Answers, Even-Numbered Problems, Chapter 10

10.2 The net torque is $28.0\ \mathrm{N\cdot m}$, clockwise.

10.4

The net torque is $0.31\ \mathrm{N\cdot m}$ and is clockwise.

10.6

(a) $2.56\ \mathrm{N\cdot m}$. The torque is counterclockwise.
(b) The torque is maximum when $\phi = 90^\circ$ and the force is perpendicular to the wrench. This maximum torque is $4.25\ \mathrm{N\cdot m}$.

10.8

$-0.0524\ \mathrm{N\cdot m}$

10.10

(a) $\alpha_z = 34.8\ \mathrm{rad/s^2}$. $a = 8.70\ \mathrm{m/s^2}$.
(b) The force exerted by the axle has magnitude 98.6 N and is directed at 66.1° above the horizontal, away from the direction of the pull on the cord.
(c) The force exerted by the axle has magnitude 50.2 N and is upward.

10.12

(a) $2.00\ \mathrm{kg}$.
(b) $14.0\ \mathrm{N}$

10.14

(a). $42.0\ \mathrm{N}$.
(b) $v_y^2 = v_{0y}^2 + 2a_y(y - y_0)$ gives $11.8\ \mathrm{m/s}$.
(c), ,. $1.69\ \mathrm{s}$
(d) $160\ \mathrm{N}$.

10.16

(a) The tension to the left of the pulley is 32.6 N and below the pulley it is 35.4 N.
(b) $a = 2.72\ \mathrm{m/s^2}$
(c) $55.0\ \mathrm{N}$.

10.18

$$\alpha = \frac{3F}{Ml}.$$

10.20

(a) $33.9\ \mathrm{rad/s}$.
(b) $2.71\ \mathrm{m/s}$

10.22

(a) $a_{cm} = 3.62 \text{ m/s}^2$. $f = 4.83 \text{ N}$. The friction is static since there is no slipping at the point of contact.. $\mu_s = 0.313$.

(b) The acceleration is independent of *m* and doesn't change. The friction force is proportional to *m* so will double; $f = 9.66 \text{ N}$. The normal force will also double, so the minimum μ_s required for no slipping wouldn't change.

10.24

(a). $h' = \dfrac{v^2}{2g} = \dfrac{\frac{10}{7}gh}{2g} = \dfrac{5}{7}h$

(b) $mgh = mgh'$ so $h' = h$.

(c) With friction on both halves, all the initial potential energy gets converted back to potential energy. Without friction on the right half some of the energy is still in rotational kinetic energy when the marble is at its maximum height.

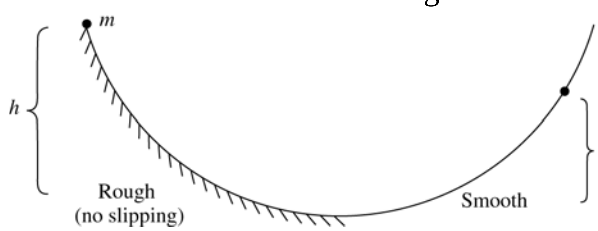

Figure 10.24

10.26

(a) The angular speed of the ball must decrease, and so the torque is provided by a friction force that acts up the hill.

(b) $a_{cm} = \left(5/7\right) g \sin\beta$.

(c) $\mu_s \geq \left(2/7\right) \tan\beta$.

10.28

(a) $519 \text{ N} \cdot \text{m}$.

(b) 3260 J

10.30

$0.382 \text{ N} \cdot \text{m}$

10.32

(a) 46.2 rad/s^2.

(b) 53.9 rad/s.

(c) $6.13 \times 10^4 \text{ J}$.

(d) $P_{av} = 52.5 \text{ kW}$.

(e) P_{av} is half the instantaneous power at the end of the 5.00 revolutions.

10.34

$5.28 \times 10^3 \ \mathrm{kg \cdot m^2/s}$

10.36

(a) $2.67 \times 10^{40} \ \mathrm{kg \cdot m^2/s}$.

The radius of the earth is much less than its orbit radius, so it is very reasonable to model it as a particle for this calculation.

(b) $7.07 \times 10^{33} \ \mathrm{kg \cdot m^2/s}$

10.38

(a) $A = 1.50 \ \mathrm{rad/s^2}$ and $B = 1.10 \ \mathrm{rad/s^4}$, so that $\theta(t)$ will have units of radians.

(b) (i). $59.0 \ \mathrm{kg \cdot m^2/s}$.

(ii) $56.1 \ \mathrm{N \cdot m}$.

10.40

(a) Yes, angular momentum is conserved. The moment arm for the tension in the cord is zero so this force exerts no torque and there is no net torque on the block.

(b) $7.00 \ \mathrm{rad/s}$

(c) $0.0103 \ \mathrm{J}$

(d) $0.0103 \ \mathrm{J}$

10.42

$0.60 \ \mathrm{rev}$

10.44

$0.223 \ \mathrm{rad/s}$.

Ignoring the mass of the mud $\omega = 0.225 \ \mathrm{rad/s}$, so the mass of the mud in the moment of inertia does affect the third significant figure.

10.46

. $m = 0.100M$.

10.48

The sketches are given in Figures 10.48a–d.

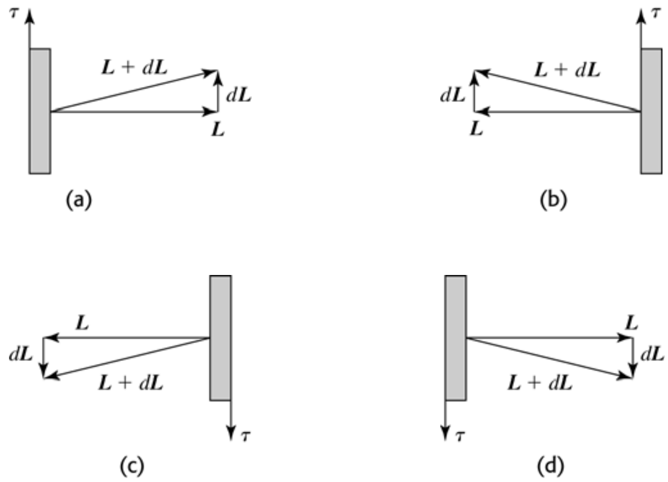

Figure 10.48

10.50

$0.0825\ \text{rad/s}\,.$

10.52

(a) $\tau = 5.4\ \text{N}\cdot\text{m}\,.$

10.54

(a). $I = 0.956\ \text{kg}\cdot\text{m}^2$

(b) $-0.0801\ \text{N}\cdot\text{m}$

(c) $654\ \text{rad} = 104\ \text{rev}$

10.56

$3.74\ \text{m/s}$

10.58

$0.675\ \text{s}$

10.60

(a) A distance $L/4$ from the end with the clay.

(b $\alpha = (9\,g/8L)\sin\theta\,.$

(c $\alpha = (3\,g/2\,L)\sin\theta.$ This is greater than in part (b).

(d) The greater the angular acceleration of the upper end of the cue, the faster you would have to react to overcome deviations from the vertical.

10.62

$1200\ \text{N}$

10.64

(a) $1.12\ \mathrm{m/s^2}$
(b) $14.0\ \mathrm{N}$

10.66

$a_{\mathrm{cm}} = F / 2M,$ and $f = F / 2.$

10.68

(a) $0.957\ \mathrm{m}$

(b) The results from the two methods agree; the disk rolls 0.957 m up the ramp before it stops.
The mass *M* enters both in the linear inertia and in the gravity force so divides out. The mass *M* and radius *R* enter in both the rotational inertia and the gravitational torque so divide out.

10.70

(a) $\frac{17}{6}R$.

(b) $n = \frac{11}{5}mg$.

(c) Now $K = \frac{1}{2}mv^2$ instead of $\frac{5}{6}mv^2$. The shell would be moving faster at *A* than with friction and would still make the complete loop.

(d) In part (c): $mgh_0 = mg(2R) + \frac{1}{2}mv^2$. $h_0 = \frac{17}{6}R$ gives $v^2 = \frac{5}{3}gR$. $\sum \vec{F} = m\vec{a}$ at point *A* gives $mg + n = m\dfrac{v^2}{R}$ and $n = m\left(\dfrac{v^2}{R} - g\right) = \frac{2}{3}mg$. In part (a), $n = 0$, since at this point gravity alone supplies the net downward force that is required for the circular motion.

10.72

(a) $1.76\ \mathrm{N}$.

(b) $122.5\ \mathrm{rad/s^2}$.

(c) $9.8\ \mathrm{m/s^2}$

(d) *T* would be unchanged because the mass *M* is the same, α and a would be twice as great because *I* is now $\frac{1}{2}MR^2$.

10.74

(a) $22.6\ \mathrm{m}$.

(b) $\frac{1}{2}I\omega^2 = \frac{1}{5}mv^2$, independent of *R*. *I* is proportional to R^2 but ω^2 is proportional to $1 / R^2$ for a given translational speed *v*.

(c) $16.6\ \mathrm{m}$.

10.76

(a)

The ball travels horizontally $36.5\ \text{m}.$

Just before it lands, $v = 28.0\ \text{m/s}$

(b) EVALUATE: At the bottom of the hill, $\omega = v\ /\ r = (25.0\ \text{m/s})\ /\ r.$ The rotation rate doesn't change while the ball is in the air, after it leaves the top of the cliff, so just before it lands $\omega = (15.3\ \text{m/s})\ /\ r.$ The total kinetic energy is the same at the bottom of the hill and just before it lands, but just before it lands less of this energy is rotational kinetic energy, so the translational kinetic energy is greater.

10.78

(a) $2.07\ \text{m/s}.$

(b) $3.16\ \text{rad/s} = 0.503\ \text{rev/s}$

(c) $9.41\ \text{rad/s} = 1.50\ \text{rev/s}$

10.80

(a) $9.34\ \text{m/s}.$

(b) $2v_{\text{cm}} = 18.7\ \text{m/s}$

(c) $v = 0$ at the bottom of the ball.

(d) $5.60\ \text{m}$

10.82

$3.40\ \text{m}.$

10.84

(a) $0.919\ \text{rad/s}^2.$

(b) α_z depends on the angle the bridge makes with the horizontal. α_z is not constant during the motion and $\omega_z = \omega_{0z} + \alpha_z t$ cannot be used.

(c) $1.78\ \text{rad/s}.$

10.86

(a) $\omega_2 = 7.5\ \text{rev/min}.$

(b) The forces and torques that the rings and the rod exert on each other will vanish, but the common angular velocity will be the same, 7.5 rev/min.

10.88

$\omega = 0.514\ \text{rad/s}.$

10.90

$-1.1\ \text{cm}.$

10.92

$r = 0.440\ \text{m}.$

10.94

(a). $I = (7.00 \times 10^{-3}) M_0 L_0^2$.

(b). $\tau_f = (7.00 \times 10^{-3}) M_0 L_0^2 \dfrac{\omega_0}{T}$

10.96

$-0.776\ \text{rad/s}$.

10.98

$0.710\ \text{m}$.

10.100

(a) Consider the sketch in Figure 10.100.
The distance from the center of the ball to the midpoint of the line joining the points where the ball is in contact with the rails is $\sqrt{R^2 - (d/2)^2}$, so $v_{cm} = \omega\sqrt{R^2 - d^2/4}$.
When $d = 0$, this reduces to $v_{cm} = \omega R$, the same as rolling on a flat surface. When $d = 2R$, the rolling radius approaches zero, and $v_{cm} \to 0$ for any ω.

(b)

$$K = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}\left[mv_{cm}^2 + (2/5)mR^2\left(\frac{v_{cm}}{\sqrt{R^2 - (d^2/4)}}\right)^2\right] = \frac{mv_{cm}^2}{10}\left[5 + \frac{2}{(1 - d^2/4R^2)}\right]$$

Setting this equal to mgh and solving for v_{cm} gives the desired result.

(c) The denominator in the square root in the expression for v_{cm} is larger than for the case $d = 0$, so v_{cm} is smaller. For a given speed, ω is larger than in the $d = 0$ case, so a larger fraction of the kinetic energy is rotational, and the translational kinetic energy, and hence v_{cm}, is smaller.

(d) Setting the expression in part (b) equal to 0.95 of that of the $d = 0$ case and solving for the ratio d/R gives $d/R = 1.05$. Setting the ratio equal to 0.995 gives $d/R = 0.37$.

If we set $d = 0$ in the expression in part (b), $v_{cm} = \sqrt{\dfrac{10gh}{7}}$, the same as for a sphere rolling down a ramp. When $d \to 2R$, the expression gives $v_{cm} = 0$, as it should.

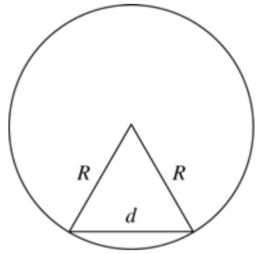

Figure 10.100

10.102

I

(a) $\Omega = 0, F_L = F_R = 39.2\ \text{N}$.

(b) $\Omega = 0.05\ \text{rev/s} = 0.314\ \text{rad/s},\ F_L = 60.0\ \text{N},\ F_R = 18.4\ \text{N}.$

(c) $\Omega = 0.3\ \text{rev/s} = 1.89\ \text{rad/s},\ F_L = 165\ \text{N},\ F_R = -86.2\ \text{N}$, with the minus sign indicating a downward force.

(e) $F_R = 0\ \text{ gives }\ \Omega = \dfrac{39.2\ \text{N}}{66.4\ \ \text{N}\cdot\text{s}} = 0.575\ \text{rad/s},\ \text{which is } 0.0916\ \text{rev/s}.$