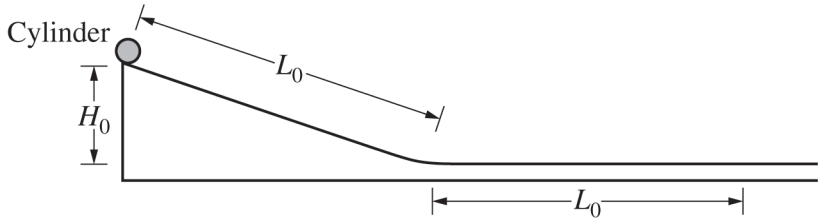
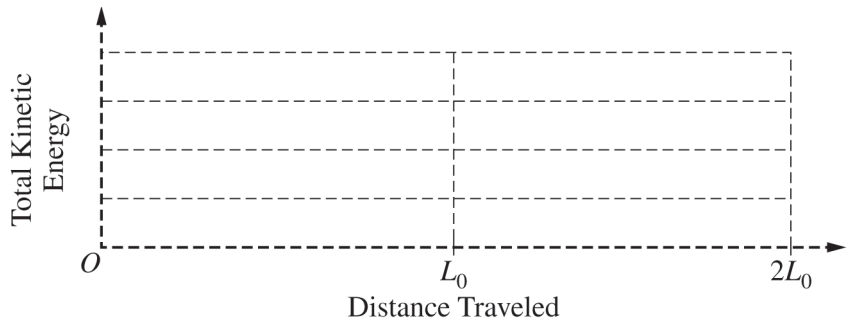
Begin your response to **QUESTION 4** on this page.



4. (7 points, suggested time 13 minutes)

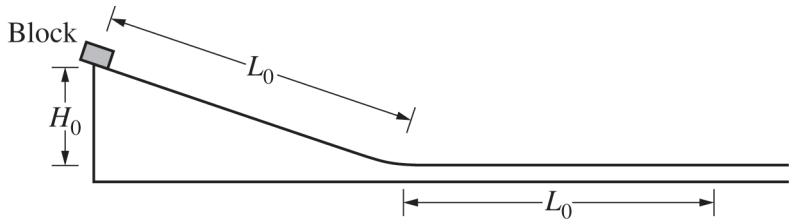
A cylinder of mass m_0 is placed at the top of an incline of length L_0 and height H_0, as shown above, and released from rest. The cylinder rolls without slipping down the incline and then continues rolling along a horizontal surface.

(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.



GO ON TO THE NEXT PAGE.

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



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.

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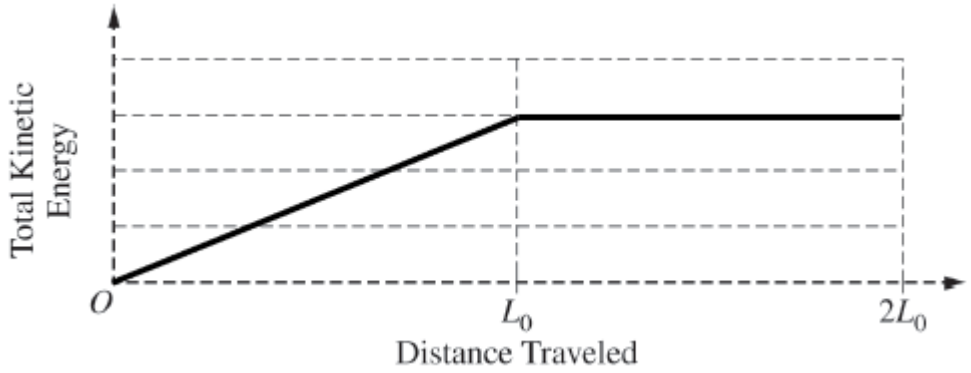
Question 4: Paragraph-Length Response — 7 points

(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**