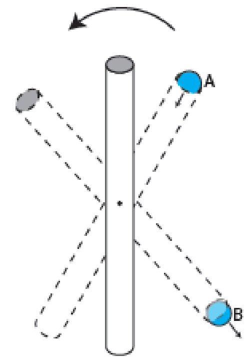
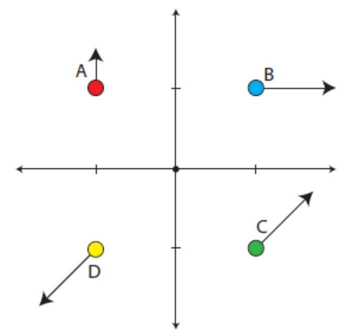
1. A 50-kg boy and a 40-kg girl sit on opposite ends of a 3-meter see-saw. How far from the girl should the fulcrum be placed in order for the boy and girl to balance on opposite ends of the see-saw?



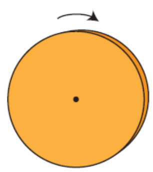
2. A uniform hollow tube of length L rotates vertically about its center of mass as shown. A ball is dropped into the tube at position A, and exits a short time later at position B. From the perspective of a stationary observer watching the tube rotate, the distance the ball travels is

(A) less than L
(B) greater than L
(C) equal to L



3. Four particles, each of mass M, move in the x-y plane with varying velocities as shown in the diagram. The velocity vectors are drawn to scale. Rank the magnitude of the angular momentum about the origin for each particle from largest to smallest.

4. A disc rotates clockwise about its axis as shown in the diagram. The direction of the angular momentum vector is:



(A) out of the plane of the page
(B) into the plane of the page
(C) toward the top of the page
(D) toward the bottom of the page

5. A hoop with moment of inertia $I=0.1\ kg\cdot m^2$ spins about a frictionless axle with an angular velocity of 5 radians per second. At what radius from the center of the hoop should a force of 2 newtons be applied for 3 seconds in order to accelerate the hoop to an angular speed of 10 radians per second?

(A) 8.3 cm
(B) 12.5 cm
(C) 16.7 cm
(D) 25 cm

6. Jean stands at the exact center of a large spinning frictionless uniform disk of mass M and radius R with moment of inertia $I=\frac{1}{2}MR^2$. As she walks from the center to the edge of the disk, the angular speed of the disk is quartered. Which of the following statements is true?

(A) Jean's mass is less than the mass of the disk.
(B) Jean's mass is equal to the mass of the disk.
(C) Jean's mass is between the mass of the disk and twice the mass of the disk.
(D) Jean's mass is more than twice the mass of the disk.

7. 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?

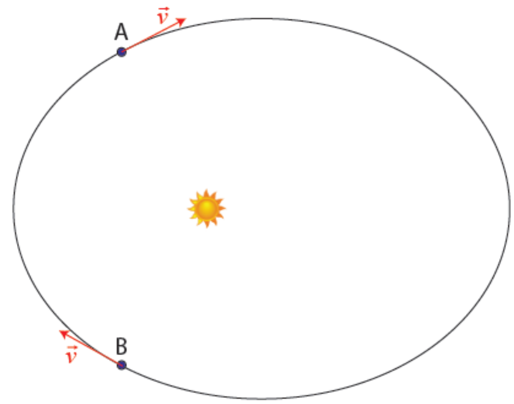
(A) $F = \dfrac{I\omega}{r\Delta t}$

(C) $F = \dfrac{\omega r^2}{I\Delta t}$

(B) $F = \dfrac{Ir}{\omega\Delta t}$

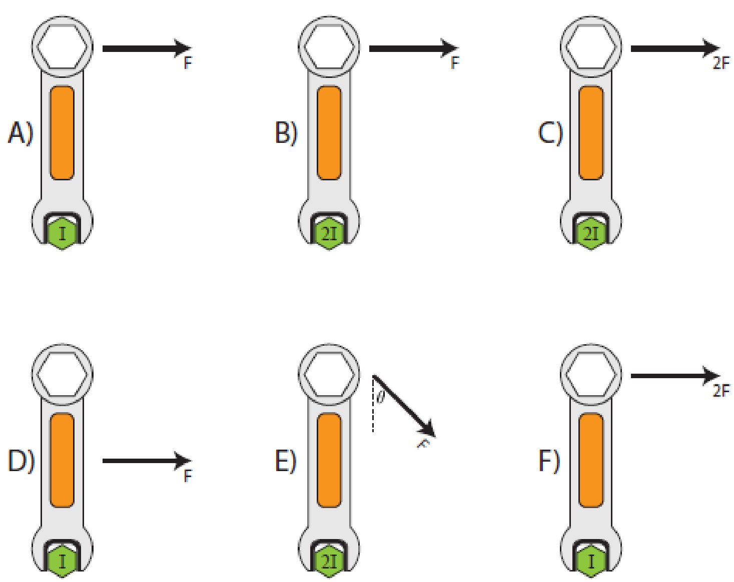
(D) $F = \dfrac{Ir^2}{\omega\Delta t}$

8. A planet orbits a sun in an elliptical orbit as shown. Which principles of physics most clearly and directly explain why the speed of the planet is the same at positions A and B? Select two answers.



(A) Conservation of Energy
(B) Conservation of Angular Velocity
(C) Conservation of Angular Momentum
(D) Conservation of Charge

9. A given force is applied to a wrench to turn a bolt of specific rotational inertia I which rotates freely about its center as shown in the following diagrams. Which of the following correctly ranks the resulting angular acceleration of the bolt?



(A) $\alpha_F > \alpha_A = \alpha_C > \alpha_B = \alpha_D > \alpha_E$

(B) $\alpha_C = \alpha_F > \alpha_A = \alpha_B > \alpha_D > \alpha_E$

(C) $\alpha_A = \alpha_F > \alpha_C = \alpha_E > \alpha_B = \alpha_D$

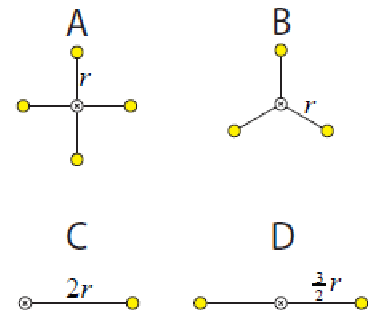
(D) $\alpha_D = \alpha_F > \alpha_A = \alpha_C > \alpha_B > \alpha_E$

10. Gina races her bike across a horizontal path. Suddenly, a squirrel runs in front of her. Gina slams on both her front and rear brakes, which results in the bike flipping over the front wheel and Gina flying over the handle bars. Which of the following do NOT contribute to an explanation of why the bike flips and Gina flies over the handlebars?

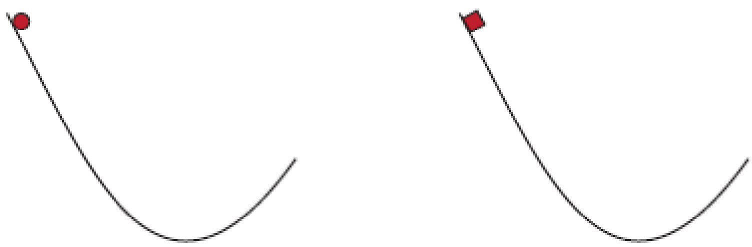
(A) Gina has a tendency to continue moving at a constant velocity, so while the bike stops, Gina continues her previous motion.
(B) Conservation of angular momentum of the bike and wheels indicates that if the wheels stop spinning in one direction, the bike must spin in the opposite direction.
(C) The large negative acceleration of the bike/rider system reduces the moment of inertia of the system, increasing the system's angular acceleration and causing a rotation of the bike.

(D) The force of the applied brakes at a distance from the center of mass of the bike and rider produces a net torque on the bike, causing a rotation bringing the back wheel of the backup.

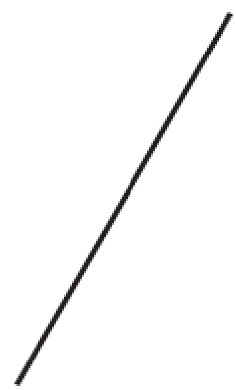
11. Identical point masses are arranged in space and connected by massless rods in four different configurations, as shown in the diagram below. Rank the moment of inertia of the configurations from greatest to least, assuming the masses are rotated about the point indicated with an x.



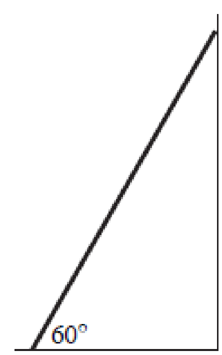
12. A ball and a block of equal mass are situated on ramps with the same shape. The objects are released from the same height. The ball rolls without slipping, and the block travels without friction. After leaving the ramp, which object travels higher and why?



(A) The ball travels higher because it leaves the ramp with a higher speed.
(B) The ball travels higher because it gains rotational kinetic energy alongs its path.
(C) The block travels higher because it experiences no rotation.
(D) The block travels higher because energy is not conserved in a rolling system.

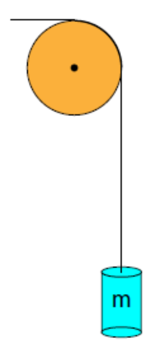


13. A 20-kg ladder of length 8 m sits against a frictionless wall at an angle of 60 degrees. The ladder just barely keeps from slipping.
(a) On the diagram to the right, draw and label the forces acting on the ladder.



14. A student designs an experiment in which a mass (m) attached to a one-meter-long string is wrapped around a pulley of mass M=1 kg and radius R=0.1 m and dropped. The pulley includes a sensor which measures and records its rotational velocity. The mass is dropped from rest and the final rotational velocity of the pulley as well as the time the mass is in the air is measured. Data is shown in the table below.

m (kg)	ω_f (rad/s)	time (s)	α (rad/s^2)
0.2	24	0.84	
0.4	30	0.68	
0.6	33	0.61	
0.8	35	0.58	
1.0	36	0.55	

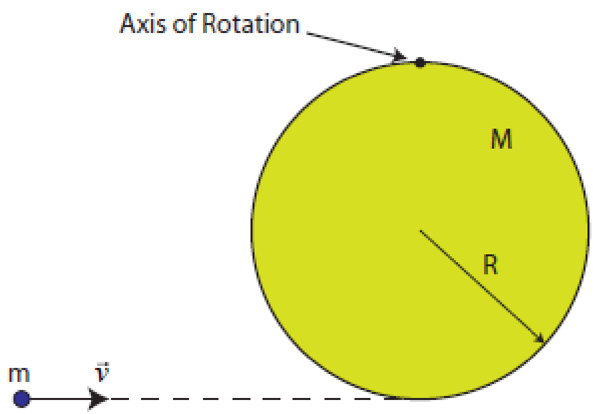


(a) Complete the table above by calculating the angular acceleration for each of the hanging masses.

(b) Plot the angular acceleration vs. the hanging mass. Make sure to label all axes appropriately.

(c) Using your plot, estimate the angular acceleration of the pulley for a hanging mass of 500g.

15. A particle of mass *m* is launched with velocity *v* toward a uniform disk of mass *M* and radius *R* which can rotate about a point on its edge as shown. The disk is initially at rest. After the particle strikes the edge of the disk and sticks, the magnitude of the final angular velocity of the disk-particle system is given by the below formula. Determine the moment of inertia of the disk about its axis of rotation.



$$|\vec{\omega}| = \left(\frac{4m}{8m+3M}\right)\left(\frac{v}{R}\right)$$

16. A round object of mass *m* and radius *r* sits at the top of a track of length *L* inclined at an angle of *θ* with the horizontal.

(a) Derive an expression for the gravitational potential energy of the object in terms of *m*, *L*, and *θ*.

(b) Describe an experimental procedure the student could use to collect the data necessary, including any equipment the student would need. Your description should include a listing of the independent and dependent variable(s).

(c) Derive an expression for the velocity of the object at the bottom of the ramp in terms of the length of the ramp, *L*, and the time it takes to travel down the ramp, *t*.

(d) Derive an expression for the moment of inertia of the object in terms of *m*, *r*, *θ*, *t*, *L*, and any fundamental constants.

(e) The student plots the square of the time it takes for the object to travel down the ramp, *t2*, as a function of 1/ sin (θ) to obtain a linear graph. How should the student determine the moment of inertia of the object from this graph? Highlight the calculation(s) used.

(f) Now suppose that you were not given the radius of the object. Describe an experimental procedure you could use to determine it, including any equipment you would need.

(g) Derive the expression for the moment of inertia of the object in terms of *m, r,* θ*, t, L,* and any fundamental constants using an alternate approach to your method from part (d).