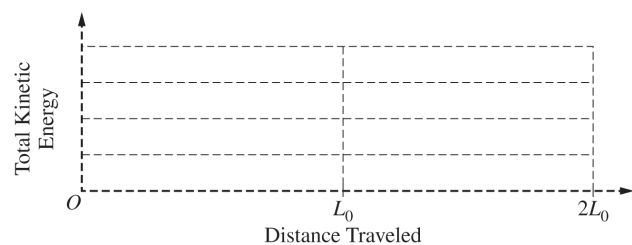


(7 points, suggested time 13 minutes)

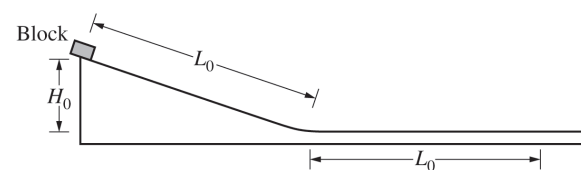
A cylinder of mass m_0 is placed at the top of an incline of length L_0 and height H_0 , as shown above, and released from rest. The cylinder rolls without slipping down the incline and then continues rolling along a horizontal surface.

- (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.



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Use a pencil or pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.



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.

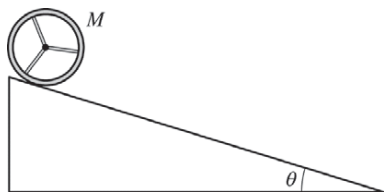
- (b) In terms of energy, explain why the two objects reach the bottom of their respective inclines with the same translational speed. Provide your answer in a clear, coherent paragraph-length response that may also contain figures and/or equations.

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Use a pencil or pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

PHYSICS 1**Section II****5 Questions****Time—90 minutes**

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.

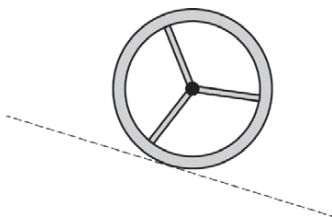


1. (7 points, suggested time 13 minutes)

A wooden wheel of mass M , consisting of a rim with spokes, rolls down a ramp that makes an angle θ with the horizontal, as shown above. The ramp exerts a force of static friction on the wheel so that the wheel rolls without slipping.

(a)

- i. On the diagram below, draw and label the forces (not components) that act on the wheel as it rolls down the ramp, which is indicated by the dashed line. To clearly indicate at which point on the wheel each force is exerted, draw each force as a distinct arrow starting on, and pointing away from, the point at which the force is exerted. The lengths of the arrows need not indicate the relative magnitudes of the forces.



- ii. As the wheel rolls down the ramp, which force causes a change in the angular velocity of the wheel with respect to its center of mass?

Briefly explain your reasoning.

- (b) For this ramp angle, the force of friction exerted on the wheel is less than the maximum possible static friction force. Instead, the magnitude of the force of static friction exerted on the wheel is 40 percent of the magnitude of the force or force component directed opposite to the force of friction. Derive an expression for the linear acceleration of the wheel's center of mass in terms of M , θ , and physical constants, as appropriate.

- (c) In a second experiment on the same ramp, a block of ice, also with mass M , is released from rest at the same instant the wheel is released from rest, and from the same height. The block slides down the ramp with negligible friction.

- i. Which object, if either, reaches the bottom of the ramp with the greatest speed?

_____ Wheel _____ Block _____ Neither; both reach the bottom with the same speed.

Briefly explain your answer, reasoning in terms of forces.

- ii. Briefly explain your answer again, now reasoning in terms of energy.