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

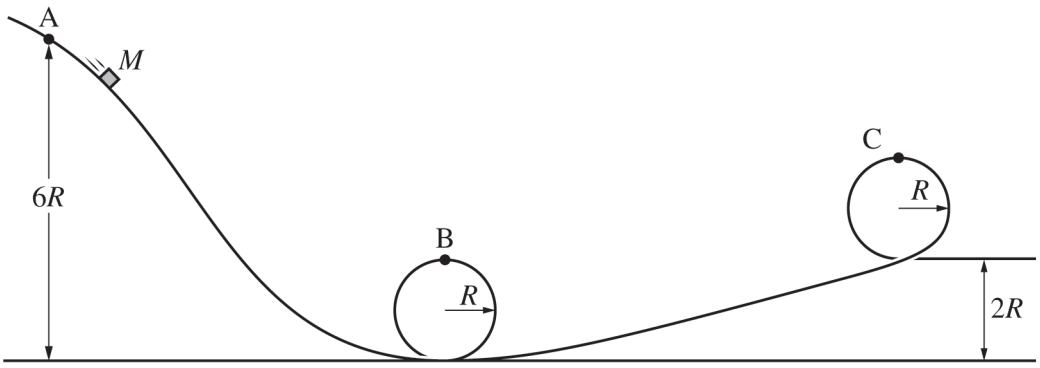
PHYSICS 1

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

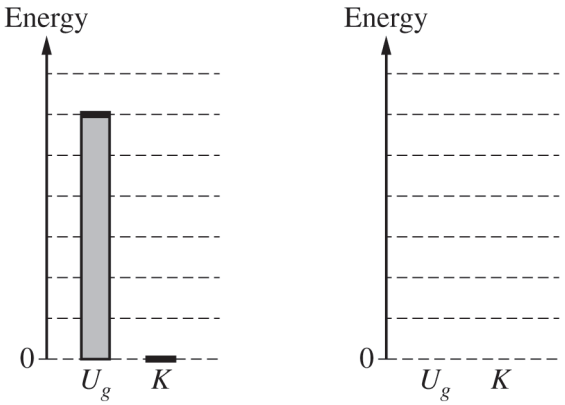

Diagram A shows an energy bar chart that represents the gravitational potential energy U_g of the block-Earth system and the kinetic energy K of the block at Point A, when the block is released from rest at height $6R$.

(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.

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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.

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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

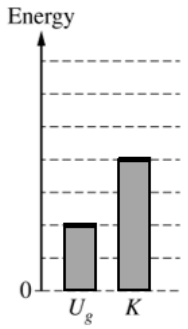


Diagram B

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

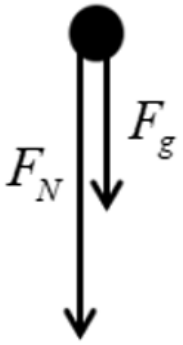
$$E_i = E_f$$
$$U_{g\mathrm{A}} = U_{g\mathrm{B}} + K_{\mathrm{B}}$$
$$mgy_{\mathrm{A}} = mgy_{\mathrm{B}} + \frac{1}{2}mv^2$$
$$Mg(6R) = Mg(2R) + \frac{1}{2}Mv^2$$
$$g(6R) = g(2R) + \frac{1}{2}v^2$$
$$\frac{1}{2}v^2 = 4gR$$
$$v = \sqrt{8gR}$$

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