2024

AP® Physics 1: Algebra-Based

Sample Student Responses and Scoring Commentary

Inside:

Free-Response Question 1

- ☑ **Scoring Guidelines**
- ☑ **Student Samples**
- ☑ **Scoring Commentary**

Question 1: Short Answer — 7 points

(a) For drawing bars whose total heights add up to 6 units — **1 point**

Scoring Note: This point may be earned if only one bar is drawn.

For drawing a bar for U_g that has a height of 2 units — **1 point**

Example Response

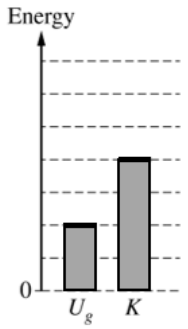


Diagram B

Total for part (a) 2 points

(b) For a multi-step derivation that begins with conservation of energy — **1 point**

For **one** of the following: — **1 point**

- The correct answer for the speed at Point B $v = \sqrt{8gR}$
- The correct substitutions for the initial and final heights
- Substitutions for initial and final heights consistent with part (a)

Example Response

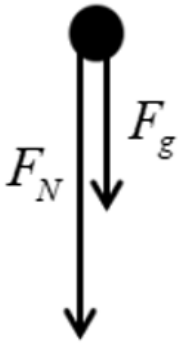
$$E_i = E_f$$
$$U_{g\mathrm{A}} = U_{g\mathrm{B}} + K_{\mathrm{B}}$$
$$mgy_{\mathrm{A}} = mgy_{\mathrm{B}} + \frac{1}{2}mv^2$$
$$Mg(6R) = Mg(2R) + \frac{1}{2}Mv^2$$
$$g(6R) = g(2R) + \frac{1}{2}v^2$$
$$\frac{1}{2}v^2 = 4gR$$
$$v = \sqrt{8gR}$$

Total for part (b) 2 points

(c)(i) For drawing a downward arrow labeled as the gravitational force **1 point**

For drawing a downward arrow labeled as the normal force **1 point**

Example Response



Scoring Note: Examples of appropriate labels for the gravitational force include F_G, F_g, F_{grav}, W, mg, Mg, "grav force," "F Earth on block," "F on block by Earth," $F_{\text{Earth on Block}}$, $F_{\text{E,Block}}$, or $F_{\text{Block,E}}$. The labels G or g are not appropriate labels for the gravitational force.

Scoring Note: Examples of appropriate labels for the normal force include F_n, F_N, N, "normal force," or "track force."

Scoring Note: Arrows of any nonzero magnitude can earn these points.

(c)(ii) For indicating **one** of the following: **1 point**

- The block must be moving at the top of the loop to remain in contact with the loop
- If the block has zero speed at Point C the block will lose contact with the loop
- The block does not have enough kinetic energy and will lose contact with the loop
- The block does not have enough momentum and will lose contact with the loop

Scoring Note: Responses that use relevant derivations may earn this point.

Example Response

If the block were released from a height $4R$ above the ground, then based on energy conservation, the block will have a speed equal to zero at Point C. If the speed is zero, the block will lose contact with the track.

Total for part (c) 3 points

Total for question 1 7 points

Question 1

Begin your response to **QUESTION 1** on this page.

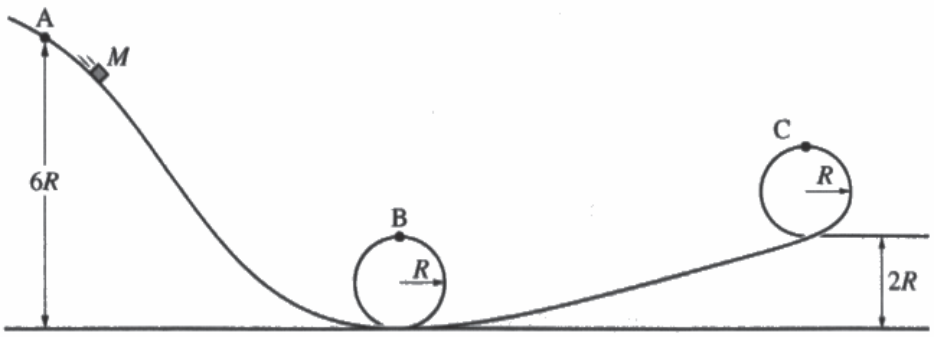
PHYSICS 1

SECTION II

Time—1 hour and 30 minutes

5 Questions

Directions: Questions 1, 4, and 5 are short free-response questions that require about 13 minutes each to answer and are worth 7 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



1. (7 points, suggested time 13 minutes)

A block of mass M is released from rest at Point A, a height $6R$ above the horizontal. After being released, the block slides down a track, as shown. When released from Point A, the block does not lose contact with the track at any point. Points B and C are located at the highest points of their respective circular loops, both of radius R. All frictional forces are negligible.

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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

Continue your response to **QUESTION 1** on this page.

$6RMg = \frac{1}{2}mv^2$

$= 6$

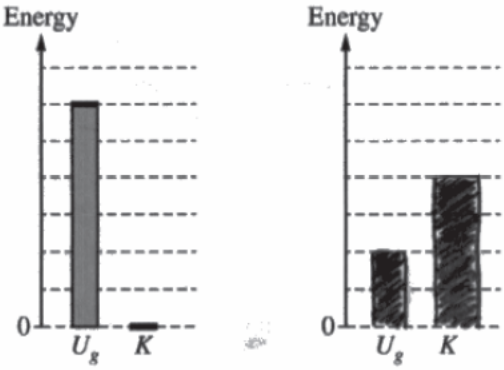

Diagram A Diagram B

Diagram A shows an energy bar chart that represents the gravitational potential energy U_g of the block-Earth system and the kinetic energy K of the block at Point A, when the block is released from rest at height $6R$.

(a) **Draw** shaded regions in Diagram B that represent the gravitational potential energy U_g and kinetic energy K of the block-Earth system when the block is located at Point B, a height $2R$ above the horizontal.

- Shaded regions should start at the dashed line that represents 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 in Diagram A.

(b) Starting with conservation of energy, **derive** an expression for the speed of the block at Point B. Express your answer in terms of R and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference book.

Follow conservation of energy

$6MR_g$ = Total ME

$6MR_g = 2MR_g + \frac{1}{2}Mv^2$

$4MR_g = \frac{1}{2}Mv^2$

$8R_g = v^2$

$\sqrt{8R_g} = v$

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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

Continue your response to **QUESTION 1** on this page.

(c)

i. On the following dot that represents the block, **draw** and **label** the forces (not components) that are exerted on the block at the instant the block slides through Point C. Each force must be represented by a distinct arrow starting on, and pointing away from, the dot.

ii. A student claims that $4R$ is the minimum height of Point A, such that the block can slide through Point C without losing contact with the track after the block is released from rest. Briefly **explain** why this claim is incorrect.

If the height at Point A is 4R, then the total mechanical energy of the system is 4MRg. At point A, the potential energy is equal to the total mechanical energy, & there is 0 kinetic energy. Therefore, at Point C, which also has a height of 4R, there is 0 kinetic energy, meaning the block will have 0 velocity at Point C & will not be able to slide through Point C without losing contact.

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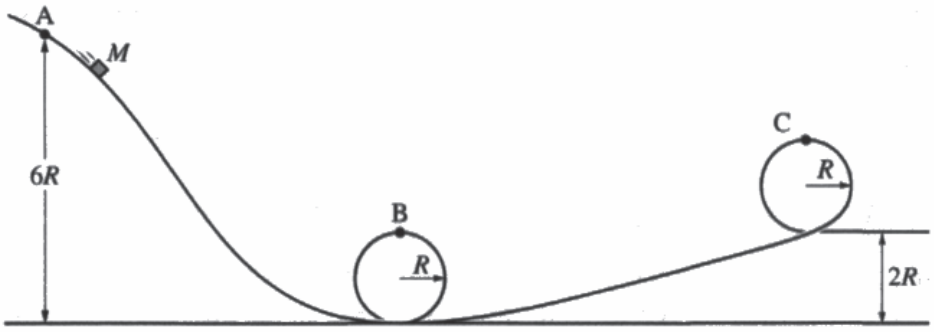

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A block of mass M is released from rest at Point A, a height $6R$ above the horizontal. After being released, the block slides down a track, as shown. When released from Point A, the block does not lose contact with the track at any point. Points B and C are located at the highest points of their respective circular loops, both of radius R. All frictional forces are negligible.

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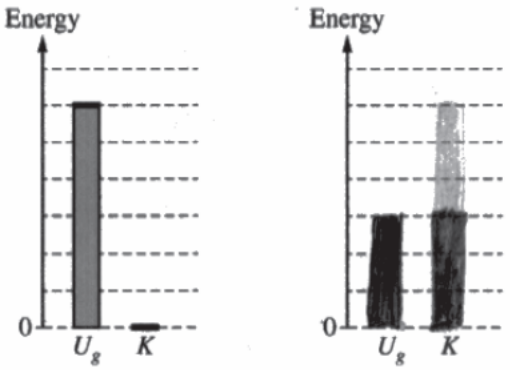

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Diagram A shows an energy bar chart that represents the gravitational potential energy U_g of the block-Earth system and the kinetic energy K of the block at Point A, when the block is released from rest at height $6R$.

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(b) Starting with conservation of energy, **derive** an expression for the speed of the block at Point B. Express your answer in terms of R and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference book.

$\frac{1}{2}mv^2 = mgR$

$\frac{1}{2}v^2 = gR$

$\sqrt{v^2} = \sqrt{2gR}$

$v = \sqrt{2gR}$ m/s

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ii. A student claims that $4R$ is the minimum height of Point A, such that the block can slide through Point C without losing contact with the track after the block is released from rest. Briefly **explain** why this claim is incorrect.

This is incorrect because the block would not gain enough speed, [illegible] since there would be less kinetic energy, because of conservation of energy and how $U_g = mgh$. A lesser height would cause less potential energy.

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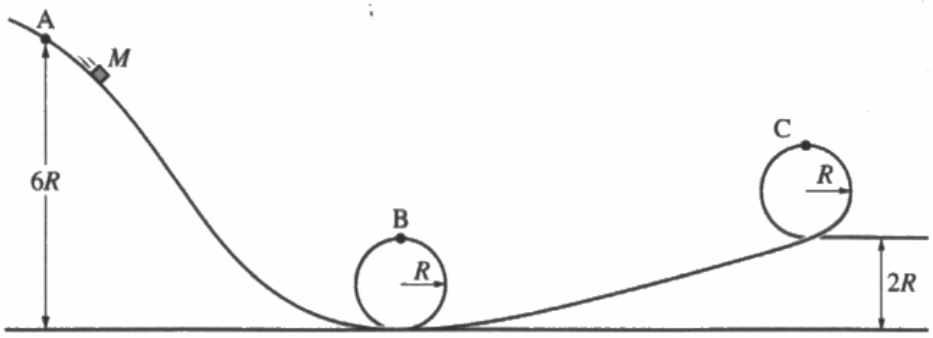

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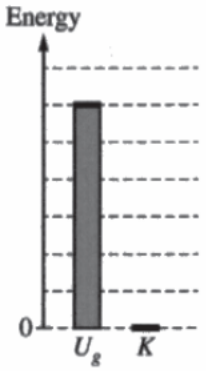

Diagram A

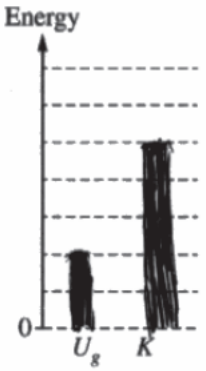

Diagram B

Diagram A shows an energy bar chart that represents the gravitational potential energy U_g of the block-Earth system and the kinetic energy K of the block at Point A, when the block is released from rest at height $6R$.

(a) **Draw** shaded regions in Diagram B that represent the gravitational potential energy U_g and kinetic energy K of the block-Earth system when the block is located at Point B, a height $2R$ above the horizontal.

- Shaded regions should start at the dashed line that represents zero energy.
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(b) Starting with conservation of energy, **derive** an expression for the speed of the block at Point B. Express your answer in terms of R and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference book.

$\Delta E = W = F_{\parallel} d = F d \cos\theta$

$P = \frac{\Delta E}{\Delta t}$

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ii. A student claims that $4R$ is the minimum height of Point A, such that the block can slide through Point C without losing contact with the track after the block is released from rest. Briefly **explain** why this claim is incorrect.

This claim is incorrect due to the fact that ~~it will~~ the block will lose contact with the track after the block is released from rest.

Question 1

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

The responses were expected to demonstrate the ability to:

- Recognize and apply the principle of conservation of energy through multiple representations including an energy bar chart and a mathematical derivation.
- Construct a free-body diagram to show the gravitational and normal forces.
- Identify how a changing height affects the gravitational potential energy and kinetic energy at different positions.
- Demonstrate an understanding as to how velocity and kinetic energy can affect an object moving in a loop and experiencing centripetal acceleration.
- Construct an explanation to support a claim made in the prompt and give evidence as to why the original claim was incorrect.

Sample: 1A
Score: 7

Part (a) earned 2 points. The first point was earned for drawing two bars whose heights add to 6 units. The second point was earned for drawing a bar for U_g that has a height of 2 units. Part (b) earned 2 points. The first point was earned for beginning a multi-step derivation with conservation of energy by stating: "$6MRg = 2MRg + \frac{1}{2}Mv^2$." The second point was earned for stating the correct answer: $v = \sqrt{8Rg}$. Part (c) earned 3 points. The first point was earned for drawing one downward arrow labeled "F_g." The second point was earned for drawing one downward arrow labeled "F_N." The third point was earned for stating, "There is 0 kinetic energy, meaning the block will have 0 velocity at Point C & will not be able to slide through Point C without losing contact."

Sample: 1B
Score: 5

Part (a) earned 1 point for drawing two bars whose heights add to 6 units. (Note: Bars were erased.) The second point was not earned because the response does not correctly draw a bar for U_g that has a height of 2 units. Part (b) earned 1 point for beginning a multi-step derivation with conservation of energy by stating: "$\frac{1}{2}Mv^2 = MgR$." The second point was not earned because the response does not have the correct substitution for the initial and final heights. The response does not have the correct answer. Part (c) earned 3 points. The first point was earned for drawing one downward arrow labeled "mg." The second point was earned for drawing a downward arrow labeled "F_N." The third point was earned for stating, "the block would not gain enough speed, because there would be less kinetic energy."

Question 1 (continued)

Sample: 1C
Score: 2

Part (a) earned 1 point. The first point was not earned because the response does not draw two bars whose heights add to 6 units. The second point was earned for correctly drawing a bar for U_g that has a height of 2 units.

Part (b) did not earn any points. The first point was not earned because the response does not begin with a statement of conservation of energy. The second point was not earned because the response does not have the correct substitution for the initial and final heights. The response does not have the correct answer. Part (c) earned 1 point for drawing one downward arrow labeled "F_g." The second point was not earned because the response does not draw a downward arrow labeled as the normal force. The arrow is incorrectly labeled "F_f." The third point was not earned because the response does not explain why the claim is incorrect in terms of speed, kinetic energy, or momentum.