

ANSWERS TO MULTIPLE CHOICE QUESTIONS

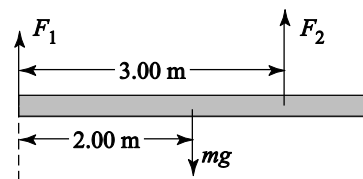
1. $\tau = rF \sin \theta = 0.500 \text{ m} \cdot 80.0 \text{ N} \cdot \sin 60.0^\circ = 36.4 \text{ N} \cdot \text{m}$ which is choice (a).

2. Using the left end of the plank as a pivot and requiring that

$$\Sigma \tau = 0 \text{ gives } -mg \cdot 2.00 \text{ m} + F_2 \cdot 3.00 \text{ m} = 0, \text{ or}$$

$$F_2 = \frac{2mg}{3} = \frac{2 \cdot 20.0 \text{ kg} \cdot 9.80 \text{ m/s}^2}{3} = 131 \text{ N}$$

so choice (d) is the correct response.



3. Assuming a uniform, solid disk, its moment of inertia about a perpendicular axis through its center is

$$I = MR^2/2, \text{ so } \tau = I\alpha \text{ gives}$$

$$\alpha = \frac{2\tau}{MR^2} = \frac{2 \cdot 40.0 \text{ N} \cdot \text{m}}{25.0 \text{ kg} \cdot 0.800 \text{ m}^2} = 5.00 \text{ rad/s}^2$$

and the correct answer is (b).

4. For a uniform, solid sphere,

$$I = 2MR^2/5 \text{ and } \omega_E = \frac{2\pi \text{ rad}}{1 \text{ d}} \left(\frac{1 \text{ d}}{8.64 \times 10^4 \text{ s}} \right) = 7.27 \times 10^{-5} \text{ rad/s}$$

so

$$KE_r = \frac{1}{2} I \omega_E^2 = \frac{1}{2} \left(\frac{2 \cdot 5.98 \times 10^{24} \text{ kg} \cdot 6.38 \times 10^6 \text{ m}^2}{5} \right) (7.27 \times 10^{-5} \text{ rad/s})^2$$

yielding $KE_r \sim 3 \times 10^{29} \text{ J}$, making (a) the correct choice.

5. In order for an object to be in equilibrium, it must be in both translational equilibrium and rotational equilibrium. Thus, it must meet two conditions of equilibrium, namely $\vec{F}_{\text{net}} = 0$ and $\vec{\tau}_{\text{net}} = 0$. The correct answer is therefore choice (d).
6. In a rigid, rotating body, all points in that body rotate about the axis at the same rate (or have the same

angular velocity). The centripetal acceleration, tangential acceleration, linear velocity, and total acceleration of a point in the body all vary with the distance that point is from the axis of rotation. Thus, the only correct choice is (b).

7. The moment of inertia of a body is determined by its mass and the way that mass is distributed about the rotation axis. Also, the location of the body's center of mass is determined by how its mass is distributed. As long as these qualities do not change, both the moment of inertia and the center of mass are constant. From $\tau = I\alpha$, we see that when a body experiences a constant, nonzero torque, it will have a constant, nonzero angular acceleration. However, since the angular acceleration is nonzero, the angular velocity ω (and hence the angular momentum, $L = I\omega$) will vary in time. The correct responses to this question are then (b) and (e).
8. When objects travel down ramps of the same length, the one with the greatest translational kinetic energy at the bottom will have the greatest final translational speed (and, hence, greatest average translational speed). This means that it will require less time to travel the length of the ramp. Of the objects listed, all will have the same *total* kinetic energy at the bottom, since they have the same decrease in gravitational potential energy (due to the ramps having the same vertical drop) and no energy has been spent overcoming friction. All of the block's kinetic energy is in the form of translational kinetic energy. Of the rolling bodies, the fraction of their total kinetic energy that is in the translational form is

$$f = \frac{KE_t}{KE_t + KE_r} = \frac{\frac{1}{2} M v^2}{\frac{1}{2} M v^2 + \frac{1}{2} I \omega^2} = \frac{1}{1 + \frac{I}{M} \frac{\omega^2}{v^2}} = \frac{1}{1 + \frac{I}{MR^2}}$$

Since the ratio I/MR^2 equals $2/5$ for a solid ball and $2/3$ for a hollow sphere, the ball has the larger translational kinetic energy at the bottom and will arrive before the hollow sphere. The correct rankings of arrival times, from shortest to longest, is then block, ball, sphere, and choice (e) is the correct response.

9. Please read the answer to Question 8 above, since most of what is said there also applies to this question. The total kinetic energy of either the disk or the hoop at the bottom of the ramp will be $KE_{\text{total}} = Mgh$, where M is the mass of the body in question and h is the vertical drop of the ramp. The translational kinetic energy of this body will then be $KE_t = f KE_{\text{total}} = f Mgh$, where f is the fraction discussed in Question 8. Hence, $\frac{1}{2} M v^2 = f Mgh$ and the translational speed at the bottom is $v = \sqrt{2fgh}$.

Since $f = 1/(1+1/2) = 2/3$ for the disk and $f = 1/(1+1) = 1/2$ for the hoop, we see that the disk will have the greater translational speed at the bottom, and hence, will arrive first. Notice that both the mass and radius of the object has canceled in the calculation. Our conclusion is then independent of the object's mass and/or radius. Therefore, the only correct response is choice (d)

10. The ratio of rotational kinetic energy to the total kinetic energy for an object that rolls without slipping is

$$\frac{KE_r}{KE_{\text{total}}} = \frac{KE_r}{KE_t + KE_r} = \frac{\frac{1}{2} I \omega^2}{\frac{1}{2} M v^2 + \frac{1}{2} I \omega^2} = \frac{1}{\frac{M}{I} \left(\frac{v}{\omega} \right)^2 + 1} = \frac{1}{\frac{MR^2}{I} + 1}$$

For a solid cylinder, $I = MR^2/2$ and this ratio becomes

$$\frac{KE_r}{KE_{\text{total}}} = \frac{1}{2 + 1} = \frac{1}{3}$$

so the correct answer is (c).

11. If a car is to reach the bottom of the hill in the shortest time, it must have the greatest translational speed at the bottom (and hence, greatest average speed for the trip). To maximize its final translational speed, the car should be designed so as much as possible of the car's total kinetic energy is in the form of translational kinetic energy. This means that the rotating parts of the car (i.e., the wheels) should have as little kinetic energy as possible. Therefore, the mass of these parts should be kept small, and the mass they do have should be concentrated near the axle in order to keep the moment of inertia as small as possible. The correct response to this question is (e).
12. Please review the answers given above for questions 8 and 9. In the answer to question 9, it is shown that the translational speed at the bottom of the hill of an object that rolls without slipping is $v = \sqrt{2fgh}$ where h is the vertical drop of the hill and f is the ratio of the translational kinetic energy to the total kinetic energy of the rolling body. For a solid sphere, $I = 2MR^2/5$, so the ratio f is

$$f = \frac{1}{1 + I/MR^2} = \frac{1}{1 + 2/5} = \frac{1}{1.4}$$

and the translational speed at the bottom of the hill is $v = \sqrt{2gh/1.4}$. Notice that this result is the same for *all uniform, solid, spheres*. Thus, the two spheres have the same translational speed at the bottom of the hill. This also means that they have the same average speed for the trip, and hence, both make the trip in the same time. The correct answer to this question is (d).

13. Since the axle of the turntable is frictionless, no external agent exerts a torque about this vertical axis of the mouse-turntable system. This means that the total angular momentum of the mouse-turntable system will remain constant at its initial value of zero. Thus, as the mouse starts walking around the axis (and developing an angular momentum, $L_{\text{mouse}} = I_m \omega_m$, in the direction of its angular velocity), the turntable

must start to turn in the opposite direction so it will possess an angular momentum, $L_{\text{table}} = I_t \omega_t$, such that $L_{\text{total}} = L_{\text{mouse}} + L_{\text{table}} = I_m \omega_m + I_t \omega_t = 0$. Thus, the angular velocity of the table will be $\omega_t = - I_m / I_t \omega_m$. The negative sign means that if the mouse is walking around the axis in a clockwise direction, the turntable will be rotating in the opposite direction, or counterclockwise. The correct choice for this question is (d).