CHAPTER SEVEN SOLUTIONS

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Review

(a) Newton's Universal Gravitation Law may be written as

\[ F = \frac{G m_1 m_2}{r^2} = \frac{m_1 G m_2}{r^2}. \]

If \( F \) is the gravitational force (weight) a mass \( m_1 \) located on the surface of a planet experiences, then \( m_2 \) is the mass of the planet and \( r \), the distance separating \( m_1 \) and \( m_2 \) is the radius of the planet \( R \). Comparing the above expression to weight = \( m_1 g \), we see that the acceleration due to gravity at the surface of the planet is given by

\[ g = \frac{G m_2}{R^2}. \]

For Mars, \( m_2 = 6.42 \times 10^{23} \text{ kg} \), and \( R = 3.37 \times 10^6 \text{ m} \).

Therefore, \( g_{\text{Mars}} = (6.673 \times 10^{-11}) \frac{6.42 \times 10^{23}}{(3.37 \times 10^6)^2} = 3.77 \text{ m/s}^2 \).

(b) Using \( y = v_0 t + \frac{1}{2} a t^2 \) with \( v_0 y = 0 \), and \( a_y = g_{\text{Mars}} \), we find

\[ t = \frac{2y}{g_{\text{Mars}}} = \frac{2(20.0 \text{ m})}{3.77 \text{ m/s}^2} = 3.26 \text{ s}. \]

7.3

(a) \( \omega = (33 \text{ rev/min})(2\pi \text{ rad/rev})(1 \text{ min}/60 \text{ s}) = 3.5 \text{ rad/s} \).

(b) \( \theta = \omega t = (3.5 \text{ rad/s})(1.5 \text{ s}) = 5.2 \text{ rad} \).

7.8

\( \omega_f = 2.51 \times 10^4 \text{ rev/min} = 2.63 \times 10^3 \text{ rad/s} \)

(a) \( \alpha = \frac{\omega_f - \omega_0}{t} = \frac{2.63 \times 10^3 \text{ rad/s} - 0}{3.20 \text{ s}} = 8.22 \times 10^2 \text{ rad/s}^2 \).

(b) \( \theta = \omega_0 t + \frac{1}{2} \alpha t^2 = 0 + \frac{1}{2} (8.22 \times 10^2 \text{ rad/s}^2)(3.20 \text{ s})^2 = 4.21 \times 10^3 \text{ rad} \).

7.13

\( \theta = \frac{\omega^2 - \omega_0^2}{2 \alpha} = \frac{0 - (18.0 \text{ rad/s})^2}{2(-1.90 \text{ rad/s}^2)} = 85.3 \text{ rad} \).

\( s = r \theta \) and \( r = \frac{1}{2} \text{ diameter} = 1.20 \text{ cm} \),

so \( s = (1.20 \text{ cm})(85.3 \text{ rad}) = 102 \text{ cm} = 1.02 \text{ m} \).

7.14

\( s = v_0 t + \frac{1}{2} a t^2 = (17.0 \text{ m/s})(5.00 \text{ s}) + \frac{1}{2} (2.00 \text{ m/s}^2)(5.00 \text{ s})^2 = 110 \text{ m} \).

\( s = r \theta \), and \( r = 48 \text{ cm} = 0.480 \text{ m} \)

Thus, \( \theta = \frac{s}{r} = \frac{110 \text{ m}}{0.480 \text{ m}} = 229.2 \text{ rad} = 36.5 \text{ rev} \).

7.21

Let \( m \) be the mass of a red corpuscle and let \( r \) be the radius of the centrifuge. We are given

\[ F_c = 4.0 \times 10^{-11} \text{ N} = \frac{m v^2}{r} = m r \omega^2, \]

so

\[ \omega = \sqrt{\frac{F_c}{m r}} = \sqrt{\frac{4.00 \times 10^{-11}}{(3.00 \times 10^{-16})(0.15)}} = 942.8 \text{ rad/s} = 150 \text{ rev/s}. \]
7.29 (a) At A the forces on the car are the normal force, \(N\), and its weight. We have \(F_c = \frac{mv^2}{r} = N - mg\), or \(N = mg + \frac{mv^2}{r}\), which gives
\[
N = (500 \text{ kg})(9.80 \text{ m/s}^2) + \frac{(500 \text{ kg})(20.0 \text{ m/s})^2}{10.0 \text{ m}} = 2.49 \times 10^4 \text{ N}.
\]
(b) At B we have, \(F_c = \frac{mv^2}{r} = mg - N\), or \(N = m(g - \frac{v^2}{r})\).
For the vehicle to remain on the track, it is necessary to have \(N \geq 0\) which means \(g \geq \frac{v^2}{r}\) or \(v = \sqrt{rg}\).
Thus, \(v_{\text{max}} = \sqrt{rg} = \sqrt{(15.0 \text{ m})(9.80 \text{ m/s}^2)} = 12.1 \text{ m/s}\).

7.39 (a) \(PE = -\frac{GM_Em}{r} = \frac{(6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2)(5.98 \times 10^{24} \text{ kg})(100 \text{ kg})}{(8.38 \times 10^6 \text{ m})} = -4.76 \times 10^9 \text{ J}\)
(b) \(F = \frac{GM_Em}{r^2} = \frac{(6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2)(5.98 \times 10^{24} \text{ kg})(100 \text{ kg})}{(8.38 \times 10^6 \text{ m})^2} = 5.68 \times 10^2 \text{ N}\)

7.50 (a) At the bottom of the swing, \(T - mg = \frac{mv^2}{L}\), or
\[
T = mg + \frac{mv^2}{L} = (0.400)(9.80) + \frac{(0.400)(3.00)^2}{0.800} = 8.42 \text{ N}.
\]
(b) From conservation of energy, we may write \((PE)_{\text{at top of swing}} = (KE)_{\text{at bottom}}\), or
\[
mgL(1 - \cos \theta_{\text{max}}) = \frac{1}{2} \frac{mv^2}{\text{bottom}}, \text{ giving}
\]
\[
\cos \theta_{\text{max}} = 1 - \frac{v^2_{\text{bottom}}}{2gL} = 1 - \frac{(3.00 \text{ m/s})^2}{2(9.80 \text{ m/s}^2)(0.800 \text{ m})} = 0.426.
\]
Thus, \(\theta_{\text{max}} = 64.8^\circ\).
(c) At \(\theta = \theta_{\text{max}}\), the pendulum is at rest, so the radial force
\[
F_c = \frac{mv^2}{L} = T - Mg\cos \theta_{\text{max}} = 0.
\]
Thus, \(T = Mg\cos \theta_{\text{max}} = (0.400 \text{ kg})(9.80 \text{ m/s}^2)\cos 64.8^\circ = 1.67 \text{ N}\).

7.57 Using Kepler’s Third law \(T^2 = ka^3\), we have
\[
(75.6)^2 = \left(\frac{0.57 + x}{2}\right)^3
\]
The farthest distance \(x = 2(75.6)^{2/3} - 0.57 = 35.2 \text{ A.U.} \) (near the orbit of Pluto)

ANSWERS TO EVEN ASSIGNED CONCEPTUAL QUESTIONS

4. The speedometer will be inaccurate. The speedometer measures the number of revolutions per second of the tires.