2021

AP® CollegeBoard

AP® Physics 1: Algebra-Based

Sample Student Responses and Scoring Commentary

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Free Response Question 4

- ☑ Scoring Guideline
- ☑ Student Samples
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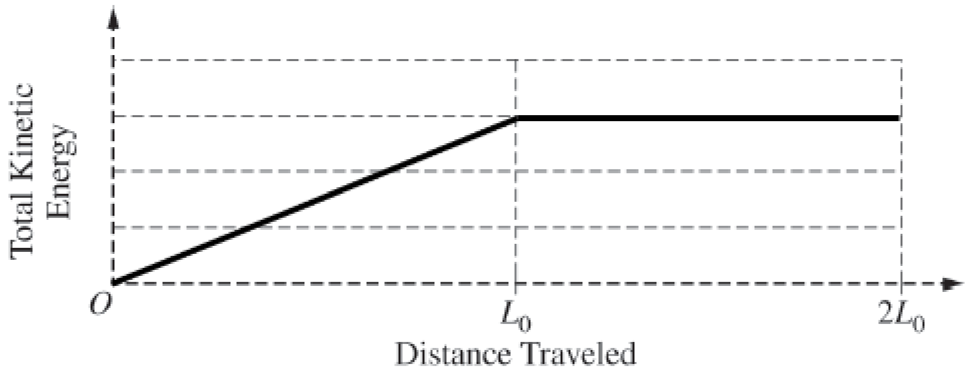
Question 4: Paragraph-Length Response — 7 points

(a)	For a straight line with a positive slope beginning at the origin and reaching a maximum value when the distance traveled is L_0	**1 point**
	For a nonzero horizontal line between L_0 and $2L_0$	**1 point**

Example response for part (a)



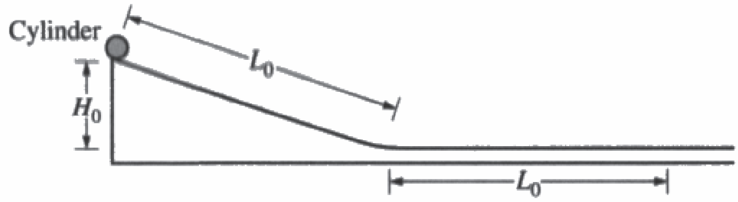
	Total for part (a)	**2 points**
(b)	For indicating that both objects start with the same gravitational potential energy in the object-Earth system	**1 point**
	For a correct statement about the energy transformations that occur to the cylinder as it travels down the ramp	**1 point**
	For a correct statement about the energy transformations that occur to the block as it travels down the ramp	**1 point**
	For indicating that the cylinder's final rotational kinetic energy is equal to the amount of the block-Earth system's initial mechanical energy that is dissipated by friction	**1 point**
	For a logical, relevant, and internally consistent argument that addresses the required argument or question asked, and follows the guidelines described in the published requirements for the paragraph-length response	**1 point**

Example response for part (b)

Both objects start with the same gravitational potential energy in the object-Earth system. The block-Earth system's mechanical energy is converted into kinetic energy, and some of it is dissipated by friction as the block slides down the ramp. The cylinder-Earth system's mechanical energy is transformed into translational kinetic energy and some is transformed into rotational kinetic energy. The cylinder's final rotational kinetic energy is equal to the amount of the block-Earth system's initial mechanical energy that is dissipated by friction.

	Total for part (b)	**5 points**
	Total for question 4	**7 points**

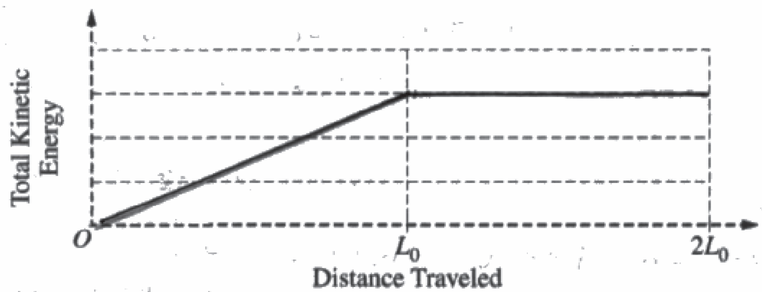
Begin your response to **QUESTION 4** on this page.



4. (7 points, suggested time 13 minutes)

A cylinder of mass m_0 is placed at the top of an incline of length L_0 and height H_0, as shown above, and released from rest. The cylinder rolls without slipping down the incline and then continues rolling along a horizontal surface.

(a) On the grid below, sketch a graph that represents the total kinetic energy of the cylinder as a function of the distance traveled by the cylinder as it rolls down the incline and continues to roll across the horizontal surface.

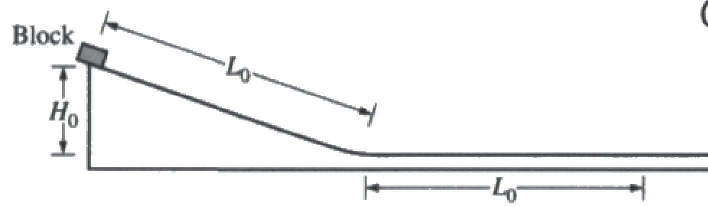


$U_g \downarrow$ $ke \uparrow$, until $h = 0$, then

ke = constant

Continue your response to **QUESTION 4** on this page.

CM = center of mass



The cylinder is again placed at the top of the incline. A block, also of mass m_0, is placed at the top of a separate rough incline of length L_0 and height H_0, as shown above. When the cylinder and block are released at the same instant, the cylinder begins to roll without slipping while the block begins to accelerate uniformly. The cylinder and the block reach the bottoms of their respective inclines with the same translational speed.

(b) In terms of energy, explain why the two objects reach the bottom of their respective inclines with the same translational speed. Provide your answer in a clear, coherent paragraph-length response that may also contain figures and/or equations.

cylinder: $U_g \rightarrow KE_{tran.} + \underline{KE_{rot}}$

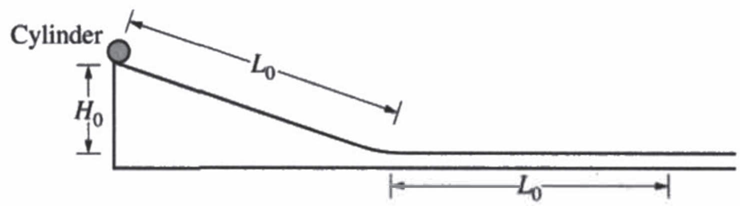
block: ~~$U_g \rightarrow KE$~~

$E_i + W_{ext} = E_f$

$U_g + \underline{W_{friction}} = KE_{tran}$

- The cylinder gains kinetic energy since it's CM is moving down the incline but since it is rolling without slipping (ie. not sliding), some of the initial U_g gets converted into rotational kinetic energy along with translational kinetic energy.
- The block starts at the same height (ie same U_g), but in this case also all of the U_g cant be converted directly into kinetic energy. The U_g gets mostly converted into KE, but some is lost as thermal energy through friction.
- Since the cylinder has energy going into rotational kinetic energy & the block has energy going into thermal energy, both objects end up with a resultant translational kinetic energy, and therefore end with the same speed.

Begin your response to QUESTION 4 on this page.



4. (7 points, suggested time 13 minutes)

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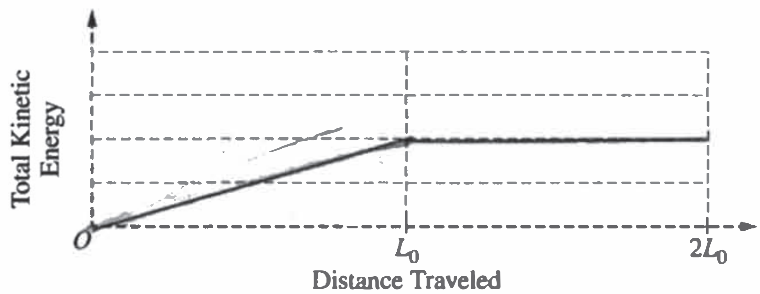

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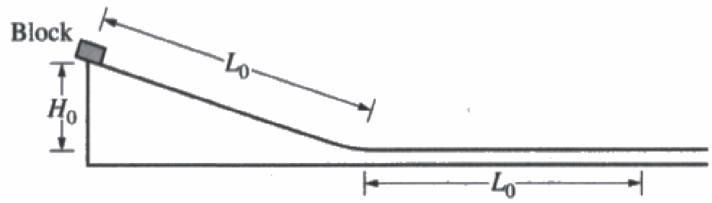
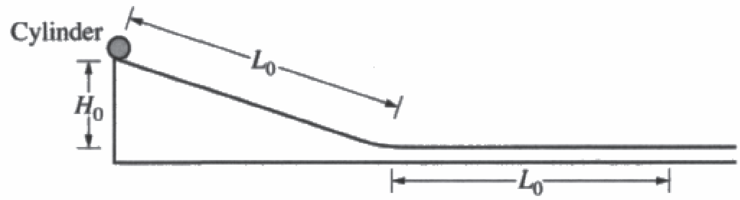


The cylinder is again placed at the top of the incline. A block, also of mass m_0, is placed at the top of a separate rough incline of length L_0 and height H_0, as shown above. When the cylinder and block are released at the same instant, the cylinder begins to roll without slipping while the block begins to accelerate uniformly. The cylinder and the block reach the bottoms of their respective inclines with the same translational speed.

(b) In terms of energy, explain why the two objects reach the bottom of their respective inclines with the same translational speed. Provide your answer in a clear, coherent paragraph-length response that may also contain figures and/or equations.

The two objects reach the bottom of their inclines with the same translational speed because both objects lose some ~~translational~~ energy. The cylinder loses some translational energy to rotational energy and the block loses some translational energy to friction.

Begin your response to **QUESTION 4** on this page.



4. (7 points, suggested time 13 minutes)

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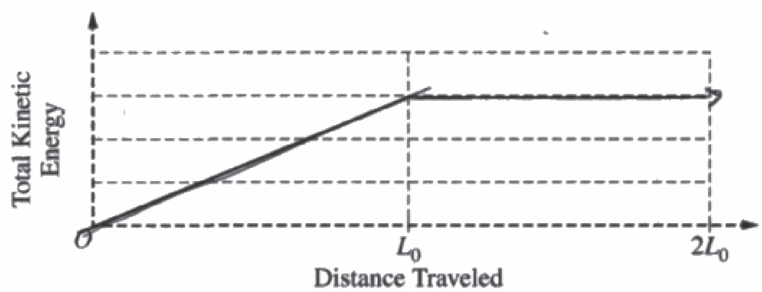
(a) On the grid below, sketch a graph that represents the total kinetic energy of the cylinder as a function of the distance traveled by the cylinder as it rolls down the incline and continues to roll across the horizontal surface.



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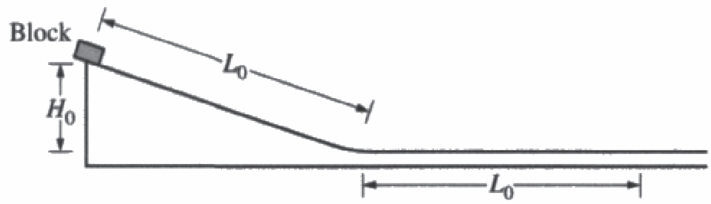

The cylinder is again placed at the top of the incline. A block, also of mass m_0, is placed at the top of a separate rough incline of length L_0 and height H_0, as shown above. When the cylinder and block are released at the same instant, the cylinder begins to roll without slipping while the block begins to accelerate uniformly. The cylinder and the block reach the bottoms of their respective inclines with the same translational speed.

(b) In terms of energy, explain why the two objects reach the bottom of their respective inclines with the same translational speed. Provide your answer in a clear, coherent paragraph-length response that may also contain figures and/or equations.

The 2 objects reach the bottom of their respective inclines with the same transiational speed because $\Delta E = Fd \cos\theta$ and $K = \Delta E$ if both objects cover the same distance and have the same amount of force on them their speed should stay relatively the same

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Question 4

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

Overview

- In terms of physics content, responses were expected to demonstrate an understanding of energy transformations into a variety of forms: gravitational, translational, rotational, and thermal.
- In terms of skills, the question required students to communicate their understanding of energy transformations in graphical and verbal (as opposed to numeric or algebraic) form.

Sample: P1 Q4 A
Score: 6

Part (a) earned 2 points. The first segment is a straight line from the origin to a maximum at *L*o, and the second segment continues horizontally between *L*o and 2*L*o. Part (b) earned 4 points. One point was earned for stating "the block starts at the same height (i.e. same Ug)" in the second bullet. One point was earned for "…converted into rotational kinetic energy..." in the first bullet. One point was earned for "...but some is lost as thermal energy through friction" in the second bullet. Though the response indicates that both objects have the same translational kinetic energy, that's easily inferred from the problem statement. To earn this point, the response must somehow indicate equivalence between the cylinder's rotational energy and the block's thermal energy. This equivalence needs to be reasonably explicit. The final point was earned for a logical, relevant, and internally consistent response.

Sample: P1 Q4 B
Score: 4

Part (a) earned 2 points. The first segment is a straight line from the origin to a maximum at *L*o, and the second segment continues horizontally between *L*o and 2*L*o. Part (b) earned 3 points. One point was earned, even though the language is imprecise, because the response shows explicit recognition that the cylinder possesses rotational energy. One point was earned, even though the language is imprecise, because the response shows recognition that for the block energy is dissipated by ("lost to") friction. The response does not address the relative magnitudes of the cylinder's rotational energy and the block's frictional energy loss and makes no reference to gravitational potential energy at the top of the incline. The final point was not earned because, for example, the response incorrectly indicates that the objects "lose translational energy." The translational kinetic energy is initially zero and cannot be lost, and it actually increases as either object rolls or slides down the incline.

Sample: P1 Q4 C
Score: 2

Part (a) earned 2 points. The first segment is a straight line from the origin to a maximum at *L*o, and the second segment continues horizontally between *L*o and 2*L*o. Part (b) earned no points. Though general equations for energy are included, neither of these equations, nor the subsequent prose indicates that the objects start with the same gravitational energy at the top of the incline. There is no reference made to rotational kinetic energy or to the energy dissipated by the force of friction, and by extension, the response cannot earn the point for these amounts of energy being equivalent. The final point was not earned because, for example, the response gives equations relating force and distance to energy, but the prose that follows connects the force and distance to speed without mentioning the connection to kinetic energy or the connection between kinetic energy and speed.