15. The acceleration due to gravity at Earth's surface is g. Astronauts are traveling to another planet that has three times the radius and four times the mass of Earth. The acceleration due to gravity at the surface of the other planet is

(A) $\frac{4}{9}g$

(B) g

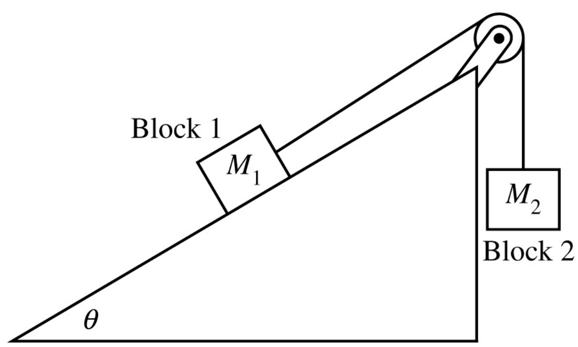
(C) $\frac{4}{3}g$

(D) $\frac{16}{9}g$

(E) $\frac{9}{4}g$

Section II: Free-Response Questions

The following are examples of the of free-response questions found on the exam. Note that on the actual AP Exam, there will be three questions.



1. Students set up a system of two blocks and an inclined plane, as shown in the figure. Block 1 of mass M_1 is on an surface that is inclined at an angle θ to the horizontal. The friction between block 1 and the surface is negligible. A string is attached to block 1, extends over an ideal pulley, and is then attached to block 2 of mass M_2.

   (a) In an initial setup, $M_1 = 3M$ and $M_2 = M$. Calculate the value of θ that would allow the system to remain in equilibrium.

   The original inclined plane is now replaced with one that has a rough surface. The coefficients of static and kinetic friction between block 1 and the surface are μ_s and μ_k, respectively. Block 1 is again chosen so that $M_1 = M$.

   (b) Derive an expression for the maximum value of M_2 that would allow this system to remain in equilibrium. Express your answer in terms of M, μ_s, μ_k, and physical constants, as appropriate.

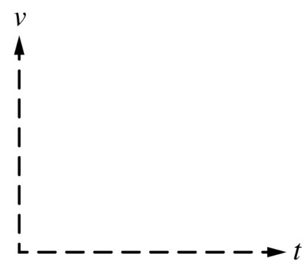
   Block 2 of mass M_2 is now chosen such that block 1 will accelerate up the inclined plane.

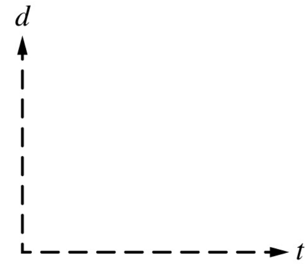
   (c)

      i. Derive an expression for the magnitude of the acceleration of block 1. Express your answer in terms of M_1, M_2, μ_s, μ_k, θ, and physical constants, as appropriate.

      ii. Derive an expression for the tension in the string. Express your answer in terms of M_1, M_2, μ_s, μ_k, θ, and physical constants, as appropriate.

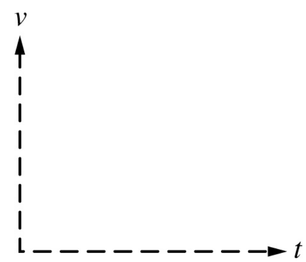
(d) On the axes below, sketch the speed v and distance d moved by block 1 up the inclined plane as functions of time.



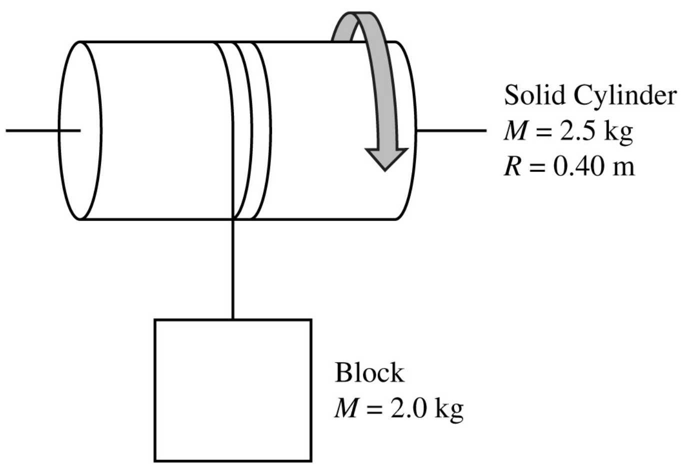


(e) During the experiments, students collect data that shows the acceleration of the blocks actually increases while the blocks are in motion.

i. On this axis below, sketch the speed v of block 1 as a function of t.



ii. Explain why the experiment may have produced an increasing acceleration instead of the predicted constant acceleration.



2. A block of mass 2.0 kg is attached to a light string that is wrapped around a solid cylinder, as shown in the figure. The cylinder has a mass of $M = 2.5 \text{ kg}$ and a radius of $R = 0.40 \text{ m}$. The cylinder can rotate with negligible friction about a light rod through its central axis. The block-cylinder system is initially held at rest.

(a) Using integral calculus, show that the rotational inertia of the cylinder about its central axis is $\frac{1}{2}MR^2$.

(b) The block is released from rest and the string unwinds, causing the cylinder to rotate on the rod.

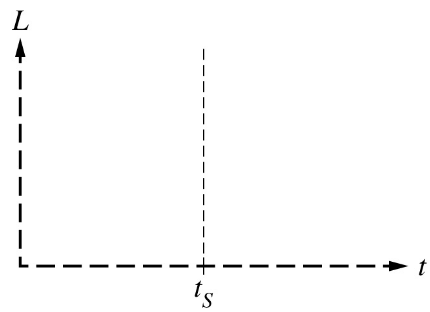
i. Calculate the linear acceleration of the block.

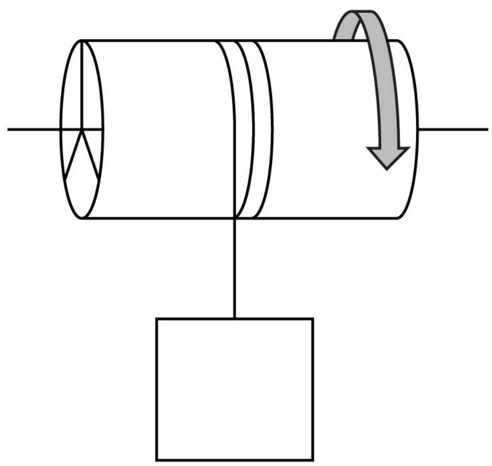
ii. Calculate the net torque exerted on the cylinder.

iii. Calculate the tension in the string.

At time t_S, the block reaches its lowest point as the string has completely unwound. The string then begins to rewind on the cylinder, and the mass is raised back upward.

(c) On the axis below, sketch the angular momentum L of the cylinder as a function of time t from the moment the mass is released to shortly after t_S.





The solid cylinder is replaced by a hollow cylinder with the same mass and radius. Lightweight spokes attach the hollow cylinder to a light rod through its central axis. The hollow cylinder can rotate around its central axis with negligible friction. The string is wound around the hollow cylinder so that the block is at the same initial position as before. The block is again released from rest. The time it takes for the string to completely unwind from the hollow cylinder is t_H.

(d) Is the time t_H greater than, less than, or equal to the time t_S ?

__________ Greater than __________ Less than __________ Equal to

Justify your answer.