AP Physics C   Name: ______________________________

Unit 5&6: Rotation Test

Part 1: Multiple Choice - Choose the answers that best answers the questions below. If an exact answer is not present, chose the closest available answer. (4 points each)

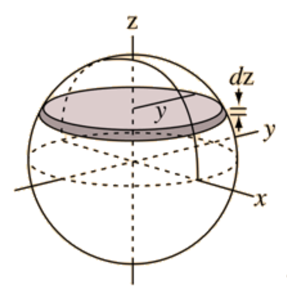
1. The wheel in the sky keeps on turning. I don't know where I'll be tomorrow, but I do that the angular displacement of the wheel over time is given by: $\theta(t) = 4t^2 - 2$ and that the wheel has a radius of 3 m. Calculate the instantaneous linear speed of a point on the edge of the wheel at time t = 2 s.

A) 160 m/s   B) 16 m/s   C) 14 m/s   D) 48 m/s   E) 42 m/s

2. Just a small-town girl, living in a lonely world. She took the midnight train going anywhere. Just a city boy, born and raised in South Detroit. He applied a tangential force of 40 N on a wheel of the midnight train. Don't stop believin' that the wheel has a radius of 1.5 m and moment of inertia 4.0 kg·m^2 is turning at 50 rad/s when the force is applied. How many complete revolutions does the wheel make while slowing down to a stop?

A) 19   B) 83   C) 121   D) 27   E) 13

3. A solid sphere of density ρ and radius R can be broken up into many infinitely small discs of thickness dz as shown on the right, each with a moment of inertia equal to $dI = \frac{1}{2}y^2dm$. Which of the follow integrals can be used, when evaluated, to find the moment of inertia of the solid sphere?



A) $\int_{-R}^{R} \frac{1}{2}\rho(R^2 - z^2)^2\pi dz$

B) $\int_{-R}^{R} \frac{1}{2}\rho y^4 \pi dy$

C) $\int_{0}^{R} \frac{1}{2}\rho(R^2 - z^2)\pi dz$

D) $\int_{0}^{R} \frac{1}{2}\rho(R^2 - y^2)^2\pi dz$

E) $\int_{-R}^{R} \frac{1}{2}\rho(R^2 - y^2)^2\pi dy$

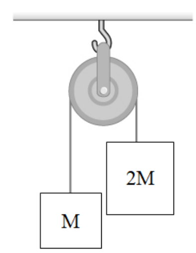
4. A hollow sphere has a moment of inertia given by $\frac{2}{5}MR^2$ about its center. If a sphere instead rotates about an axis tangent to the sphere, what would the moment of inertia be?

A) $\frac{2}{5}MR^2$ B) $\frac{2}{3}MR^2$ C) $\frac{7}{10}MR^2$ D) $\frac{12}{5}MR^2$ E) $\frac{7}{5}MR^2$

5. A solid cylinder ($I = \frac{1}{2}mr^2$) with a mass m and radius r is mounted so that it can be rotated about an axis that passes through the center of both ends. At what angular speed ω must the cylinder rotate to have the same total kinetic energy that it would have if it were moving horizontally with a speed v without rotation?

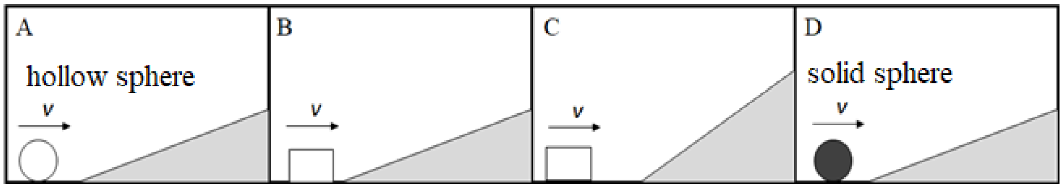
A) $\omega = \frac{v}{r}$ B) $\omega = \frac{v^2}{2r}$ C) $\omega = \frac{v}{r}\sqrt{2}$ D) $\omega = \frac{v^2}{r^2}$ E) $\omega = \frac{v^2}{2r}$

6. Two masses of magnitude M and 2M are connected by a light spring over a pulley as shown. The rope does not slip on the pulley, which has a mass of M and radius R and has moment of inertia $I = \frac{2}{3}MR^2$. What is the magintude of the downward acceleration of the larger mass?



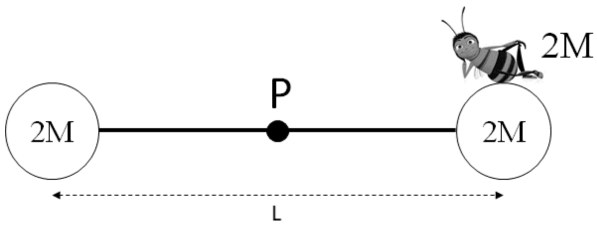
A) $\frac{2g}{7}$ B) $\frac{g}{7}$ C) $\frac{g}{4}$ D) $\frac{9g}{11}$ E) $\frac{3g}{11}$

7. In each case shown below, a 1.0 kg object is launched up an incline with an initial speed of v = 10 m/s. Both spheres roll without slipping, and the blocks slide without friction. The ramps are identical in case A and D. Ramp C is steeper than ramp B.



Rank the maximum height reached by the objects.

A) $A > D > (B = C)$
B) $(B = C) > D > A$
C) $D > A > (B = C)$
D) $(A = D) > (B = C)$
E) $(B = C) > (A = D)$

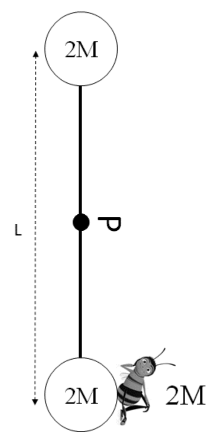


(8-9) A rod of mass M and length L is pivoted about its center (I of rod about center: $I = \frac{mL^2}{12}$). Two masses of equal mass 2M are attached at each end of the rod such that each mass's center is at the end of the rod. A bee of mass 2M lands on and sticks on one of the masses as shown, causing the system to rotate. The size of the masses and bee are negligible compared to the length of the rod.

8. What is the angular acceleration of the system the instant the bee lands on it?

A) $\frac{24g}{19L}$
B) $\frac{24g}{37L}$
C) $\frac{24g}{13L}$
D) $\frac{12g}{19L}$
E) $\frac{12g}{7L}$

9. What is the angular velocity of the rod when it has reached a vertical position with the mass with the bee at the bottom as shown?

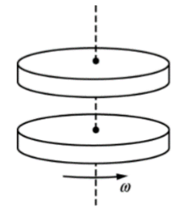


A) $\sqrt{\frac{17g}{12L}}$
B) $\sqrt{\frac{24g}{19L}}$
C) $\sqrt{\frac{37g}{13L}}$
D) $\sqrt{\frac{7g}{6L}}$
E) $\sqrt{\frac{4g}{L}}$

10. A spherical star is spinning with some angular velocity when it collapses to half its original radius without any loss of mass. Assume that the star has uniform density before and after collapse. What happens to the angular momentum and rotational kinetic energy of the star?

A) The angular momentum stays the same. The kinetic energy halves.
B) The angular momentum and kinetic energy stays the same.
C) The angular momentum stays the same. The kinetic energy doubles.
D) The angular momentum increases. The kinetic energy doubles.
E) The angular momentum increases. The kinetic energy halves.

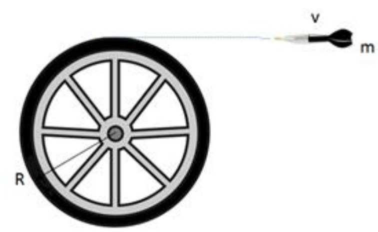
11. A solid disk of mass M and radius R is freely rotating horizontally in a with angular speed ω about a vertical axis through its center with negligible friction. The rotational inertia of the disk is $MR^2/2$. A second identical disk is at rest and suspended above the first disk with the centers of the two disks aligned, as shown. The second disk is dropped onto the first disk. The interval of time elapsed from the moment of first contact until both disks have the same angular speed if t. Which of the following gives the magnitude of the average torque that the first disk exerts on the second disk?



A) $\frac{MR^2}{2t}$ B) $\frac{2MR^2}{t}$ C) $\frac{MR^2}{4t}$ D) $\frac{MR^2}{t}$ E) $\frac{4MR^2}{t}$

12. A dart of mass m is fired at a speed v towards a bicycle wheel. The dart hits the tire at the edge and becomes embedded in it, causing the tire to rotate. In this situation, which of the following occurs?

A) Linear momentum and angular momentum are both conserved.
B) Kinetic energy is converted to angular momentum.
C) Rotational kinetic energy is conserved.
D) Translational kinetic energy is conserved.
E) Linear momentum is converted into angular momentum.



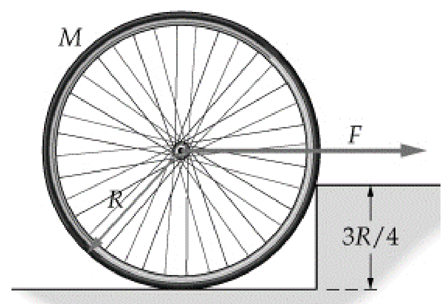
13. A particle of mass $m = 2.0\ kg$ moves with a constant speed $v = 10\ m/s$ along the line y = 3. When the particle is located at the point (4,3), what is the magnitude of the angular momentum of the particle with respect to the origin?

A) 180 $\frac{kgm^2}{s}$ B) 20 $\frac{kgm^2}{s}$ C) 100 $\frac{kgm^2}{s}$ D) 80 $\frac{kgm^2}{s}$ E) 60 $\frac{kgm^2}{s}$

14. A wheel of weight W and radius R is to be pushed over a curb of height 3R/4 as shown. A force is applied to the wheel at its center of mass. In terms of W, what minimum force is needed to push the wheel over the curb?

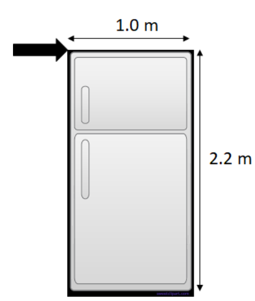
A) $\frac{\sqrt{15}}{5}W$ B) $\sqrt{15}W$ C) $\frac{\sqrt{3}}{2}W$

D) $\frac{\sqrt{7}}{5}W$ E) $\sqrt{7}W$

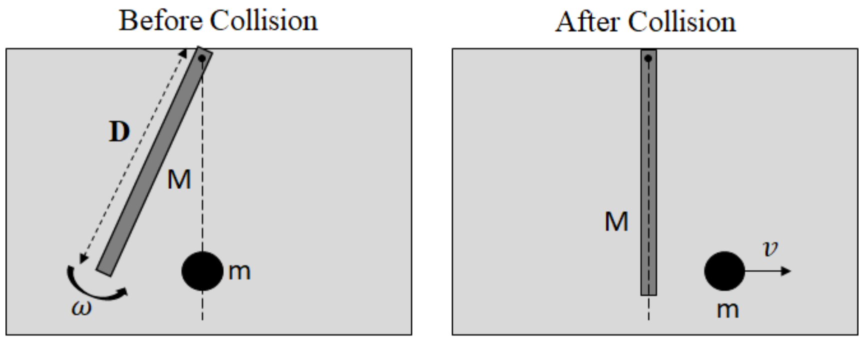


15. Josh's refrigerator isn't running, so he needs to push it. He applies a horizontal force to the very top of the refrigerator as shown. The refrigerator has a width of 1.0 m, a height of 2.2 m and a mass of 80 kg. What is the minimum coefficient of static friction required so that the fridge tips instead of sliding?

A) 0.45 B) 0.57 C) 0.28 D) 0.23 E) 0.92



Part 2: Free Response. You must show all steps required to arrive at the correct answer for problems. Any numerical must have the correct units.



16. (14 pts) A hockey puck of mass m is initially at rest on a frictionless surface, as shown in the diagram above (which is an aerial view). A uniform rod of length D and mass M is pivoted at the end opposite the puck and is rotating at an angular velocity of ω when it collides with the puck. After the collision, the rod stops moving completely and the puck moves with some velocity away from the rod.

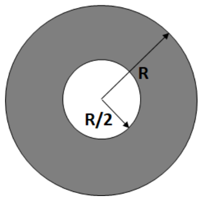
a) Determine an expression for the linear speed of the puck after the collision. Answer in terms of ω, D, M and m.

b) How would the value of linear of v after the collision compare if the puck instead starting at a distance of D/2 from the pivot instead of D? Assume the rod still stops in the case. Justify your answer.

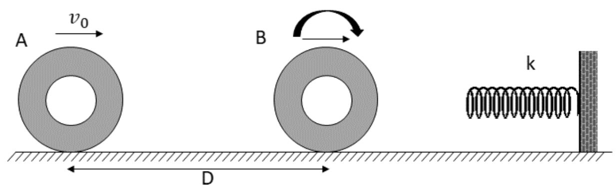
c) Determine the value of the ratio of $\frac{m}{M}$ for the collision from part A to be elastic.

17. (17 pts) A cylindrical wheel of mass M has an inner radius of R/2 and outer radius of R as shown. The area inside the inner radius is hollow, with all the mass between the inner and outer radius.

a) Using integral calculus, show that the wheel's moment of inertia is given by $I = \frac{5}{8}MR^2$.



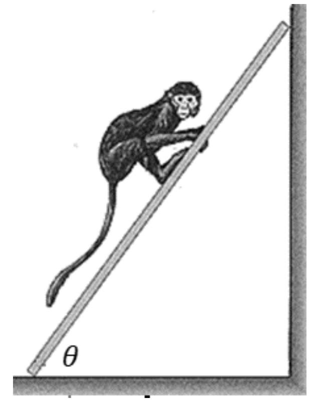
b) The wheel is placed on the ground with an initial linear velocity of v_0 at point A, where the wheel only has linear velocity. The wheel slips and rolls for a distance D until it starts to roll without slipping at point B. There is friction on the ground, with a coefficient of friction of μ. After point B, the wheel continues rolls without slipping and compresses a spring of elastic constant k.



i. Determine an expression for the distance D.

ii. Determine an expression for the maximum distance the spring compresses.

18. (11 pts) A 10 kg monkey climbs a 4 m long ladder. The ladder itself has a mass of 5 kg. The ladder is set at an angle of $\theta = 60°$ above the floor as shown and rests against a smooth wall. The coefficient of static friction between the floor and ladder is 0.30.



a) Draw a free-body diagram of all forces acting on the ladder. Draw each force at its point of action.

b) Calculate the maximum distance up the ladder the monkey can climb before the ladder slips.

c) How would your answer to a) (the distance the monkey could climb before the ladder slips) change if the angle of the ladder were some value less than θ? Explain your answer.

Bonus: A uniform wooden beam with a mass of 20 kg extends horizontally from a wall, as shown above. A support cable (of negligible mass) extends from the far end of the beam to the wall, forming a 40° angle with the beam. The beam has a sign with a mass of 5 kg hanging from the end of it. Find magnitude of the force that the wall exerts on the wooden beam.