AP PHYSICS C: ROTATIONAL MOTION

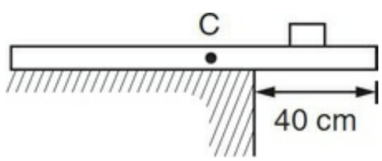
Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box on the student answer sheet.

Note: To simplify calculations, you may use $g = 10\,\text{m/s}^2$ in all problems.

1. Linear acceleration is to force as angular acceleration is to

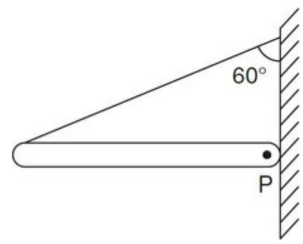
(A) kinetic energy
(B) angular velocity
(C) rotational inertia
(D) torque
(E) angular momentum

2. A meter stick of mass 0.1 kg rests on a table as shown. A length of 40 cm extends over the edge of the table. How far from the edge of the table could a 0.05 kg mass be placed on the meter stick so that the stick just begins to tip?



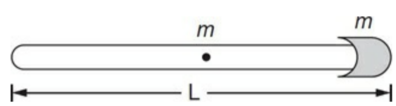
(A) 5 cm
(B) 10 cm
(C) 15 cm
(D) 20 cm
(E) 30 cm

3. A metal bar of constant density and weight W is attached to a pivot on the wall at point P and supported by a rope that makes an angle of 60° with the vertical wall. The reaction force exerted by the pivot on the bar at point P is best represented by which arrow?



(A) ↗
(B) ↑
(C) ↓
(D) ↖
(E) ↘

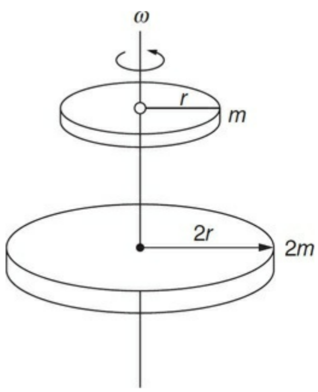
4. A uniform rod of length L and mass m has a rotational inertia of $\frac{1}{12}mL^2$ about its center. A particle, also of mass m, is attached to one end of the stick. The combined rotational inertia of the stick and particle about the center of the rod is



(A) $\dfrac{mL^2}{3}$
(B) $\dfrac{12mL^2}{13}$
(C) $\dfrac{13mL^2}{12}$
(D) $\dfrac{mL^2}{156}$
(E) $\dfrac{13mL^2}{156}$

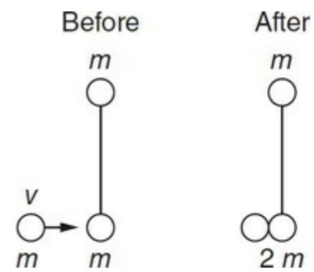
5. Two disks are fixed to a vertical axle that is rotating with a constant angular speed ω. The smaller disk

has a mass m and a radius r, and the larger disk has a mass $2m$ and radius $2r$. The general equation for the rotational inertia of a disk of mass M and radius R is $\frac{1}{2}MR^2$. The ratio of the angular momentum of the larger disk to the smaller disk is



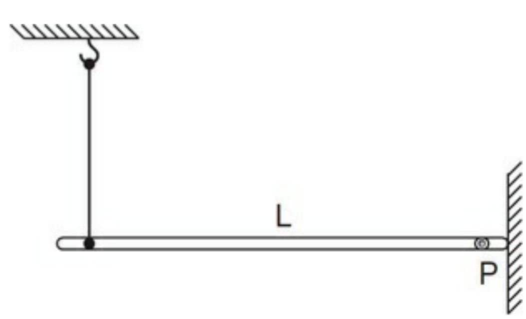
(A) 1 : 4
(B) 4 : 1
(C) 1 : 2
(D) 2 : 1
(E) 8 : 1

6. Astronauts are conducting an experiment in a negligible gravity environment. Two spheres of mass m are attached to either end of a light rod. As the rod and spheres float motionless in space, an astronaut launches a piece of sticky clay, also of mass m, toward one of the spheres so that the clay strikes and sticks to the sphere perpendicular to the rod. Which of the following statements is true of the motion of the rod, clay, and spheres after the collision?



(A) Linear momentum is not conserved, but angular momentum is conserved.
(B) Angular momentum is not conserved, but linear momentum is conserved.
(C) Kinetic energy is conserved, but angular momentum is not conserved.
(D) Kinetic energy is conserved, but linear momentum is not conserved.
(E) Both linear momentum and angular momentum are conserved, but kinetic energy is not conserved.

7. One end of a stick of length L, rotational inertia I, and mass m is pivoted on an axle with negligible friction at point P. The other end is tied to a string and held in a horizontal position. When the string is cut, the stick rotates counterclockwise. The angular speed ω of the stick when it reaches the bottom of its swing is



(A) $\dfrac{mgL}{I}$

(B) $\sqrt{\dfrac{mgL}{I}}$

(C) $\sqrt{\dfrac{2mgL}{I}}$

(D) $\sqrt{\dfrac{mgL}{2I}}$

(E) $\sqrt{\dfrac{4mgL}{I}}$

8. A disk is mounted on a fixed axle. The rotational inertia of the disk is I. The angular velocity of the disk is decreased from ω_0 to ω_f during a time Δt due to friction in the axle. The magnitude of the average net torque acting on the wheel is

(A) $\dfrac{\omega_f - \omega_0}{\Delta t}$

(B) $\dfrac{(\omega_f - \omega_o)^2}{\Delta t}$

(C) $\dfrac{I(\omega_f - \omega_o)}{\Delta t}$

(D) $\dfrac{I(\omega_f - \omega_o)^2}{\Delta t}$

(E) $\dfrac{I(\omega_f - \omega_o)}{\Delta t^2}$

9. The average power developed by the friction in the axle of the disk from the previous question to bring it to a complete stop is

(A) $\dfrac{\omega_o}{\Delta t}$

(B) $\dfrac{(\omega_o)^2}{\Delta t}$

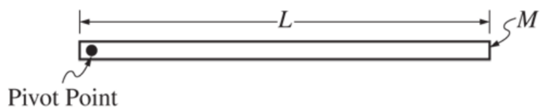
(C) $\dfrac{I(\omega_f - \omega_o)}{2\Delta t}$

(D) $\dfrac{I\omega_o^2}{2\Delta t}$

(E) $\dfrac{I(\omega_f - \omega_o)}{\Delta t^2}$

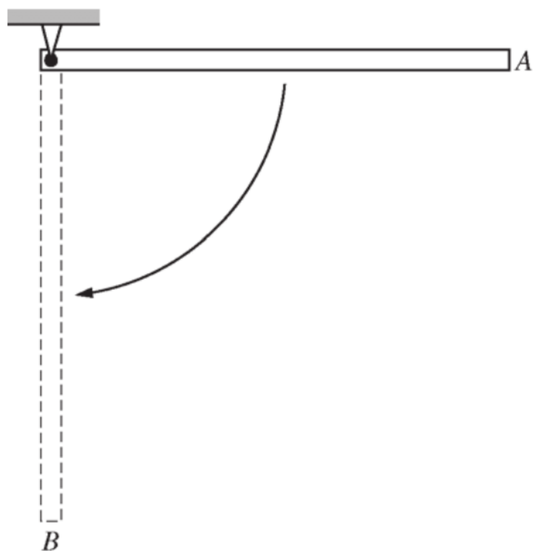
AP PHYSICS 1 & C: CIRCULAR MOTION AND SIMPLE HARMONIC MOTION
SECTION II
6 Questions

Directions: Answer all questions. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should show your work. Credit also depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should clearly indicate which part of a question your work is for. 10



1. A uniform, thin rod of length L and mass M is allowed to pivot about its end, as shown in the figure above.

   (a) Using integral calculus, derive the rotational inertia for the rod around its end to show that it is $ML^2/3$.



The rod is fixed at one end and allowed to fall from the horizontal position A through the vertical position B.

   (b) Derive an expression for the velocity of the free end of the rod at position B. Express your answer in terms of M, L, and physical constants, as appropriate.

An experiment is designed to test the validity of the expression found in part (b). A student uses rods of various lengths that all have a uniform mass distribution. The student releases each of the rods from the horizontal position *A* and uses photogates to measure the velocity of the free end at position *B*. The data are recorded below.

Length (m)	0.25	0.50	0.75	1.00	1.25	1.50
Velocity (m/s)	2.7	3.8	4.6	5.2	5.8	6.3

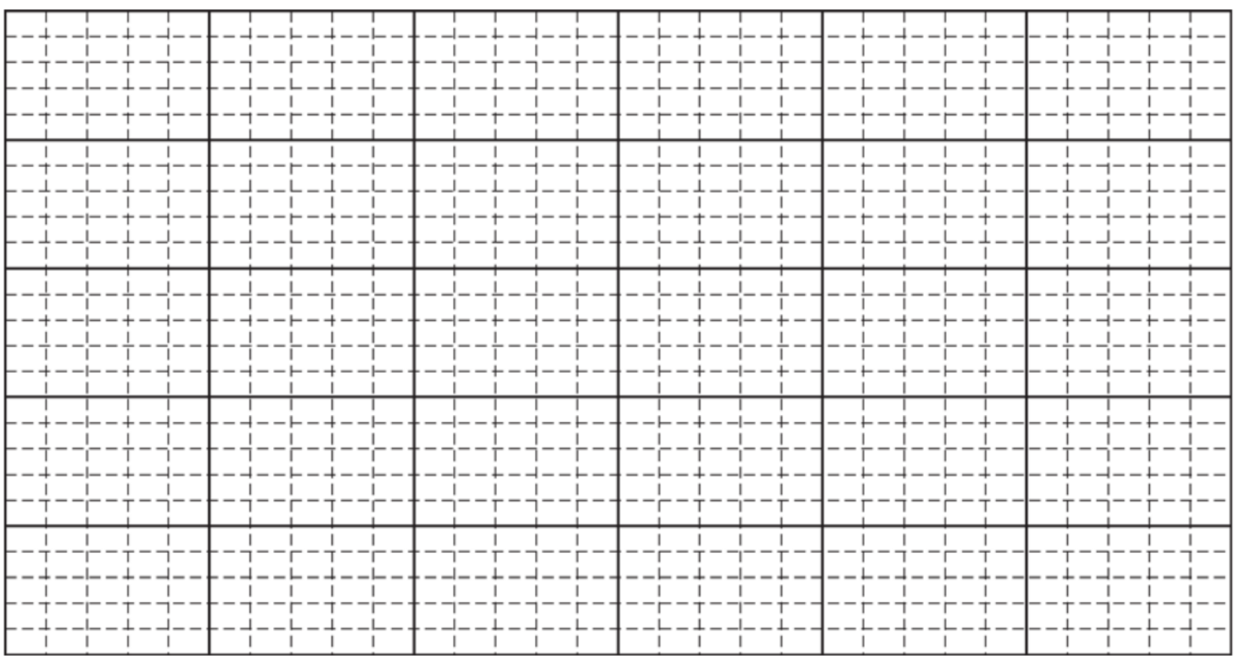
(c) Indicate below which quantities should be graphed to yield a straight line whose slope could be used to calculate a numerical value for the acceleration due to gravity g.

Horizontal axis: _____________

Vertical axis: _____________

Use the remaining rows in the table above, as needed, to record any quantities that you indicated that are not given. Label each row you use and include units.

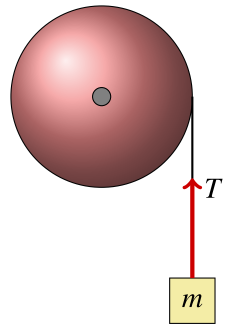
(d) Plot the straight line data points on the grid below. Clearly scale and label all axes, including units as appropriate. Draw a straight line that best represents the data.



(e) i. Using your straight line, determine an experimental value for g.

ii. Describe two ways in which the effects of air resistance could be reduced.

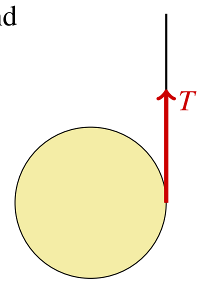
2. A uniform sphere of mass M and radius R is free to rotate, without friction, about a horizontal axis through its center. A string is wrapped around the sphere and is attached to a body of mass m as shown in the figure below. Find



(a) the acceleration of the body, and

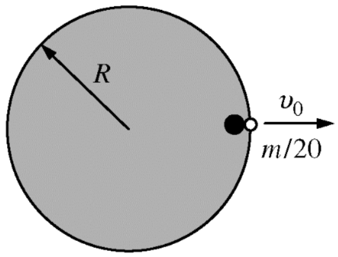
(b) the tension in the string.

3. A uniform cylinder of mass M and radius R has a string wrapped around it. The string is held fixed, and the cylinder falls vertically as shown in the figure below. Find

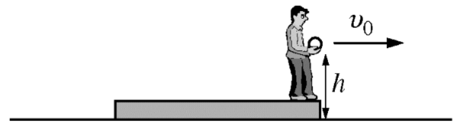


(a) the acceleration of the body, and

(b) the tension in the string.



Top View



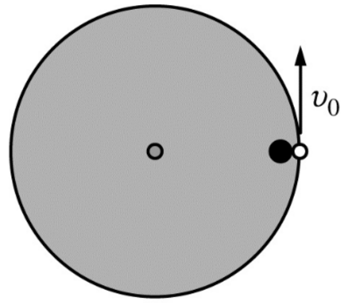
Side View

4. A large circular disk of mass m and radius R is initially stationary on a horizontal icy surface. A person of mass $m/2$ stands on the edge of the disk. Without slipping on the disk, the person throws a large stone of mass $m/20$ horizontally at initial speed v_0 from a height h above the ice in a radial direction, as shown in the figures above. The coefficient of friction between the disk and the ice is μ. All velocities are measured relative to the ground. The time it takes to throw the stone is negligible. Express all algebraic answers in terms of m, R, v_0, h, m, and fundamental constants, as appropriate.

   (a) Derive an expression for the length of time it will take the stone to strike the ice.

   (b) Assuming that the disk is free to slide on the ice, derive an expression for the speed of the disk and person immediately after the stone is thrown.

   (c) Derive an expression for the time it will take the disk to stop sliding.



Top View

The person now stands on a similar disk of mass m and radius R that has a fixed pole through its center so that it can only rotate on the ice. The person throws the same stone horizontally in a tangential direction at initial speed u_0, as shown in the figure above. The rotational inertia of the disk is $mR^2/2$.

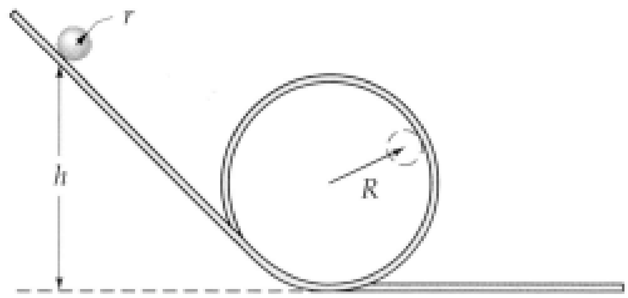
(d) Derive an expression for the angular speed ω of the disk immediately after the stone is thrown.

(e) The person now stands on the disk at rest R 2 from the center of the disk. The person now throws the stone horizontally with a speed v_0 in the same direction as in part (d). Is the angular speed of the disk immediately after throwing the stone from this new position greater than, less than, or equal to the angular speed found in part (d) ?

____ Greater than ____ Less than ____ Equal to

Justify your answer.

5. A uniform ball of radius r rolls without slipping along the loop-the-loop track in the figure below. The ball starts at rest at a height of h above the bottom of the loop.



(a) If it is not to leave the track at the top of the loop, what is the least value h can have (in terms of radius R of the loop)?

(b) What would h have to be if, instead of rolling, the ball slides without friction?