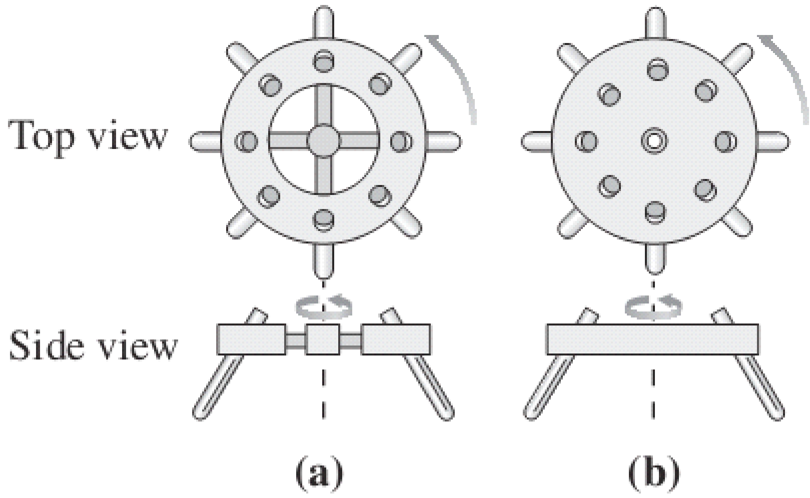
Section Four   The motion of Rigid Body

Part one

Centrifuges are widely used in biology and medicine to separate cells and other particles from liquid suspensions. Figure 4.1 shows top and side views of two centrifuge designs. In both designs, the round holes are for tubes holding samples to be separated; the side views show two tubes in place. The total mass and radius of the rotating structure are the same for both, the sample-hole tubes are at the same radius, and the sample tubes are identical.



1. Which design has greater rotational inertia?

a. design A

b. design B

c. Both have the same rotational inertia.

2. If both centrifuges are made thicker in the vertical direction, without changing their masses or mass distribution, their rotational inertias will

a. remain the same.

b. increase.

c. decrease.

3. If the sample tubes are made longer, the rotational inertia of the centrifuges with sample tubes inserted will

a. remain the same.

b. increase.

c. decrease.

4. While the centrifuges are spinning, the net force on samples in the tubes is

a. outward.

b. inward.

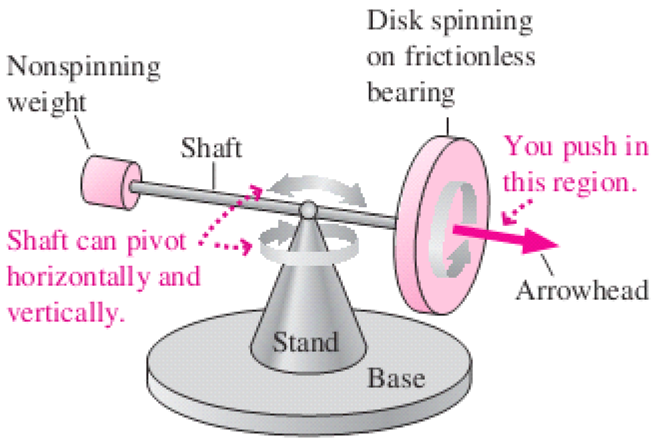
c. zero.

5. If a centrifuge's radius and mass are both doubled without other-wise changing the design, its rotational inertia will

a. double.

b. quadruple.
c. increase by a factor of 8.
d. increase by a factor of 16.

Figure 4.2 shows a demonstration gyroscope, consisting of a solid disk mounted on a shaft. The disk spins about the shaft on essentially frictionless bearings. The shaft is mounted on a stand so it's free to pivot both horizontally and vertically. A weight at the far end of the shaft balances the disk, so in the configuration shown there's no torque on the system. An arrowhead mounted on the disk end of the shaft indicates the direction of the disk's angular velocity.



6. If you push on the shaft between the arrowhead and the disk, pushing horizontally away from you (that is, into the page in Fig.4.2), the arrowhead end of the shaft will move
a. away from you (i.e., into the page).
b. toward you (i.e., out of the page).
c. downward.
d. upward.

7. If you push on the shaft between the arrowhead and the disk, pushing directly upward on the bottom of the shaft, the arrow-head end of the shaft will move
a. away from you (i.e., into the page).
b. toward you (i.e., out of the page).
c. downward.
d. upward.

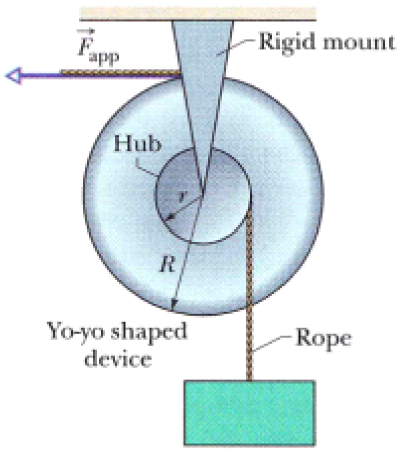
8. If an additional weight is hung on the left end of the shaft, the arrow head will
a. pivot upward until the weighted end of the shaft hits the base.
b. pivot downward until the arrowhead hits the base.
c. precess counterclockwise when viewed from above.
d. precess clockwise when viewed from above.

9. If the system is precessing, and only the disk's rotation rate is increased, the precession rate will
a. decrease.
b. increase.
c. stay the same.
d. become zero.

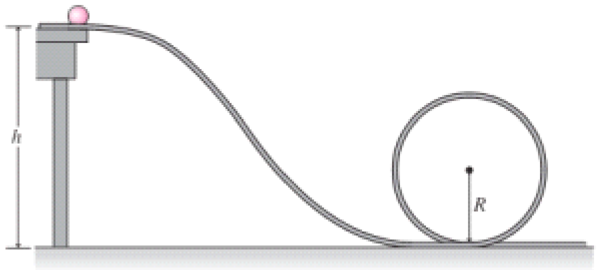
Part Two

1 A disk of radius R and thickness w has a mass density that increases from the center outward, given by , where r is the distance from the disk axis. Calculate (a) the disk's total mass M and (b) its rotational inertia about its axis in terms of M and R.

2 A yo-yo-shaped device mounted on a horizontal frictionless axis is used to lift a 30 kg box as shown in Fig. 4.3. The outer radius R of the device is 0.50 m, and the radius r of the hub is 0.20 m. When a constant horizontal force Fapp of magnitude 140 N is applied to a rope wrapped around the outside of the device, the box, which is suspended from a rope wrapped around the hub, has an upward acceleration of magnitude 0.80 mls2.Whatis the rotational inertia of the device about its axis of rotation?



3 A solid marble starts from rest and rolls without slipping on the loop-the-loop track in Fig. 4.4. Find the minimum starting height from which the marble will remain on the track through the loop. Assume the marble's radius is small compared with R.



4 In Fig.4.5, a 1.0 g bullet is fired into a 0.50 kg block attached to the end of a 0.60 m non-uniform rod of mass 0.50 kg. The block-rod-bullet system then rotates in the plane of the figure, about a fixed axis at A. The rotational inertia of the rod alone about that axis at A is 0.060 kg.m^2. Treat the block as a particle. (a) What then is the rotational inertia of the block-rod-bullet system about point A? (b) If the angular speed of the system about A just after impact is 4.5 rad/s, what is the bullet's speed just before impact?