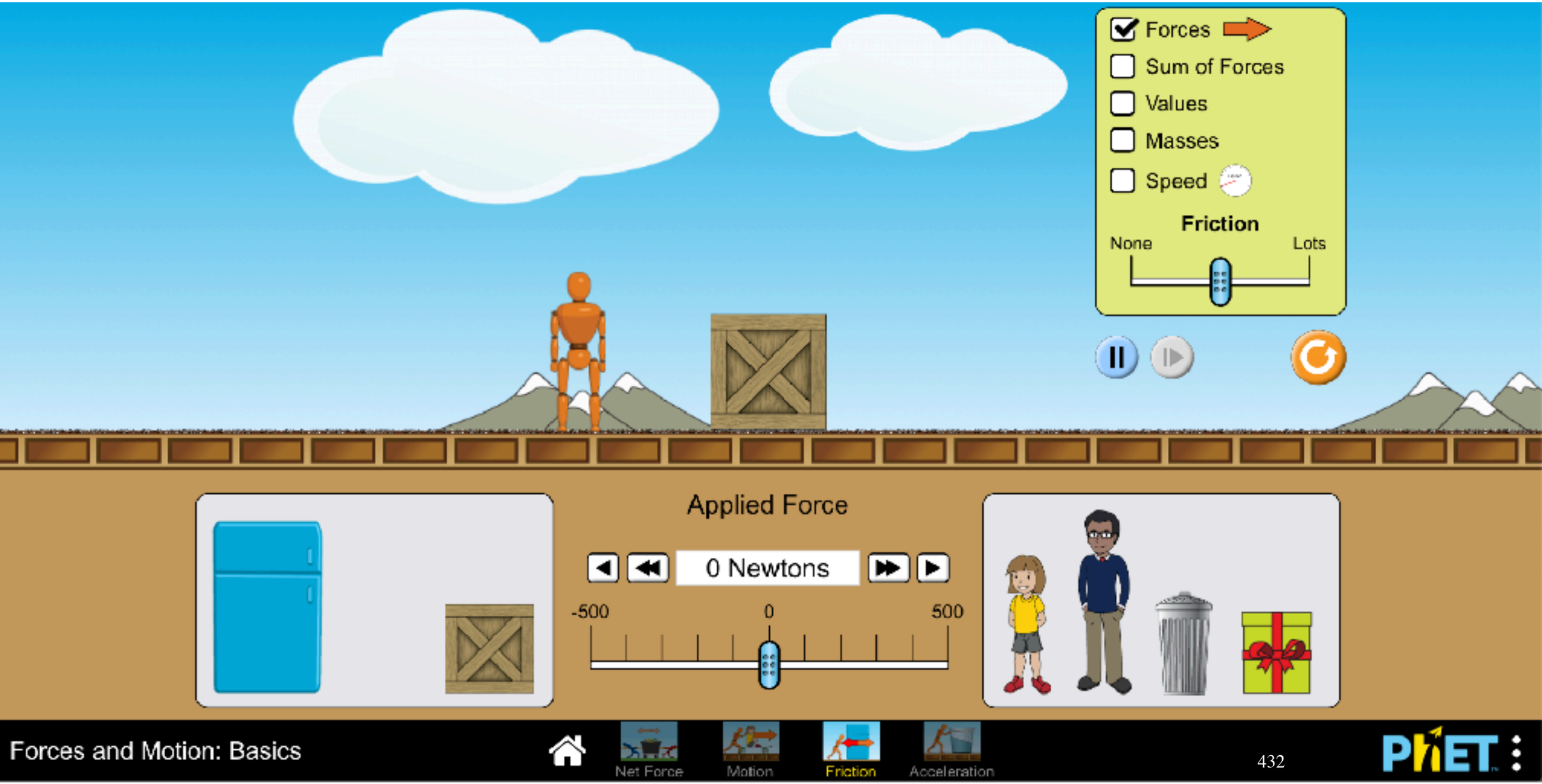
A student wants to determine the coefficient of static friction between a long, flat wood board and a small wood block.

(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

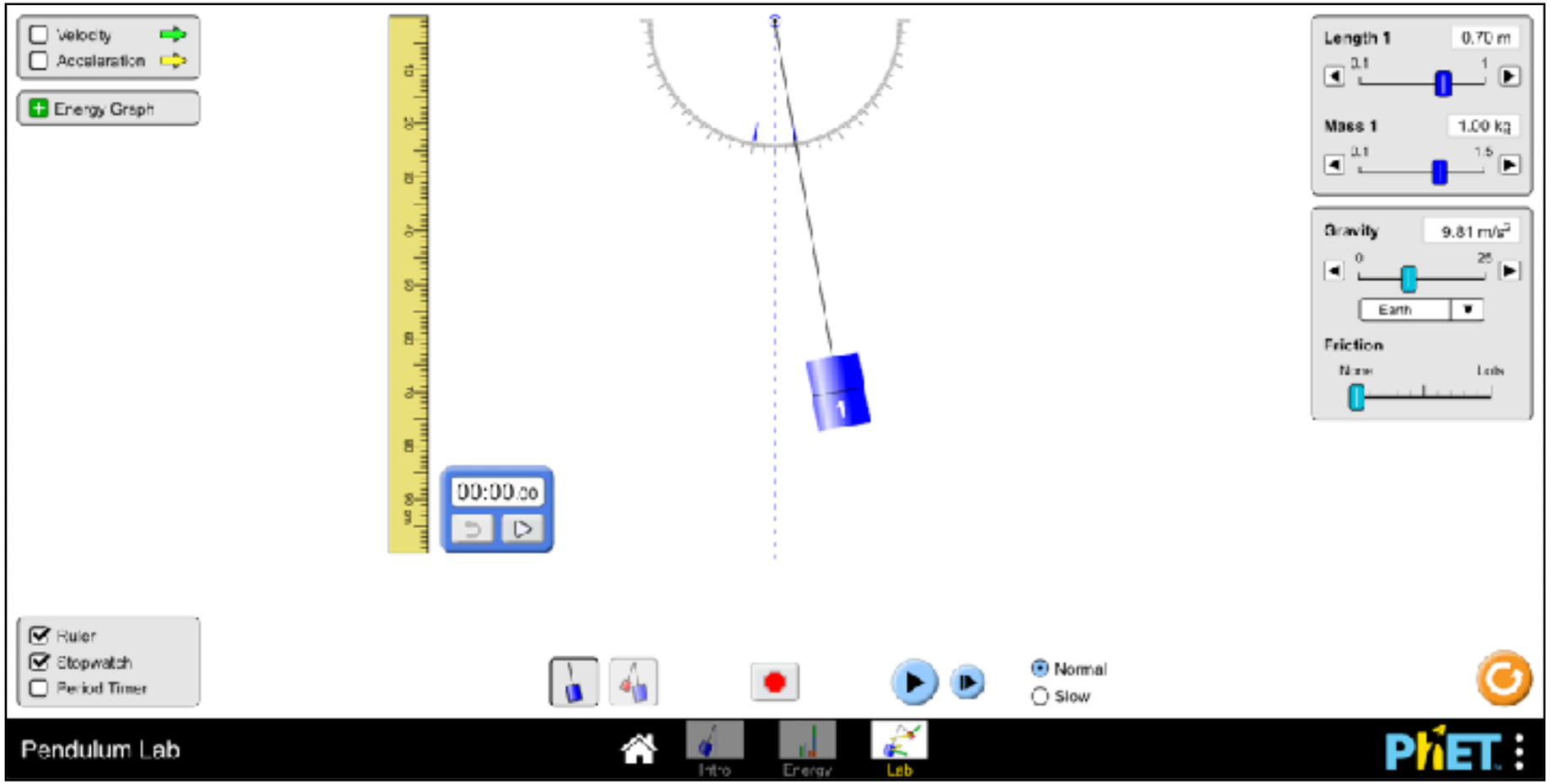
Pre-Lab and Post-Lab Uses for Online Simulations

Supplement Hands-On Lab Experiences

Use as a Pre-Lab Activity

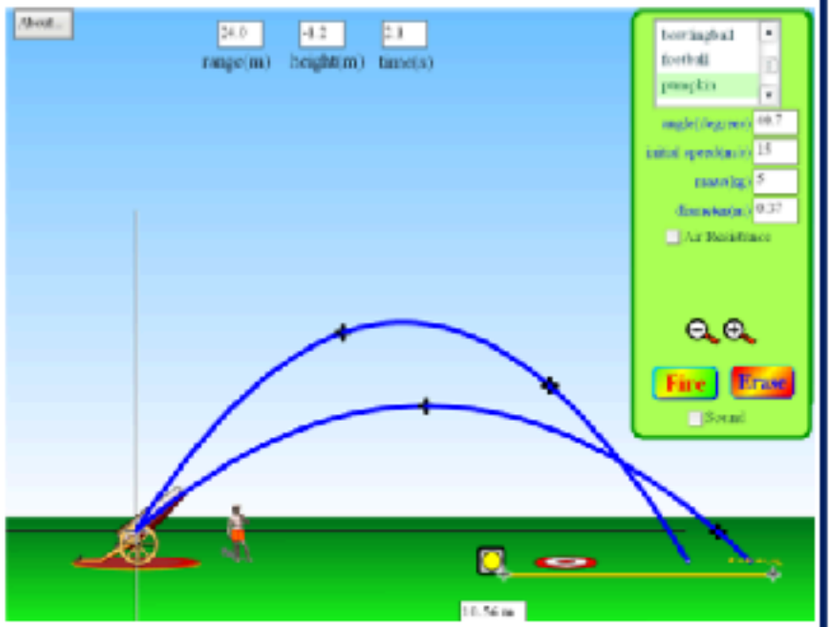
- See a basic image of the setup
- Have students begin to investigate possible Independent Variables and how they affect the Dependent Variable (directly or inversely)
- Start to make a list of required equipment and measuring devices
- Reinforces what values to measure and how to measure them

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

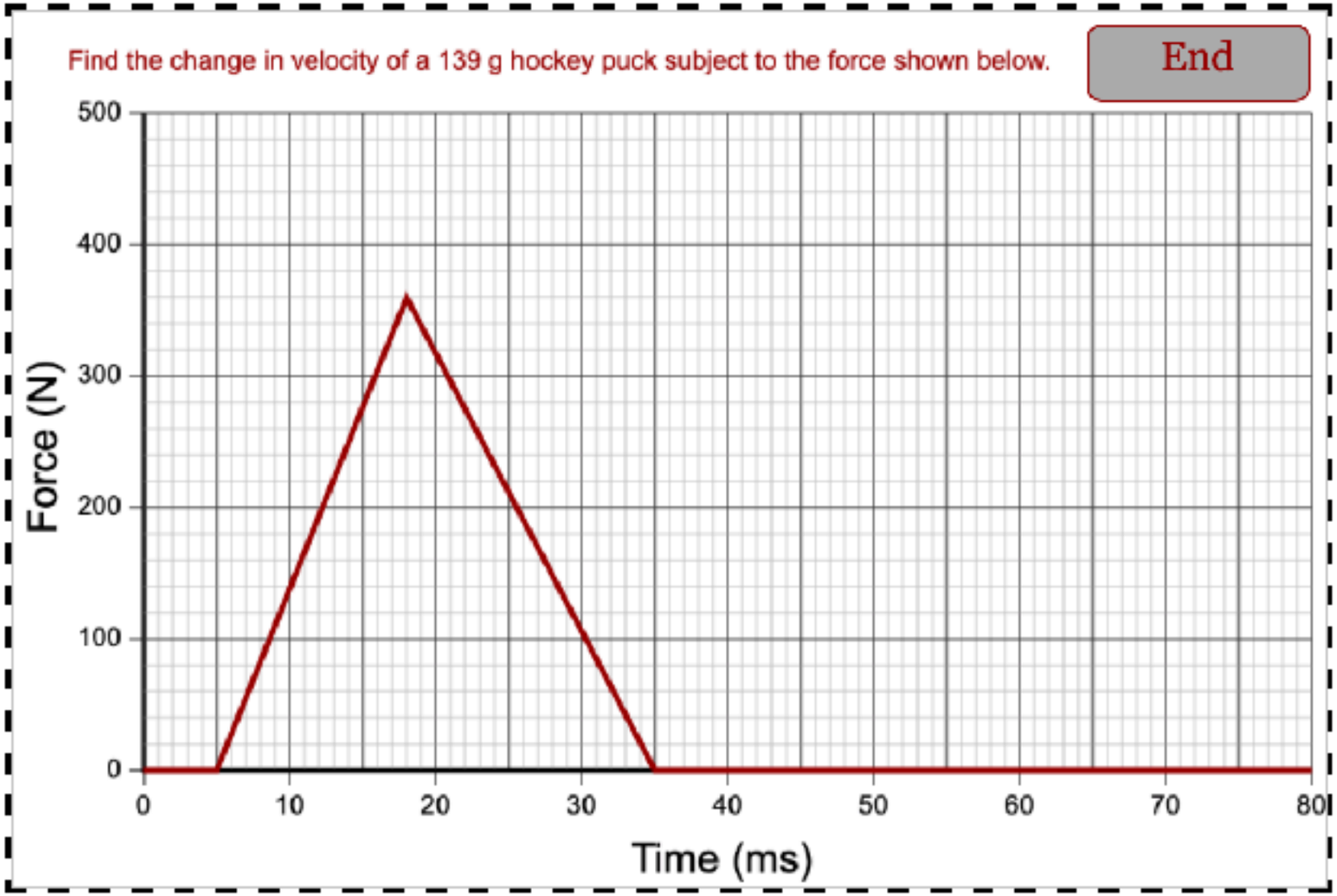


Video Series: Facilitating PhET Activities in K12 Classrooms

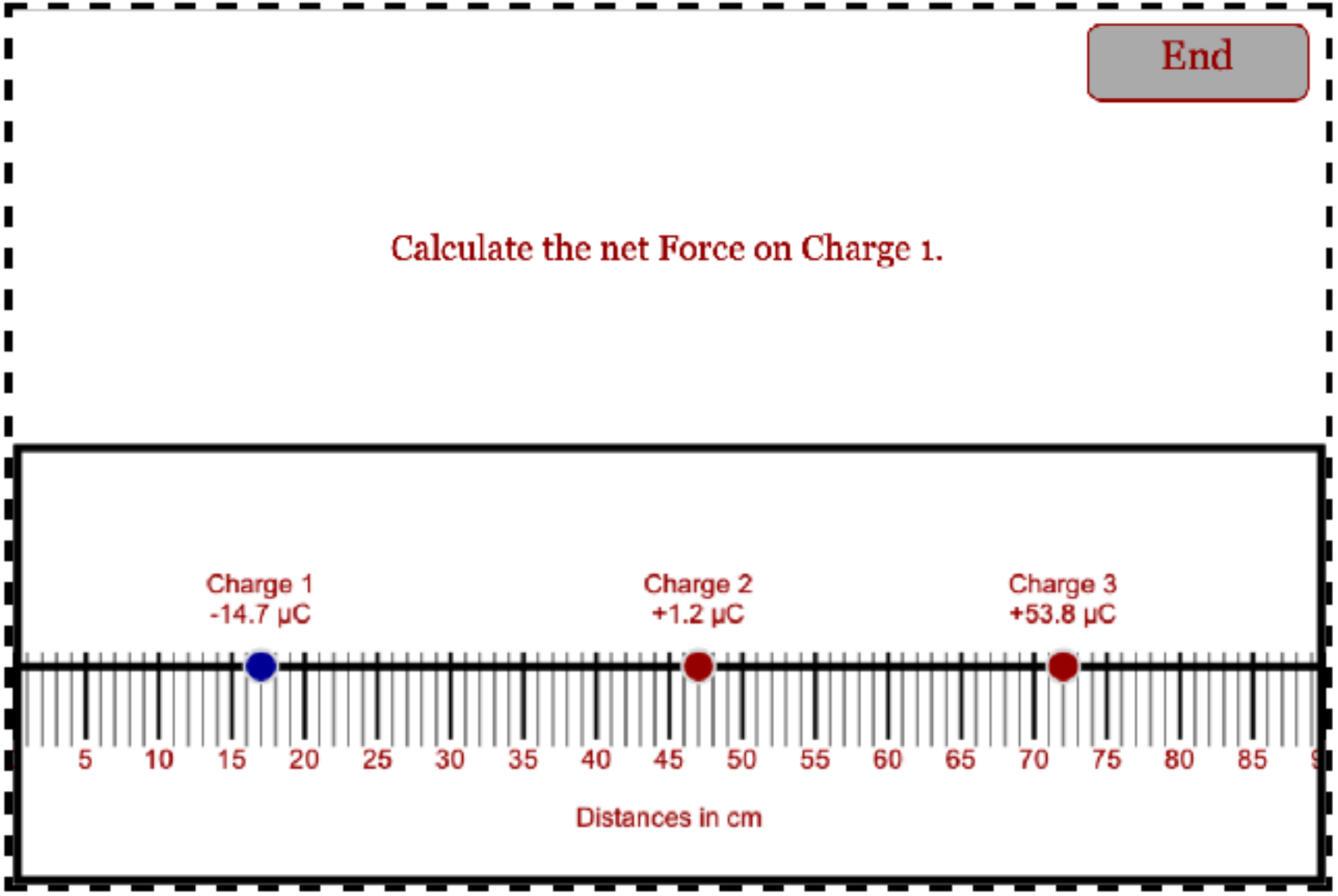


Take a Virtual PhET Workshop

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.

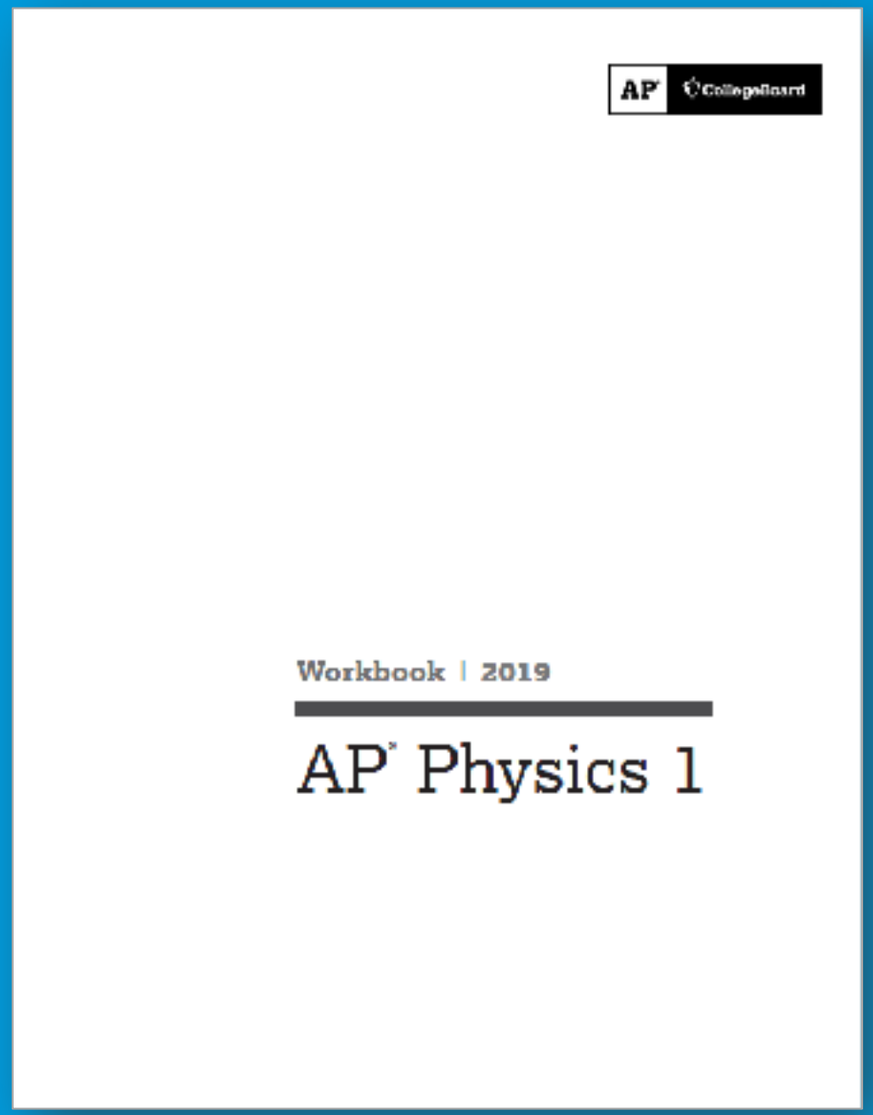
16118529190 25

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



Oather Strawderman

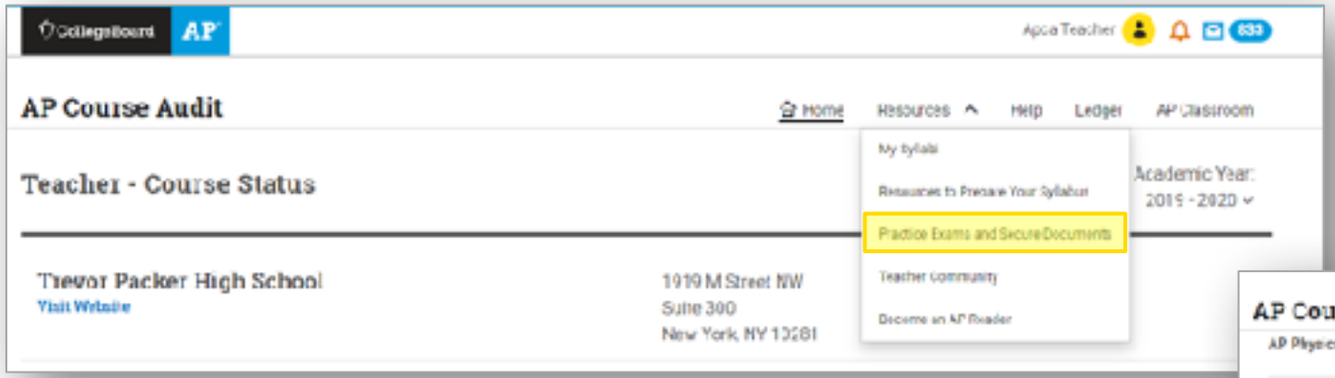
International Lead AP Physics Consultant



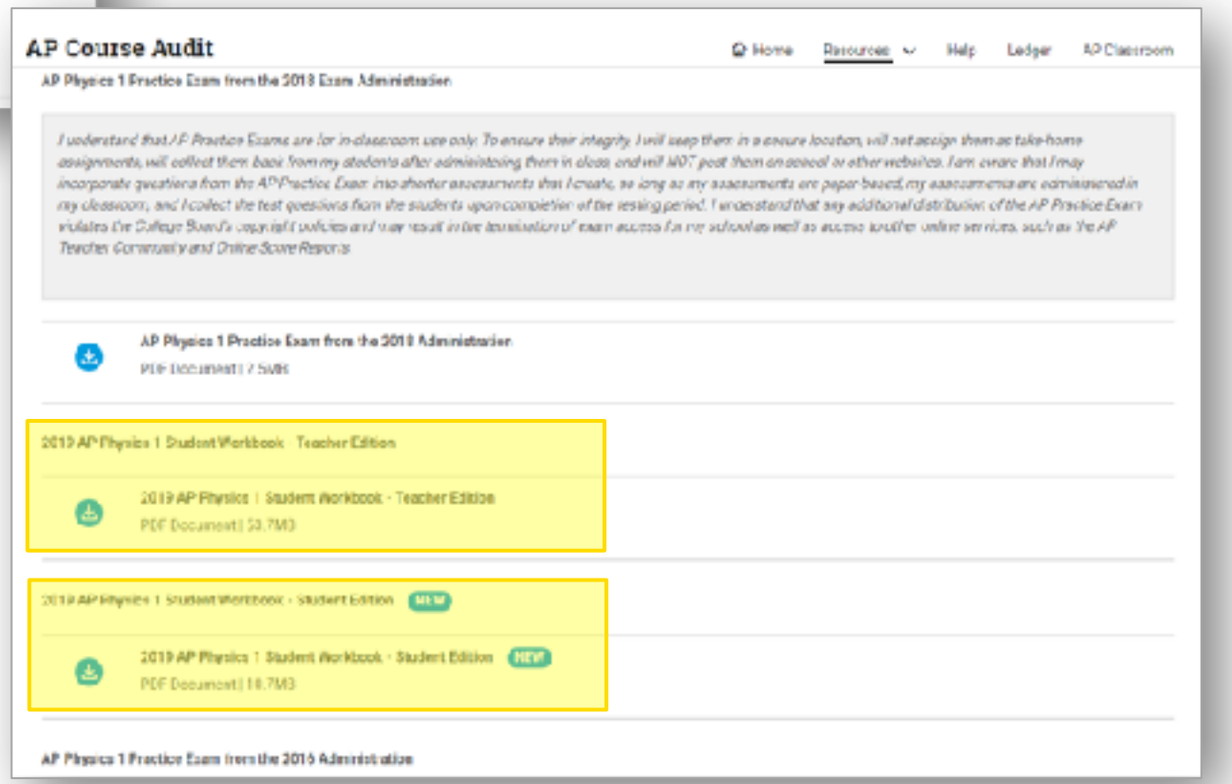
What is the Student Workbook?

- **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?



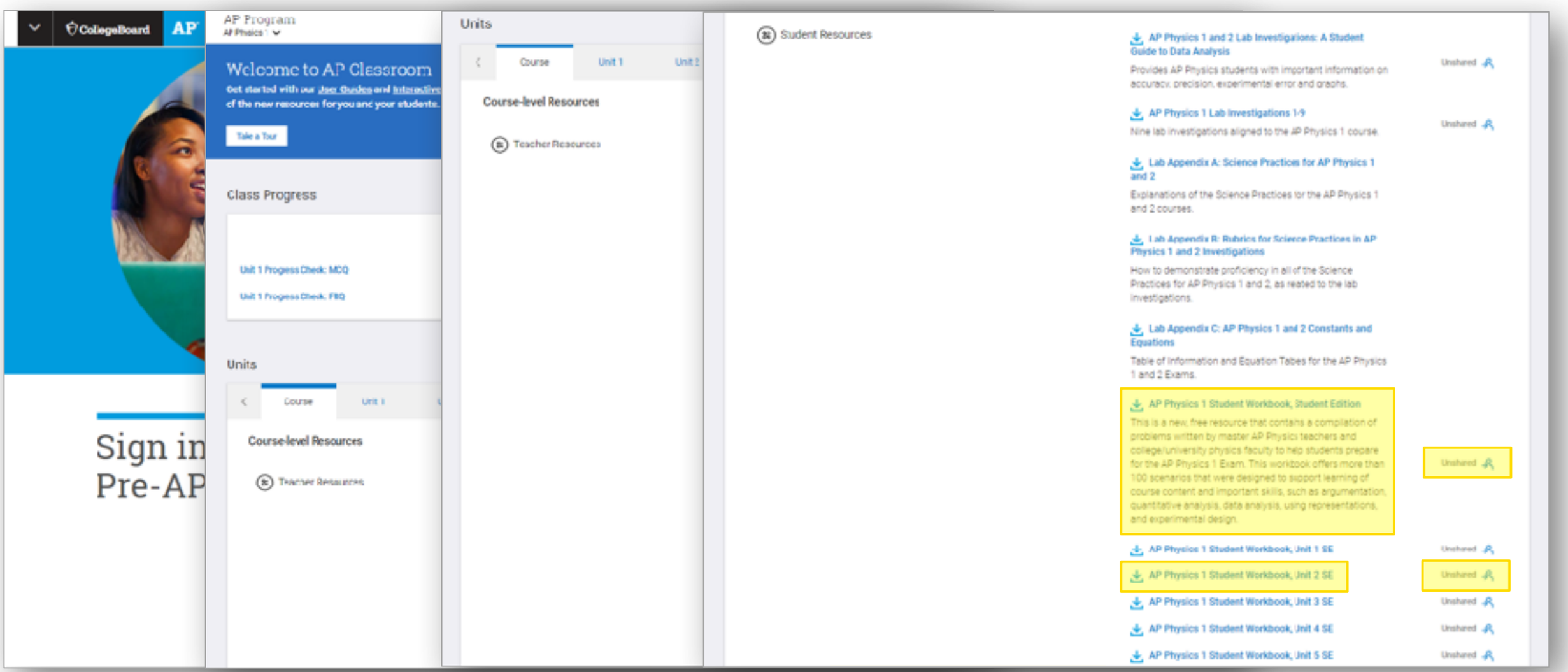
Option #1: AP Course Audit
apcentral.collegeboard.org/ap-course-audit

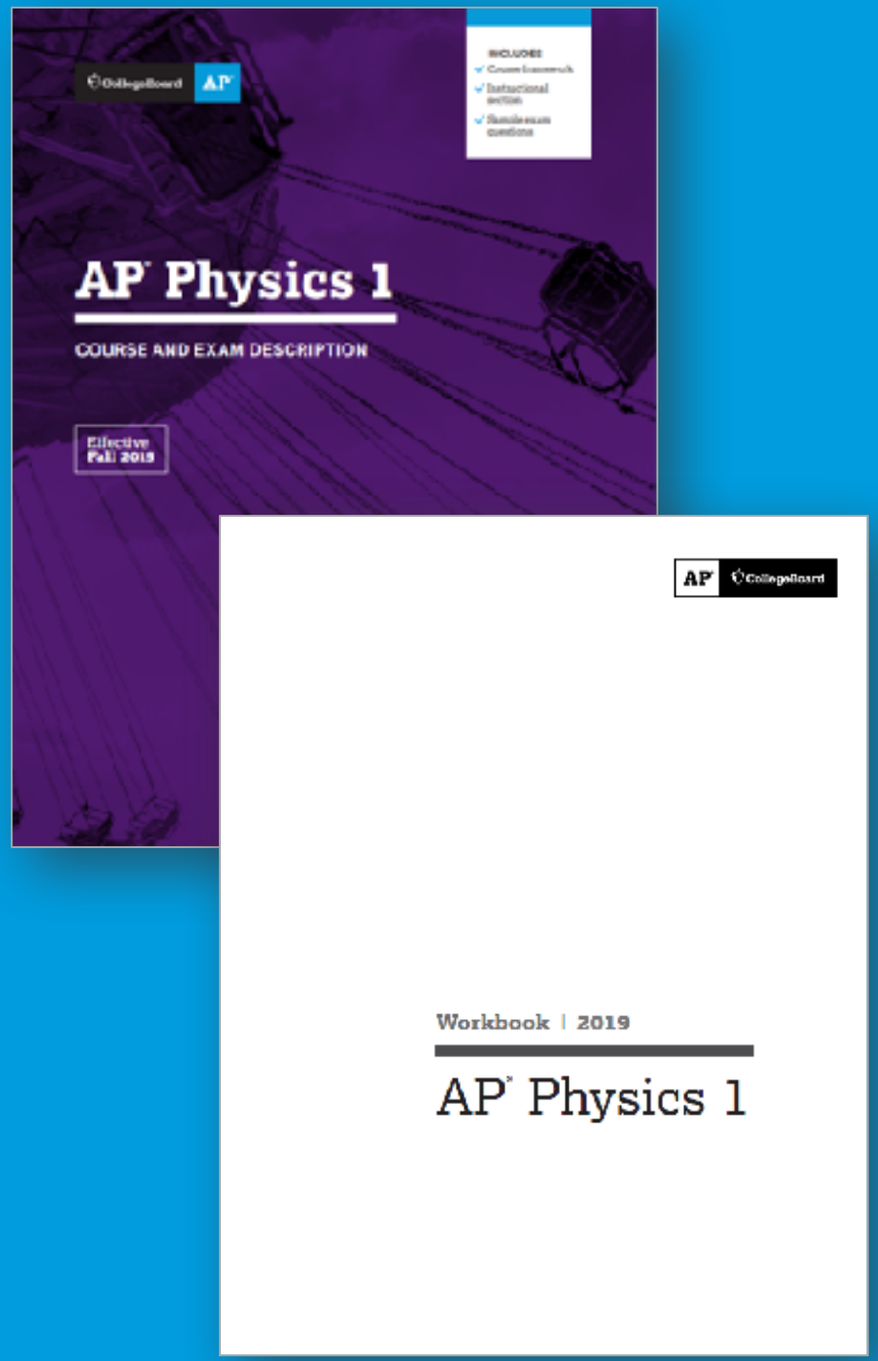


- You must be a course-authorized AP Physics 1 teacher to access the Student Workbook
- Student version may be printed and distributed to students
- Teacher version should not be shared with students

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

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.

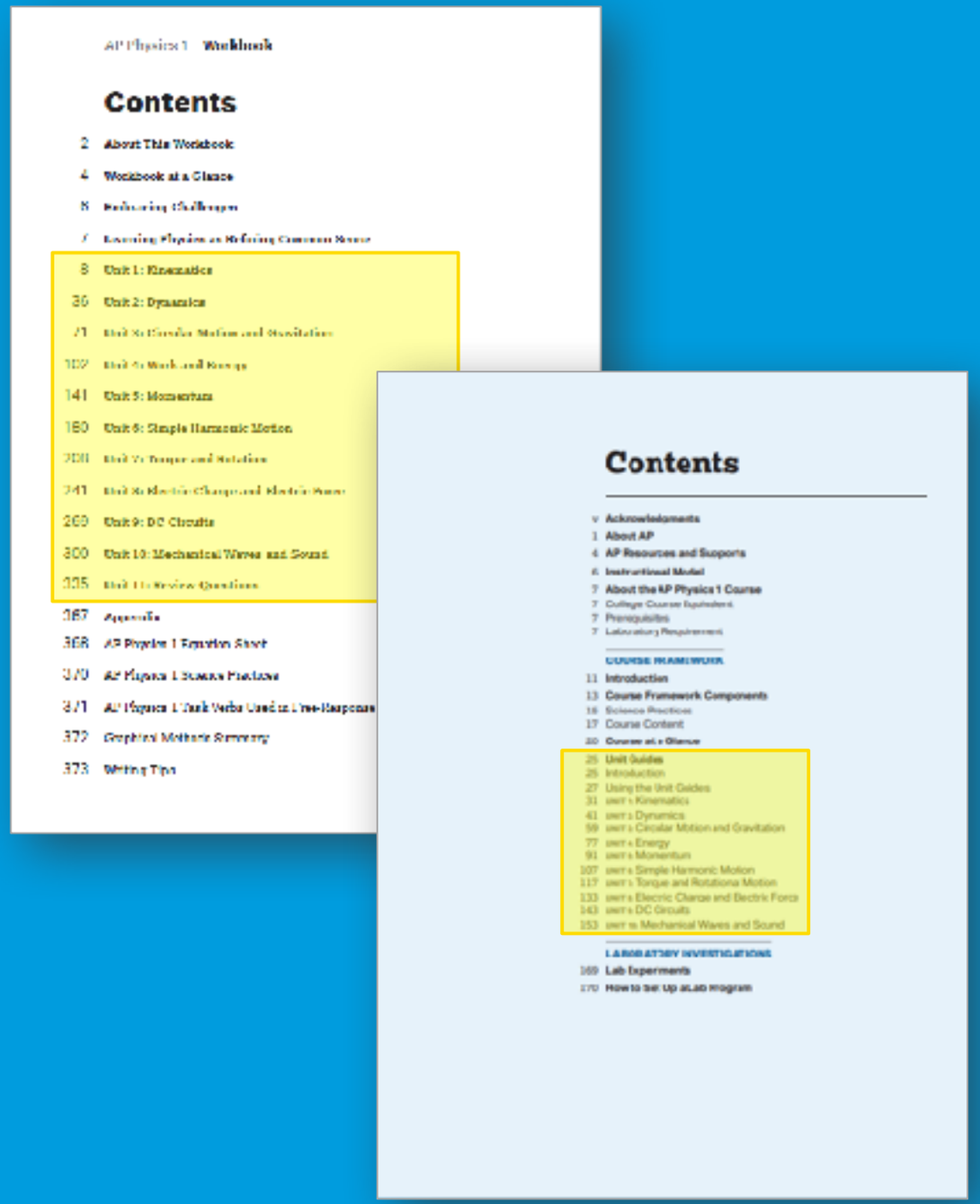
SCAFFOLDING

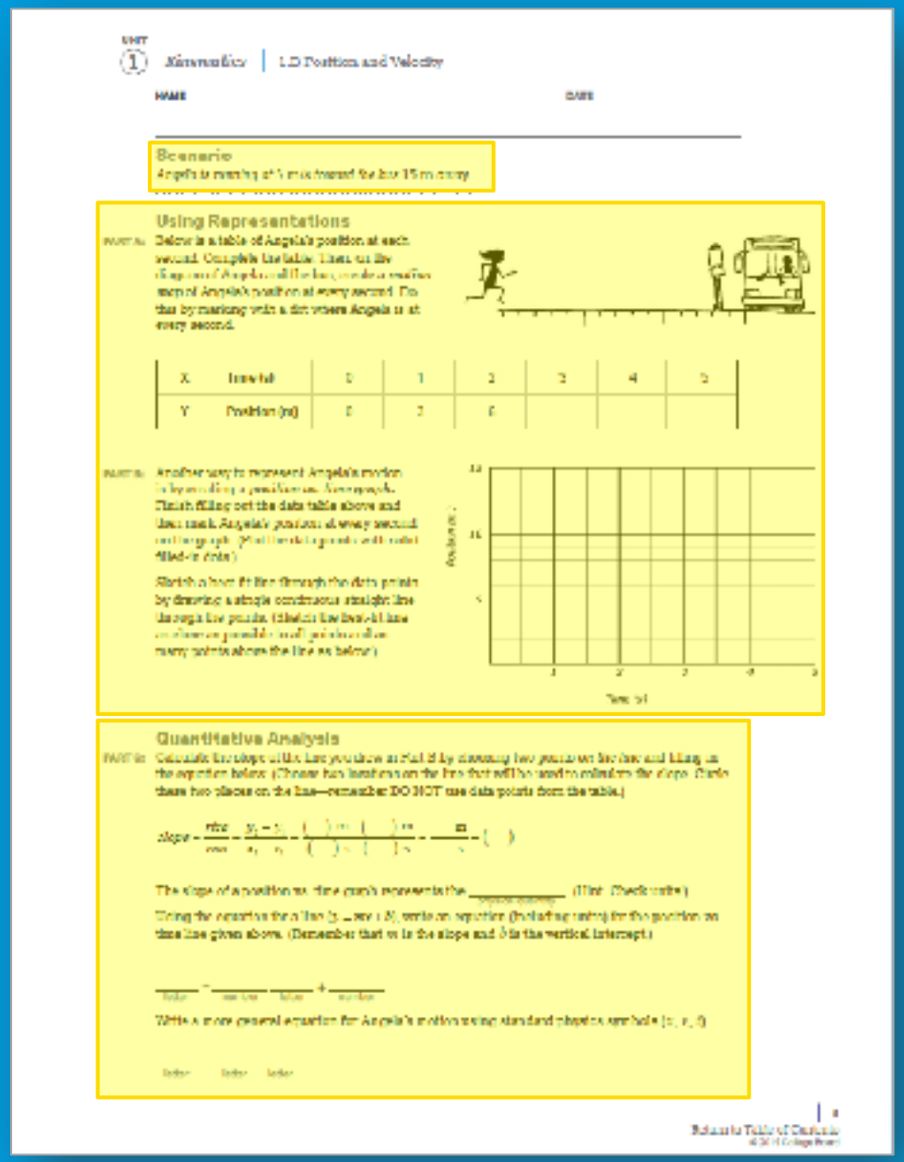
- Instructional technique used to move students progressively toward stronger understanding and, ultimately, greater independence in the learning process
- Provides success levels of temporary support that help students reach higher levels of content comprehension and skill acquisition
- Supports are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

What's Covered?

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

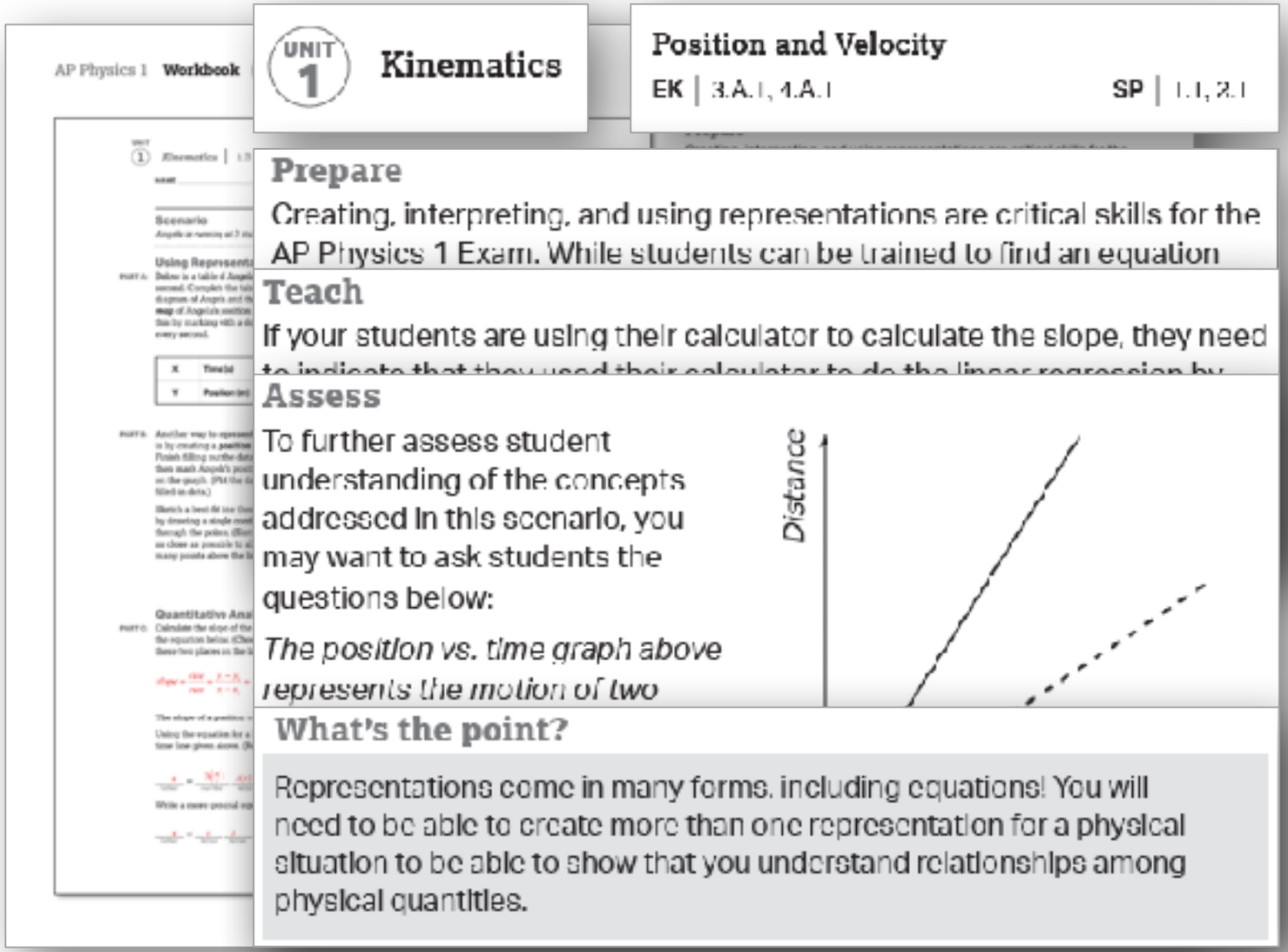




How does it work?

- 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

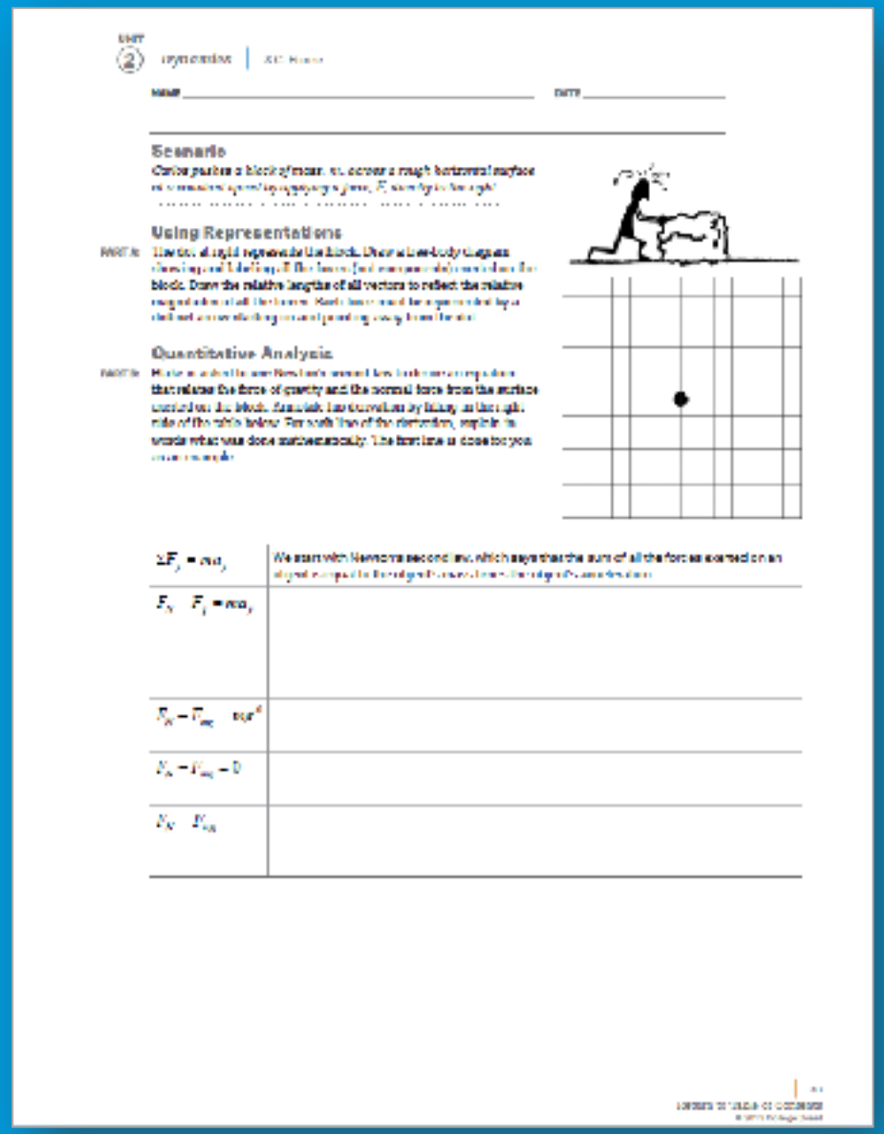
There's more for teachers …



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.



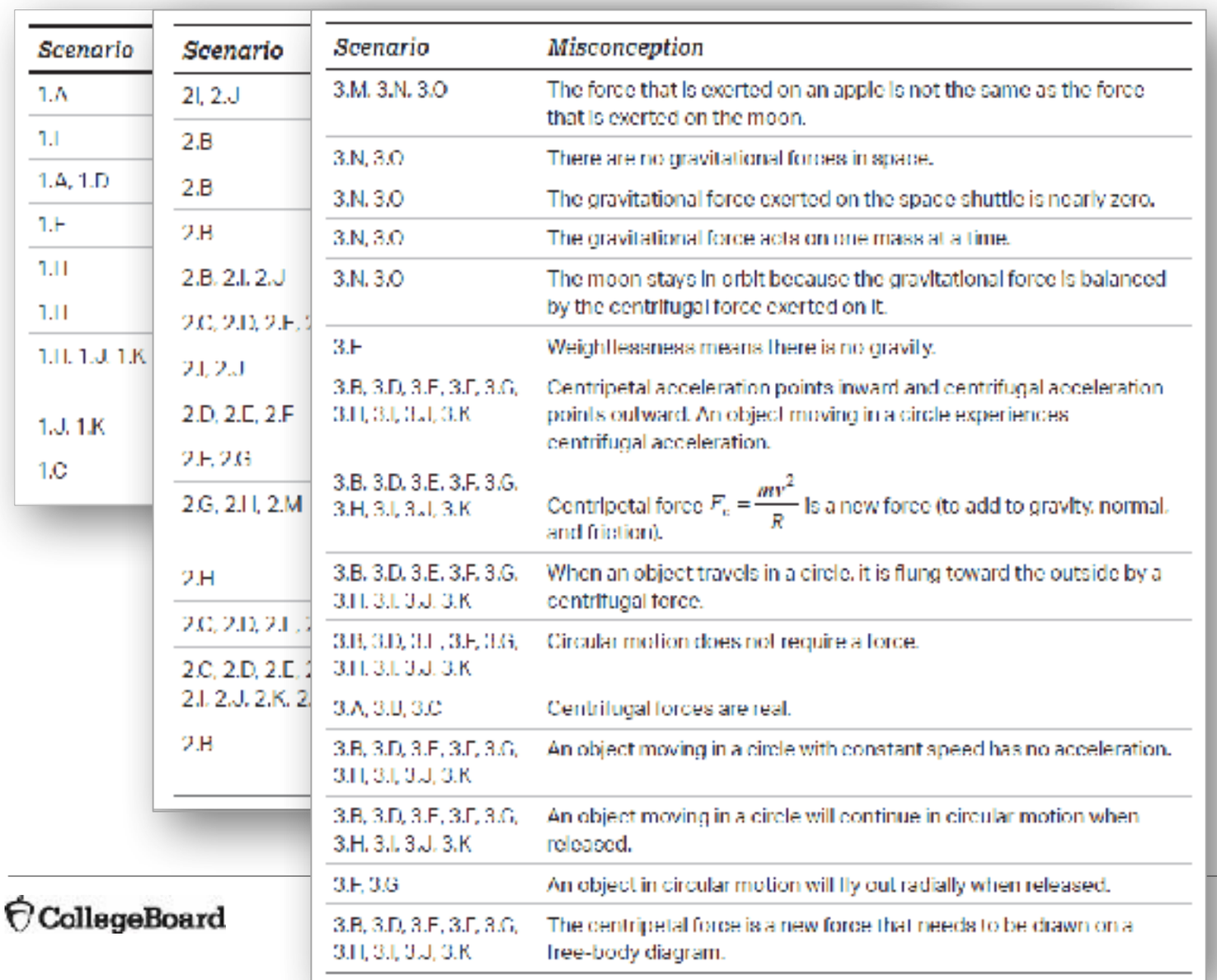
How can I use the workbook?

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

Student Misconceptions

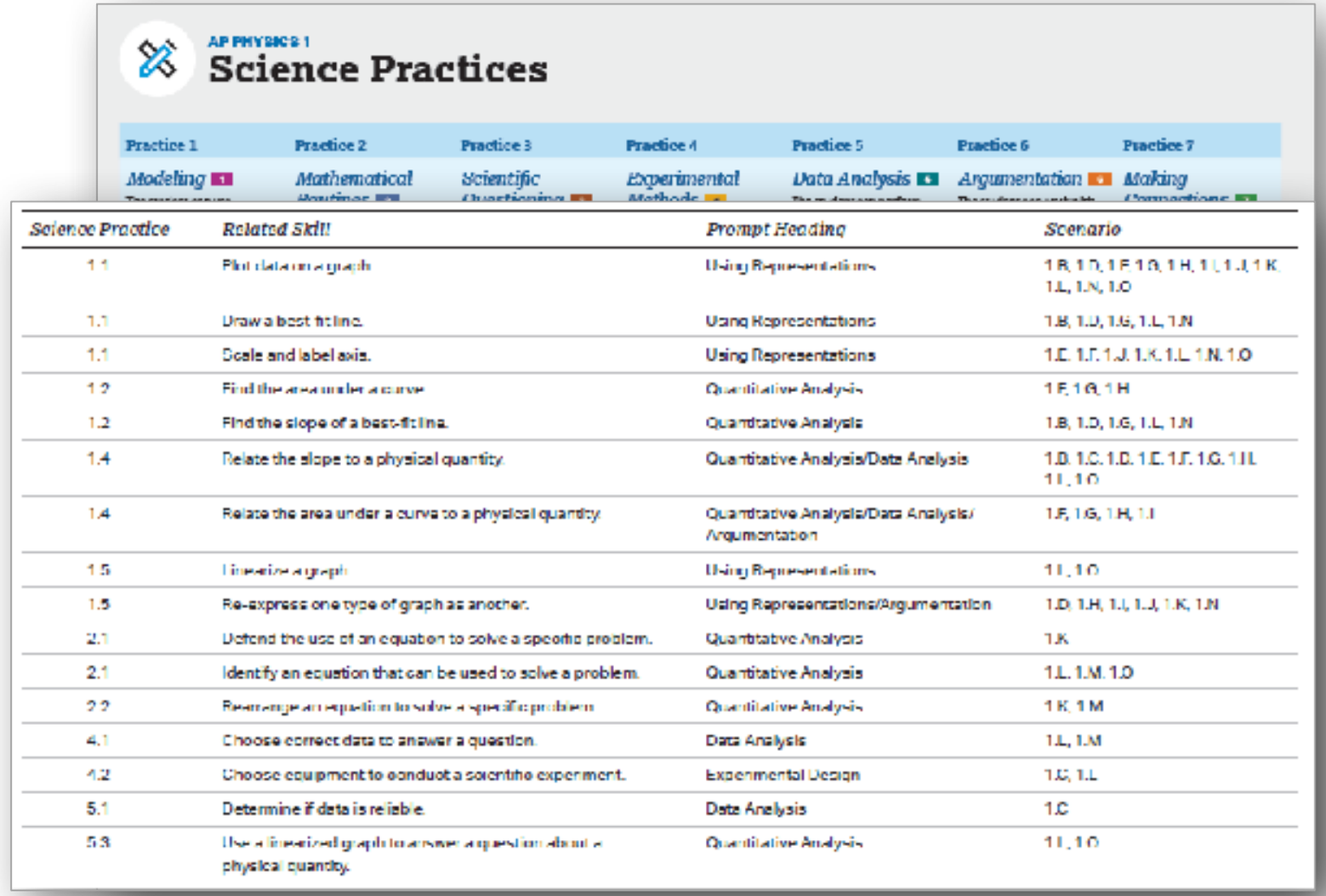


Scenario	Misconception
3.M, 3.N, 3.O	The force that is exerted on an apple is not the same as the force that is exerted on the moon.
3.N, 3.O	There are no gravitational forces in space.
3.N, 3.O	The gravitational force exerted on the space shuttle is nearly zero.
3.N, 3.O	The gravitational force acts 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.L, 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.L, 1.O



Student Resources: AP Physics 1 Student Workbook

CollegeBoard

AP Physics 1 Workbook at a Glance

NAME _____ DATE _____

Scenario

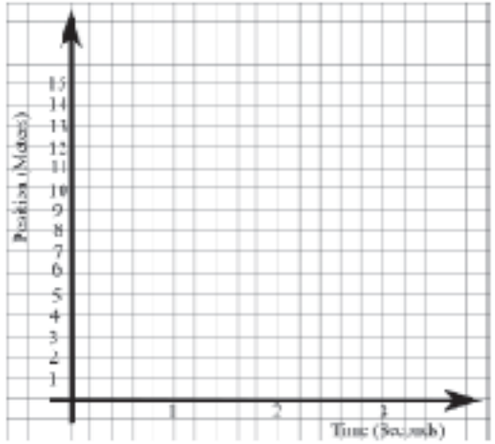
Angela and Blake are running toward each other from 15 m away. At time t = 0 s, Angela runs to the right at 5m/s, and Blake runs to the left at 3m/s.



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:

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

AP Physics 1 Workbook at a Glance

UNIT 1 Kinematics | Velocity is a Vector!

NAME _____ DATE _____

Scenario

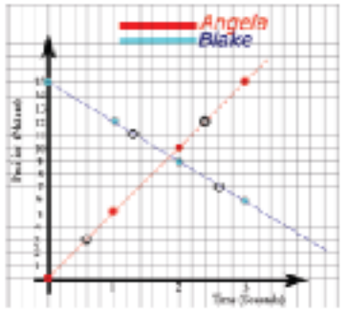
Angela and Blake are running. Angela runs to the right at ... and Blake runs to the left at ...



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	9
3	15	6



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:

$$slope = \frac{rise}{run} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{12m - 3m}{2.1s - 0.6s} = \frac{9m}{1.5s} = 5\frac{m}{s}$$

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:

$$slope = \frac{rise}{run} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{7m - 18m}{3.6s - 1.3s} = \frac{-4m}{1.3s} = -3\frac{m}{s}$$

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?

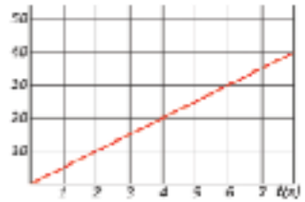
What would a graph of position vs. time look like for someone who took a break in the middle of running?

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

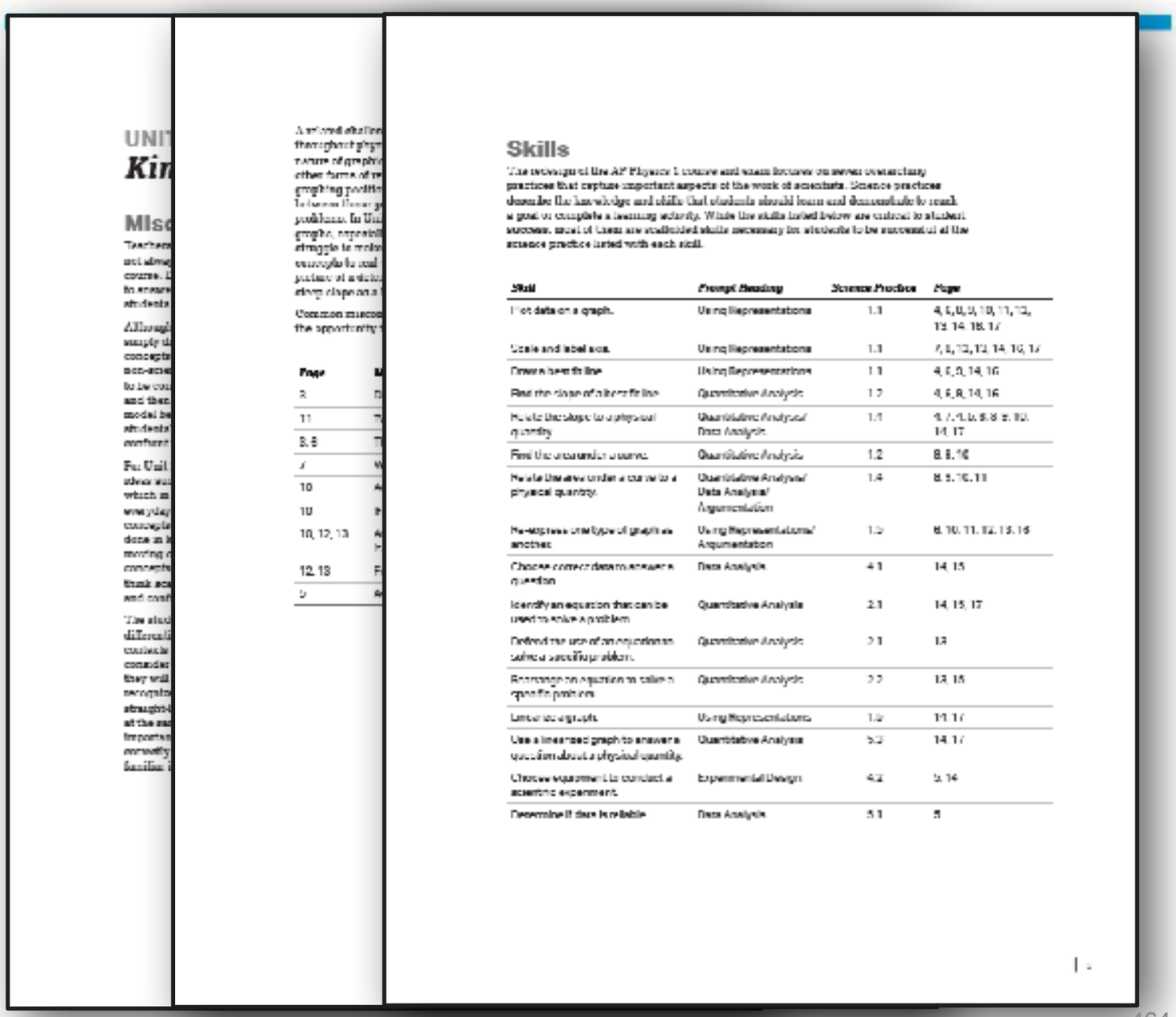
What's the point?

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 coverage 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 multifaceted 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, 5, 6, 9, 10, 11, 12, 13, 14, 16, 17
Scale and label axes.	Using Representations	1.1	7, 8, 12, 13, 14, 16, 17
Draw a best-fit line.	Using Representations	1.1	4, 5, 9, 14, 16
Find the slope of a best-fit line.	Quantitative Analysis	1.2	4, 5, 8, 14, 16
Relate the slope to a physical quantity.	Quantitative Analysis/ Data Analysis	1.1	5, 7–9, 13, 5.8 a–b, 10, 14, 17
Find the area under a curve.	Quantitative Analysis	1.2	8, 9, 16
Relate the area under a curve to a physical quantity.	Quantitative Analysis/ Data Analysis/ Argumentation	1.4	8, 9, 16, 18
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 qualitative 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	11, 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

Physics 1
Student Workbook

Scaffolded Sample Tasks

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.

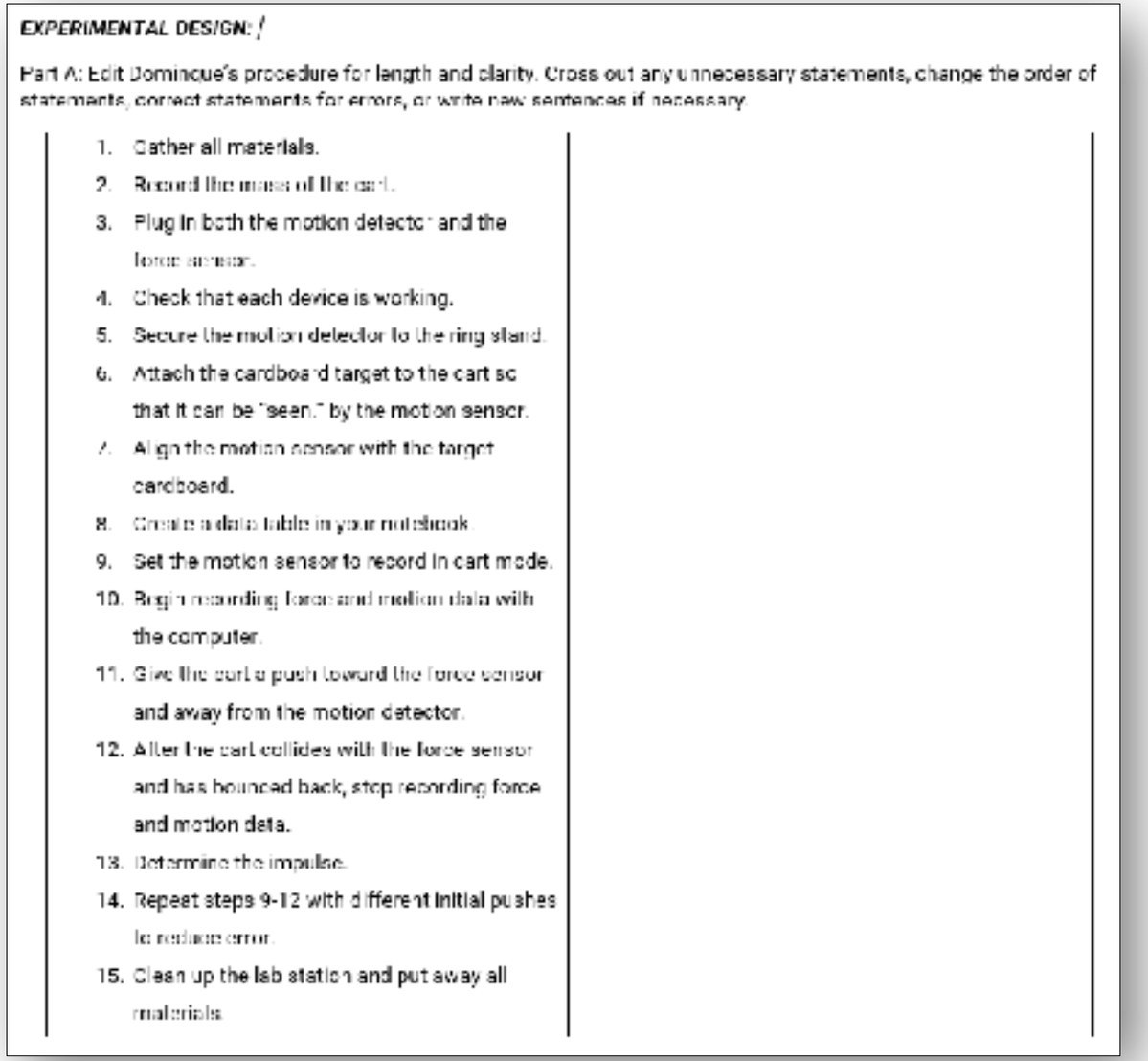
_____ Measure and record the time the car took to travel the 2 meters with a stopwatch.

_____ 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.

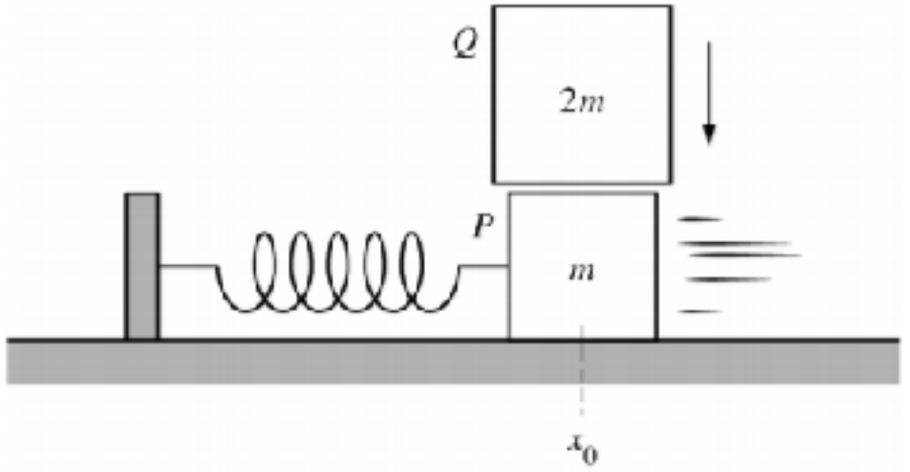
Part B: Outline a procedure that Blake could follow to make a single set of measurements that can be used to calculate an estimate of the speed of sound in air. Include a labeled diagram of the experimental setup. Explain how the measurements can be used to make the calculation.



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.

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 _____ meters. Angela's initial position was

number

_____ meters.

number

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 _____ meters minus _____ meters which equals _____

number number 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.

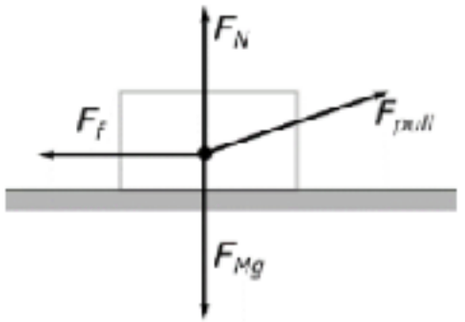
"After Blake stops pushing, Angela will travel at a constant speed for a few seconds before she runs out of force. Then she will decelerate and stop."

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.

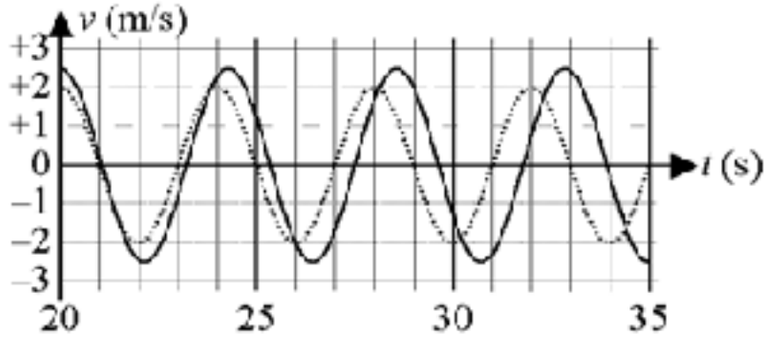
Part B: In a few short sentences, state the net force on the ball at the top of the circle, and support your claim with evidence.

Task: Writing About Physics

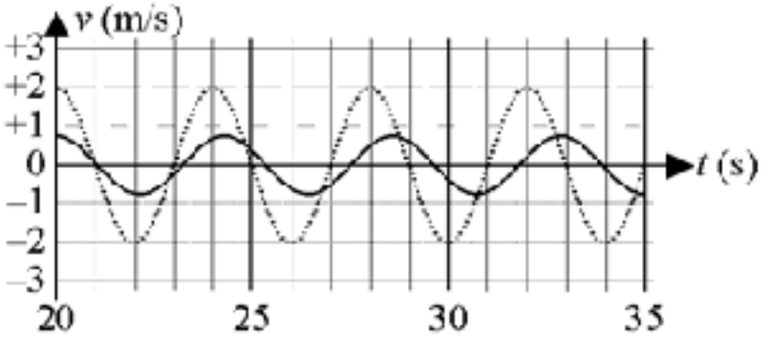
Unit 6, Physics 1 Student Workbook 6.I

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.

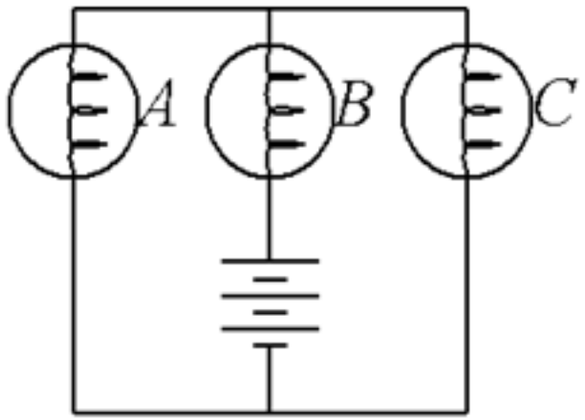
Checklist	
√	I answered the question directly.
	I stated a law of physics that is always true.
	I connected the law or laws of physics to the specific circumstances of the situation.
	I compared the situation (stated what was the same in all cases).
	I contrasted the situations (stated what was different 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

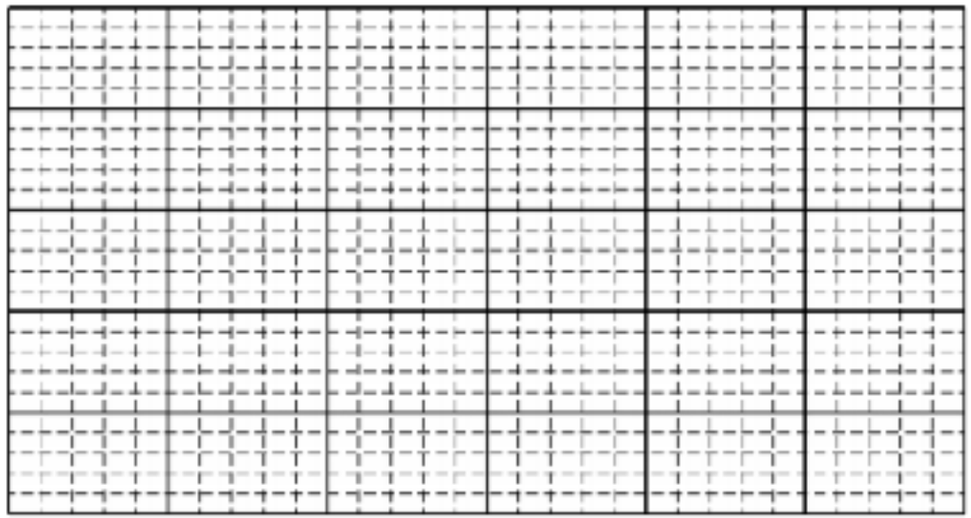
2018 AP Physics 1: Algebra-Based Exam

(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

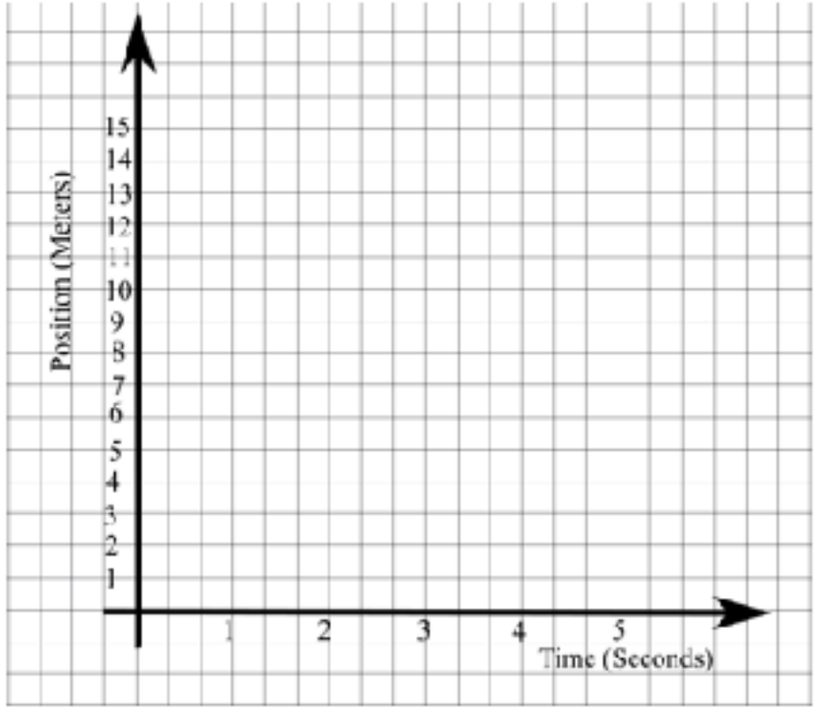
SCENARIO: Angela is running at 3m/s toward the bus stop, 15 m away.

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	

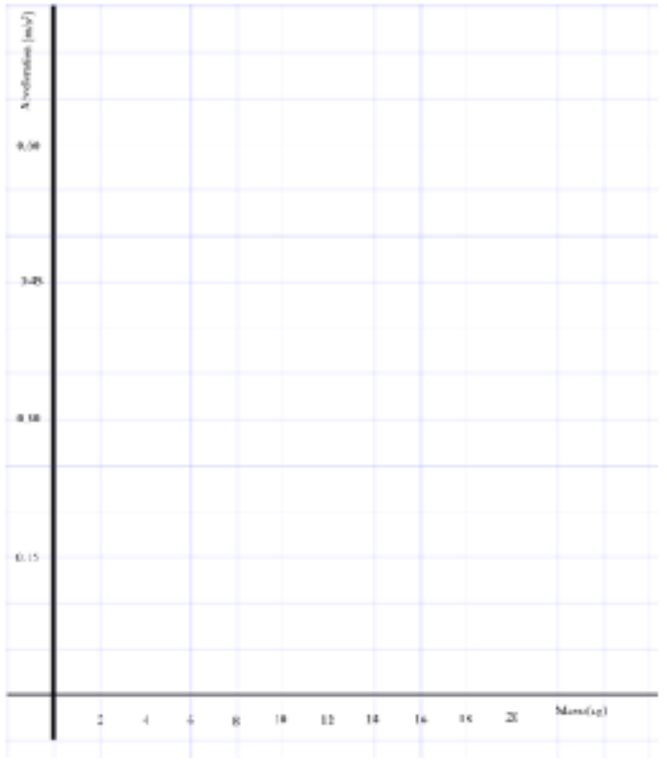
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Task: Graphing

Unit 2, Physics 1 Student Workbook 2.A

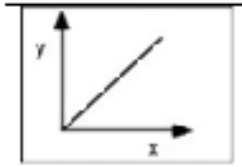
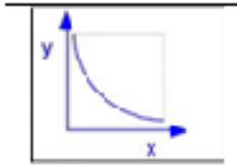
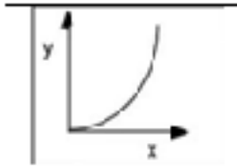
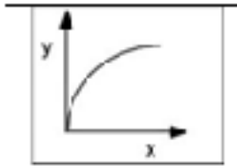
SCENARIO: Carlos and Dominique collect the following data from an experiment where they applied the same force, F, to identical boxes with different masses and recorded the acceleration.

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.

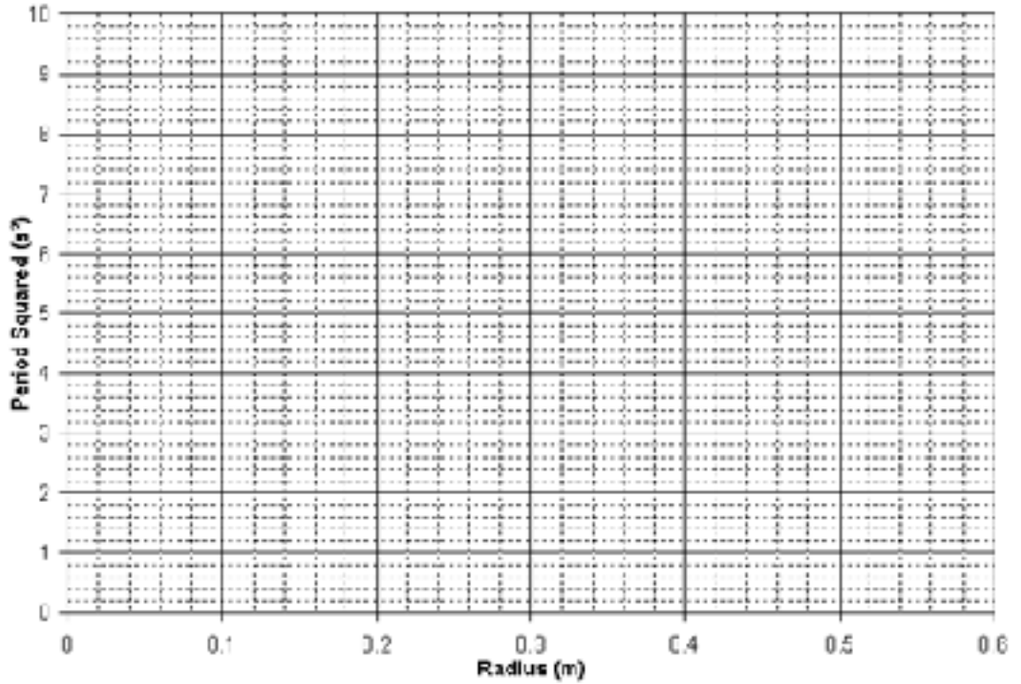
GRAPH	RELATIONSHIP
	As *x* increases, *y* increases proportionally. *Y* is directly proportional to *x*.
	As *x* increases, *y* decreases. *Y* is inversely proportional to *x*.
	*Y* is proportional to the square of *x*.
	The square of *y* is proportional to *x*.

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.

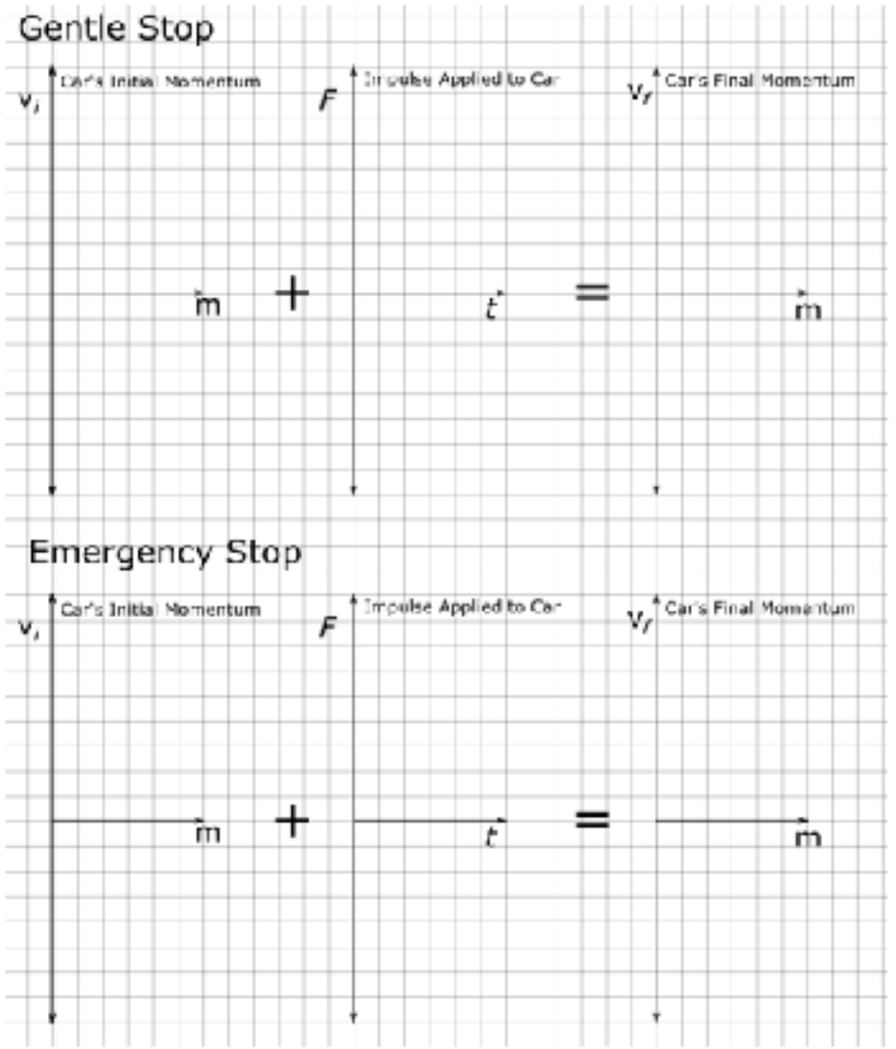
Task: Graphing

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.

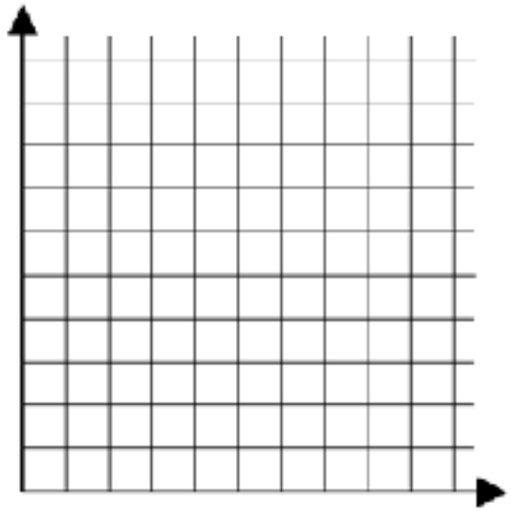


Task: Graphing

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.

Experimental Design and Analysis: Ball Drop FRQ Lab

Students are given a small sphere, a stopwatch, and a meterstick and are asked to take measurements to create a graph that could be used to determine the acceleration due to gravity.

(a) **Describe** a procedure for collecting data that can be graphed to determine the acceleration due to gravity. Students have access only to the sphere, stopwatch, and meterstick. Include any steps necessary to reduce experimental uncertainty.

(b) Describe how the data collected in part (a) would be graphed, and how that graph would be analyzed to determine the acceleration due to gravity.

Another group of students is given a cart on an inclined track. At the end of the track is a motion sensor which records the velocity of the cart as a function of time. The following table shows the data collected by the students.

	Velocity (m/s)	Time (s)	
	1.0	0.1	
	1.7	0.3	
	3.0	0.5	
	3.7	0.7	
	5	0.9	

The students correctly determine that the relationship between velocity and time is given by $v = (g \sin\theta)t$. The students create a graph with t plotted on the horizontal axis.

(c)

i. **Indicate** which measured or calculated quantity could be plotted on the vertical axis to yield a linear graph whose slope can be used to calculate an experimental value for the angle of the track. You may use the remaining columns in the table, as needed, to record any quantities (including units) that are not already in the table.

Vertical: _____ Horizontal: ____t____

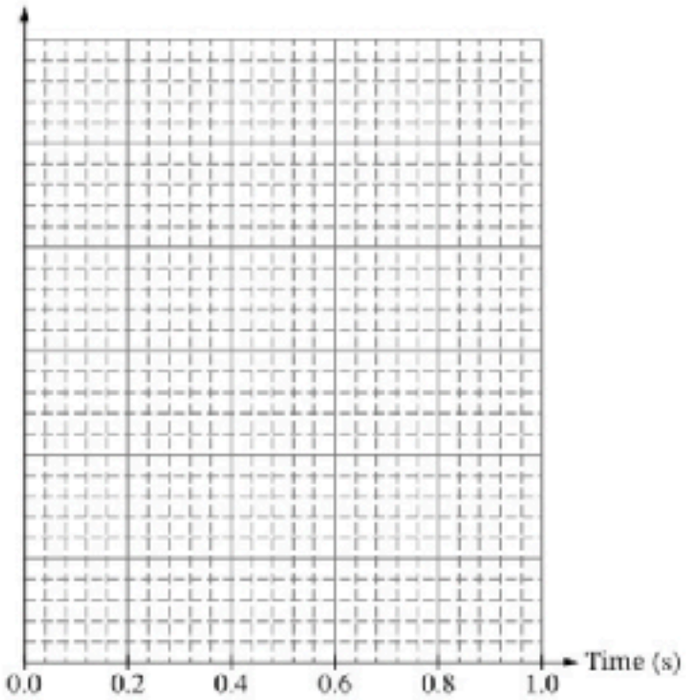


Figure 1

ii. On the grid shown in Figure 1, **plot** the data points for the quantities indicated in part (c)(i) that can be used to **determine** θ. Scale the graph as appropriate. Clearly **label** the vertical axis, including units.

iii. **Draw** a best–fit line for the data graphed in part (c)(ii).

(d) Calculate an experimental value for θ, using the best fit-line you drew in Figure 1 in part (c)(iii).

Thank You!!!

oather@PhluidPhysics.com