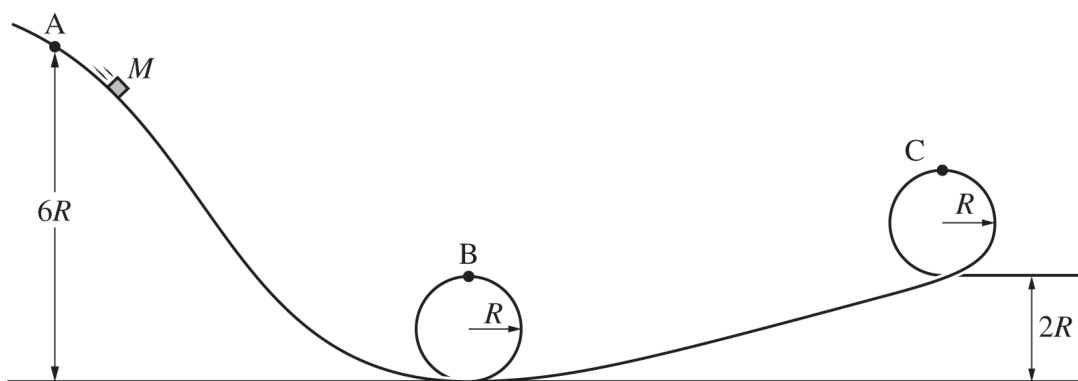


Begin your response to **QUESTION 1** on this page.**PHYSICS 1****SECTION II****Time—1 hour and 30 minutes****5 Questions**

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.

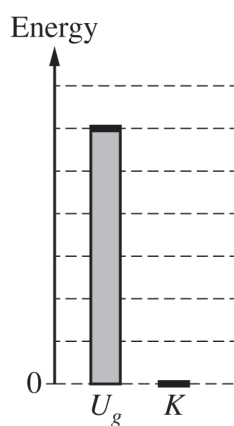


Diagram A

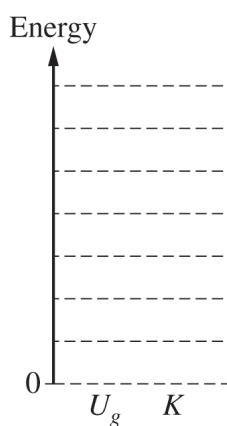


Diagram B

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.

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

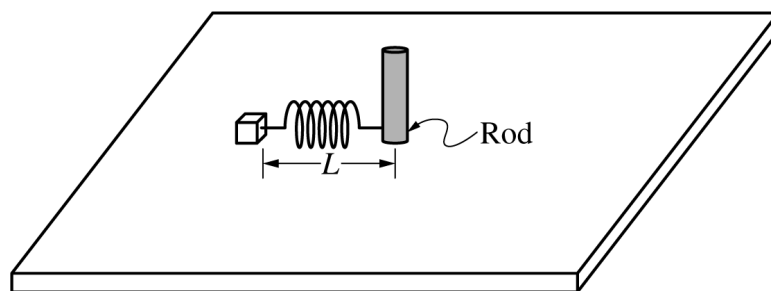
(c)

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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(12 points, suggested time 25 minutes)

A small block of mass m_0 is attached to the end of a spring of spring constant k_0 that is attached to a rod on a horizontal table. The rod is attached to a motor so that the rod can rotate at various speeds about its axis. When the rod is not rotating, the block is at rest and the spring is at its unstretched length L , as shown. All frictional forces are negligible.

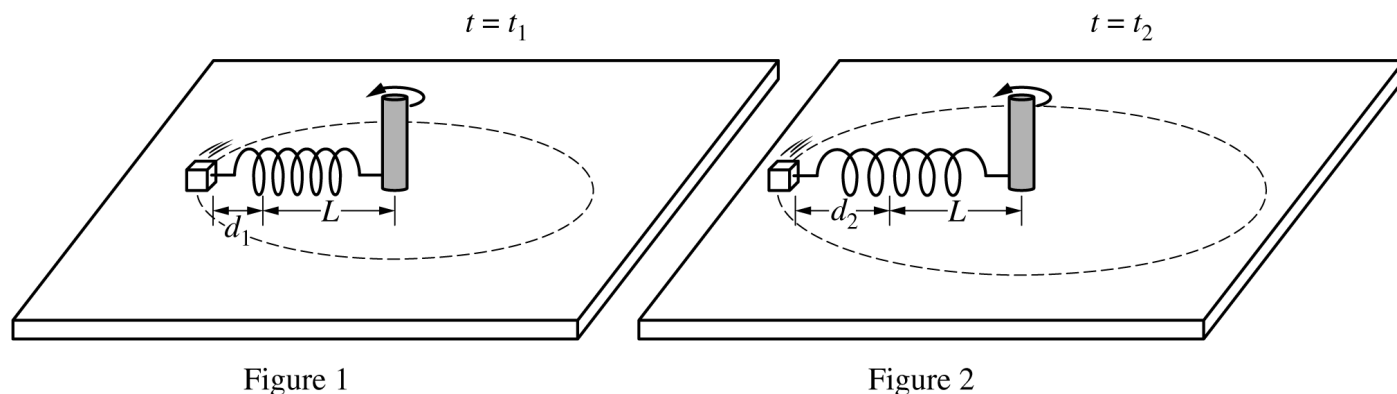


Figure 1

Figure 2

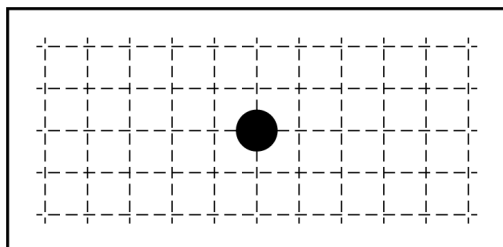
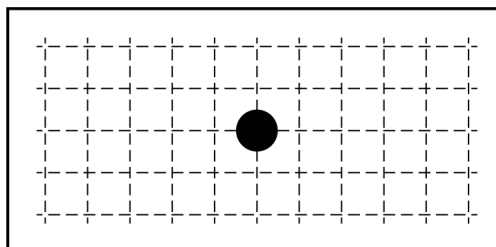
- (a) At time $t = t_1$, the rod is spinning such that the block moves in a circular path with a constant tangential speed v_1 and the spring is stretched a distance d_1 from the spring's unstretched length, as shown in Figure 1. At time $t = t_2$, the rod is spinning such that the block moves in a circular path with a constant tangential speed v_2 and the spring is stretched a distance d_2 from the spring's unstretched length, where $d_2 > d_1$, as shown in Figure 2.

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

- i. On the following dots, which represent the block at the locations shown in Figure 1 and Figure 2, draw the force that is exerted on the block by the spring at times $t = t_1$ and $t = t_2$. The spring force must be represented by a distinct arrow starting on, and pointing away from, the dot.

Note: Draw the relative lengths of the vectors to reflect the relative magnitudes of the forces exerted by the spring at both times.

 $t = t_1$  $t = t_2$

- ii. Referencing d_1 and d_2 , describe your reasoning for drawing the arrows the length that you did in part (a)(i).

- iii. Is the tangential speed v_1 of the block at time $t = t_1$ greater than, less than, or equal to the tangential speed v_2 of the block at time $t = t_2$?

_____ $v_1 > v_2$ _____ $v_1 < v_2$ _____ $v_1 = v_2$

Justify your answer without using equations.

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- (b) Consider a scenario where the block travels in a circular path where the spring is stretched a distance d from its unstretched length L .
- i. Determine an expression for the magnitude of the net force F_{net} exerted on the block. Express your answer in terms of m_0 , k_0 , L , d , and fundamental constants, as appropriate.
- ii. Derive an equation for the tangential speed v of the block. Express your answer in terms of m_0 , k_0 , L , d , and fundamental constants, as appropriate.
- (c) Does your equation for the tangential speed v of the block from part (b)(ii) agree with your reasoning from part (a) ?

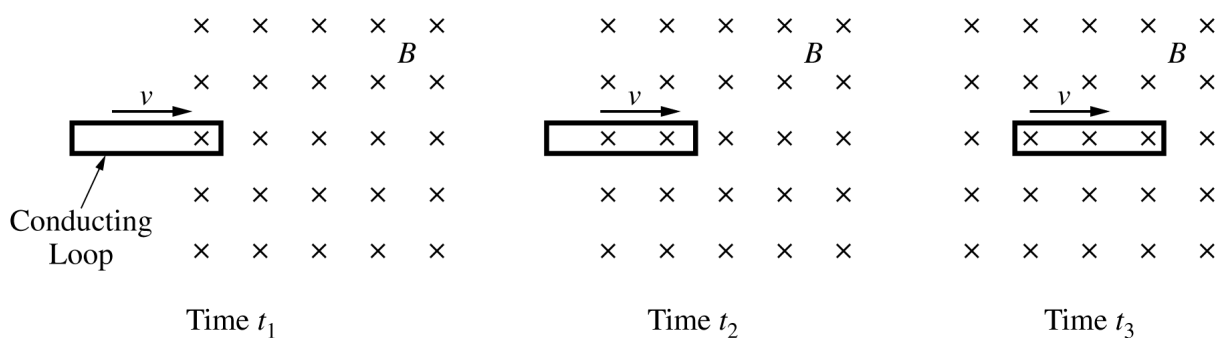
____ Yes ____ No

Explain your reasoning.

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PHYSICS 2**Section II****Time—1 hour and 30 minutes****4 Questions**

Directions: Questions 1 and 4 are short free-response questions that require about 20 minutes each to answer and are worth 10 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.

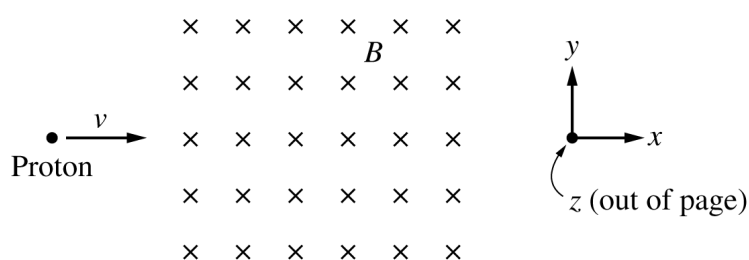


1. (10 points, suggested time 20 minutes)

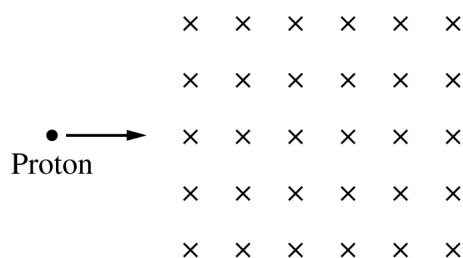
The figures above show a rectangular conducting loop at three instants in time. The loop moves at a constant speed v into and through a region of constant, uniform magnetic field B directed into the page. The magnetic field is zero outside the region.

- (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.

- (b) The loop is removed. A proton traveling to the right in the plane of the page, as shown below, then enters the region of magnetic field with a speed $v = 3.0 \times 10^5$ m/s. The magnitude of the field is 0.030 T. The effects of gravity are negligible.



- i. Calculate the magnitude of the force on the proton as it enters the field.
- ii. On the figure below, sketch a possible path of the proton as it travels through the magnetic field. Clearly label the path P1.



- iii. A second proton now enters the magnetic field at the same point and from the same direction but at a greater speed than the first proton. On the figure above, draw the path of the second proton as it travels through the field. Clearly label the path P2.
- iv. Next an electric field is applied in the same region as the magnetic field, such that there is no net force on the first proton as it enters the region. Calculate the magnitude and indicate the direction of the electric field relative to the coordinate system shown in part (b).