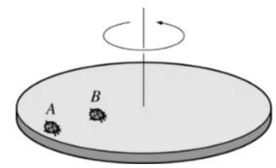
AP Physics 1
Unit 5&6 Practice Exercises

Directions: Show the steps required to arrive at the answer. Work out the problems on separate page.

5.1 – Rotational Kinematics

1. Classify each of the following as circular motion or rotational motion:
   a) The motion of the earth around the sun.
   b) The motion of the hands of a clock.
   c) A racecar going around a circular track.
   d) A vinyl record the smash hit *Africa* by Toto spins on a record player.

2. Two ladybugs are placed on a circular disc as shown.
   a) In one minute, which ladybug travels a greater linear distance?
   b) In one minute, which ladybug travels a greater angular distance?
   c) Which ladybug experiences a greater centripetal force?



3. a) Find the angular velocity of earth in radians per second.
   b) Suppose you are 6400 from the center of the earth and are at rest doing your physics homework. Calculate your linear speed.

4. A circular saw blade 0.6 m in diameter starts from rest and accelerates with constant angular acceleration to an angular velocity of 100 rads/s in 20 seconds. Find the:
   a) angular acceleration
   b) angle through which the blade has turned.

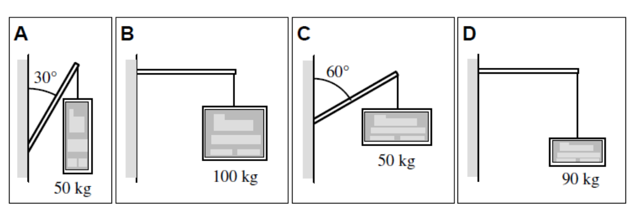
5. A Suncoast student rides the merry-go-round at the Magic Kingdom, for some reason. The merry-go-round rotates at rate of $\boldsymbol{\omega}$ rad/s. The merry-go-round is slowed down a friction and accelerates at $-\boldsymbol{\alpha}$ rad/s. How long will it take the merry-go-round to come to rest.

6. A basketball with a mass of 0.60 kg and radius of 7 cm is rolling across a level floor at a constant speed of 2.0 m/s.
   a) Determine the ball's angular velocity.
   b) What is the ball's angular acceleration?
   c) How many turns will the ball make in 2 seconds?

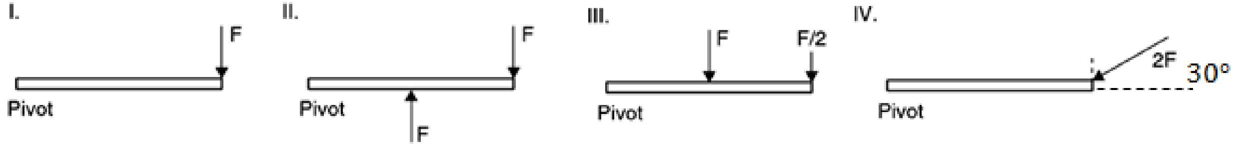
7. One car wheel accelerates at 1.2 rad/s^2 for 24 s. The angular displacement of the wheel is 640 rad. The radius of the wheel is .90 m.
   a) What was the initial angular velocity of the wheel (in rad/s)?
   b) What is the final angular velocity of the wheel?
   c) A 1.0 kg stone is caught in the tire tread of the wheel. What is the final linear speed of the stone?

5.2 – Torque

1. Signs are suspended from equal-length rods on the side of a building. For each case, the mass of the rod compared to the mass of the sign is small and can be ignored. The mass of the sign is given in each figure. In Cases B and D, the rod is horizontal; in the other cases, the angle that the rod makes with the vertical is given.Rank the magnitude of the torque the signs exert about the point at which the rod is attached to the side of the building.

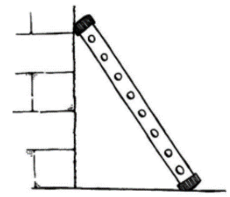


2. Four identical rods shown below experience the forces as shown.



Rank the magnitude of the torques about the pivot point on the left end of the rod.

3. A ladder is set against a wall so that the ladder makes a 30° angle from the floor. The wall is very smooth, but the floor is not. The ladder only remains motionless as long as a person holds it in place. When the person lets go, the ladder accelerates down and to the right. A student analyzes this scenario and identifies that the four forces acting on the ladder are its weight F_g, the normal force from the wall N_W, the normal force from the floor N_F, and the friction between the ladder and the floor F_F. Rank the magnitude of these forces. Justify your answer.

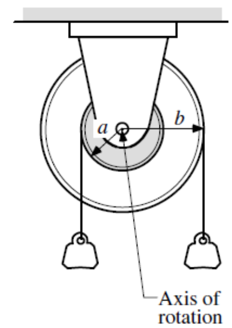


4. A wheel is composed of two pulleys with different radii (labeled *a* and *b*) that are attached to one another so that they rotate together. Each pulley has a string wrapped around it with a weight hanging from it as shown. The pulleys rotate about a horizontal axis at the center. When the wheel is released it is found to have an angular acceleration that is directed out of the page.

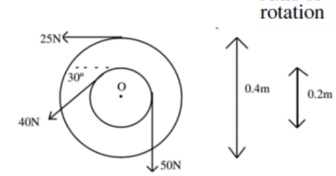
a) Is the wheel going to rotate (i) *clockwise,* (ii) *counterclockwise,* or (iii) *none*?

b) What is the direction of the net torque on the pulley?

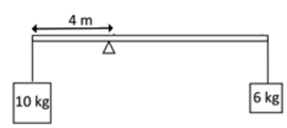
c) How do the masses of the two weights compare? Explain your reasoning.



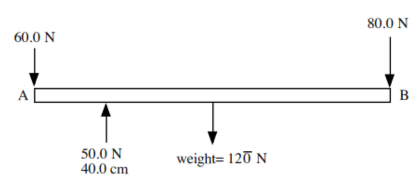
5. The figure to the below shows the top view of a wheel. The diameter of the large circle is 0.4 m and the diameter of the small circle 0.2 m. Assume that a friction torque of 0.5 Nm opposes the motion of the wheel. Calculate the net torque about the axle of the wheel.



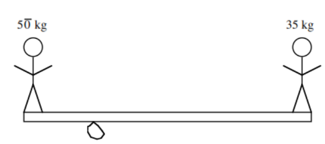
6. Two masses of mass 10 and 6 kg are hung from massless strings at the end of a light rod. The rod itself is virtually weightless. A pivot is placed off center and the system is free to rotate. For what distance of the 6 kg mass from the pivot will the system be in static equilibrium?



7. A uniform bar AB is 2.00 m long and weighs 12$\bar{0}$ N. An upward force of 50.0 N is applied 40.0 cm from end A. A downward force of 60.0 N is applied at end A and a downward force of 80.0 N is applied at end B. Find the magnitude, direction and location of a force that could be added to bring the system into equilibrium.



8. A board is 3.0 m long. A 5$\bar{0}$ kg child stands on one end and a 35 kg child stands on the other end. How far should a rock be placed from the 5$\bar{0}$ kg child so that the board is balanced in the horizontal position? Ignore the weight of the board.



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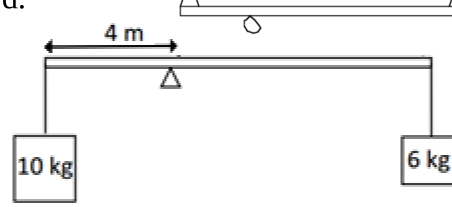
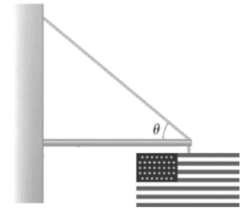


9. A horizontal boom is constructed to support a 150 N flag. The horizontal boom itself weights 50 N and is 2 m long. Determine the tension in the supporting cable if the cable makes an angle of 30º with the horizontal boom.

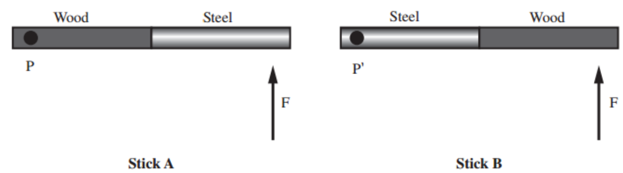


10. A uniform scaffold 4.00 m long hangs horizontally by a rope at each end. The scaffold weighs 250 N. A 700 N painter stands 1.00 m from the left end. How much tension is in left and right ropes of the scaffold?

11. A uniform board is carried by Righteous Roger and Trippy Tim. Tim holds up the left end of the board. The board is held horizontally and is 6.0 m long. Where should Roger hold the board so that he supports twice as much of its weight as Tim?

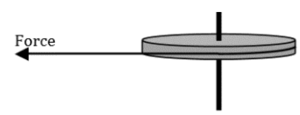
5.3 – Newton's 2nd Law for Rotation

1. The figure below shows two identical sticks, both half wood and half steel, with stick A pivoted at its wood end and Stick B pivoted at its steel end. Identical torques are exerted on both sticks. Which undergoes the greatest angular acceleration?



2. What is the angular acceleration produced when a torque of 60.0 N·m acts on an object whose rotational inertia is 1100 kg·m?

3. A bicycle wheel has a rotational inertia of 650 kg·m^2. If the angular velocity of the wheel is 400 rev/min, how long will it take a torque of 1200 N·m to stop the wheel?

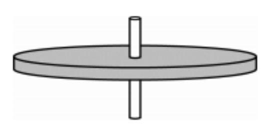


4. A uniform rod 2.0 m long with mass 3.6 kg is hinged on its left side. The rotational inertia for a rod hinged on one end is given by $\boldsymbol{I = \frac{1}{3}mL^2}$. What is the angular acceleration of the rod if it is brought to a horizontal position and then released?

5. The rotational inertia of a wheel is 160 kg·m^2. The wheel starts from rest and reaches a speed of 40 rev/min after making 20 revolutions. What tangential force will produce this motion if it is applied 0.80 from the center of the wheel?

6. A spinning plate in a microwave with moment of inertia I rotates about its center of mass at a constant angular speed ω. When the microwave ends its cook cycle, the plate comes to rest in time Δt due to a constant frictional force F applied a distance r from the axis of rotation. What is the magnitude of the frictional force F?

7. The disk shown spins about the axle at its center. A student's experiments reveal that, while the disk is spinning, friction between the axle and the disk exerts a constant torque on the disk.



a) At time $t = 0$, the disk has initial counterclockwise (+) angular velocity ω_0. The disk later comes to rest at time $t = t_1$.

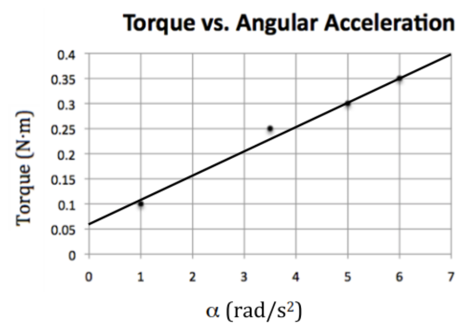
i. Sketch a graph that could represent the disk's angular velocity as a function of time from $t = 0$ until it comes to rest.

ii. Sketch the disk's angular acceleration as a function of of time from $t = 0$ until it comes to rest.

b) The magnitude of the friction torque exerted on the disk is τ_0. Derive an equation for the rotational inertia I of the disk in terms of τ_0, ω_0, t_1 and physics constants, as appropriate.

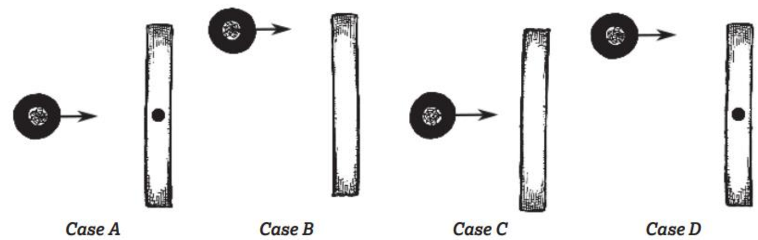
8. The wheel in the sky keeps on turning. A pair of students measure the torque applied to the wheel supported by a vertical axle. They also measure the resulting angular acceleration. A plot of their data results are in the graph below:

a) Calculate the rotational inertia of the wheel.
b) Calculate the torque supplied by friction.



5.4 – Angular Momentum

1. The four cases show our pucks (viewed from above) sliding to the right on a smooth table. Each puck collides with and sticks to a rod that can move or rotate with negligible friction. In all four cases, the pucks are identical, the rods are identical, the initial rightward velocities of the puck are identical, and the initial velocities of the pucks are perpendicular to the rods' lengths. In Cases A and D, the rod is fixed to the table by a pin with negligible friction, but in Cases B and C, the rod is free to move.



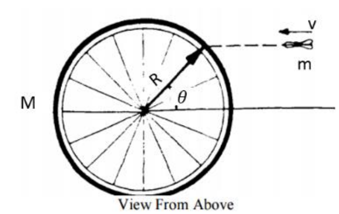
a) Rank the cases in terms of rightward momentum after the collision.
b) Rank the cases in terms of clockwise momentum after the collision.

2. Kim Yoona, an Olympic ice skater rotates at ω_i before pulling her arms in. The force of friction of the ice is negligible. Her final angular velocity after pulling her arms in is ω_f.

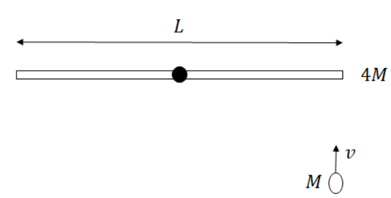
a) How does Kim Yoona's final angular momentum compare with her initial angular momentum?
b) How does Kim Yoona's final kinetic energy compare with her initial kinetic energy?
c) If Yoona's initial moment of inertia is I_i and her final moment of inertia if I_f, then find the value of $\frac{Final\ Kinetic\ Energy}{Initial\ Kinetic\ energy}$.

3. A bicycle wheel of mass M and radius R is mounted horizontally so it may turn without friction on a vertical axis. A dart of mass m is thrown with velocity v as shown and strikes the tire.

a) If the wheel is initially at rest, determine the velocity of the wheel after the dart strikes. (Moment of inertia for dart/wheel is $(m+M)R^2$)
b) Find the change in kinetic energy of the system before and after the dart strikes.



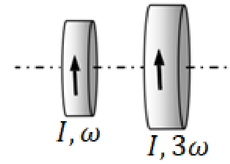
4. A rod of length L and mass 4M is pivoted about its center and allowed to rotate. Initially, it is at rest. A ball of silly putty of mass M hits the very right end of the rod and sticks to it, as shown.



a) Determine an expression for the angular speed of the rod after putty sticks to it.
b) Suppose that the silly putty instead hit the rod closer to the center than in part a). How would this affect the angular velocity after the collision? Justify your answer.

5. A large turntable of radius 2.0 m and total mass 120 kg is rotating about a vertical axis through its center, with angular velocity of 3.0 rad/s. A 100 kg crate is dropped vertically onto the turntable on its outer edge. Find the angular velocity of the turntable after the crate is dropped.

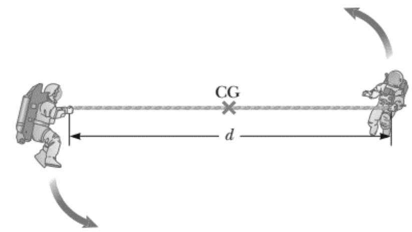
6. Two disks rotating in the same direction about the same axis are shown on the right. Both disks have the same rotational motion, I. The initial angular speeds are ω and 3ω as shown. If the two disks slide together along the axis, collide and stick together. What is the angular velocity after they stick together?



7. Two astronauts each having a mass of 75.0 kg, are connected by a 10.0-m rope of negligible mass. They are isolated in space, moving in circles around the point halfway between them at a speed of 5.00 m/s. The astronauts shorten the rope to 5 m by pulling.

a) Calculate the new speeds of the astronauts.

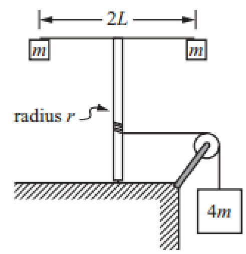
b) The astronauts sped up as a result of puling inwards. Suggest why this might not violate conservation of energy.



8. A light string that is attached at to a large block of mass $4m$ passes over a pulley with negligible rotational inertia and is wrapped around a vertical pole of radius r, as shown. The system is released from rest, and as the block descends the string unwinds and the vertical pole with its attached apparatus rotations. The apparatus consist of a horizontal rod of length $2L$, with a small block of mass m attached at each end. The rotational inertia of the apparatus is $2mL^2$.

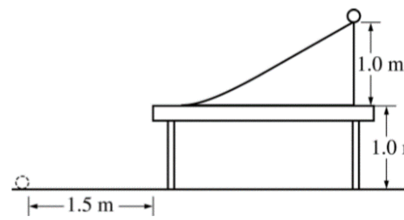
a) If the downward acceleration of the large block is measured to be a, determine the tension T, in terms of m, a, and fundamental constants.

b) Determine the torque exerted on the rotating pole by the string.



6.1 – Work & Energy in Rotation

1. A cylinder at rest is released from the top of a ramp, as shown above. The ramp is 1.0 m high, and the cylinder rolls down the ramp without slipping. At the bottom of the ramp, the cylinder makes a smooth transition to a small section of a horizontal table and then travels over the edge at a height of 1.0 m above the floor, eventually landing on the floor.

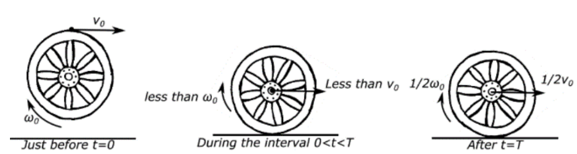


a) How does the i. linear kinetic energy and ii. rotational kinetic energy of the cylinder change as it rolls down the ramp?

b) How does the i. linear kinetic energy and ii. rotational kinetic energy of the cylinder change after it rolls down the ramp and falls freely off the table?

2. A hollow sphere ($I = 2/3mr^2$) rolls without slipping along a horizontal surface. What percentage of its total kinetic energy is rotational kinetic energy?

3. A wheel of radius R and mass M is held at rest just above a rough table (coefficient of kinetic friction μ). The wheel spins with initial angular speed ω_0 so that all points on the edge of the wheel circle the wheel's center with speed v_0. At time t = 0, the wheel is released from rest, lands on the table, and does not bounce. The wheel's rotational speed decreases while the linear speed of its center of mass increases until the wheel begins to roll without slipping at time t = T. Explain how friction does work for this to occur.



4. A soccer ball rolls across a field with a velocity of 5 m/s. The ball is a hollow sphere ($I = \frac{2}{3}mr^2$) with a mass of .50 kg and a radius of 10 cm.

a) Calculate the linear and rotational kinetic energy of the ball.

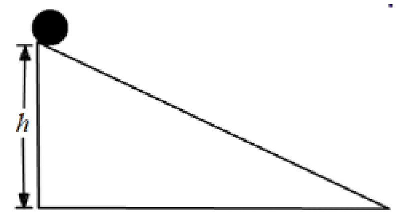
b) Suppose a solid ball of the same mass and radius rolls at the same speed.

i. Which ball (solid or hollow) has a greater linear kinetic energy?

ii. Which ball has a greater rotational kinetic energy?

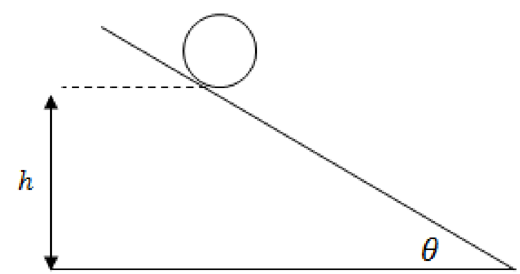
5. A horizontally-mounted disk with moment of inertia I spins about a frictionless axle. At time t=0, the initial angular speed of the disk is ω. A constant torque τ is applied to the disk, causing it to come to a halt in time t. How much power is required to dissipate the wheel's energy during this time?

6. A flat disk of mass M, radius R, and rotational inertia ½MR is released from rest at the top of an inclined plane of height h as shown right.



a) If the plane is frictionless, what is the speed of the center of mass of the disk at the bottom of incline?
b) If the plane has friction so that the disk rolls without slipping, what is the speed of the center of mass of the disk at the bottom of the incline?
c) If the plane is frictionless, what is the acceleration down the incline
d) If the plane has friction so that the disk rolls without slipping, what is the acceleration down the incline?

7. A solid sphere (I = $\frac{2}{5}mr^2$) of mass M and radius R rolls down an inclined plane without slipping. Answer the following in terms of M, R, g, θ, and h. The sphere is released from rest.



a) What is the sphere's linear kinetic energy at the bottom?
b) What is the sphere's rotational kinetic energy at the bottom?
c) At what rate does the sphere accelerate down the plane?
d) What is the magnitude of the frictional force acting on the sphere?
e) Assume that now the solid sphere is replaced by a hollow sphere and released from the same location. How would the speed of the bottom compare?