White-boarding and Multiple Representations to Improve Understanding: AP Physics 1 & 2

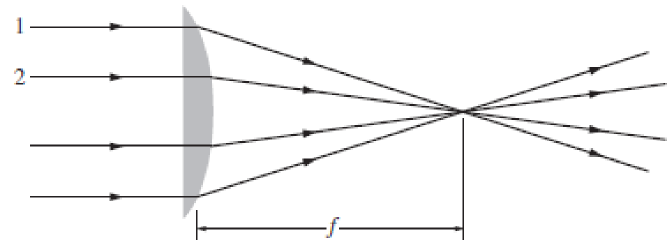
Changes to AP Physics B Course and Exam

Goal: Deepen student understanding

- Improve student ability to:
  - Interpret & Create graphs.
  - Use & Create Physics Diagrams.
  - Create & Apply Mathematical routines.

AP Questions: Sample Free Response Exam Question

Quantitative/Qualitative Translation



1. The figure above represents a glass lens that has one flat surface and one curved surface. After incoming parallel rays pass through the lens, the rays pass through a focal point. The focal length f is the distance from the center of the lens to the focal point.

   (a) The rays undergo refraction and change direction at the right surface of the lens, as shown. Explain why the angle of refraction of ray 1 is greater than that of ray 2.

   (b) The index of refraction of the glass is n_{glass}, and the radius of curvature of the lens's right edge is R. (The radius of curvature is the radius of the sphere of which that edge is a part. A smaller R corresponds to a lens that curves more.) A teacher who wants to test a class's understanding about lenses asks the students if the equation $f = n_{glass}R$ makes sense for the focal length of the lens in air. Is the teacher's equation reasonable for determination of the focal length? Qualitatively explain your reasoning, making sure you address the dependence of the focal length on both R and n_{glass}.

   (c) An object is placed a distance f / 2 (half of the focal length) to the left of the lens. On which side of the lens does the image form, and what is its distance from the lens in terms of f? Justify your answer. (Assume this is a thin lens.)

   (d) The lens is now placed in water, which has an index of refraction that is greater than air but less than the glass. Indicate below whether the new focal length is greater than, less than, or equal to the focal length f in air.

   Justify your answer qualitatively, with no equations or calculations.

AP Questions: Sample Free Response Exam Question

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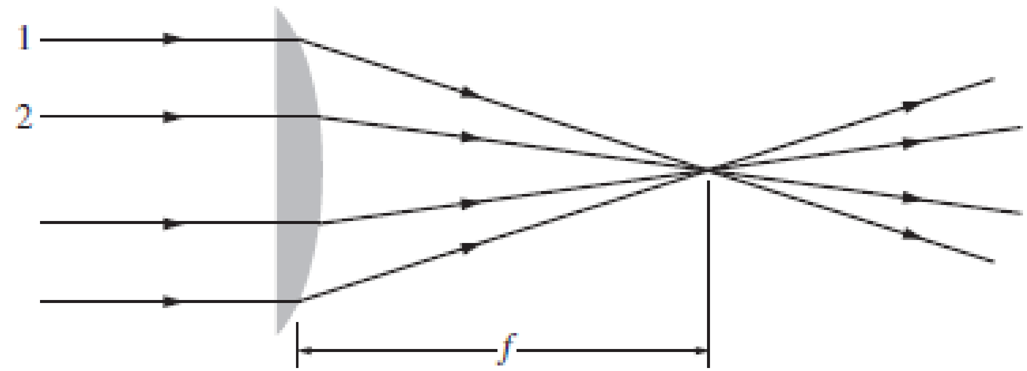

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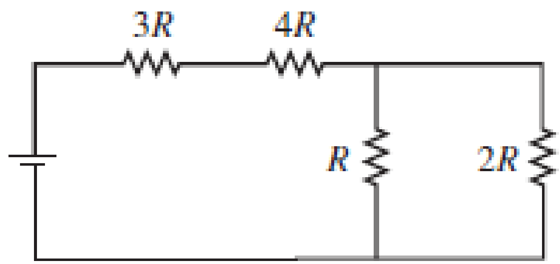
AP Questions: Sample MC Question

Sample Multiple–Choice Questions



1. The figure above shows four resistors connected in a circuit with a battery. Which of the following correctly ranks the potential difference, ΔV, across the four resistors?

(A) $\Delta V_{4R} > \Delta V_{3R} > \Delta V_{2R} > \Delta V_{R}$

(B) $\Delta V_{4R} > \Delta V_{3R} > \Delta V_{2R} = \Delta V_{R}$

(C) $\Delta V_{4R} = \Delta V_{3R} > \Delta V_{R} > \Delta V_{2R}$

(D) $\Delta V_{2R} = \Delta V_{R} > \Delta V_{3R} > \Delta V_{4R}$

Answer: B

AP Questions: Free Response Question types.

Four Free Response Questions. Include:

- Translation:
  - Create Word description
  - Translate word description to Math Model.
- Lab Design Problems.
- Paragraph length response.
- Additional Question

Multiple Representations

- Sketch:
  - General sketch of scenario.
- Physics Diagram:
  - motion map, free body diagram, field
- Graphical Representation:
  - x vs t, F vs x, P vs V etc…
- Word Model:
  - This is proportional to that…
  - The object moves at constant something…
- Mathematical Model:
  - $W = \boldsymbol{F}\Delta\boldsymbol{x}$ area under F vs x graph.

Whiteboarding

- Students use dry-erase boards (often roughly 2’x3’)
- Small student groups present their lab / problem to class
- Class & Groups form circle. Not present from front.
- Take turns presenting.

Non-Content Reasons for White-boarding - 1

- Student led
  - Students must actively participate in
    - Presenting:
      - Experimental setup or Problem Scenario
      - Results
      - Analysis
    - Respond to Questions.
      - Student peers and staff ask questions

Non-Content Reasons for White-boarding - 2

- Peer review of small group lab or problems
  - Students ask questions of peers if:
    - Don’t understand analysis
    - Think a mistake may have been made
  - Emphasize *Good Questions* are highly valued.
    - It’s ok to ask questions
    - Encourage depth of thought.
    - Question for both mistake & not understanding reduces shame
  - Emphasize Good Questions might be hard to answer.
    - Response might require time. That’s ok.
    - Think about how to answer in multiple modes.

Physics Content Reasons for Whiteboarding - 2

Different Layouts for Whiteboarding: HW

Sketch Scenario

Physics Diagram

Graph if chosen / helpful / appropriate

Plan Solution

Execute Plan

Check reasonableness

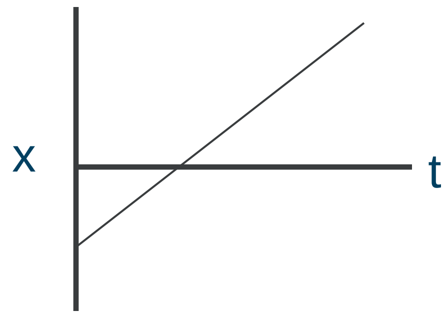
Ex: Car Lab – 1

- Determine a graphical and mathematical model to describe the motion of the (constant velocity) buggy.

Ex: Car Lab - 2

Physics Diagram

Graph



Word Model

Car starts in the –x position and travels in positive direction.
The position of the car changes directly with time.

Math Model

$$y = mx + b$$

$$x_f = v\Delta t + x_o$$

$$x_f = {}^{+}5\frac{m}{s}\Delta t + {}^{-}10m$$

Meaning of Slope

Velocity of object

Meaning of y-intercept

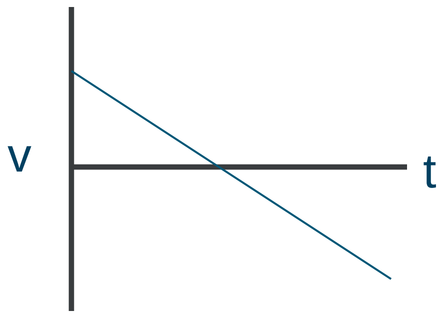
original position of object

Ex: Changing Representations-1 Graph Prob i

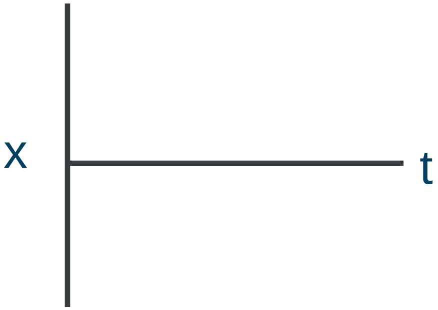
Sketch Scenario

Physics Diagram

Given Graph



New Graph



Word Model

Math Model

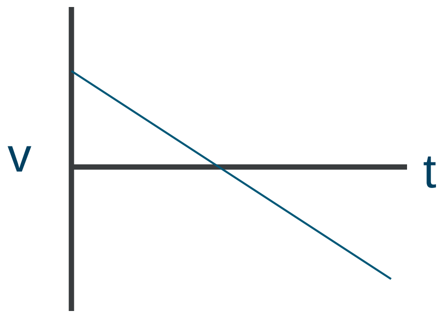
Ex: Changing Representations-1 Graph Prob i

Sketch Scenario

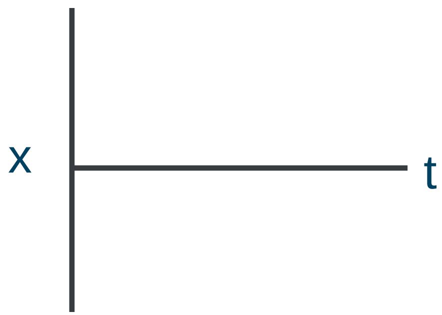
Physics Diagram

- Translating from one representation to another requires more complete understanding of physics phenomena.

Given Graph



New Graph



Word Model

Math Model

Ex: Changing Representations – 2 Word Prob i

OPTION 1: One Problem Per Group

Sketch Scenario

Physics Diagram

Graph

New Graph

Word Model: Problem Statement

One liter of a 1 mole sample of gas is at 1 atmosphere. The gas is adiabatically compressed to 3 atmospheres. What work was done to the gas?

Math Model

Ex: Changing Representations-2 Word Prob ii

Sketch Scenario

Requires students to think about experimental setup. How can they create an adiabatic transition?

Physics Diagram

Graph

New Graph

Word Model: Problem Statement

One liter of a 1 mole sample of gas is at 1 atmosphere. The gas is adiabatically compressed to 3 atmospheres. What work was done to the gas?

Math Model

Ex: Changing Representations-2 Word Prob ii

Sketch Scenario

Requires students to think about experimental setup. How can they create an adiabatic transition?

Physics Diagram

Energy bar chart here helps student think about what is in system. Should Work be + or -?

Graph

New Graph

Word Model: Problem Statement

One liter of a 1 mole sample of gas is at 1 atmosphere. The gas is adiabatically compressed to 3 atmospheres. What work was done to the gas?

Math Model

Ex: Changing Representations-2 Word Prob ii

Sketch Scenario

Requires students to think about experimental setup. How can they create an adiabatic transition?

Physics Diagram

Energy bar chart here helps student think about what is in system. Should Work be + or -?

Graph

PV graphs are common ways for students to analyze Work in a thermo system.

New Graph

Word Model: Problem Statement

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Math Model

Ex: Changing Representations-2 Word Prob ii

Sketch Scenario

Requires students to think about experimental setup. How can they create an adiabatic transition?

Physics Diagram

Energy bar chart here helps student think about what is in system. Should Work be + or -?

Graph

PV graphs are common ways for students to analyze Work in a thermo system.

New Graph

Requiring a VT graph could help develop other analysis. What should the shape of the graph be? Why?

Word Model: Problem Statement

One liter of a 1 mole sample of gas is at 1 atmosphere. The gas is adiabatically compressed to 3 atmospheres. What work was done to the gas?

Math Model

Ex: Changing Representations-2 Word Prob ii

Sketch Scenario

Requires students to think about experimental setup. How can they create an adiabatic transition?

Physics Diagram

Energy bar chart here helps student think about what is in system. Should Work be + or -?

Graph

PV graphs are common ways for students to analyze Work in a thermo system.

New Graph

Requiring a VT graph could help develop other analysis. What should the shape of the graph be? Why?

Word Model: Problem Statement

One liter of a 1 mole sample of gas is at 1 atmosphere. The gas is adiabatically compressed to 3 atmospheres. What work was done to the gas?

Math Model

Graph and physics diagram / energy bar chart can help lead students to a numerical solution.

Ex: Changing Representations-3 Word Prob iii

OPTION 2: One Problem Per Class

Sketch Scenario

Assign to group 1.

Physics Diagram

Assign to group 3.

How does this change if work gas does? Assign to group 6.

Graph

Assign to group 2.

New Graph

Assign to group 4.

Word Model: Problem Statement

One liter of a 1 mole sample of gas is at 1 atmosphere. The gas is adiabatically compressed to 3 atmospheres. What work was done to the gas?

Math Model

Assign to group 5.

How does this change if work gas does? Assign to group 7.

Ex: Changing Representations-3 Word Prob iv

Sketch Scenario

Physics Diagram

Graph

New Graph

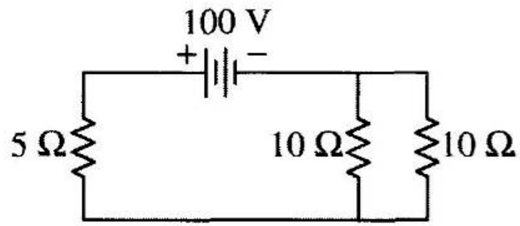
Word Model: Problem Statement

How do the graph and mathematical model change if the process is adiabatic instead of isothermal?

One liter of a 1 mole sample of gas is at 1 atmosphere. The gas is adiabatically compressed to 3 atmospheres. What work was done to the gas?

Math Model

Ex: Adapt Old AP MC questions for HW



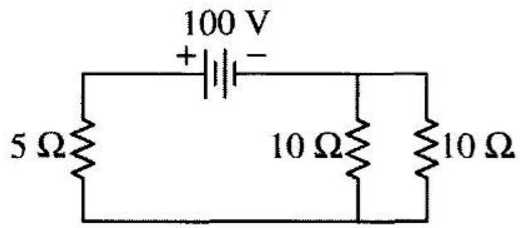
- In the circuit shown above, what is the current in the 5 Ω resistor?
  (A) 40 A
  (B) 25 A
  (C) 20 A
  (D) 10 A
  (E) 4 A

- Remove the choice options and turn it to a free response problem.

Physics Content Reasons for Whiteboarding - 2

Different Layouts for Whiteboarding: HW

Sketch Scenario



Physics Diagram

Graph if chosen / helpful / appropriate

Plan Solution

Execute Plan

Check reasonableness

For a translation, can ask students what happens to the value for current if the battery is not ideal and the internal resistance of the battery is 1 ohm.

Solution Scategories

- Pose a problem to the class.
  - Student groups create accurate representation of the problem.
  - Each correct representation earns points.
  - Each unique correct representation earns extra credit.

Citations (incomplete with apologies)

- Solving physics problems with multiple representations Robert J. Dufresne[1], William J. Gerace[1] and William J. Leonard[1] Phys. Teach. **35**, 270 (1997); http://dx.doi.org/10.1119/1.2344681
- Multiple representations of work–energy processes Alan Van Heuvelen[1] and Xueli Zou[1] Am. J. Phys. **69**, 184 (2001); http://dx.doi.org/10.1119/1.1286662
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- Playing Physics Jeopardy Alan Van Heuvelen[1] and David P. Maloney[2] Am. J. Phys. **67**, 252 (1999); http://dx.doi.org/10.1119/1.19233

Thanks

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Questions?

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