Worked solutions Unit 3A

Contents

Heinemann Physics Content and Contexts Units 3A and 3B
ISBN 978 1 4425 1140 8

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Fairground physics

E1

$r = (6.00 \div 2)$ m

$g = 9.80$ m s^{-2}

$a_c = 0.0200 \times g$

$$a_c = \frac{v^2}{r}$$

$$v = \sqrt{[(0.0200 \times 9.80)(3.00)]}$$

$$v = 7.67 \times 10^{-1} \text{ m s}^{-1}$$

E2 A. Inside column, as a smaller distance is covered in the same time period, which means that the centripetal force is less on the small child

E3 Outside column, as a greater distance is covered in the same time period, which means that the centripetal force will be greater on the older child.

E4

$a_c = 0.0500 \times 9.80$ m s^{-2}

$m = (20.0 + 50.0)$ kg

$$F_c = ma_c$$

$$F_c = (70.0)(4.90 \times 10^{-1})$$

$$F_c = 3.43 \times 10^1 \text{ N}$$

$$F_{attachment} = (3.43 \times 10^1) \times 12$$

$$F_{attachment} = 4.12 \times 10^2 \text{ N}$$

E5

$\updownarrow$ $^{+}_{-}$

$m = 60.0$ kg

$r = 5.00$ m

$v = 4.00$ m s^{-1}

$$F_{c\text{ wall on rider}} = \frac{mv^2}{r}$$

$$F_{c\text{ wall on rider}} = \frac{(60.0)(4.00)^2}{(5.00)}$$

$$F_{c\text{ wall on rider}} = 1.92 \times 10^2 \text{ N towards the centre}$$

E6

$\updownarrow$ $^{+}_{-}$

$a_{\text{wall on rider}} = 2.00 \times g$

$r = 10.0$ m

$$a_{c\text{ wall on rider}} = \frac{v^2}{r}$$

$$v = \sqrt{a_{c\text{ wall on rider}} r}$$

$$v = \sqrt{(2 \times 9.80)(10.0)} = \sqrt{196}$$

$$v = 4.47 \times 10^1 \text{ m s}^{-1}$$

$$v = 14 \text{ m s}^{-1}$$

$$= 1.4 \times 10^1 \text{ m s}^{-1}$$

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E7

$m = 1.00 \times 10^3$ kg
$g = 9.80$ m s^{-2}
$\theta = 50.0°$

$$F_{\text{down track}} = mg\cos\theta$$
$$F_{\text{down track}} = (1.00 \times 10^3)(9.80)\cos 40°$$
$$F_{\text{down track}} = 7.51 \times 10^3 \text{ N down the slope}$$

E8

$F_{\text{down slope}} = 500.0$ N
$g = 9.80$ m s^{-2}
$\theta = 60.0$

$$F_{\text{down slope}} = mg\cos\theta$$
$$m = \frac{(500.0)}{(9.80)(\cos 60°)}$$
$$m = 1.02 \times 10^2 \text{ kg}$$

E9

$\Delta h_y = 50.0$ m
$g = 9.80$ m s^{-2}

$$E_{\text{k, gain}} = E_{\text{p, lost}}$$
$$\tfrac{1}{2}mv^2 = mg\Delta h_y$$
$$v = \sqrt{2g\Delta h_y}$$
$$v = \sqrt{2(9.80)(50.0)}$$
$$v = 3.13 \times 10^1 \text{ m s}^{-1}$$

E10

$\Delta h_y = (75.0 - 62.0)$ m
$g = 9.80$ m s^{-2}
$m = 900.0$ kg

$$E_{\text{friction}} = E_{\text{p,start}} - E_{\text{p,end}} = mg\Delta h_y$$
$$E_{\text{friction}} = mg\Delta h_y$$
$$E_{\text{friction}} = (900.0)(9.80)(13.0)$$
$$E_{\text{friction}} = 1.15 \times 10^5 \text{ J}$$

E11

$v = 100.0$ km h^{-1}
$v = 27.78$ m s^{-1}
$g = 9.80$ m s^{-2}

$$E_{\text{k,gain}} = E_{\text{p,lost}}$$
$$\tfrac{1}{2}mv^2 = mg\Delta h_y$$
$$\Delta h_y = \frac{v^2}{2g}$$
$$\Delta h_y = \frac{(27.78)^2}{2(9.80)}$$
$$\Delta h_y = 3.94 \times 10^1 \text{ m}$$

E12 Same maximum speed, as the mass of the car and riders cancels out of the equation.

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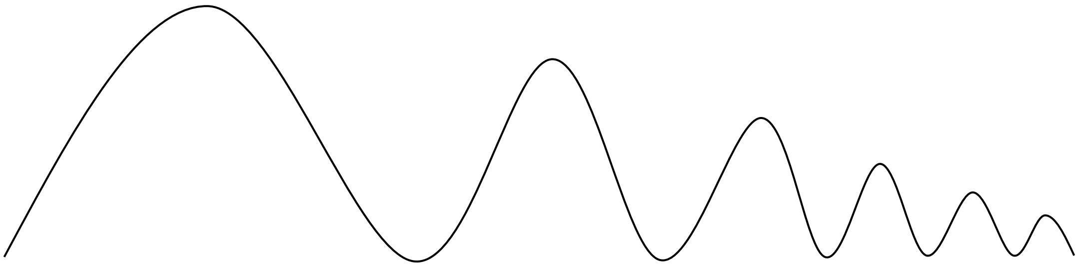
E13

$v = 19.0 \text{ m s}^{-1}$

$g = 9.80 \text{ m s}^{-2}$

$$E_{p,gain} = E_{k,lost}$$
$$mg\Delta h = \tfrac{1}{2}mv^2$$
$$\Delta h = \frac{v^2}{2g}$$
$$\Delta h = \frac{(19.0)^2}{2(9.80)}$$
$$\Delta h = 1.84 \times 10^1 \text{ m}$$

E14



E15

$v = 6.00 \text{ m s}^{-1}$

$g = 9.80 \text{ m s}^{-2}$

$$\frac{mv^2}{r} = 2 \times mg$$
$$r = \frac{v^2}{2g} = \frac{(6.00)^2}{2(9.80)}$$
$$r = 1.84 \text{ m}$$

E16

$r = 10.0 \text{ m}$

$g = 9.80 \text{ m s}^{-2}$

$$\frac{mv^2}{r} = 1.5 \times mg$$
$$v = \sqrt{1.5rg} = \sqrt{(1.50)(10.0)(9.80)}$$
$$v = 1.21 \times 10^1 \text{ m s}^{-1}$$

E17

$v = 15.0 \text{ m s}^{-1}$

$m = 1.00 \times 10^3 \text{ kg}$

$r = 20.0 \text{ m}$

$$F_c = \frac{mv^2}{r}$$
$$F_c = \frac{(1.00 \times 10^3)(15.0)^2}{(20.0)}$$
$$F_c = 1.13 \times 10^4 \text{ N}$$

E18 A 2.00*g* ride can be created if the accelerating force is vertical as opposed to horizontal, for example a 2.00*g* force can be experienced at the bottom of a curve.

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E19

$$r_{\text{small}} = 2.00 \text{ m} \qquad F_{\text{c, total}} = F_{\text{c, small}} + F_{\text{c, large}}$$

$$v_{\text{small}} = 0.500 \text{ m s}^{-1} \qquad F_{\text{c, total}} = \frac{mv_{\text{small}}^{2}}{r_{\text{small}}} + \frac{mv_{\text{large}}^{2}}{r_{\text{large}}}$$

$$r_{\text{large}} = 10.0 \text{ m} \qquad F_{\text{c, total}} = \frac{(50.0)(0.500)^2}{(2.00)} + \frac{(50.0)(2.00)^2}{(10.0)}$$

$$v_{\text{large}} = 2.00 \text{ m s}^{-1} \qquad F_{\text{c, total}} = (6.25 + (20.0)$$

$$m = 50.0 \text{ kg} \qquad F_{\text{c, total}} = 2.63 \times 10^{1} \text{ N}$$

E20

$$r_{\text{small}} = 2.00 \text{ m} \qquad a_{\text{c, total}} = a_{\text{c, small}} + a_{\text{c, large}}$$

$$v_{\text{small}} = 1.00 \text{ m s}^{-1} \qquad a_{\text{c, total}} = \frac{v_{\text{small}}^{2}}{r_{\text{small}}} + \frac{v_{\text{large}}^{2}}{r_{\text{large}}}$$

$$r_{\text{large}} = 10.0 \text{ m} \qquad a_{\text{c, total}} = \frac{(1.00)^2}{(2.00)} + \frac{(0.600)^2}{(10.0)}$$

$$v_{\text{large}} = 0.600 \text{ m s}^{-1} \qquad a_{\text{c, total}} = (0.500) + (0.0036)$$

$$a_{\text{c, total}} = 5.36 \times 10^{-1} \text{ m s}^{-2}$$

E21 a

- +

$$u_{\text{yellow}} = 13.0 \text{ km h}^{-1} = 3.61 \text{ m s}^{-1}$$

$$m_{\text{yellow}} = 420.0 \text{ kg}$$

$$u_{\text{purple}} = -7.00 \text{ km h}^{-1} = -1.94 \text{ m s}^{-1}$$

$$m_{\text{purple}} = 500.0 \text{ kg}$$

$$m_{\text{yellow+purple}} = 920.0 \text{ kg}$$

momentum is conserved, so:

$$m_{\text{yellow}} u_{\text{yellow}} + m_{\text{purple}} u_{\text{purple}} = m_{\text{yellow+purple}} v_{\text{yellow+purple}}$$

$$v_{\text{yellow+purple}} = \frac{m_{\text{yellow}} u + m_{\text{purple}} u_{\text{purple}}}{m_{\text{yellow+purple}}}$$

$$v_{\text{yellow+purple}} = \frac{(420.0)(3.61) + (500.0)(-1.94)}{(920.0)}$$

$$v_{\text{yellow+purple}} = 5.92 \times 10^{-1} \text{ m s}^{-1} \quad \text{or} \quad 2.13 \text{ km h}^{-1}$$

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b

$-$ $+$

$u_{\text{yellow}} = 6.00\ \text{km h}^{-1} = 1.67\ \text{m s}^{-1}$

$m_{\text{yellow}} = 420.0\ \text{kg}$

$u_{\text{purple}} = -6.00\ \text{km h}^{-1} = -1.67\ \text{m s}^{-1}$

$m_{\text{purple}} = 500.0\ \text{kg}$

$m_{\text{yellow+purple}} = 920.0\ \text{kg}$

momentum is conserved, so:

$$m_{\text{yellow}}u_{\text{yellow}} + m_{\text{purple}}u_{\text{purple}} = m_{\text{yelloow+purple}}v_{\text{yellow+purple}}$$

$$v_{\text{yellow+purple}} = \frac{m_{\text{yellow}}u_{\text{yellow}} + m_{\text{purple}}u_{\text{purple}}}{m_{\text{yellow+purple}}}$$

$$v_{\text{yellow+purple}} = \frac{(420.0)(1.67) + (500.0)(-1.67)}{(920.0)}$$

$$v_{\text{yellow+purple}} = -1.45 \times 10^{-1}\ \text{m s}^{-1} \quad \text{or} \quad -5.22\ \text{km h}^{-1}$$

E22

$-$ $+$

$u_{\text{orange}} = 10.0\ \text{km h}^{-1} = 2.78\ \text{m s}^{-1}$

$m_{\text{orange}} = 410.0\ \text{kg}$

$m_{\text{silver}} = 350.0\ \text{kg}$

$v_{\text{orange+silver}} = 0.00\ \text{m s}^{-1}$

$m_{\text{orange+silver}} = 760.0\ \text{kg}$

momentum is conserved, so:

$$m_{\text{orange}}u_{\text{orange}} + m_{\text{silver}}u_{\text{silver}} = m_{\text{orange+silver}}v_{\text{orange+silver}}$$

$$u_{\text{silver}} = \frac{m_{\text{orange+silver}}v_{\text{orange+silver}} - m_{\text{orange}}u_{\text{orange}}}{m_{\text{silver}}}$$

$$u_{\text{silver}} = \frac{(760.0)(0.00) - (410.0)(2.78)}{(350.0)}$$

$$u_{\text{silver}} = -3.26\ \text{m s}^{-1} \quad \text{or} \quad -1.17 \times 10^{1}\ \text{km h}^{-1}$$

E23

$-$ $+$

$u_{\text{gold}} = 15.0\ \text{km h}^{-1} = 4.17\ \text{m s}^{-1}$

$m_{\text{gold}} = 530.0\ \text{kg}$

$m_{\text{green}} = 800.0\ \text{kg}$

$u_{\text{green}} = 0.00\ \text{m s}^{-1}$

$m_{\text{green+gold}} = 1330.0\ \text{kg}$

momentum is conserved, so:

$$m_{\text{gold}}u_{\text{gold}} + m_{\text{green}}u_{\text{green}} = m_{\text{green+gold}}v_{\text{green+gold}}$$

$$v_{\text{green+gold}} = \frac{m_{\text{gold}}u_{\text{gold}} + m_{\text{green}}u_{\text{green}}}{m_{\text{green+gold}}}$$

$$v_{\text{green+gold}} = \frac{(530.0)(4.17) + (800.0)(0.00)}{(1330.0)}$$

$$v_{\text{green+gold}} = 1.66\ \text{m s}^{-1} \quad \text{or} \quad 5.98\ \text{km h}^{-1}$$

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E24

In the x direction:

$u_{\text{turquoise}} = 6.00 \text{ km h}^{-1} = 1.67 \text{ m s}^{-1}$

$m_{\text{turquoise}} = 425.0 \text{ kg}$

momentum in the x direction is conserved, so:

$$\rho_{x\ \text{final}} = m_{\text{turquoise}} u_{\text{turquoise}}$$

$$\rho_{x\ \text{final}} = (425)(1.67)$$

$$\rho_{x\ \text{final}} = 7.08 \times 10^{2} \text{ kg m s}^{-1}$$

As the final direction is south-east, then the momentum in the z direction must be equal to that in the x direction.

$\rho_{\text{white}} = 7.08 \times 10^{2} \text{ kg m s}^{-1}$

$m_{\text{white}} = 675.0 \text{ kg}$

momentum in the z direction is conserved, so:

$$\rho_{z\ \text{final}} = m_{\text{white}} u_{\text{white}}$$

$$u_{\text{white}} = \frac{\rho_{z\ \text{final}}}{m_{\text{white}}} = \frac{(7.08 \times 10^{2})}{(675.0)}$$

$$u_{\text{white}} = 1.05 \text{ m s}^{-1}$$

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Power distribution and generation

E1

$$\rho_{Al} = 2.65 \times 10^{-8}\ \Omega\,\text{m} \qquad R_{cable} = \frac{\rho L}{A} = \frac{\rho L}{\pi r^2}$$

$$r = \frac{2.00 \times 10^{-2}}{2}\ \text{m} \qquad R_{cable} = \frac{(2.65 \times 10^{-8})(2.00)}{\pi(1.00 \times 10^{-2})^2}$$

$$L = 2.00\ \text{m} \qquad R_{cable} = 1.69 \times 10^{-4}\ \Omega$$

E2 **a**

$$V_{peak} = 15.0 \times 10^3\ \text{V} \qquad V_{rms} = \frac{V_{peak}}{\sqrt{2}}$$

$$V_{rms} = \frac{(15.0 \times 10^3)}{\sqrt{2}}$$

$$V_{rms} = 1.06 \times 10^4\ \text{V}$$

b **i**

$$V_s = 9.00 \times 10^3\ \text{V} \qquad \text{turns ratio} = \frac{N_s}{N_p} = \frac{V_s}{V_p}$$

$$V_p = 15.0 \times 10^3\ \text{V} \qquad \text{turns ratio} = \frac{(9.00 \times 10^3)}{(15.0 \times 10^3)}$$

$$\text{turns ratio} = 0.600:1 \ \text{ or } \ 1:1.67$$

ii The current in the secondary coil of a step-down transformer is always greater than the current in the primary coil, as current and voltage are inversely proportional in a transformation.

E3

$$P_{total} = P_{ac} + P_r + P_{cb} + P_{ts} + P_{sp} + P_{dl}$$

$$P_{total} = (1.00 \times 10^3) + (10.0) + (720.0) + (50.0) + (20.0) + (30.0)$$

$$P_{total} = 1.83 \times 10^3\ \text{W}$$

Substituting into $P = VI$:

$$P_{total} = 1.83 \times 10^3\ \text{W} \qquad I_{total} = \frac{P_{total}}{V_{house}}$$

$$V_{house} = 240.0\ \text{V} \qquad I_{total} = \frac{(1.83 \times 10^3)}{(240.0)}$$

$$I_{total} = 7.63\ \text{A}$$

This is too large to run all these appliances at once; the extension cord on the power pack could heat up too much.

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E4 **a**

$P_{gen} = 20.0 \times 10^3$ W

$V_{gen} = 250.0$ V

$$I_{TL} = \frac{P_{gen}}{V_{gen}}$$

$$I_{TL} = \frac{(20.0 \times 10^3)}{(250.0)}$$

$$I_{TL} = 8.00 \times 10^1 \text{ A}$$

$I_{TL} = 8.00 \times 10^1$ A

$R_{TL} = 1.20\ \Omega$

$$P_{loss} = I_{TL}{}^2 R_{TL}$$

$$P_{loss} = (8.00 \times 10^1)^2(1.20)$$

$$P_{loss} = 7.68 \times 10^3 \text{ W}$$

b

$P_{loss} = 7.68 \times 10^3$ W

$I_{TL} = 8.00 \times 10^1$ A

$$V_{drop} = \frac{P_{loss}}{I_{TL}}$$

$$V_{drop} = \frac{(7.68 \times 10^3)}{(8.00 \times 10^1)}$$

$$V_{drop} = 9.60 \times 10^1 \text{ V}$$

$V_{start\ TL} = 250.0$ V

$V_{drop\ TL} = 9.60 \times 10^1$ V

$$V_{end\ TL} = V_{start\ TL} - V_{drop\ TL}$$

$$V_{end\ TL} = (250.0) - (9.60 \times 10^1)$$

$$V_{end\ TL} = 1.54 \times 10^2 \text{ V}$$

c They should be able to use some appliances; however, lights would not be as bright, motors would not go as fast. Electronic devices may not function at all.

d

$P_s = 20.0 \times 10^3$ W

$V_s = 6.00 \times 10^3$ V

$$I_{TL} = \frac{P_s}{V_s}$$

$$I_{TL} = \frac{(20.0 \times 10^3)}{(6.00 \times 10^3)}$$

$$I_{TL} = 3.33 \text{ A}$$

$I_{TL} = 3.33$ A

$R_{TL} = 1.20\ \Omega$

$$P_{loss} = I_{TL}{}^2 R_{TL}$$

$$P_{loss} = (3.33)^2(1.20)$$

$$P_{loss} = 1.33 \times 10^1 \text{ W}$$

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e

$$P_{\text{loss}} = 1.33 \times 10^{1}\ \text{W} \qquad V_{\text{drop}} = \frac{P_{\text{loss}}}{I_{\text{TL}}}$$

$$I_{\text{TL}} = 3.33\ \text{A} \qquad V_{\text{drop}} = \frac{(1.33 \times 10^{1})}{(3.33)}$$

$$V_{\text{drop}} = 4.00\ \text{V}$$

$$V_{\text{start TL}} = 6.00 \times 10^{3}\ \text{V} \qquad V_{\text{end TL}} = V_{\text{start TL}} - V_{\text{drop TL}}$$

$$V_{\text{drop TL}} = 4.00\ \text{V} \qquad V_{\text{end TL}} = (6.00 \times 10^{3}) - (4.00)$$

$$V_{\text{end TL}} = 5.996 \times 10^{3}\ \text{V}$$

$$V_{\text{s}} = 240.0\ \text{V} \qquad \text{turns ratio} = \frac{N_{\text{s}}}{N_{\text{p}}} = \frac{V_{\text{s}}}{V_{\text{p}}}$$

$$V_{\text{p}} = 5.996 \times 10^{3}\ \text{V} \qquad \text{turns ratio} = \frac{(240.0)}{(5.996 \times 10^{3})}$$

$$\text{turns ratio} = 0.0400:1\ \text{ or }\ 1:25.0$$

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Chapter 1 Analysing motion

1.1 Projectile motion

1 **a**

$\updownarrow^{+}_{-}$ $\quad s_y = u\Delta t + \frac{1}{2}a\Delta t^2$

$s_y = -4.90$ m $\quad (-4.90) = (0)\Delta t + \frac{1}{2}(-9.80)\Delta t^2$

$g = -9.80$ m s^{-2} $\quad \Delta t = \sqrt{\dfrac{2(-4.90)}{(-9.80)}}$

$\Delta t = 1.00$ s

b

$- \leftrightarrow +$ $\quad s_x = v_x\Delta t = (20.0)(1.00)$

$v_x = 20.0$ m s^{-1} $\quad s_x = 20.0$ m

$\Delta t = 1.00$ s

c The only force acting on the ball is gravity, therefore the only acceleration is $g = -9.80$ m s^{-2}.

d

$\updownarrow^{+}_{-}$ $\quad v_y = u + a\Delta t = (0) + (-9.80)(0.800)$

$u_y = 0$ m s^{-1} $\quad v_y = -7.84$ m s^{-1}

$g = -9.80$ m s^{-2}

$\Delta t = 0.800$ s $\quad v = \sqrt{v_x^2 + v_y^2} = \sqrt{(20.0)^2 + (-7.84)^2}$

$v = 18.4$ m s^{-1}

e

$\updownarrow^{+}_{-}$ $\quad v_y = u + a\Delta t = (0) + (-9.80)(1.00)$

$u_y = 0$ m s^{-1} $\quad v_y = -9.80$ m s^{-1}

$g = -9.80$ m s^{-2}

$\Delta t = 1.00$ s $\quad v = \sqrt{v_x^2 + v_y^2} = \sqrt{(20.0)^2 + (-9.80)^2}$

$v = 22.3$ m s^{-1}

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2 **a** Horizontal velocity remains constant, so $v_x = 10.0$ m s^{-1}.

b

$\updownarrow^{+}_{-}$ $\qquad$ $v_y^2 = u_y^2 + 2as_y = \sqrt{(0)^2 + 2(-9.80)(-1.00)}$

$u_y = 0 \text{ m s}^{-1}$ $\qquad$ $v_y = -4.43 \text{ m s}^{-1}$

$g = -9.80 \text{ m s}^{-2}$ $\qquad$ $v_y = 4.43 \text{ m s}^{-1} \text{ down}$

$s_y = -1.00 \text{ m}$

c

$\updownarrow^{+}_{-}$ $\qquad$ $v = \sqrt{v_x^2 + v_y^2} = \sqrt{(10.0)^2 + (-4.43)^2}$

$v_y = -4.43 \text{ m s}^{-1}$ $\qquad$ $v = 10.9 \text{ m s}^{-1}$

$v_x = 10.0 \text{ m s}^{-1}$

$\Delta t = 0.800 \text{ s}$ $\qquad$ $\sin\theta = \dfrac{4.43}{10.9} = 0.4048$

$\theta = 23.9^\circ$

$$v = 10.9 \text{ m s}^{-1}\ 23.9^\circ \text{ down from horizontal}$$

d

$\updownarrow^{+}_{-}$ $\qquad$ $s_y = u\Delta t + \frac{1}{2}a\Delta t^2$

$s_y = -1.00 \text{ m}$ $\qquad$ $(-1.00) = (0)\Delta t + \frac{1}{2}(-9.80)\Delta t^2$

$g = -9.80 \text{ m s}^{-2}$ $\qquad$ $\Delta t = \sqrt{\dfrac{2(-1.00)}{(-9.80)}}$

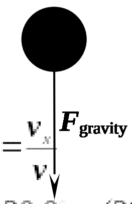
$\Delta t = 0.452 \text{ s}$

e

$\Delta t = 0.452 \text{ s}$ $\qquad$ $s_x = v_x\Delta t = (10.0)(0.452)$

$v_x = 10.0 \text{ m}$ $\qquad$ $s_x = 4.52 \text{ m}$

f



3 **a**

$\cos 30.0^\circ = \dfrac{v_x}{v}$

$v_x = v\cos 30.0^\circ = (28.0)(0.8660)$

$v_x = 24.2 \text{ m s}^{-1}$

b $\qquad$ $v_x = 24.2 \text{ m s}^{-1}$

c $\qquad$ $v_x = 24.2 \text{ m s}^{-1}$

4 **a**

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$$\sin 30.0^\circ = \frac{\boldsymbol{v}_y}{\boldsymbol{v}}$$

$$\boldsymbol{v}_y = \boldsymbol{v}\sin 30.0^\circ = (28.0)(0.5000)$$

$$\boldsymbol{v}_x = 14.0 \text{ m s}^{-1} \text{ up}$$

b

$\updownarrow {}^{+}_{-}$

$\boldsymbol{u}_y = 14.0 \text{ m s}^{-1}$

$\boldsymbol{g} = -9.80 \text{ m s}^{-2}$

$\Delta t = 1.00 \text{ s}$

$$\boldsymbol{v}_y = \boldsymbol{u} + \boldsymbol{a}\Delta t = (14.0) + (-9.80)(1.00)$$

$$\boldsymbol{v}_y = 4.20 \text{ m s}^{-1} \text{ up}$$

c

$\updownarrow {}^{+}_{-}$

$\boldsymbol{u}_y = 14.0 \text{ m s}^{-1}$

$\boldsymbol{g} = -9.80 \text{ m s}^{-2}$

$\Delta t = 2.00 \text{ s}$

$$\boldsymbol{v}_y = \boldsymbol{u} + \mathbf{a}\Delta t = (14.0) + (-9.80)(2.00)$$

$$\boldsymbol{v}_y = -5.60 \text{ m s}^{-1}$$

$$\boldsymbol{v}_y = 5.60 \text{ m s}^{-1} \text{ down}$$

5 a

$\updownarrow {}^{+}_{-}$

$\boldsymbol{u}_y = 14.0 \text{ m s}^{-1}$

$\boldsymbol{g} = -9.80 \text{ m s}^{-2}$

$\boldsymbol{v}_y = 0 \text{ m s}^{-1}$

$$\boldsymbol{v}_y = \boldsymbol{u}_y + \boldsymbol{a}\Delta t$$

$$\Delta t = \frac{\boldsymbol{v}_y - \boldsymbol{u}_y}{\mathbf{a}} = \frac{(0-14.0)}{(-9.80)}$$

$$\Delta t = 1.43 \text{ s}$$

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b

$\updownarrow$ + / −

$u_y = 14.0 \text{ m s}^{-1}$

$g = -9.80 \text{ m s}^{-2}$

$\Delta t = 1.43 \text{ s}$

$$s_y = u_y \Delta t + \tfrac{1}{2} a \Delta t^2$$

$$s_y = (14.0)(1.43) + \tfrac{1}{2}(-9.80)(1.43)^2$$

$$s_y = 10.0 \text{ m}$$

c The acceleration of the ball is constant, due to gravity = –9.80 m s^{-2}.

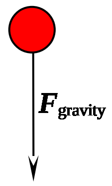
6 **a** At its maximum height, this is the point at which the ball has zero vertical velocity, while maintaining its horizontal velocity.

b $v_x = 24.2 \text{ m s}^{-1}$

c $\Delta t = 1.43 \text{ m s}^{-1}$

d

7 **a**



$\updownarrow$ + / −

$u_y = 14.0 \text{ m s}^{-1}$

$v_y = -14.0 \text{ m s}^{-1}$

$g = -9.80 \text{ m s}^{-2}$

$$g = \frac{v_y - u_y}{\Delta t}$$

$$\Delta t = \frac{v_y - u_y}{g}$$

$$\Delta t = \frac{(-14.0) - (14.0)}{(-9.80)}$$

$$\Delta t = 2.86 \text{ s}$$

b

$\updownarrow$ + / −

$v_y = -14.0 \text{ m s}^{-1}$

$v_x = 24.2 \text{ m s}^{-1}$

$\Delta t = 0.800 \text{ s}$

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{(-14.0)^2 + (24.2)^2}$$

$$v = 19.8 \text{ m s}^{-1}$$

$$\sin\theta = \frac{14.0}{19.8} = 0.7071$$

$$\theta = 45.0^\circ$$

$$v = 19.8 \text{ m s}^{-1} \ 45.0^\circ \text{ down from horizontal}$$

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c

$\Delta t = 2.86$ s $\qquad s_x = v_x \Delta t = (24.2)(2.86)$

$v_x = 24.2$ m s^{-1} $\qquad s_x = 69.3$ m

8 C

9 **a**

At maximum height loss of E_k is due to gain in E_p

$E_{\text{k final}} = 16.0$ J

$m = 0.2500$ kg $\qquad E_p = E_{\text{k initial}} - E_{\text{k final}}$

$u = 16.0$ m s^{-1} $\qquad mgh = \frac{1}{2}mu^2 - E_{\text{k final}}$

$g = 9.80$ m s^{-2} $\qquad h = \dfrac{\frac{1}{2}mu^2 - E_{\text{k final}}}{mg} = \dfrac{\frac{1}{2}(0.2500)(16.0)^2 - (16.0)}{(0.2500)(9.80)}$

$h = 6.53$ m

b

$\updownarrow^{+}_{-}$ $\qquad v^2 = u^2 + 2as$

$s = 6.53$ m $\qquad u = \sqrt{v^2 - 2as}$

$v_y = 0$ m s^{-1} $\qquad u = \sqrt{(0)^2 - 2(-9.80)(6.53)}$

$g = -9.80$ m s^{-2} $\qquad u = 11.3$ m s^{-1}

c

$$\cos\theta = \frac{v_x}{v} = \frac{(11.3)}{(16.0)} = 0.7071$$

$\theta = 45.0$

d

$\updownarrow^{+}_{-}$ $\qquad v_y = u + a\Delta t = (11.3) + (-9.80)(1.00)$

$u_y = +11.3$ m s^{-1} $\qquad v_y = 1.51$ m s^{-1} up

$g = -9.80$ m s^{-2}

$\Delta t = 1.00$ s $\qquad v = \sqrt{(1.51)^2 + (11.3)^2}$

$v = 11.4$ m s^{-1}

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e

$\updownarrow^{+}_{-}$

$u_y = 11.3 \text{ m s}^{-1}$

$g = -9.80 \text{ m s}^{-2}$

$\Delta t = 1.00 \text{ s}$

$$s_y = u_y \Delta t + \tfrac{1}{2} a \Delta t^2$$

$$s_y = (11.3)(1.00) + \tfrac{1}{2}(-9.80)(1.00)^2$$

$$s_y = 6.41 \text{ m}$$

$$s_x = v_x \Delta t = (11.3)(1.00) = 11.3 \text{ m}$$

$$s = \sqrt{s_y^2 + s_x^2} = \sqrt{(6.41)^2 + (11.3)^2} \qquad \tan\theta = \frac{(6.41)}{(11.3)} = 0.5669$$

$s = 13.1$ m 29.5 up from horizontal

f

$\updownarrow^{+}_{-}$

$u_y = 11.3 \text{ m s}^{-1}$

$g = -9.80 \text{ m s}^{-2}$

$v_y = -11.3 \text{ m s}^{-1}$

$$v_y = u_y + g\Delta t$$

$$\Delta t = \frac{v_y - u_y}{g} = \frac{(-11.3) - (11.3)}{(-9.80)}$$

$$\Delta t = 2.31 \text{ s}$$

g

$\Delta t = 2.31 \text{ s}$

$v_x = 11.3 \text{ m s}^{-1}$

$$s_x = v_x \Delta t = (11.3)(2.31)$$

$$s_x = 26.1 \text{ m}$$

10 a

$\updownarrow^{+}_{-}$

$\Delta t = 1.50 \text{ s}$

$g = -9.80 \text{ m s}^{-2}$

$v_y = 0 \text{ m s}^{-1}$

$$v_y = u_y + g\Delta t$$

$$u_y = v_y - g\Delta t = (0) - (-9.80)(1.50)$$

$$u_y = 14.7 \text{ m s}^{-1}$$

$$v = \frac{u_y}{\sin\theta} = \frac{(14.7)}{\sin 40.0} = 22.9 \text{ m s}^{-1}$$

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b

$\updownarrow$ $^{+}_{-}$

$u_y = 14.7 \text{ m s}^{-1}$

$g = -9.80 \text{ m s}^{-2}$

$\Delta t = 1.50 \text{ s}$

$$s_y = u_y\Delta t + \tfrac{1}{2}a\Delta t^2$$
$$s_y = (14.7)(1.50) + \tfrac{1}{2}(-9.80)(1.50)^2$$
$$s_y = 11.0 \text{ m}$$

c

$\updownarrow$ $^{+}_{-}$

$u_y = 14.7 \text{ m s}^{-1}$

$g = -9.80 \text{ m s}^{-2}$

$s_y = -10.0 \text{ m}$

$$v_y^{\,2} = u_y^{\,2} + 2as_y$$
$$v_y = \sqrt{(14.7)^2 + 2(-9.80)(-10.0)}$$
$$v_y = -20.3 \text{ m s}^{-1}$$

$$a = \frac{v_y - u_y}{\Delta t}$$
$$\Delta t = \frac{v_y - u_y}{a} = \frac{(-20.3) - (14.7)}{(-9.8)}$$
$$\Delta t = 3.57 \text{ s}$$

1.2 Circular motion in a horizontal plane

1 **a** A, D

b She has continued to travel in a straight line, while the car has turned, so the right side of the cabin is actually accelerating towards her.

2 **a** $v = 8.00 \text{ m s}^{-1}$

b $\boldsymbol{v} = 8.00 \text{ m s}^{-1}$ south

c

$v = 8.00 \text{ m s}^{-1}$

$r = 9.20 \text{ m}$

$$a_c = \frac{v^2}{r} = \frac{(8.00)^2}{(9.20)}$$
$$a_c = 6.96 \text{ m s}^{-2} \text{ east}$$

3 **a**

$v = 8.00 \text{ m s}^{-1}$

$r = 9.20 \text{ m}$

$m = 1.20 \times 10^3 \text{ kg}$

$$F_c = \frac{mv^2}{r} = \frac{(1.20\times10^3)(8.00)^2}{(9.20)}$$
$$F_c = 8.35\times10^3 \text{ N east}$$

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b The force that causes the centripetal force is the reaction of the sideways frictional force of the car's tyres on the road, that is the sideways force of friction of the road on the car's tyres.

4 **a** $\boldsymbol{v} = 8.00 \text{ m s}^{-1}$ north

b west

5 The car would probably skid off the road as the centripetal force required would increase to a value greater than the force of friction could provide.

6 **a**

$v = 2.00 \text{ m s}^{-1}$ $\quad$ $\boldsymbol{a}_c = \dfrac{v^2}{r} = \dfrac{(2.00)^2}{(1.50)}$

$r = 1.50 \text{ m}$ $\quad$ $\boldsymbol{a}_c = 2.67 \text{ m s}^{-2}$ towards the centre

b The forces are unbalanced as she is accelerating. According to Newton's first law an unbalanced force will cause an object to change its motion, in this case the direction of the motion is changing, not the magnitude.

c

$v = 2.00 \text{ m s}^{-1}$ $\quad$ $\boldsymbol{F}_c = \dfrac{mv^2}{r} = \dfrac{(50.0)(2.00)^2}{(1.50)}$

$r = 1.50 \text{ m}$ $\quad$ $\boldsymbol{F}_c = 1.33 \times 10^2$ N towards the centre

$m = 50.0 \text{ kg}$

d The sideways reaction force of the skate on the ice, which is the sideways force of the ice on the skate.

7 **a**

$f = 2.00 \text{ rev s}^{-1}$ $\quad$ $T = \dfrac{1}{f} = \dfrac{1}{(2.00)} = 5.00 \times 10^{-1} \text{ s}$

b

$T = 5.00 \times 10^{-1} \text{ s}$ $\quad$ $v = \dfrac{2\pi r}{T} = \dfrac{2\pi(0.800)}{(5.00 \times 10^{-1})}$

$v = 10.1 \text{ m s}^{-1}$

c

$v = 10.1 \text{ m s}^{-1}$ $\quad$ $\boldsymbol{a}_c = \dfrac{v^2}{r} = \dfrac{(10.1)^2}{(0.800)}$

$r = 0.800 \text{ m}$ $\quad$ $\boldsymbol{a}_c = 1.26 \times 10^2 \text{ m s}^{-2}$ towards the centre

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d

$v = 10.1\ \text{m s}^{-1}$ $\qquad F_c = \dfrac{mv^2}{r} = \dfrac{(2.50)(10.1)^2}{(0.800)}$

$r = 0.800\ \text{m}$ $\qquad F_c = 3.16 \times 10^2$ N towards the centre

$m = 2.50\ \text{kg}$

e The force causing the centripetal acceleration of the ball is the tension force of the cable on the ball.

f The ball would continue in a straight line that is tangential to the circular path at the point at which the wire breaks.

8 **a**

$l = 2.40\ \text{m}$ $\qquad \cos\theta = \dfrac{r}{l}$

$$r = l\cos\theta = (2.40)(\cos 60.0^\circ)$$

$$r = 1.20\ \text{m}$$

b The forces acting on Ella are gravity and the tension force of the rope on her.

c Ella's acceleration is towards the centre of rotation about the pole.

d

$g = 9.80\ \text{m s}^{-2}$ $\qquad \tan\theta = \dfrac{F_g}{F_c}$

$m = 30.0\ \text{kg}$ $\qquad F_c = \dfrac{mg}{\tan\theta} = \dfrac{(30.0)(9.80)}{(\tan 60.0^\circ)}$

$$F_c = 1.70 \times 10^2 \text{ N towards the centre}$$

e

$F_c = 1.70 \times 10^2\ \text{N}$ $\qquad F_c = \dfrac{mv^2}{r}$

$r = 1.20\ \text{m}$ $\qquad v = \sqrt{\dfrac{F_c r}{m}} = \sqrt{\dfrac{(1.70 \times 10^2)(1.20)}{(30.0)}}$

$m = 30.0\ \text{kg}$ $\qquad v = 2.61\ \text{m s}^{-1}$

9 **a**

$v = 18.0\ \text{m s}^{-1}$ $\qquad F_c = \dfrac{mv^2}{r} = \dfrac{(1.20 \times 10^3)(18.0)^2}{(80.0)}$

$r = 80.0\ \text{m}$ $\qquad F_c = 4.86$ kN towards the centre

$m = 1.20 \times 10^3\ \text{kg}$

b

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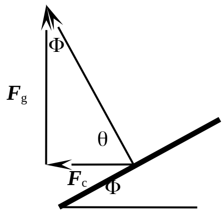
$$\tan\theta = \frac{F_g}{F_c} = \frac{(1.20\times10^3)(9.80)}{(4.86\times10^3)} = 2.42$$

$$\theta = 67.5°$$

$$\Phi = (90.0°) - (67.5°)$$

$$\Phi = 22.5°$$



10 The driver will have to turn the car's tyres down the track to enable the horizontal component of the sideways frictional force to help turn the car. The combined centripetal force of the banked track and the horizontal component of the sideways frictional force will enable the car to turn at this higher speed while maintaining the same radius as before.

1.3 Circular motion in a vertical plane

1 **a** The acceleration is towards the centre of the circular path of the yo-yo.
b At the bottom of the circular path the tension in the string is greatest.
c At the top of the circular path the tension in the string is lowest.
d At the bottom of the circular path where the tension in the string is greatest.

2

$g = -9.80\ \text{m s}^{-2}$

$r = -1.50\ \text{m}$

critical speed when $a_g = a_c$

$$g = \frac{v^2}{r}$$

$$v = \sqrt{rg} = \sqrt{(-1.50)(-9.80)}$$

$$v = 3.83\ \text{m s}^{-1}$$

3 **a** The force of gravity and the reaction force of the road on the car.

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b

$\updownarrow^{+}_{-}$

$m = 800.0\text{ kg}$	$\boldsymbol{F}_{\text{road on car}} = \boldsymbol{F}_{\text{c}} + (-\boldsymbol{F}_{\text{g}})$
$r = -10.0\text{ m}$	$\boldsymbol{F}_{\text{road on car}} = \dfrac{mv^2}{r} + (-m\boldsymbol{g})$
$v = 14.4\text{ km h}^{-1}$	$\boldsymbol{F}_{\text{road on car}} = \dfrac{(800.0)(4.00)^2}{(-10.0)} + (-(800.0)(-9.80))$
$v = 4.00\text{ m s}^{-1}$	$\boldsymbol{F}_{\text{road on car}} = (-1.28\times10^3) + (7.84\times10^3)$
$\boldsymbol{g} = -9.80\text{ m s}^{-2}$	$\boldsymbol{F}_{\text{road on car}} = 6.56\times10^3\text{ N upwards}$

c Yes it is possible, however it is her apparent weight she was ‘feeling’ not her mass, which doesn’t change. The force that the seat applies to her is less as she goes over the hump, therefore she feels like she is lighter on the seat.

d

$g = -9.80\text{ m s}^{-2}$	critical speed when $\boldsymbol{a}_{\text{g}} = \boldsymbol{a}_{\text{c}}$
$r = -10.0\text{ m}$	$\boldsymbol{g} = \dfrac{v^2}{r}$
	$v = \sqrt{r\boldsymbol{g}} = \sqrt{(-10.0)(-9.80)}$
	$v = 9.90\text{ m s}^{-1}$
	$v = 35.6\text{ km h}^{-1}$

4 a

$u = 2.00\text{ m s}^{-1}$	$E_{\text{k at Y}} = E_{\text{k at X}} + E_{\text{p gain}}$
$\Delta s_y = 50.0\text{ m}$	$\frac{1}{2}mv^2 = \frac{1}{2}mu^2 + mg\Delta s_y$
$\boldsymbol{g} = 9.80\text{ m s}^{-2}$	$v = \sqrt{2(\frac{1}{2}u^2 + g\Delta s_y)} = \sqrt{2(\frac{1}{2}(2.00)^2 + (9.80)(50.0))}$
$m = 500.0\text{ kg}$	$v = 31.4\text{ m s}^{-1}$

b

$u = 2.00\text{ m s}^{-1}$	$E_{\text{k at Z}} = E_{\text{k at X}} + E_{\text{p gain}}$
$\Delta s_y = 20.0\text{ m}$	$\frac{1}{2}mv^2 = \frac{1}{2}mu^2 + mg\Delta s_y$
$\boldsymbol{g} = 9.80\text{ m s}^{-2}$	$v = \sqrt{2(\frac{1}{2}u^2 + g\Delta s_y)} = \sqrt{2(\frac{1}{2}(2.00)^2 + (9.80)(20.0))}$
$m = 500.0\text{ kg}$	$v = 19.9\text{ m s}^{-1}$

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c

$\updownarrow^{+}_{-}$

$m = 500.0\ \text{kg}$

$r = -15.0\ \text{m}$

$v = 19.9\ \text{m s}^{-1}$

$\boldsymbol{g} = -9.80\ \text{m s}^{-2}$

$$\boldsymbol{F}_{\text{track on cart}} = \boldsymbol{F}_{\text{c}} + (-\boldsymbol{F}_{\text{g}})$$
$$\boldsymbol{F}_{\text{track on cart}} = \frac{mv^2}{r} + (-m\mathbf{g})$$
$$\boldsymbol{F}_{\text{track on cart}} = \frac{(500.0)(19.9)^2}{(-15.0)} + (-(500.0)(-9.80))$$
$$\boldsymbol{F}_{\text{track on cart}} = (-1.32\times10^4) + (4.90\times10^3)$$
$$\boldsymbol{F}_{\text{track on cart}} = -8.30\times10^3\ \text{N}$$
$$\boldsymbol{F}_{\text{track on cart}} = 8.30\times10^3\ \text{N downwards}$$

5

$g = -9.80\ \text{m s}^{-2}$

$r = -15.0\ \text{m}$

critical speed when $\boldsymbol{a}_{\text{g}} = \boldsymbol{a}_{\text{c}}$

$$\boldsymbol{g} = \frac{v^2}{r}$$
$$v = \sqrt{r\boldsymbol{g}} = \sqrt{(-15.0)(-9.80)}$$
$$v = 12.1\ \text{m s}^{-1}$$

6

$\updownarrow^{+}_{-}$

$m = 80.0\ \text{kg}$

$r = -100.0\ \text{m}$

$v = 35.0\ \text{m s}^{-1}$

$\boldsymbol{g} = -9.80\ \text{m s}^{-2}$

$$\boldsymbol{F}_{\text{seat on pilot}} = \boldsymbol{F}_{\text{c}} + (-\boldsymbol{F}_{\text{g}})$$
$$\boldsymbol{F}_{\text{seat on pilot}} = \frac{mv^2}{r} + (-m\boldsymbol{g})$$
$$\boldsymbol{F}_{\text{seat on pilot}} = \frac{(80.0)(35.0)^2}{(-100.0)} + (-(80.0)(-9.80))$$
$$\boldsymbol{F}_{\text{seat on pilot}} = (-9.80\times10^2) + (7.84\times10^2)$$
$$\boldsymbol{F}_{\text{seat on pilot}} = -1.96\times10^2\ \text{N}$$
$$\boldsymbol{F}_{\text{seat on pilot}} = 1.96\times10^2\ \text{N downwards}$$

7

$g = -9.80\ \text{m s}^{-2}$

$r = -100.0\ \text{m}$

critical speed when $\boldsymbol{a}_{\text{g}} = \boldsymbol{a}_{\text{c}}$

$$\boldsymbol{g} = \frac{v^2}{r}$$
$$v = \sqrt{r\boldsymbol{g}} = \sqrt{(-100.0)(-9.80)}$$
$$v = 31.3\ \text{m s}^{-1}$$

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8

$\updownarrow {}^{+}_{-}$

$\boldsymbol{g} = -9.80 \text{ m s}^{-2}$

$r = 100.0 \text{ m}$

$$\boldsymbol{a}_{\text{seat on pilot}} = 9 \times (-\boldsymbol{g})$$

$$\boldsymbol{a}_{\text{seat on pilot}} = \frac{v^2}{r} + (-\boldsymbol{g})$$

$$9 \times (-(-9.80)) = \frac{v^2}{(100.0)} + (-(-9.80))$$

$$v = \sqrt{8 \times (-(-9.80))(100.0)}$$

$$v = 88.5 \text{ m s}^{-1}$$

9 **a**

$m = 4.00 \text{ kg}$

$\boldsymbol{g} = -9.80 \text{ m s}^{-2}$

$$\boldsymbol{T} = -\boldsymbol{F}_g = -m\boldsymbol{g} = -(4.00)(-9.80)$$

$$\boldsymbol{T} = 39.2 \text{ N}$$

b

$m = 4.00 \text{ kg}$

$\boldsymbol{g} = -9.80 \text{ m s}^{-2}$

$\Delta s_y = 2.00 \text{ m}$

$$E_k = E_p$$

$$\tfrac{1}{2}mv^2 = m\boldsymbol{g}\Delta s_y$$

$$v = \sqrt{2(9.80)(2.00)}$$

$$v = 6.26 \text{ m s}^{-1}$$

$\updownarrow {}^{+}_{-}$

$$\boldsymbol{T} = \boldsymbol{F}_c + (-\boldsymbol{F}_g)$$

$$\boldsymbol{T} = \frac{mv^2}{r} + (-m\boldsymbol{g})$$

$$\boldsymbol{T} = \frac{(4.00)(6.26)^2}{(2.00)} + (-(4.00)(-9.80))$$

$$\boldsymbol{T} = (7.84 \times 10^1) + (3.92 \times 10^1)$$

$$\boldsymbol{T} = 1.18 \times 10^2 \text{ N}$$

10 The wire is more likely to break when the ball is moving through position X as the tension in the wire is three times the tension it had when it was stationary at point X.

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1.4 Vectors and free-body diagrams

1 **a**

$- \quad +$

$u_x = 15.0\ \text{m s}^{-1}\ \text{west} = -15.0\ \text{m s}^{-1}$

$v_x = 20.0\ \text{m s}^{-1}\ \text{west} = -20.0\ \text{m s}^{-1}$

$\boldsymbol{v} + \boldsymbol{u} = (-15.0) + (-20.0)$

$\boldsymbol{v} + \boldsymbol{u} = -35.0$

$\boldsymbol{v} + \boldsymbol{u} = 35.0\ \text{m s}^{-1}\ \text{west}$

b

$- \quad +$

$u_x = 15.0\ \text{m s}^{-1}\ \text{west} = -15.0\ \text{m s}^{-1}$

$v_x = 20.0\ \text{m s}^{-1}\ \text{east} = +20.0\ \text{m s}^{-1}$

$\boldsymbol{v} + \boldsymbol{u} = (-15.0) + (+20.0)$

$\boldsymbol{v} + \boldsymbol{u} = +5.0$

$\boldsymbol{v} + \boldsymbol{u} = 5.0\ \text{m s}^{-1}\ \text{east}$

c

$\updownarrow \ {}^{+}_{-}$

$F_{y1} = 10.0\ \text{N up} = +10.0\ \text{N}$

$F_{y2} = 12.0\ \text{N down} = -12.0\ \text{N}$

$\boldsymbol{F}_{y1} + \boldsymbol{F}_{y2} = (+10.0) + (-12.0)$

$\boldsymbol{F}_{y1} + \boldsymbol{F}_{y2} = -2.0$

$\boldsymbol{F}_{y1} + \boldsymbol{F}_{y2} = 2.0\ \text{N down}$

2

a

$- \quad +$

$u_x = 15.0\ \text{m s}^{-1}\ \text{west}$

$-u_x = 15.0\ \text{m s}^{-1}\ \text{east} = +15.0\ \text{m s}^{-1}$

$v_x = 20.0\ \text{m s}^{-1}\ \text{west} = -20.0\ \text{m s}^{-1}$

$\boldsymbol{v} + (-\boldsymbol{u}) = (-20.0) + (+15.0)$

$\boldsymbol{v} + (-\boldsymbol{u}) = -5.0$

$\boldsymbol{v} + (-\boldsymbol{u}) = 5.0\ \text{m s}^{-1}\ \text{west}$

b

$- \quad +$

$u_x = 15.0\ \text{m s}^{-1}\ \text{west}$

$-u_x = 15.0\ \text{m s}^{-1}\ \text{east} = +15.0\ \text{m s}^{-1}$

$v_x = 20.0\ \text{m s}^{-1}\ \text{east} = +20.0\ \text{m s}^{-1}$

$\boldsymbol{v} + (-\boldsymbol{u}) = (+20.0) + (+15.0)$

$\boldsymbol{v} + (-\boldsymbol{u}) = +35.0$

$\boldsymbol{v} + (-\boldsymbol{u}) = 35.0\ \text{m s}^{-1}\ \text{east}$

c

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$\updownarrow {}^{+}_{-}$

$\boldsymbol{F}_{y1} = 10.0 \text{ N up} = +10.0 \text{ N}$

$-\boldsymbol{F}_{y1} = 10.0 \text{ N down} = -10.0 \text{ N}$

$\boldsymbol{F}_{y2} = 12.0 \text{ N down} = -12.0 \text{ N}$

$\boldsymbol{F}_{y2} + (-\boldsymbol{F}_{y1}) = (-12.0) + (-10.0)$

$\boldsymbol{F}_{y2} + (-\boldsymbol{F}_{y1}) = -22.0$

$\boldsymbol{F}_{y2} + (-\boldsymbol{F}_{y1}) = 22.0 \text{ N down}$

3 **a**

$\boldsymbol{a}_x = 17.5 \text{ m s}^{-2} \text{ south}$

$\boldsymbol{a}_z = 70.0 \text{ m s}^{-2} \text{ west}$

$(\boldsymbol{a}_x + \boldsymbol{a}_z)^2 = \boldsymbol{a}_x^{\,2} + \boldsymbol{a}_z^{\,2}$

$(\boldsymbol{a}_x + \boldsymbol{a}_z) = \sqrt{(17.5)^2 + (70.0)^2}$

$(\boldsymbol{a}_x + \boldsymbol{a}_z) = 7.22 \times 10^1 \text{ m s}^{-2}$

$\tan\theta = \dfrac{\boldsymbol{a}_z}{\boldsymbol{a}_x} = \dfrac{(70.0)}{(17.5)}$

$\theta = \tan(4.00)$

$\theta = 76.0$

$\therefore (\boldsymbol{a}_x + \boldsymbol{a}_z) = 7.22 \times 10^1 \text{ m s}^{-2} \text{ south} 76.0 \text{ west}$

b

$\boldsymbol{v}_x = 15.0 \text{ m s}^{-1} \text{ west}$

$\boldsymbol{v}_z = 23.0 \text{ m s}^{-1} \text{ north}$

$(\boldsymbol{v}_x + \boldsymbol{v}_z)^2 = \boldsymbol{v}_x^{\,2} + \boldsymbol{v}_z^{\,2}$

$(\boldsymbol{v}_x + \boldsymbol{v}_z) = \sqrt{(15.0)^2 + (23.0)^2}$

$(\boldsymbol{v}_x + \boldsymbol{v}_z) = 2.75 \times 10^1 \text{ m s}^{-1}$

$\tan\theta = \dfrac{\boldsymbol{v}_z}{\boldsymbol{v}_x} = \dfrac{(23.0)}{(15.0)}$

$\theta = \tan(1.53)$

$\theta = 56.9$

$\therefore (\boldsymbol{v}_x + \boldsymbol{v}_z) = 2.75 \times 10^1 \text{ m s}^{-1} \text{ north } 56.9 \text{ west}$

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c

$F_y = 15.0$ N up

$F_x = 20.0$ N west

$$(F_y + F_x)^2 = F_y^2 + F_x^2$$
$$(F_y + F_x) = \sqrt{(15.0)^2 + (20.0)^2}$$
$$(F_y + F_x) = 2.50 \times 10^1 \text{ N}$$

$$\tan\theta = \frac{F_y}{F_x} = \frac{(15.0)}{(20.0)}$$
$$\theta = \tan(0.750)$$
$$\theta = 36.9$$

44

$$\therefore (F_y + F_x) = 2.50 \times 10^1 \text{ N } 36.9 \text{ up from horizontal to the west}$$

a

$v_x = 19.0$ m s^{-2} west

$-v_x = 19.0$ m s^{-2} east

$v_z = 20.0$ m s^{-2} south

$$\left[v_z + (-v_x)\right]^2 = v_z^2 + (-v_x)^2$$
$$v_z + (-v_x) = \sqrt{(20.0)^2 + (19.0)^2}$$
$$v_z + (-v_x) = 2.76 \times 10^1 \text{ m s}^{-2}$$

$$\tan\theta = \frac{(-v_x)}{v_z} = \frac{(19.0)}{(20.0)}$$
$$\theta = \tan(0.950)$$
$$\theta = 43.5$$

$$\therefore v_z + (-v_x) = 2.76 \times 10^1 \text{ m s}^{-2} \text{ south } 43.5 \text{ east}$$

b

$p_x = 11.0$ kg m s^{-1} north

$-p_x = 11.0$ kg m s^{-1} south

$p_z = 30.0$ kg m s^{-1} east

$$\left[p_z + (-p_x)\right]^2 = p_z^2 + (-p_x)^2$$
$$p_z + (-p_x) = \sqrt{(30.0)^2 + (11.0)^2}$$
$$p_z + (-p_x) = 3.20 \times 10^1 \text{ kg m s}^{-1}$$

$$\tan\theta = \frac{p_z}{(-p_x)} = \frac{(30.0)}{(11.0)}$$
$$\theta = \tan(2.73)$$
$$\theta = 69.9$$

$$\therefore p_z + (-p_x) = 3.20 \times 10^1 \text{ kg m s}^{-1} \text{ south } 69.9 \text{ east}$$

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c

$F_y = 10.0$ N down

$-F_y = 10.0$ N up

$F_x = 12.0$ N right

$$\left[F_x + (-F_y)\right]^2 = F_x^2 + (-F_y)^2$$

$$F_x + (-F_y) = \sqrt{(12.0)^2 + (10.0)^2}$$

$$F_x + (-F_y) = 1.56 \times 10^1 \text{ N}$$

$$\tan\theta = \frac{(-F_y)}{F_x} = \frac{(10.0)}{(12.0)}$$

$$\theta = \tan(0.833)$$

$$\theta = 39.8$$

$\therefore F_x + (-F_y) = 1.56 \times 10^1$ N 39.8 up from horizontal to the right

5 **a**

$v_x = \text{west}$

$$v_x = v \times \cos 35.0$$

$$v_x = (255)(0.819)$$

$$v_x = 2.09 \times 10^2 \text{ m s}^{-1} \text{ west}$$

$v_z = \text{south}$

$$v_z = v \times \sin 35.0$$

$$v_z = (255)(0.574)$$

$$v_z = 1.46 \times 10^2 \text{ m s}^{-1} \text{ south}$$

b

$p_x = \text{east}$

$$p_x = p \times \sin 67.5$$

$$p_x = (0.250)(0.924)$$

$$p_x = 2.31 \times 10^{-1} \text{ kg m s}^{-1} \text{ east}$$

$p_z = \text{north}$

$$p_z = p \times \cos 67.5$$

$$p_z = (0.250)(0.383)$$

$$p_z = 9.57 \times 10^{-2} \text{ kg m s}^{-1} \text{ north}$$

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c

$F_x = \text{left} \qquad F_x = F \times \cos 27.5^\circ$

$$F_x = (100.0)(0.8874)$$

$$F_x = 8.87 \times 10^1 \text{ N left}$$

$F_y = \text{down} \qquad F_y = F \times \sin 27.5^\circ$

$$F_y = (100.0)(0.462)$$

$$F_y = 4.62 \times 10^1 \text{ N down}$$

6 a

$v_{plane} = 100.0 \text{ m s}^{-1} \text{ south}$

$v_{wind} = 25.0 \text{ m s}^{-1} \text{ west}$

$$(v_{plane} + v_{wind})^2 = v_{plane}{}^2 + v_{wind}{}^2$$

$$(v_{plane} + v_{wind}) = \sqrt{(100.0)^2 + (25.0)^2}$$

$$(v_{plane} + v_{wind}) = 1.03 \times 10^2 \text{ m s}^{-1}$$

$$\tan\theta = \frac{v_{wind}}{v_{plane}} = \frac{(25.0)}{(100.0)}$$

$$\theta = \tan(0.250)$$

$$\theta = 14.0^\circ$$

$$\therefore\ (v_{plane} + v_{wind}) = 1.03 \times 10^2 \text{ m s}^{-1} \text{ south } 14.0^\circ \text{ west}$$

b The plane should steer south 14.0° east to maintain a southerly path.

c

$v_{plane} = 100.0 \text{ m s}^{-1} \text{ south } 14.0^\circ \text{ east}$

$v_{wind} = 25.0 \text{ m s}^{-1} \text{ west}$

$$(v_{plane})^2 = v_{plane\ south}{}^2 + v_{wind}{}^2$$

$$v_{plane\ south} = \sqrt{(100.0)^2 - (25.0)^2}$$

$$v_{plane\ south} = 9.68 \times 10^1 \text{ m s}^{-1} \text{ south}$$

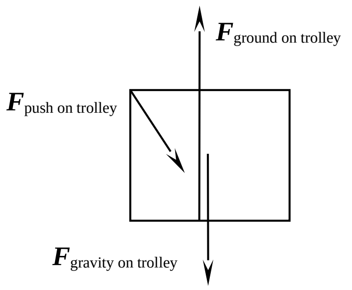
7 a

$F_x = \text{right} \qquad F_x = F \times \cos 60.0^\circ$

$$F_x = (50.0)(0.500)$$

$$F_x = 2.50 \times 10^1 \text{ N right}$$

b



c

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$\vec{F} = 50.0\ \text{N}\ 60.0^\circ$ below horizon to rt

$-\quad +$

$F_{x,\ \text{push}} = 25.0\ \text{N right}$

$F_{x,\ \text{friction}} = 10.0\ \text{N left}$

$F_{x,\ \text{friction}} = -10.0\ \text{N}$

$$F_x = F_{x,\ \text{push}} + F_{x,\ \text{friction}}$$
$$F_x = (+25.0) + (-10.0)$$
$$F_x = 1.50 \times 10^1\ \text{N right}$$

$$F_y = F\sin 60.0^\circ$$
$$F_y = (50.0)(0.866)$$
$$F_y = 4.33 \times 10^1\ \text{N down}$$

$$F_{\text{resultant}}{}^2 = F_x{}^2 + F_y{}^2$$
$$F_{\text{resultant}} = \sqrt{(1.50 \times 10^1)^2 + (4.33 \times 10^1)^2}$$
$$F_{\text{resultant}} = 4.58 \times 10^1\ \text{N}$$

$$\tan\theta = \frac{F_y}{F_x} = \frac{(4.33 \times 10^1)}{(1.50 \times 10^1)}$$
$$\theta = \tan^{-1}(2.887)$$
$$\theta = 70.8^\circ$$

$\therefore\ F_{\text{resultant}} = 4.58 \times 10^1\ \text{N}\ 70.8^\circ$ down from horizontal to the right

8 a

$u_x = 16.0\ \text{m s}^{-1}$

$v_x = 16.0\ \text{m s}^{-1}$

$$\Delta\text{speed} = \Delta v_x = v_x - u_x$$
$$\Delta v_x = (16.0 - 16.0)$$
$$\Delta v_x = 0.00\ \text{m s}^{-1}$$

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b

$$\boldsymbol{u} = 16.0 \text{ m s}^{-1} \text{ north} \qquad \Delta\text{speed} = \Delta\boldsymbol{v} = \boldsymbol{v} + (-\boldsymbol{u})$$

$$-\boldsymbol{u} = 16.0 \text{ m s}^{-1} \text{ south} \qquad \Delta\boldsymbol{v}^2 = \boldsymbol{v}^2 + (-\boldsymbol{u})^2$$

$$\boldsymbol{v} = 16.0 \text{ m s}^{-1} \text{ east} \qquad \Delta\boldsymbol{v} = \sqrt{(16.0)^2 + (16.0)^2}$$

$$\Delta\boldsymbol{v} = 2.26 \times 10^1 \text{ m s}^{-1}$$

$$\tan\theta = \frac{-\boldsymbol{u}}{\boldsymbol{v}} = \frac{(16.0)}{(16.0)}$$

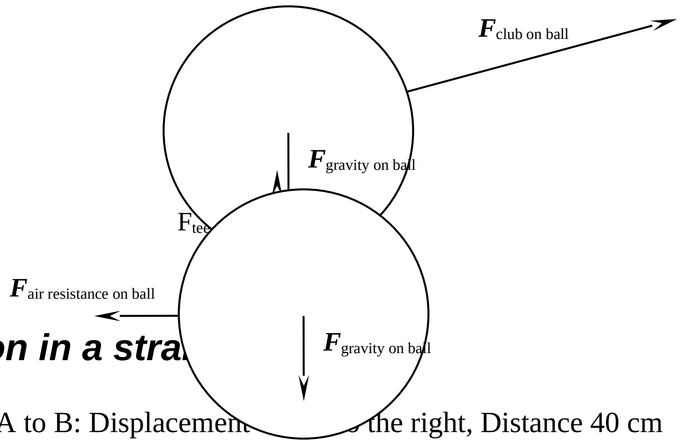
$$\theta = \tan(1.00)$$

$$\theta = 45.0^\circ$$

$$\therefore \Delta\boldsymbol{v} = 2.26 \times 10^1 \text{ m s}^{-1} \text{ south } 45.0^\circ \text{ east}$$

9

10



1.5 Motion in a stra

1 **a** A to B: Displacement [illegible] the right, Distance 40 cm
b C to B: Displacement 10 cm to the left, Distance 10 cm
c C to D: Displacement 20 cm to the right, Distance 20 cm
d C to E and then to D: Displacement 20 cm to the right, Distance 80 cm

2 **a** Distance 80.0 km
b Displacement 20.0 km north

3 **a** 10 m down
b 60 m up
c 70 m
d 50 m up

4 displacement

5 **a** D
b D
c C
d A

6 **a** 39 steps
b 1 step west of the clothes line
c 1 step west

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7 **a**

$u = 0 \text{ m s}^{-1}$ $\quad v_{av} = \frac{v + u}{2} = \frac{(33.3) + (0)}{2}$

$v = \frac{120.0}{3.6} = 33.3 \text{ m s}^{-1}$ $\quad v_{av} = 16.7 \text{ m s}^{-1}$

b

$\boldsymbol{u} = 0 \text{ km h}^{-1}$ $\quad \boldsymbol{a}_{av} = \frac{\boldsymbol{v} - \boldsymbol{u}}{\Delta t} = \frac{(120.0) - (0)}{(18.0)}$

$\boldsymbol{v} = 120 \text{ km h}^{-1}$ $\quad \boldsymbol{a}_{av} = 6.67 \text{ km h}^{-1} \text{ s}^{-1} \text{ forwards}$

$\Delta t = 18.0 \text{ s}$

c

$\boldsymbol{u} = 0 \text{ m s}^{-1}$ $\quad \boldsymbol{a}_{av} = \frac{\boldsymbol{v} - \boldsymbol{u}}{\Delta t} = \frac{(33.3) - (0)}{(18.0)}$

$\boldsymbol{v} = \frac{120}{3.6} = 33.3 \text{ m s}^{-1}$ $\quad \boldsymbol{v} = 1.85 \text{ m s}^{-2}$

$\Delta t = 18.0 \text{ s}$

d

$v = 33.3 \text{ m s}^{-1}$ $\quad s = v\Delta t = (33.3)(0.600)$

$\Delta t = 0.600 \text{ s}$ $\quad s = 20.0 \text{ m}$

8 **a**

$u = 25.0 \text{ m s}^{-1}$ $\quad \Delta v = v - u = (15.0) - (25.0)$

$v = 15.0 \text{ m s}^{-1}$ $\quad \Delta v = -10.0 \text{ m s}^{-1}$

b

$- \leftrightarrow +$

$\boldsymbol{u} = 25.0 \text{ m s}^{-1} \text{ east}$

$-\boldsymbol{u} = 25.0 \text{ m s}^{-1} \text{ west}$

$-\boldsymbol{u} = -25.0 \text{ m s}^{-1}$

$\boldsymbol{v} = 15.0 \text{ m s}^{-1} \text{ west}$

$\boldsymbol{v} = -15.0 \text{ m s}^{-1}$

$\Delta\boldsymbol{v} = \boldsymbol{v} - \boldsymbol{u}$

$\Delta\boldsymbol{v} = \boldsymbol{v} + (-\boldsymbol{u}) = (-15.0) - (-25.0)$

$\Delta v = +10.0 \text{ m s}^{-1}$

$\Delta\boldsymbol{v} = 10.0 \text{ m s}^{-1} \text{ east}$

c

$- \leftrightarrow +$

$-\boldsymbol{u} = -25.0 \text{ m s}^{-1}$

$\boldsymbol{v} = -15.0 \text{ m s}^{-1}$

$\Delta t = 0.0500 \text{ s}$

$$\boldsymbol{a}_{av} = \frac{\boldsymbol{v} - \boldsymbol{u}}{\Delta t} = \frac{(-15.0) - (-25.0)}{(0.0500)}$$

$\boldsymbol{a}_{av} = +2.00 \times 10^{2}$

$\boldsymbol{a}_{av} = 2.00 \times 10^{2} \text{ m s}^{-2} \text{ east}$

9 **a**

$\boldsymbol{u} = 60.0 \text{ km h}^{-1} \text{ north}$

$\boldsymbol{v} = 0 \text{ km h}^{-1}$

$\Delta t = 5.00 \text{ s}$

$$\boldsymbol{a}_{av} = \frac{\boldsymbol{v} - \boldsymbol{u}}{\Delta t} = \frac{(0) - (60.0)}{(5.00)}$$

$\boldsymbol{a}_{av} = -12.0 \text{ km h}^{-1} \text{ s}^{-1} \text{ north}$

b

$$\boldsymbol{u} = \frac{60.0}{3.6} = 16.7 \text{ m s}^{-1}$$

$\boldsymbol{v} = 0 \text{ m s}^{-1}$

$\Delta t = 5.00 \text{ s}$

$$\boldsymbol{a}_{av} = \frac{\boldsymbol{v} - \boldsymbol{u}}{\Delta t} = \frac{(0) - (16.7)}{(5.00)}$$

$\boldsymbol{a}_{av} = -3.33 \text{ m s}^{-2} \text{ north}$

10 **a**

$l = 50.0 \text{ m}$

$\text{laps} = 30$

$s = l \times \text{laps} = (50.0)(30)$

$s = 1.50 \times 10^{3} \text{ m}$

b

$s = 1.50 \times 10^{3} \text{ m}$

$\Delta t = 14{:}38$

$\Delta t = 878 \text{ s}$

$$v_{av} = \frac{s}{\Delta t} = \frac{(1.50 \times 10^{3})}{(878)}$$

$v_{av} = 1.71 \text{ m s}^{-1}$

c 0 m

d 0 m s^{-1}

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1.6 Energy and momentum

1 **a**

$m = 8.00 \times 10^2$ kg $\qquad W_d = Fs_y = mgs_y$

$g = 9.80$ m s^{-2} $\qquad W_d = (8.00 \times 10^2)(9.80)(90.0)$

$s_y = 90.0$ m $\qquad W_d = 7.06 \times 10^5$ J

b

$m = 8.00 \times 10^2$ kg $\qquad E_{total} = E_k + E_p = \frac{1}{2}mv^2 + mgs_y$

$g = 9.80$ m s^{-2} $\qquad E_{total} = \frac{1}{2}(8.00 \times 10^2)(2.00)^2 + (8.00 \times 10^2)(9.80)(50.0)$

$s_y = 50.0$ m $\qquad E_{total} = 3.94 \times 10^5$ J

$v = 2.00$ m s^{-1}

c

$m = 8.00 \times 10^2$ kg $\qquad P = Fv = mgv$

$g = 9.80$ m s^{-2} $\qquad P = (8.00 \times 10^2)(9.80)(2.00)$

$v = 2.00$ m s^{-1} $\qquad P = 1.596 \times 10^4$ W

2 **a**

$- \leftrightarrow +$ $\qquad E_{total} = E_{k1} + E_{k2} = \frac{1}{2}m_1u_1^{\ 2} + \frac{1}{2}m_2u_2^{\ 2}$

$m_1 = 2.00 \times 10^{-1}$ kg $\qquad E_{total} = \frac{1}{2}(2.00 \times 10^{-1})(+9.00)^2 + \frac{1}{2}(1.00 \times 10^{-1})(0)^2$

$u_1 = +9.00$ m s^{-1} $\qquad E_{total} = 8.10$ J

$m_2 = 1.00 \times 10^{-1}$ kg

$u_2 = 0$ m s^{-1}

b

$- \leftrightarrow +$ $\qquad E_{total} = E_{k1} + E_{k2} = \frac{1}{2}m_1v_1^{\ 2} + \frac{1}{2}m_2v_2^{\ 2}$

$m_1 = 2.00 \times 10^{-1}$ kg $\qquad E_{total} = \frac{1}{2}(2.00 \times 10^{-1})(+3.00)^2 + \frac{1}{2}(1.00 \times 10^{-1})(+12.0)^2$

$v_1 = +3.00$ m s^{-1} $\qquad E_{total} = 8.10$ J

$m_2 = 1.00 \times 10^{-1}$ kg

$v_2 = +12.0$ m s^{-1}

c This collision is elastic as no kinetic energy is lost in the collision.

d This is an unrealistic situation as is all macroscopic collisions some kinetic energy is always lost in the form of heat or sound.

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3 **a**

$m = 8.00 \times 10^1$ kg $\quad \Delta E_p = mg\Delta s_y$

$g = 9.80$ m s^{-2} $\quad \Delta E_p = (8.00 \times 10^1)(9.80)(5.00)$

$s_y = 5.00$ m $\quad \Delta E_p = 3.92 \times 10^3$ J

b

$m = 8.00 \times 10^1$ kg $\quad v^2 = u^2 + 2as_y = (0)^2 + 2(5.00)(5.00)$

$a = 5.00$ m s^{-2} $\quad v = \sqrt{(5.00 \times 10^1)}$

$s_y = 5.00$ m $\quad v = 7.07$ m s^{-1}

$$\Delta E_k = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(8.00 \times 10^1)(7.07)^2$$
$$\Delta E_k = 2.00 \times 10^3 \text{ J}$$

c Some energy potential energy would have been lost to heat or sound energy as the firefighter slid down the pole, therefore there would be less energy converted into kinetic energy.

d The work done is equal to the gain in energy of the firefighter, equal to 2.00×10^3 J.

e

Assume that all lost energy is transferred into heat.

$\Delta E_p = 3.92 \times 10^3$ J $\quad E_{heat} = \Delta E_p - \Delta E_k = (3.92 \times 10^3) - (2.00 \times 10^3)$

$\Delta E_k = 2.00 \times 10^3$ J $\quad E_{heat} = 1.92 \times 10^3$ J

4 D

5 **a**

$u = 10.0$ m s^{-1} $\quad \Delta v = v - u = (8.00) - (10.0)$

$v = 8.00$ m s^{-1} $\quad \Delta v = -2.00$ m s^{-1}

b

$\updownarrow {}^{+}_{-}$ $\quad \Delta \boldsymbol{v} = \boldsymbol{v} - \boldsymbol{u} = (+8.00) - (-10.0)$

$\boldsymbol{u} = -10.0$ m s^{-1} $\quad \Delta \boldsymbol{v} = +18.0$

$\boldsymbol{v} = +8.00$ m s^{-1} $\quad \Delta \boldsymbol{v} = 18.0$ m s^{-1} up

c

$\updownarrow {}^{+}_{-}$ $\quad \Delta \boldsymbol{p} = m\Delta \boldsymbol{v} = (80.0 \times 10^{-3})(+18.0)$

$\Delta \boldsymbol{v} = +18.0$ m s^{-1} $\quad \Delta \boldsymbol{p} = +1.44$

$m = 80.0 \times 10^{-3}$ m s^{-1} $\quad \Delta \boldsymbol{p} = 1.44$ kg m s^{-1} up

d Impulse is equal to change in momentum = 1.44 kg m s^{-1} up.

6 **a**

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$\updownarrow\,^{+}_{-}$

$\Delta p = +1.44\ \text{kg m s}^{-1}$

$\Delta t = 0.0500\ \text{s}$

$F_{\text{av net}} = \dfrac{\Delta p}{\Delta t} = \dfrac{(+1.44)}{(0.0500)}$

$F_{\text{av net}} = +28.8$

$F_{\text{av net}} = 28.8\ \text{N up}$

b

$\updownarrow\,^{+}_{-}$

$F_{\text{av}} = 28.8\ \text{N}$

$m = 80.0 \times 10^{-3}\ \text{kg}$

$g = -9.80\ \text{m s}^{-1}$

$F_{\text{av}} = F_{\text{av net}} + (-F_{\text{wt}})$

$F_{\text{av}} = (+28.8) + (-80 \times 10^{-3})(-9.80)$

$F_{\text{av}} = 29.6$

$F_{\text{av}} = 29.6\ \text{N up}$

c According to Newton's third law, the force of the ball on the floor is 29.6 N down

7 **a**

$- \leftrightarrow +$

$v = +36.0\ \text{km h}^{-1}$

$= +10.0\ \text{m s}^{-1}$

$m = 1.00 \times 10^{3}\ \text{kg}$

$p_{\text{sc}} = mv = (1.00 \times 10^{3})(+10.0)$

$p_{\text{sc}} = +1.00 \times 10^{4}$

$p_{\text{sc}} = 1.00 \times 10^{4}\ \text{kg m s}^{-1}\ \text{east}$

b

$- \leftrightarrow +$

$v = -18.0\ \text{km h}^{-1}$

$= -5.0\ \text{m s}^{-1}$

$m = 2.00 \times 10^{3}\ \text{kg}$

$p_{\text{wag}} = mv = (2.00 \times 10^{3})(-5.0)$

$p_{\text{wag}} = -1.00 \times 10^{4}$

$p_{\text{wag}} = 1.00 \times 10^{4}\ \text{kg m s}^{-1}\ \text{west}$

c

$- \leftrightarrow +$

$p_{\text{sc}} = +1.00 \times 10^{4}\ \text{kg m s}^{-1}$

$p_{\text{wag}} = -1.00 \times 10^{4}\ \text{kg m s}^{-1}$

$p_{\text{total}} = p_{\text{sc}} + p_{\text{wag}} = (+1.00 \times 10^{4}) + (-1.00 \times 10^{4})$

$p_{\text{total}} = 0\ \text{kg m s}^{-1}$

8 **a**

$- \leftrightarrow +$

$\Sigma p_{\text{before}} = 0\ \text{kg m s}^{-1}$

$\Sigma p_{\text{before}} = \Sigma p_{\text{after}}$

$\Sigma p_{\text{after}} = 0$

$v_{\text{combined}} = 0\ \text{m s}^{-1}$

b The initial momentum has gone into changing the momentum of the other vehicle.

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c

$- \leftrightarrow +$

$\boldsymbol{u} = +10.0 \text{ m s}^{-1}$

$\boldsymbol{v} = 0 \text{ m s}^{-1}$

$m = 1.00 \times 10^3 \text{ kg}$

$\Delta \boldsymbol{p}_{sc} = m(\boldsymbol{v} - \boldsymbol{u}) = (1.00 \times 10^3)[(0) - (+10.0)]$

$\Delta \boldsymbol{p}_{sc} = -1.00 \times 10^4$

$\Delta \boldsymbol{p}_{sc} = 1.00 \times 10^4 \text{ kg m s}^{-1} \text{ west}$

d

$- \leftrightarrow +$

$\boldsymbol{u} = -5.00 \text{ m s}^{-1}$

$\boldsymbol{v} = 0 \text{ m s}^{-1}$

$m = 2.00 \times 10^3 \text{ kg}$

$\Delta \boldsymbol{p}_{wag} = m(\boldsymbol{v} - \boldsymbol{u}) = (2.00 \times 10^3)[(0) - (-5.00)]$

$\Delta \boldsymbol{p}_{wag} = +1.00 \times 10^4$

$\Delta \boldsymbol{p}_{wag} = 1.00 \times 10^4 \text{ kg m s}^{-1} \text{ east}$

9 Mary was correct, as the momentum before is equal to the momentum after, so the momentum of the railway tanker and water (combined) will be equal to the sum of the momentum of the tanker and water (separated). The sum of the masses of the water and tanker will be the same after as it was before therefore the speed of the tanker and water will be the same after as it was before.

10 **a**

$- \leftrightarrow +$

$\boldsymbol{u}_{girl} = +4.00 \text{ m s}^{-1}$

$m = 48.0 \text{ kg}$

$\boldsymbol{p}_{girl\ before} = m\boldsymbol{u} = (48.0)(+4.00)$

$\boldsymbol{p}_{girl\ before} = +1.92 \times 10^2$

$\boldsymbol{p}_{girl\ before} = 1.92 \times 10^2 \text{ kg m s}^{-1} \text{ to the right}$

b

$- \leftrightarrow +$

$\boldsymbol{u}_{girl} = +4.00 \text{ m s}^{-1}$

$m_{girl} = 48.0 \text{ kg}$

$\boldsymbol{u}_{sb} = 0 \text{ m s}^{-1}$

$m_{sb} = 2.00 \text{ kg}$

$\Sigma \boldsymbol{p}_{before} = \Sigma \boldsymbol{p}_{after} = m_{sb}\boldsymbol{u}_{sb} + m_{girl}\boldsymbol{u}_{girl} = m_{girl+sb}\boldsymbol{v}_{girl+sb}$

$(2.00)(0) + (48.0)(+4.00) = (50.0)\boldsymbol{v}_{girl+sb}$

$\boldsymbol{v}_{girl+sb} = 3.84 \text{ m s}^{-1} \text{ to the right}$

c

$- \leftrightarrow +$

$\boldsymbol{u}_{girl+sb} = +3.84 \text{ m s}^{-1}$

$m_{girl+sb} = 50.0 \text{ kg}$

$\boldsymbol{v}_{girl} = +3.84 \text{ m s}^{-1}$

$m_{girl} = 48.0 \text{ kg}$

$m_{sb} = 2.00 \text{ kg}$

$\Sigma \boldsymbol{p}_{before} = \Sigma \boldsymbol{p}_{after} = m_{girl+sb}\boldsymbol{u}_{girl+sb} = m_{sb}\boldsymbol{v}_{sb} + m_{girl}\boldsymbol{v}_{girl}$

$m_{girl+sb}\boldsymbol{u}_{girl+sb} = m_{sb}\boldsymbol{v}_{sb} + m_{girl}\boldsymbol{v}_{girl}$

$$\boldsymbol{v}_{sb} = \frac{(50.0)(+3.84) - (48.0)(+3.84)}{(2.00)}$$

$\boldsymbol{v}_{sb} = +3.84 \text{ m s}^{-1}$

$\boldsymbol{v}_{sb} = 3.84 \text{ m s}^{-1} \text{ to the right}$

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Chapter 1 Review

1 **a**

$u = 3.50 \text{ m s}^{-1}$ $\quad\quad \Delta v = v - u = (3.00) - (3.50)$

$v = 3.00 \text{ m s}^{-1}$ $\quad\quad \Delta v = -0.50 \text{ m s}^{-1}$

b

$\updownarrow {}^{+}_{-}$ $\quad\quad \Delta v = v - u = (3.00) - (-3.50)$

$u = -3.50 \text{ m s}^{-1}$ $\quad\quad \Delta v = 6.50 \text{ m s}^{-1}$ upwards

$v = 3.00 \text{ m s}^{-1}$

2 **a** The force increases as the bounce continues to the point where the springs are stretched to their maximum, then decreases as the bounce continues to the point where Hannah leaves the trampoline. The force is usually named the reaction force.

b D

3 **a**

$\boldsymbol{u} = 16.7 \text{ m s}^{-1}$ $\quad\quad \boldsymbol{v}^2 = \boldsymbol{u}^2 + 2\boldsymbol{as}$

$\boldsymbol{v} = 0 \text{ m s}^{-1}$ $\quad\quad \boldsymbol{a}_{av} = \dfrac{\boldsymbol{v}^2 - \boldsymbol{u}^2}{2\boldsymbol{s}} = \dfrac{(0)^2 - (16.7)^2}{2(15.0)}$

$\boldsymbol{s} = 15.0 \text{ m}$ $\quad\quad \boldsymbol{a}_{av} = -9.26 \text{ m s}^{-2}$

b

$\boldsymbol{u} = 16.7 \text{ m s}^{-1}$ $\quad\quad \boldsymbol{v} = \boldsymbol{u} + \boldsymbol{a}\Delta t$

$\boldsymbol{a}_{av} = -9.26 \text{ m s}^{-2}$ $\quad\quad \boldsymbol{v} = (16.7) + (-9.26)(1.50)$

$\Delta t = 1.50 \text{ s}$ $\quad\quad \boldsymbol{v} = 2.78 \text{ m s}^{-1}$

c

$m = 120.0 \text{ kg}$ $\quad\quad \boldsymbol{F}_{av} = m\boldsymbol{a} = (120.0)(-9.26)$

$\boldsymbol{a}_{av} = -9.26 \text{ m s}^{-2}$ $\quad\quad \boldsymbol{F}_{av} = -1.11 \text{ kN}$

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4 **a**

$\updownarrow \, ^{+}_{-}$ for ball X $\qquad s_y = u\Delta t + \frac{1}{2}a\Delta t^2$

$u = 0 \text{ m s}^{-1} \qquad (-2.00) = (0)\Delta t + \frac{1}{2}(-9.80)\Delta t^2$

$g = -9.80 \text{ m s}^{-2} \qquad \Delta t = \sqrt{\frac{2(-2.00)}{(-9.80)}}$

$s_y = -2.00 \text{ m} \qquad \Delta t = 0.639 \text{ s}$

$\updownarrow \, ^{+}_{-}$ for ball Y $\qquad s_y = u\Delta t + \frac{1}{2}a\Delta t^2$

$u = 0 \text{ m s}^{-1} \qquad (-2.00) = (0)\Delta t + \frac{1}{2}(-9.80)\Delta t^2$

$g = -9.80 \text{ m s}^{-2} \qquad \Delta t = \sqrt{\frac{2(-2.00)}{(-9.80)}}$

$s_y = -2.00 \text{ m} \qquad \Delta t = 0.639 \text{ s}$

b

$\updownarrow \, ^{+}_{-}$ for ball X $\qquad v_y = u_y + a\Delta t = (0) + (-9.80)(0.639)$

$u_y = 0 \text{ m s}^{-1} \qquad v_y = -6.26 \text{ m s}^{-1}$

$g = -9.80 \text{ m s}^{-2}$

$\Delta t = 0.639 \text{ s} \qquad v = \sqrt{v_y^2 + v_x^2} = \sqrt{(-6.26)^2 + (5.00)^2}$

$v_x = 5.00 \text{ m s}^{-1} \qquad v = 8.01 \text{ m s}^{-1}$

c

$\updownarrow \, ^{+}_{-}$ for ball Y $\qquad v_y = u_y + a\Delta t = (0) + (-9.80)(0.639)$

$u_y = 0 \text{ m s}^{-1} \qquad v_y = -6.26 \text{ m s}^{-1}$

$g = -9.80 \text{ m s}^{-2}$

$\Delta t = 0.639 \text{ s} \qquad v = \sqrt{v_y^2 + v_x^2} = \sqrt{(-6.26)^2 + (7.50)^2}$

$v_x = 7.50 \text{ m s}^{-1} \qquad v = 9.77 \text{ m s}^{-1}$

d

$- \leftrightarrow +$ for ball X $\qquad s_x = v_x\Delta t = (5.00)(0.639)$

$v_x = 5.00 \text{ m s}^{-1} \qquad s_x = 3.19$ m for ball X

$\Delta t = 0.639 \text{ s}$

for ball Y $\qquad s_x = v_x\Delta t = (7.50)(0.639)$

$v_x = 7.50 \text{ m s}^{-1} \qquad s_x = 4.79$ m for ball Y

$$\Delta s_x = (4.79) - (3.19) = 1.60 \text{ m}$$

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5

$\updownarrow\,^{+}_{-}$

$v_y = 0$ m s^{-1}

$s_y = 4.00$ m

$g = -9.80$ m s^{-2}

$$v_y^2 = u_y^2 + 2gs_y$$

$$u_y = \sqrt{v_y^2 - 2gs_y} = \sqrt{(0)^2 - 2(-9.80)(4.00)}$$

$$u_y = 8.85 \text{ m s}^{-1}$$

$$\sin\theta = \frac{u_y}{v} = \frac{(8.85)}{(10.0)} = 0.885$$

$$\theta = 62.3$$

6

$v = 10.0$ m s^{-1}

$\theta = 62.3$

$$\cos\theta = \frac{v_x}{v}$$

$$v_x = v\cos\theta = (10.0)(\cos 62.3^\circ)$$

$$v_x = 4.65 \text{ m s}^{-1}$$

7 D

8

$\updownarrow\,^{+}_{-}$

$u_y = 8.85$ m s^{-1}

$v_y = -8.85$ m s^{-1}

$v_x = 4.65$ m s^{-1}

$$\mathbf{a} = \frac{v_y - u_y}{\Delta t}$$

$$\Delta t = \frac{v_y - u_y}{a} = \frac{(-8.85) - (8.85)}{(-9.80)}$$

$$\Delta t = 1.81 \text{ s}$$

$$s_x = v_x\Delta t = (4.65)(1.81)$$

$$s_x = 8.40 \text{ m}$$

9 **a**

$$\cos\theta = \frac{v_x}{v}$$

$$v_x = v\cos\theta = (8.00)(\cos 60.0^\circ)$$

$$v_x = 4.00 \text{ m s}^{-1}$$

b

$$\sin\theta = \frac{v_y}{v}$$

$$v_y = v\sin\theta = (8.00)(\sin 60.0^\circ)$$

$$v_x = 6.92 \text{ m s}^{-1}$$

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c

$\updownarrow {}^{+}_{-}$ $\quad a = \frac{v_y - u_y}{\Delta t}$

$u_y = 6.92 \text{ m s}^{-1}$ $\quad \Delta t = \frac{v_y - u_y}{a} = \frac{(0) - (6.92)}{(-9.80)}$

$v_y = 0 \text{ m s}^{-1}$ $\quad \Delta t = 0.707 \text{ s}$

$g = -9.80 \text{ m s}^{-2}$

d

$\updownarrow {}^{+}_{-}$ $\quad s_y = u_y \Delta t + \frac{1}{2} a \Delta t^2$

$u_y = 6.92 \text{ m s}^{-1}$ $\quad s_y = (6.92)(0.707) + \frac{1}{2}(-9.80)(0.707)^2$

$\Delta t = 0.707 \text{ s}$ $\quad s_y = 2.457 \text{ m}$

$g = -9.80 \text{ m s}^{-2}$ $\quad s_{\text{total } y} = (1.50) + (2.457)$

$s_{\text{total } y} = 3.95 \text{ m}$

e

$\updownarrow {}^{+}_{-}$ $\quad v_y^2 = u_y^2 + 2as_y$

$u_y = 6.92 \text{ m s}^{-1}$ $\quad v_y = \sqrt{u_y^2 + 2as_y} = \sqrt{(6.92)^2 + 2(-9.80)(-1.50)}$

$s_y = -1.50 \text{ m}$ $\quad v_y = -8.80 \text{ m s}^{-1}$

$g = -9.80 \text{ m s}^{-2}$

$$a = \frac{v_y - u_y}{\Delta t}$$

$$\Delta t = \frac{v_y - u_y}{a} = \frac{(-8.80) - (6.92)}{(-9.80)}$$

$$\Delta t = 1.60 \text{ s}$$

f

$v_x = 4.00 \text{ m s}^{-1}$ $\quad s_x = v_x \Delta t = (4.00)(1.60)$

$\Delta t = 1.60 \text{ s}$ $\quad s_x = 6.42 \text{ m}$

10 $v_x = 4.00 \text{ m s}^{-1}$

11

$v_x = 4.00 \text{ m s}^{-1}$ $\quad E_k = \frac{1}{2}mv^2 = \frac{1}{2}(2.00)(4.00)^2$

$m = 2.00 \text{ kg}$ $\quad E_k = 16.0 \text{ J}$

12 $a = g = -9.80 \text{ m s}^{-2}$

13 C

14

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$v = 7.50 \text{ m s}^{-1}$

$F_a = 3.78 \times 10^{-5} v^2 = (3.78 \times 10^{-5})(7.50)^2$

$F_a = 2.13 \times 10^{-3}$ N in the opposite direction of the motion

15

$F_a = 2.13 \times 10^{-3}$ N

$m = 2.00$ kg

$g = 9.80 \text{ m s}^{-2}$

$$\frac{F_g}{F_{a\,max}} = \frac{(2.00)(9.80)}{(2.13 \times 10^{-3})}$$

$$\frac{F_g}{F_{a\,max}} = 9.22 \times 10^3$$

This answer tells us that the force of air resistance is insignificant when compared to the force due to gravity on the ball.

16 **a** .

$\updownarrow^{+}_{-}$

$g = -9.80 \text{ m s}^{-2}$

$s_y = -10.0$ m

$m = 0.200$ kg

$$v_y^2 = u_y^2 + 2gs_y$$

$$v_y = \sqrt{(0)^2 + 2(-9.80)(-10.0)}$$

$$v_y = -14.0 \text{ m s}^{-1}$$

$$p_{before} = mu = (0.200)(-14.0)$$

$$p_{before} = -2.80 \text{ kg m s}^{-1}$$

$$p_{before} = 2.80 \text{ kg m s}^{-1} \text{ downwards}$$

b C

$\updownarrow^{+}_{-}$

$v = 10.0 \text{ m s}^{-1}$

$m = 0.200$ kg

$$p_{after} = mu = (0.200)(10.0)$$

$$p_{after} = 2.00 \text{ kg m s}^{-1}$$

$$p_{after} = 2.00 \text{ kg m s}^{-1} \text{ upwards}$$

c D

$\updownarrow^{+}_{-}$

$p_{after} = 2.00 \text{ kg m s}^{-1}$

$p_{before} = -2.80 \text{ kg m s}^{-1}$

$$I = \Delta p = p_{after} - p_{before}$$

$$I = (2.00) - (-2.80)$$

$$I = 4.80 \text{ kg m s}^{-1} \text{ upwards}$$

d

$\updownarrow^{+}_{-}$

$I = 4.80 \text{ kg m s}^{-1}$ upwards

$\Delta t = 1.00 \times 10^{-3}$ s

$$F_{av} = \frac{I}{\Delta t} = \frac{(4.80)}{(1.00 \times 10^{-3})}$$

$$F_{av} = 4.80 \times 10^3 \text{ N upwards}$$

17 **a**

$u = 0 \text{ m s}^{-1}$

$v = 3.00 \text{ m s}^{-1}$

$$\Delta E_k = \tfrac{1}{2}mv^2 - \tfrac{1}{2}mu^2 = \tfrac{1}{2}(50.0)(3.00)^2 - \tfrac{1}{2}(50.0)(0)^2$$

$$\Delta E_k = 2.25 \times 10^2 \text{ J}$$

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b $\text{Work done} = \Delta E_k = 2.25 \times 10^2 \text{ J}$

c

$F = 200.0 \text{ N}$ $\quad F_x = F\cos\theta = (200.0)(\cos 60.0°) = 100.0 \text{ N}$

$m = 50.0 \text{ kg}$

$\Delta t = 10.0 \text{ s}$ $\quad a = \dfrac{F}{m} = \dfrac{(100.0)}{(50.0)} = 2.00 \text{ m s}^{-2}$

$u = 0 \text{ m s}^{-1}$

$$v = u + a\Delta t = (0) + (2.00)(10.0)$$
$$v = 20.0 \text{ m s}^{-1}$$

$$E_{k\text{ ideal}} = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(50.0)(20.0)^2$$
$$E_{k\text{ ideal}} = 1.00 \times 10^4 \text{ J}$$

$$E_{\text{lost to heat}} = E_{k\text{ ideal}} - E_k = (1.00 \times 10^4) - (2.25 \times 10^2)$$
$$E_{\text{lost to heat}} = 9.78 \times 10^3 \text{ J lost}$$

18 **a**

$E_{\text{total}} = 1.00 \times 10^4 \text{ J}$ $\quad P = \dfrac{E}{\Delta t} = \dfrac{(1.00 \times 10^4)}{(10.0)}$

$\Delta t = 10.0 \text{ s}$ $\quad P = 1.00 \times 10^3 \text{ W}$

b

$E_{\text{lost}} = 9.78 \times 10^3 \text{ J}$ $\quad P = \dfrac{E}{\Delta t} = \dfrac{(9.78 \times 10^3)}{(10.0)}$

$\Delta t = 10.0 \text{ s}$ $\quad P = 9.78 \times 10^2 \text{ W}$

c

$E_k = 2.25 \times 10^2 \text{ J}$ $\quad P = \dfrac{E}{\Delta t} = \dfrac{(2.25 \times 10^2)}{(10.0)}$

$\Delta t = 10.0 \text{ s}$ $\quad P = 2.25 \times 10^1 \text{ W}$

19 **a** $p_{\text{total before}} = 0 \text{ kg m s}^{-1}$

b

$v_{\text{boy}} = 4.00 \text{ m s}^{-1}$ $\quad p_{\text{boy after}} = mv_{\text{boy}} = (50.0)(4.00)$

$m_{\text{boy}} = 50.0 \text{ kg}$ $\quad p_{\text{boy after}} = 2.00 \times 10^2 \text{ kg m s}^{-1}$

c $p_{\text{sled after}} = -2.00 \times 10^2 \text{ kg m s}^{-1}$

20

$p_{\text{sled after}} = -2.00 \times 10^{2}\ \text{kg m s}^{-1}$

$m_{\text{sled}} = 200.0\ \text{kg}$

$p_{\text{sled after}} = mv$

$v = \dfrac{(-2.00 \times 10^{2})}{(200.0)}$

$v = -1.00\ \text{m s}^{-1}$

21

$u_{\text{sled}} = -1.00\ \text{m s}^{-1}$

$m_{\text{sled}} = 200.0\ \text{kg}$

$m_{\text{boy}} = 50.0\ \text{kg}$

$u_{\text{boy}} = -4.40\ \text{m s}^{-1}$

$\Sigma p_{\text{before}} = \Sigma p_{\text{after}}$

$m_{\text{sled}} u_{\text{sled}} + m_{\text{boy}} u_{\text{boy}} = m_{\text{boy+sled}} v_{\text{boy+sled}}$

$v_{\text{boy+sled}} = \dfrac{m_{\text{sled}} u_{\text{sled}} + m_{\text{boy}} u_{\text{boy}}}{m_{\text{boy+sled}}} = \dfrac{(200.0)(-1.00) + (50.0)(-4.40)}{(200.0 + 50.0)}$

$v_{\text{boy+sled}} = -1.68\ \text{m s}^{-1}$

22 **a**

$m_{\text{sled}} = 50.0\ \text{kg}$

$u_{\text{sled}} = -4.40\ \text{m s}^{-1}$

$v_{\text{sled}} = -1.68\ \text{m s}^{-1}$

$\Delta p = p_{\text{after}} - p_{\text{before}} = m_{\text{sled}} v_{\text{sled}} - m_{\text{sled}} u_{\text{sled}}$

$\Delta p = (200.0)(-1.68) - (200.0)(-1.00)$

$\Delta p = -1.36 \times 10^{2}\ \text{kg m s}^{-1}$

b

$m_{\text{boy}} = 50.0\ \text{kg}$

$u_{\text{boy}} = -4.40\ \text{m s}^{-1}$

$v_{\text{boy}} = -1.68\ \text{m s}^{-1}$

$\Delta p = p_{\text{after}} - p_{\text{before}} = m_{\text{boy}} v_{\text{boy}} - m_{\text{boy}} u_{\text{boy}}$

$\Delta p = (50.0)(-1.68) - (50.0)(-4.40)$

$\Delta p = 1.36 \times 10^{2}\ \text{kg m s}^{-1}$

23

$- \leftrightarrow +$

$m_1 = 0.3000\ \text{kg}$

$u_1 = +2.00\ \text{m s}^{-1}$

$m_2 = 0.1000\ \text{kg}$

$u_2 = -2.00\ \text{m s}^{-1}$

$\Sigma p_{\text{before}} = \Sigma p_{\text{after}}$

$m_1 u_1 + m_2 u_2 = m_{1+2} v_{1+2}$

$v_{1+2} = \dfrac{m_1 u_1 + m_2 u_2}{m_{1+2}} = \dfrac{(0.3000)(2.00) + (0.1000)(-2.00)}{(0.3000 + 0.1000)}$

$v_{1+2} = 1.00\ \text{m s}^{-1}$ east

24 C

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$- \leftrightarrow +$

$m_1 = 0.3000$ kg

$u_1 = +2.00$ m s^{-1}

$m_2 = 0.1000$ kg

$u_2 = -2.00$ m s^{-1}

$v_{1+2} = 1.00$ m s^{-1}

$$\Sigma E_{\text{k before}} = \tfrac{1}{2} m_1 u_1^{\ 2} + \tfrac{1}{2} m_2 u_2^{\ 2}$$

$$\Sigma E_{\text{k before}} = \tfrac{1}{2}(0.3000)(2.00)^2 + \tfrac{1}{2}(0.1000)(-2.00)^2$$

$$\Sigma E_{\text{k before}} = 0.800 \text{ J}$$

$$\Sigma E_{\text{k after}} = \tfrac{1}{2} m_{1+2} v_{1+2}^{\ 2}$$

$$\Sigma E_{\text{k after}} = \tfrac{1}{2}(0.4000)(1.00)^2$$

$$\Sigma E_{\text{k after}} = 0.200 \text{ J}$$

$$\%\text{Eff} = \frac{(0.200)\times 100}{(0.800)} = 25.0\%$$

25 B

26 **a** A

b D

c C

27

$v = 10.0$ m s^{-1}

$r = 20.0$ m

$$T = \frac{\text{distance}}{v} = \frac{2\pi r}{v} = \frac{2\pi(20.0)}{(10.0)}$$

$$T = 12.6 \text{ s}$$

28 **a**

$v = 10.0$ m s^{-1}

$r = 20.0$ m

$$\boldsymbol{a}_c = \frac{v^2}{r} = \frac{(10.0)^2}{(20.0)}$$

$$\boldsymbol{a}_c = 5.00 \text{ m s}^{-2} \text{ west}$$

b

$\boldsymbol{a}_c = 5.00$ m s^{-2} west

$m = 1510$ kg

$$\boldsymbol{F}_c = m\boldsymbol{a}_c = (1510)(5.00)$$

$$\boldsymbol{F}_c = 7.55 \times 10^3 \text{ N west}$$

c $\boldsymbol{F}_c = 7.55\times 10^3$ N east

29 C

30 **a** **i**

$\updownarrow {+ \atop -}$

$m = 50.0$ kg

$\boldsymbol{r} = -10.0$ m

$\boldsymbol{g} = -9.80$ m s^{-2}

$$\boldsymbol{F}_{\text{seat on boy}} = \boldsymbol{F}_c + (-\boldsymbol{F}_g)$$

$$\boldsymbol{F}_{\text{seat on boy}} = \frac{mv^2}{\boldsymbol{r}} + (-m\boldsymbol{g}) = \frac{(50.0)(5.00)^2}{(-10.0)} + (-(50.0)(-9.80))$$

$$\boldsymbol{F}_{\text{seat on boy}} = (-1.25\times 10^2) + (4.90\times 10^2)$$

$$\boldsymbol{F}_{\text{seat on boy}} = 3.65\times 10^2 \text{ N upwards}$$

ii

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$\updownarrow {}^{+}_{-}$ $\qquad F_{\text{seat on boy}} = F_c + (-F_g)$

$m = 50.0\ \text{kg}$ $\qquad F_{\text{seat on boy}} = \dfrac{mv^2}{r} + (-m\boldsymbol{g}) = \dfrac{(50.0)(5.00)^2}{(10.0)} + (-(50.0)(-9.80))$

$\boldsymbol{r} = 10.0\ \text{m}$ $\qquad F_{\text{seat on boy}} = (1.25 \times 10^2) + (4.90 \times 10^2)$

$\boldsymbol{g} = -9.80\ \text{m s}^{-2}$ $\qquad F_{\text{seat on boy}} = 6.15 \times 10^2\ \text{N upwards}$

b D

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Chapter 2 Applying forces

2.1 Gravitational fields

1 a

$m_a = 0.1000$ kg

$m_o = 0.2000$ kg

$r = 0.500$ m

$$F_g = \frac{Gm_a m_o}{r^2} = \frac{(6.67\times10^{-11})(0.1000)(0.2000)}{(0.500)^2}$$

$F_g = 5.34\times10^{-12}$ N attraction

b

$m_E = 5.98\times10^{24}$ kg

$m_s = 2.00\times10^{4}$ kg

alt $= 600.0\times10^{3}$ m

$r_E = 6.37\times10^{6}$ m

$$F_g = \frac{Gm_E m_s}{r^2} = \frac{(6.67\times10^{-11})(5.98\times10^{24})(2.00\times10^{4})}{(600.0\times10^{3} + 6.37\times10^{6})^2}$$

$F_g = 1.64\times10^{5}$ N attraction

c

$m_E = 5.98\times10^{24}$ kg

$m_m = 7.35\times10^{22}$ kg

$r_{E-m} = 3.84\times10^{8}$ m

$$F_g = \frac{Gm_E m_s}{r^2} = \frac{(6.67\times10^{-11})(5.98\times10^{24})(7.35\times10^{22})}{(3.84\times10^{8})^2}$$

$F_g = 1.99\times10^{20}$ N attraction

d

$m_p = 1.67\times10^{-27}$ kg

$m_e = 9.11\times10^{-31}$ kg

$r_{p-e} = 5.30\times10^{-11}$ m

$$F_g = \frac{Gm_p m_e}{r^2} = \frac{(6.67\times10^{-11})(1.67\times10^{-27})(9.11\times10^{-31})}{(5.30\times10^{-11})^2}$$

$F_g = 3.61\times10^{-47}$ N attraction

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2 **a**

$$F_{g1} = 160 \text{ N} \qquad F_{g1} = \frac{Gm_a m_m}{r_1^2} \qquad \mathbf{F}_{g2} = \frac{Gm_a m_m}{r_2^2}$$

$$F_{g2} = 40 \text{ N} \qquad Gm_a m_m = F_{g1} r_1^2 \qquad Gm_a m_m = F_{g2} r_2^2$$

$$r_1 = r_{moon}$$

$$F_{g1} r_1^2 = F_{g2} r_2^2$$

$$r_2^2 = \frac{F_{g1}}{F_{g2}} r_1^2$$

$$r_2^2 = \frac{(160)}{(40)} r_1^2$$

$$r_2^2 = 4r_1^2$$

$$r_2 = 2 \times r_{moon}$$

b

$$F_{g1} = 160 \text{ N} \qquad F_{g1} r_1^2 = F_{g2} r_2^2$$

$$F_{g2} = 40 \text{ N} \qquad F_{g2} = \frac{\mathbf{F}_{g1} r_1^2}{r_2^2}$$

$$r_1 = r_{moon} \qquad F_{g2} = \frac{(160) r_{moon}^2}{(4 \times r_{moon})^2}$$

$$r_2 = 4 \times r_{moon} \qquad F_{g2} = \frac{(160) r_{moon}^2}{(16) \times r_{moon}^2}$$

$$F_{g2} = 10 \text{ N attraction}$$

3

$$m_P = 1.08 \times 10^{16} \text{ kg} \qquad F_{M\text{-}P} = \frac{Gm_P m_M}{r^2} = \frac{(6.67 \times 10^{-11})(1.08 \times 10^{16})(6.42 \times 10^{23})}{(9.40 \times 10^6)^2}$$

$$m_D = 1.80 \times 10^{15} \text{ kg} \qquad F_{M\text{-}P} = 5.23 \times 10^{15} \text{ N attraction}$$

$$m_M = 6.42 \times 10^{23} \text{ kg}$$

$$r_{M-P} = 9.40 \times 10^6 \text{ m} \qquad F_{M\text{-}D} = \frac{Gm_D m_M}{r^2} = \frac{(6.67 \times 10^{-11})(1.80 \times 10^{15})(6.42 \times 10^{23})}{(2.35 \times 10^7)^2}$$

$$r_{M-D} = 2.35 \times 10^7 \text{ m} \qquad F_{M\text{-}D} = 1.40 \times 10^{14} \text{ N attraction}$$

$$\frac{F_{M\text{-}P}}{F_{M\text{-}D}} = \frac{(5.23 \times 10^{15})}{(1.40 \times 10^{14})} = 37.5$$

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4

$$\boldsymbol{F}_{g2} = 0.01 \times \boldsymbol{F}_{g1} \qquad \boldsymbol{F}_{g1} = \frac{Gm_E m_s}{r_1^2} \qquad \boldsymbol{F}_{g2} = \frac{Gm_E m_s}{r_2^2}$$

$$\boldsymbol{F}_{g1} r_1^2 = \boldsymbol{F}_{g2} r_2^2$$

$$r_2^2 = \frac{\boldsymbol{F}_{g1}}{\boldsymbol{F}_{g2}} r_1^2$$

$$r_2^2 = \frac{\boldsymbol{F}_{g1}}{0.01 \times \boldsymbol{F}_{g1}} r_1^2$$

$$r_2^2 = 100 \times r_1^2$$

$$r_2 = 10 \times r_E$$

5 a

$$m_a = M \text{ kg} \qquad \boldsymbol{F}_{a\text{-}x} = \frac{Gm_a m_x}{r^2} = \frac{(6.67 \times 10^{-11})(M)m_x}{(0.5R)^2}$$

$$m_b = 0.01M \text{ kg}$$

$$r_{a\text{-}x} = 0.5R \text{ m} \qquad \boldsymbol{F}_{b\text{-}x} = \frac{Gm_a m_x}{r^2} = \frac{(6.67 \times 10^{-11})(0.01M)m_x}{(0.5R)^2}$$

$$r_{b\text{-}x} = 0.5R \text{ m}$$

$$\frac{\boldsymbol{F}_{a\text{-}x}}{\boldsymbol{F}_{b\text{-}x}} = \frac{(6.67 \times 10^{-11})(M)m_x}{(0.5R)^2} \times \frac{(0.5R)^2}{(6.67 \times 10^{-11})(0.01M)m_x}$$

$$\frac{\boldsymbol{F}_{a\text{-}x}}{\boldsymbol{F}_{b\text{-}x}} = \frac{1}{0.01} = 100$$

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b

$m_a = M \text{ kg}$ $\qquad \dfrac{F_{a-x}}{F_{b-x}} = 8100$

$m_b = 0.01M \text{ kg}$ $\qquad 8100 = \dfrac{(6.67 \times 10^{-11})(M)m_x}{(xR)^2} \times \dfrac{[(1-x)R]^2}{(6.67 \times 10^{-11})(0.01M)m_x}$

$r_{a-x} = xR \text{ m}$ $\qquad 8100 = \dfrac{[(1-x)R]^2}{(xR)^2(0.01)}$

$r_{b-x} = (1-x)R \text{ m}$ $\qquad 81.0 = \dfrac{[(1-x)R]^2}{(xR)^2}$

$$9.00 = \frac{[(1-x)R]}{(xR)}$$

$$9.00xR = R - xR$$

$$10.0xR = R$$

$$x = \frac{R}{10.0R}$$

$$x = 0.100$$

$$\text{distance} = 0.100R$$

6

$m_a = M \text{ kg}$ $\qquad \dfrac{F_{a-x}}{F_{b-x}} = 1$

$m_b = 0.01M \text{ kg}$ $\qquad 1 = \dfrac{(6.67 \times 10^{-11})(M)m_x}{(xR)^2} \times \dfrac{[(1-x)R]^2}{(6.67 \times 10^{-11})(0.01M)m_x}$

$r_{a-x} = xR \text{ m}$ $\qquad 1 = \dfrac{[(1-x)R]^2}{(xR)^2(0.01)}$

$r_{b-x} = (1-x)R \text{ m}$ $\qquad 0.01 = \dfrac{[(1-x)R]^2}{(xR)^2}$

$$0.01 = \frac{[(1-x)R]}{(xR)}$$

$$0.01xR = R - xR$$

$$1.01xR = R$$

$$x = \frac{R}{1.01R}$$

$$x = 0.990$$

$$\text{distance} = 0.990R$$

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7

$G = 6.67 \times 10^{-11}\ \text{N kg}^{-2}\ \text{m}^2$

$m_M = 3.30 \times 10^{23}\ \text{kg}$

$r_M = 2.44 \times 10^{6}\ \text{m}$

$m_S = 5.69 \times 10^{26}\ \text{kg}$

$r_S = 6.03 \times 10^{7}\ \text{m}$

$m_J = 1.90 \times 10^{27}\ \text{kg}$

$r_J = 7.15 \times 10^{7}\ \text{m}$

$$\boldsymbol{g}_M = \frac{Gm}{r^2} = \frac{(6.67 \times 10^{-11})(3.30 \times 10^{23})}{(2.44 \times 10^{6})^2}$$

$\boldsymbol{g}_M = 3.70\ \text{N kg}^{-1}$

$$\boldsymbol{g}_S = \frac{Gm}{r^2} = \frac{(6.67 \times 10^{-11})(5.69 \times 10^{26})}{(6.03 \times 10^{7})^2}$$

$\boldsymbol{g}_S = 10.4\ \text{N kg}^{-1}$

$$\boldsymbol{g}_J = \frac{Gm}{r^2} = \frac{(6.67 \times 10^{-11})(1.90 \times 10^{27})}{(7.15 \times 10^{7})^2}$$

$\boldsymbol{g}_J = 24.8\ \text{N kg}^{-1}$

8 **a**

$m_a = 80.0\ \text{kg}$ $\quad$ $\boldsymbol{F}_{\text{wt M}} = m\boldsymbol{g} = (80.0)(3.70)$

$\boldsymbol{g}_M = 3.70\ \text{N kg}^{-1}$ $\quad$ $\boldsymbol{F}_{\text{wt M}} = 296\ \text{N}$

b

$m_a = 80.0\ \text{kg}$ $\quad$ $\boldsymbol{F}_{\text{wt S}} = m\boldsymbol{g} = (80.0)(10.4)$

$\boldsymbol{g}_S = 10.4\ \text{N kg}^{-1}$ $\quad$ $\boldsymbol{F}_{\text{wt S}} = 835\ \text{N}$

c

$m_a = 80.0\ \text{kg}$ $\quad$ $\boldsymbol{F}_{\text{wt J}} = m\boldsymbol{g} = (80.0)(24.8)$

$\boldsymbol{g}_J = 24.8\ \text{N kg}^{-1}$ $\quad$ $\boldsymbol{F}_{\text{wt J}} = 1980\ \text{N}$

9 Saturn's mass is approximately 100 times that of Earth, while the radius of Saturn is only 10 times that of earth. When the radius of the planet is squared the factor of 10 becomes 10^2, which is enough to cancel out the factor of 100 by which the mass of Saturn is greater.

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10

$$m_E = 5.98 \times 10^{24}\ \text{kg} \qquad F_E = F_M$$

$$m_M = 7.35 \times 10^{22}\ \text{kg} \qquad \frac{G m_E m_s}{x^2} = \frac{G m_M m_s}{(r - x)^2}$$

$$r = 3.84 \times 10^8\ \text{m} \qquad \frac{m_E}{x^2} = \frac{m_M}{(r - x)^2}$$

$$\frac{(r - x)^2}{x^2} = \frac{m_M}{m_E}$$

$$\frac{(3.84 \times 10^8 - x)}{x} = \sqrt{\frac{(7.35 \times 10^{22})}{(5.98 \times 10^{24})}}$$

$$3.84 \times 10^8 - x = 0.110x$$

$$1.110x = 3.84 \times 10^8$$

$$x = \frac{3.84 \times 10^8}{1.110}$$

$$x = 3.46 \times 10^8\ \text{m}$$

2.2 Satellite motion

1 D

2 As the satellite does not change its energy while orbiting around the Earth, it doesn't change its height above the surface of the Earth so its gravitational potential energy does not change, and its speed doesn't change so its kinetic energy doesn't change.

3

$$m_s = 2.30 \times 10^3\ \text{kg} \qquad F_{net} = mg = (2.30 \times 10^3)(0.220)$$

$$g = 0.220\ \text{N kg}^{-1} \qquad F_{net} = 5.06 \times 10^2\ \text{N}$$

4 The source of this force is the gravitational attraction of the Earth on the satellite.

5 **a**

$$m_N = 1.02 \times 10^{26}\ \text{kg} \qquad g = \frac{G m_N}{r_T^{\ 2}} = \frac{(6.67 \times 10^{-11})(1.02 \times 10^{26})}{(3.55 \times 10^8)^2}$$

$$r_T = 3.55 \times 10^8\ \text{m} \qquad g = 0.0540\ \text{m s}^{-2}$$

$$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$$

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b

$\boldsymbol{g} = 0.0540 \text{ m s}^{-2}$

$r_T = 3.55 \times 10^8 \text{ m}$

$$\boldsymbol{g} = \frac{v^2}{r}$$

$$v = \sqrt{gr} = \sqrt{(0.0540)(3.55 \times 10^8)}$$

$$v = 4.38 \times 10^3 \text{ m s}^{-1}$$

c

$v = 4.38 \times 10^3 \text{ m s}^{-1}$

$r_T = 3.55 \times 10^8 \text{ m}$

$$v = \frac{\text{distance}}{T}$$

$$T = \frac{\text{distance}}{v} = \frac{(2\pi(3.55 \times 10^8))}{(4.38 \times 10^3)}$$

$$T = \frac{(5.10 \times 10^8)}{(24 \times 60 \times 60)}$$

$$T = 5.90 \text{ days}$$

6 **a**

$T = 1.38 \times 10^6 \text{ s}$

$r_T = 1.22 \times 10^9 \text{ m}$

$r_T = 1.22 \times 10^6 \text{ km}$

$$v = \frac{\text{distance}}{T} = \frac{(2\pi(1.22 \times 10^6))}{(1.38 \times 10^6)}$$

$$v = 5.55 \text{ km s}^{-1}$$

b

$v = 5.55 \times 10^3 \text{ m s}^{-1}$

$r_T = 1.22 \times 10^9 \text{ m}$

$$\boldsymbol{a}_c = \frac{v^2}{r} = \frac{(5.55 \times 10^3)^2}{(1.22 \times 10^9)}$$

$$\boldsymbol{a}_c = 2.53 \text{ m s}^{-2}$$

7

$\boldsymbol{a}_c = 2.53 \times 10^{-2} \text{ m s}^{-2}$

$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$

$r = 1.22 \times 10^9 \text{ m}$

$$\boldsymbol{a}_c = \boldsymbol{g}$$

$$\boldsymbol{a}_c = \frac{Gm_S}{r^2}$$

$$m_S = \frac{\boldsymbol{a}_c r^2}{G} = \frac{(2.53 \times 10^{-2})(1.22 \times 10^9)^2}{(6.67 \times 10^{-11})}$$

$$m_S = 5.65 \times 10^{26} \text{ kg}$$

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8 a

$T = 2.10 \times 10^{7}$ s

$m_V = 4.87 \times 10^{24}$ kg

$G = 6.67 \times 10^{-11}$ N kg^{-2} m^{2}

$$v_c = \boldsymbol{F}_g$$

$$\frac{m_s v^2}{r} = \frac{G m_V m_s}{r^2}$$

$$\left(\frac{(2\pi r)}{T}\right)^2 = \frac{G m_V}{r}$$

$$\frac{(4\pi^2 r^2)}{T^2} = \frac{G m_V}{r}$$

$$r = \sqrt[3]{\frac{G m_V T^2}{4\pi^2}} = \sqrt[3]{\frac{(6.67 \times 10^{-11})(4.87 \times 10^{24})(2.10 \times 10^{7})^2}{4\pi^2}}$$

$$r = \sqrt[3]{3.63 \times 10^{27}}$$

$$r = 1.54 \times 10^{9} \text{ m}$$

b

$T = 2.10 \times 10^{7}$ s

$r = 1.54 \times 10^{9}$ m

$$v = \frac{\text{distance}}{T} = \frac{(2\pi(1.54 \times 10^{9}))}{(2.10 \times 10^{7})}$$

$$v = 4.60 \times 10^{2} \text{ m s}^{-1}$$

c

$v = 4.60 \times 10^{2}$ m s^{-1}

$r = 1.54 \times 10^{9}$ m

$$\boldsymbol{a}_c = \frac{v^2}{r} = \frac{(4.60 \times 10^{2})^2}{(1.54 \times 10^{9})}$$

$$\boldsymbol{a}_c = 1.37 \times 10^{-4} \text{ m s}^{-2}$$

9 a i

$r_A = 1.37 \times 10^{8}$ m

$T_A = 0.602$ day

$r_H = 3.77 \times 10^{8}$ m

$T_H = 2.75$ days

$$v_A = \frac{2\pi r_A}{T_A} = \frac{2\pi(1.37 \times 10^{8})}{(0.602)(24 \times 60 \times 60)} = 1.65 \times 10^{4} \text{ m s}^{-1}$$

$$v_H = \frac{2\pi r_H}{T_H} = \frac{2\pi(3.77 \times 10^{8})}{(2.75)(24 \times 60 \times 60)} = 9.97 \times 10^{3} \text{ m s}^{-1}$$

$$\frac{v_A}{v_H} = \frac{1.65 \times 10^{4}}{9.97 \times 10^{3}} = 1.66$$

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ii

$$r_A = 1.37 \times 10^8 \text{ m} \qquad a_A = \frac{v_A{}^2}{r_A} = \frac{(1.65 \times 10^4)^2}{(1.37 \times 10^8)} = 1.99 \text{ m s}^{-2}$$

$$v_A = 1.65 \times 10^4 \text{ m s}^{-1}$$

$$r_H = 3.77 \times 10^8 \text{ m} \qquad a_H = \frac{v_H{}^2}{r_H} = \frac{(9.97 \times 10^3)^2}{(3.77 \times 10^8)} = 0.264 \text{ m s}^{-2}$$

$$v_H = 9.97 \times 10^3 \text{ m s}^{-1}$$

$$\frac{a_A}{a_H} = \frac{1.99}{0.264} = 7.58$$

b

$$r_A = 1.37 \times 10^8 \text{ m} \qquad \frac{r_A{}^3}{T_A{}^2} = \frac{r_T{}^3}{T_T{}^2}$$

$$T_A = 5.20 \times 10^4 \text{ s} \qquad T_T{}^2 = \frac{r_T{}^3 T_A{}^2}{r_A{}^3}$$

$$r_T = 1.20 \times 10^9 \text{ m} \qquad T_T = \sqrt{\frac{(1.20 \times 10^9)^3 (5.20 \times 10^4)^2}{(1.37 \times 10^8)^3}}$$

$$T_T = \sqrt{1.82 \times 10^{12}}$$

$$T_T = \frac{(1.35 \times 10^6)}{(24 \times 60 \times 60)} \text{ s}$$

$$T_T = 15.6 \text{ days}$$

10

$$r_E = 6.37 \times 10^6 \text{ m} \qquad \frac{g_A}{g_B} = 1.2$$

$$g_A = 1.2 g_B$$

$$\frac{Gm_E}{r_E{}^2} = 1.2 \frac{Gm_E}{r_o{}^2}$$

$$r_o{}^2 = 1.2 \times r_E{}^2$$

$$r_o = \sqrt{1.2} \times r_E$$

$$r_o = \sqrt{1.2} \times (6.37 \times 10^6)$$

$$r_o = 6.98 \times 10^6 \text{ m}$$

2.3 Torque

1 **a** .The axis of rotation is the tap spindle; the lever arm is approximately 0.04 m

b The axis of rotation is the axle of the wheel; the lever arm is approximately 1 m

c The axis of rotation is the end of the tweezers; the lever arms are approximately 0.07 m

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d The axis of rotation is the place in which the screwdriver contacts the edge of the tin; the lever arm is approximately 0.2 m

2 **a** The line of application of the force is a larger perpendicular distance from the hinges (pivot point) when the force is applied to the handle than when it is applied to the centre of the door.

b Using a long crowbar with a small rock as a pivot a large force can be applied to the large rock if a small effort arm is used with a long effort arm, a ratio of load arm to effort arm of 1:10 will multiply the force you apply by ten times.

3

$m_H = 40.0$ kg $\qquad \tau = Fr_\perp$

$g = 9.80$ m s^{-2} $\qquad \tau = (40.0)(9.80)(2.25)$

$r_\perp = 2.25$ m $\qquad \tau = 8.82 \times 10^2$ N m

4

$\tau_{cw} = 400.0$ N m $\qquad \tau_{cw} = \tau_{acw}$

$r_\perp = 1.60$ m $\qquad F = \dfrac{\tau_{acw}}{r_\perp} = \dfrac{(400.0)}{(1.60)}$

$F = 2.50 \times 10^2$ N upwards

5 **a**

$m_w = 2.50 \times 10^3$ kg $\qquad \tau = Fr_\perp$

$g = 9.80$ m s^{-2} $\qquad \tau = (2.50 \times 10^3)(9.80)(2.00)$

$r_\perp = 2.00$ m $\qquad \tau = 4.90 \times 10^4$ N m

b Cranes use counter-weights on the other side of the pivot point to the load to provide an opposing torque to balance the torque due to the load.

6 **a**

$m_w = 1.00$ kg $\qquad \tau = Fr_\perp$

$\mathbf{g} = 9.80$ m s^{-2} $\qquad \tau = (1.00)(9.80)(0.500)$

$r_\perp = 0.500$ m $\qquad \tau = 4.90$ N m

b

$m_w = 1.00$ kg $\qquad \tau = Fr_\perp$

$g = 9.80$ m s^{-2} $\qquad \tau = (1.00)(9.80)(1.00)$

$r_\perp = 1.00$ m $\qquad \tau = 9.80$ N m

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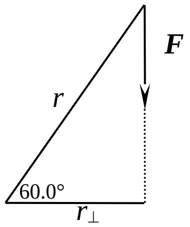
c

$m_w = 1.00$ kg
$g = 9.80$ m s^{-2}

$r_\perp = r\cos\theta = (1.00)(\cos 60.0\ )$
$r_\perp = 0.500$ m

$\tau = Fr_\perp$
$\tau = (1.00)(9.80)(0.500)$
$\tau = 4.90$ N m



7 The weights provide a large counter torque should the performer overbalance. Only a small movement of the pole is enough to balance the torque provided by the performer overbalancing.

8 The bench will not work successfully. The supports should be moved so that the centre of gravity is between the supports or bolts could be used to attach the left hand support to the bench-top.

9 **a** The weight of the bag will produce a torque about a pivot point around the base of the spine, which will tend to rotate the torso to the right. To compensate for this the person must lean to the left, or by holding the left arm out from the body to move it farther from the pivot point.

b

$m_w = 14.0$ kg
$g = 9.80$ m s^{-2}
assume $r_\perp = 0.3$ m

$\tau = Fr_\perp$
$\tau = (14.0)(9.80)(0.3)$
$\tau = 40$ N m

10 **a**

$m_w = 3.50\times10^3$ kg
$g = 9.80$ m s^{-2}

$F_{wt} = mg = (3.50\times10^3)(9.80)$
$F_{wt} = 3.43\times10^4$ N

b As the perpendicular distance from the line of action of the load to the pivot point does not change, then the torque does not change.

c

$F_{wt} = 3.43\times10^4$ N
assume $r_\perp = 15.0$ m

$\tau = Fr_\perp$
$\tau = (3.43\times10^4)(15.0)$
$\tau = 5.15\times10^5$ N m

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2.4 Equilibrium

1 A, B, D

2

$\updownarrow \, ^{+}_{-}$	$\Sigma \boldsymbol{F}_y = 0$
$m_p = 50.0$ kg	$4\boldsymbol{F}_{\text{T cable}} + \boldsymbol{F}_{\text{w1}} + \boldsymbol{F}_{\text{w2}} + (m\boldsymbol{g}) = 0$
$\boldsymbol{g} = -9.80$ m s^{-2}	$4\boldsymbol{F}_{\text{T cable}} + (-600) + (-850) + [(50.0)(-9.80)] = 0$
$\boldsymbol{F}_{\text{w1}} = -600$ N	$4\boldsymbol{F}_{\text{T cable}} - 1940 = 0$
$\boldsymbol{F}_{\text{w2}} = -850$ N	$\boldsymbol{F}_{\text{T cable}} = \dfrac{(1940)}{4} = 4.85 \times 10^2$ N

3

$\updownarrow \, ^{+}_{-}$	$\Sigma \boldsymbol{F}_y = 0$
$m_{\text{girder}} = 5000$ kg	$2\boldsymbol{F}_{\text{pillar}} + 8\left[(m_{\text{load}}\boldsymbol{g}) + (m_{\text{girder}}\boldsymbol{g})\right] = 0$
$\boldsymbol{g} = -9.80$ m s^{-2}	$2\boldsymbol{F}_{\text{pillar}} + 8\left[(20\,000)(-9.80) + (5000)(-9.80)\right] = 0$
$m_{\text{load}} = 20\,000$ kg	$2\boldsymbol{F}_{\text{pillar}} - 1.96 \times 10^6 = 0$
	$\boldsymbol{F}_{\text{pillar}} = \dfrac{(1.96 \times 10^6)}{2} = 9.80 \times 10^5$ N

4

$\updownarrow \, ^{+}_{-}$	$\Sigma \boldsymbol{F}_y = 0$
$m_{\text{girl}} = 60.0$ kg	$2\boldsymbol{F}_{\text{T vert}} + \left[(m_{\text{girl}}\boldsymbol{g}) + (m_{\text{beam}}\boldsymbol{g})\right] = 0$
$\boldsymbol{g} = -9.80$ m s^{-2}	$2\boldsymbol{F}_{\text{T vert}} + \left[(60.0)(-9.80) + (30.0)(-9.80)\right] = 0$
$m_{\text{beam}} = 30.0$ kg	$2\boldsymbol{F}_{\text{T vert}} - 8.82 \times 10^2 = 0$
	$\boldsymbol{F}_{\text{T vert}} = \dfrac{(8.82 \times 10^2)}{2} = 4.41 \times 10^2$ N

$$\sin\theta = \frac{\boldsymbol{F}_{\text{T vert}}}{\boldsymbol{F}_{\text{T}}}$$

$$\boldsymbol{F}_{\text{T}} = \frac{(4.41 \times 10^2)}{\sin 5^\circ} = 5.06 \times 10^2 \text{ N}$$

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5

$$\begin{aligned} &\boldsymbol{F}_{w1} = 200\ \text{N} && \Sigma\boldsymbol{\tau}_{cw} = \Sigma\boldsymbol{\tau}_{acw} \\ &r_1 = 1.2\ \text{m} && \boldsymbol{F}_{w1}r_1 = \boldsymbol{F}_{w2}r_2 \\ &r_2 = 1.5\ \text{m} && \boldsymbol{F}_{w2} = \frac{\boldsymbol{F}_{w1}r_1}{r_2} = \frac{(200)(1.2)}{(1.5)} \\ & && \boldsymbol{F}_{w2} = 160\ \text{N} \end{aligned}$$

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6

$$m_{\text{beam}} = 2.0 \text{ kg} \qquad \Sigma\boldsymbol{\tau} = m_{\text{beam}} r_1 + m_{\text{light}} r_2$$

$$r_1 = 0.25 \text{ m} \qquad \Sigma\boldsymbol{\tau} = (2.0)(9.80)(0.25) + (5.0)(9.80)(0.5)$$

$$m_{\text{light}} = 5.0 \text{ kg} \qquad \Sigma\boldsymbol{\tau} = 2.94 \times 10^{1} \text{ N m}$$

$$r_2 = 0.5 \text{ m}$$

$$9.80 \text{ m s}^{-2}$$

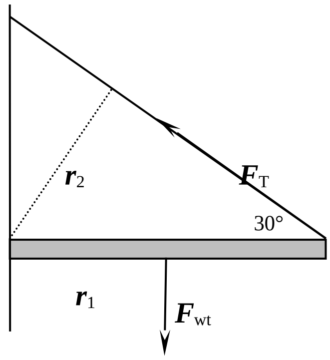
7 **a**

$$r_2 = 10 \sin 30^\circ \text{ m} \qquad \Sigma\tau_{\text{cw}} = \boldsymbol{F}_{\text{wt}} r_1$$

$$\Sigma\tau_{\text{cw}} = m_{\text{bridge}} \boldsymbol{g}\, r_1$$

$$\Sigma\tau_{\text{acw}} = 2\boldsymbol{F}_{\text{T}} r_2$$

$$\Sigma\tau_{\text{acw}} = 2\boldsymbol{F}_{\text{T}} 10 \sin 30^\circ$$



b

$$\boldsymbol{F}_{\text{T vert}} = \boldsymbol{F}_{\text{T}} \sin 30^\circ$$

$$\boldsymbol{F}_{\text{T horiz}} = \boldsymbol{F}_{\text{T}} \cos 30^\circ$$

c

$$r_2 = 10 \sin 30^\circ \text{ m} \qquad \Sigma\tau_{\text{cw}} = \Sigma\tau_{\text{acw}}$$

$$r_1 = 5.0 \text{ m} \qquad \boldsymbol{F}_{\text{wt}} r_1 = 2\boldsymbol{F}_{\text{T}} r_2$$

$$m_{\text{bridge}} = 700 \text{ kg} \qquad m_{\text{bridge}} \boldsymbol{g}\, r_1 = 2\boldsymbol{F}_{\text{T}} 10 \sin 30^\circ$$

$$g = 9.80 \text{ m s}^{-2} \qquad \boldsymbol{F}_{\text{T}} = \frac{m_{\text{bridge}} \boldsymbol{g}\, r_1}{2 \times 10 \sin 30^\circ} = \frac{(700)(9.80)(5.0)}{2 \times 10 \sin 30^\circ}$$

$$\boldsymbol{F}_{\text{T}} = 3.43 \times 10^{3} \text{ N}$$

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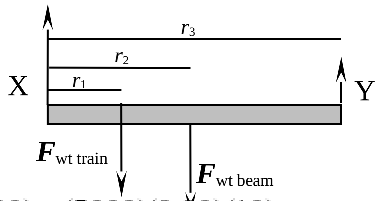
8



$r_2 = 10$ m

$r_3 = 20$ m

$m_{\text{beam}} = 5000$ kg

$m_{\text{train}} = 5000$ kg

$\boldsymbol{F}_{\text{Y}} = 30.6 \times 10^3$ N

$g = 9.80$ m s^{-2}

$$\Sigma\tau_{\text{cw}} = \Sigma\tau_{\text{acw}}$$

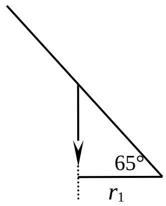
$$\boldsymbol{F}_{\text{wt train}} r_1 + \boldsymbol{F}_{\text{wt beam}} r_2 = \boldsymbol{F}_{\text{Y}} r_3$$

$$m_{\text{train}} \mathbf{g}\, r_1 + m_{\text{beam}} \mathbf{g}\, r_2 = \boldsymbol{F}_{\text{Y}} r_3$$

$$r_1 = \frac{\boldsymbol{F}_{\text{Y}} r_3 - m_{\text{beam}} \mathbf{g}\, r_2}{m_{\text{train}} \mathbf{g}} = \frac{(30.6 \times 10^3)(20) - (5000)(9.80)(10)}{(5000)(9.80)}$$

$$r_1 = 2.49 \text{ m}$$

9 **a**



$m_{\text{ladder}} = 16$ kg

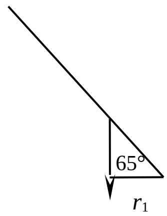
$r_1 = 2.4 \cos 65^\circ$

$$\boldsymbol{\tau}_{\text{wt ladder}} = \boldsymbol{F}_{\text{wt ladder}} r_1$$

$$\boldsymbol{\tau}_{\text{wt ladder}} = m_{\text{ladder}} g r_1 = (16)(9.80)(2.4 \cos 65^\circ)$$

$$\boldsymbol{\tau}_{\text{wt ladder}} = 159 \text{ N m}$$

b



$m_{\text{person}} = 50$ kg

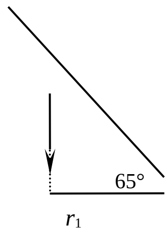
$r_1 = 1.2 \cos 65^\circ$

$$\boldsymbol{\tau}_{\text{wt person}} = \boldsymbol{F}_{\text{wt person}} r_1$$

$$\boldsymbol{\tau}_{\text{wt person}} = m_{\text{wt person}} g r_1 = (50)(9.80)(1.2 \cos 65^\circ)$$

$$\boldsymbol{\tau}_{\text{wt person}} = 248 \text{ N m}$$

c



$m_{\text{person}} = 50$ kg

$r_1 = 3.6 \cos 65^\circ$

$$\boldsymbol{\tau}_{\text{wt person}} = \boldsymbol{F}_{\text{wt person}} r_1$$

$$\boldsymbol{\tau}_{\text{wt person}} = m_{\text{wt person}} g r_1 = (50)(9.80)(3.6 \cos 65^\circ)$$

$$\boldsymbol{\tau}_{\text{wt person}} = 745 \text{ N m}$$

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10 a

$r_1 = 1.50$ m Take moments about left-hand side:

$r_2 = 2.50$ m $\Sigma\tau_{cw} = \Sigma\tau_{acw}$

$r_3 = 5.00$ m $m_{painter}\boldsymbol{g}r_1 + m_{platform}\boldsymbol{g}r_2 = \boldsymbol{F}_{RT}r_3$

$m_{platform} = 20$ kg $\boldsymbol{F}_{RT} = \dfrac{m_{painter}\boldsymbol{g}r_1 + m_{platform}\boldsymbol{g}r_2}{r_3} = \dfrac{(70)(9.80)(1.50) + (20)(9.80)(2.50)}{(5.00)}$

$m_{painter} = 70$ kg $\boldsymbol{F}_{RT} = 304$ N up

$g = 9.80$ m s^{-2}

$r_1 = 3.50$ m Take moments about right-hand side:

$r_2 = 2.50$ m $\Sigma\tau_{cw} = \Sigma\tau_{acw}$

$r_3 = 5.00$ m $m_{painter}\boldsymbol{g}r_1 + m_{platform}\boldsymbol{g}r_2 = \boldsymbol{F}_{LT}r_3$

$$\boldsymbol{F}_{LT} = \frac{m_{painter}\boldsymbol{g}r_1 + m_{platform}\boldsymbol{g}r_2}{r_3} = \frac{(70)(9.80)(3.50) + (20)(9.80)(2.50)}{(5.00)}$$

$\boldsymbol{F}_{LT} = 578$ N up

b

$r_2 = 2.50$ m Take moments about left-hand side:

$r_3 = 5.00$ m $\Sigma\tau_{cw} = \Sigma\tau_{acw}$

$\boldsymbol{F}_{LT} = 557$ N up $m_{painter}\boldsymbol{g}r_1 + m_{platform}\boldsymbol{g}r_2 = \boldsymbol{F}_{RT}r_3$

$\boldsymbol{F}_{RT} = 325$ N up $r_1 = \dfrac{\boldsymbol{F}_{RT}r_3 - m_{platform}\boldsymbol{g}r_2}{m_{painter}\boldsymbol{g}} = \dfrac{(325)(5.00) - (20)(9.80)(2.50)}{(70)(9.80)}$

$m_{painter} = 70$ kg $r_1 = 1.65$ m from left-hand side

$m_{platform} = 20$ kg

$g = 9.80$ m s^{-2}

11 a

$\boldsymbol{F}_{T\,horiz} = \boldsymbol{F}_T \cos 60^\circ = (800)\cos 60^\circ$

$\boldsymbol{F}_{T\,horiz} = 400$ N

$\boldsymbol{F}_{T\,vert} = \boldsymbol{F}_T \sin 60^\circ = (800)\sin 60^\circ$

$\boldsymbol{F}_{T\,vert} = 693$ N

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b

$r_1 = 0.85$ m

$r_2 = 1.0$ m

$\boldsymbol{F}_{\text{T horiz}} = 400$ N

Take moments about base of pole:

$$\Sigma\tau_{\text{cw}} = \Sigma\tau_{\text{acw}}$$

$$\boldsymbol{F}_{\text{T}} r_2 = \boldsymbol{F}_{\text{T horiz}} r_1$$

$$\boldsymbol{F}_{\text{T horiz}} = \frac{\boldsymbol{F}_{\text{T}} r_2}{r_1} = \frac{(400)(1.0)}{(0.85)}$$

$$\boldsymbol{F}_{\text{T horiz}} = 471 \text{ N}$$

Chapter 2 Review

1

$\boldsymbol{F} = 2.79 \times 10^{20}$ N

$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

$m_{\text{D}} = 1.05 \times 10^{21}$ kg

$m_{\text{S}} = 5.69 \times 10^{26}$ kg

$$\boldsymbol{F} = \frac{Gm_1 m_2}{r^2}$$

$$r = \sqrt{\frac{Gm_1 m_2}{\mathbf{F}}} = \sqrt{\frac{(6.67 \times 10^{-11})(1.05 \times 10^{21})(5.69 \times 10^{26})}{(2.79 \times 10^{20})}}$$

$r = 3.78 \times 10^8$ m from Saturn's centre of mass

2 **D**

3
a D
b B
c C
d A
e A

4

$$\boldsymbol{F}_{M\text{-X}} = \boldsymbol{F}_{m\text{-X}}$$

$$\frac{Gm_M m_{\text{X}}}{r_{M\text{-X}}^{\;2}} = \frac{Gm_m m_{\text{X}}}{r_{m\text{-X}}^{\;2}}$$

$$\frac{m_M}{r_{M\text{-X}}^{\;2}} = \frac{m_m}{r_{m\text{-X}}^{\;2}}$$

$$\frac{m_M}{m_m} = \frac{r_{M\text{-X}}^{\;2}}{r_{m\text{-}X}^{\;2}} = \frac{(0.8R)^2}{(0.2R)^2}$$

$$\frac{m_M}{m_m} = \frac{(0.64)}{(0.04)} = 16$$

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5 **a**

$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

$m_N = 1.02 \times 10^{26}$ kg

$$\boldsymbol{g} = \frac{Gm_N}{r^2} = \frac{(6.67 \times 10^{-11})(1.02 \times 10^{26})}{(2.48 \times 10^7)^2}$$

$$\boldsymbol{g} = 1.11 \times 10^1 \text{ N kg}^{-1}$$

b C

6

$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

$m_E = 5.98 \times 10^{24}$ kg

$m_M = 5.98 \times 10^{24}$ kg

$r = 3.84 \times 10^8$ m

$$\boldsymbol{F}_c = \boldsymbol{F}_g$$

$$\frac{m_M v^2}{r} = \frac{Gm_E m_M}{r^2}$$

$$\frac{(2\pi r)^2}{T^2} = \frac{Gm_E}{r}$$

$$T = \sqrt{\frac{4\pi^2 r^3}{Gm_E}} = \sqrt{\frac{4\pi^2 (3.84 \times 10^8)^3}{(6.67 \times 10^{-11})(5.98 \times 10^{24})}}$$

$$T = \frac{(2.37 \times 10^6)}{(24 \times 60 \times 60)} \text{ s}$$

$$T = 27.4 \text{ days}$$

7 **a**

$G = 6.67 \times 10^{-11}$ N m^2 kg^{--2}

$m_J = 1.90 \times 10^{27}$ kg

$r = 1.10 \times 10^{10}$ m

$$\boldsymbol{F}_c = \boldsymbol{F}_g$$

$$\frac{m_L v^2}{r} = \frac{Gm_J m_L}{r^2}$$

$$v = \sqrt{\frac{Gm_J}{r}}$$

$$v = \sqrt{\frac{Gm_J}{r}} = \sqrt{\frac{(6.67 \times 10^{-11})(1.90 \times 10^{27})}{(1.10 \times 10^{10})}}$$

$$v = 3.39 \times 10^3 \text{ m s}^{-1}$$

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b

$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

$m_J = 1.90 \times 10^{27}$ kg

$r = 1.10 \times 10^{10}$ m

$$\boldsymbol{g} = \frac{Gm_J}{r^2} = \frac{(6.67 \times 10^{-11})(1.90 \times 10^{27})}{(1.10 \times 10^{10})^2}$$

$\boldsymbol{g} = 1.05 \times 10^{-3}$ m s^{-2} towards Jupiter

c

$v = 3.39 \times 10^3$ m s^{-1}

$r = 1.10 \times 10^{10}$ m

$$v = \frac{2\pi r}{T}$$

$$T = \frac{2\pi r}{v} = \frac{2\pi(1.10 \times 10^{10})}{(3.39 \times 10^3)}$$

$$T = \frac{(2.04 \times 10^7)}{(24 \times 60 \times 60)} = 236 \text{ days}$$

8 **a** C

b The satellite will always be positioned above the same location on Earth therefore radio and TV signals can be exchanged with the satellite from any location on Earth that has a line of sight view of the satellite

c

$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

$m_E = 5.98 \times 10^{24}$ kg

$T = 24 \times 60 \times 60$ s

$$\boldsymbol{F}_c = \boldsymbol{F}_g$$

$$\frac{m_s v^2}{r} = \frac{Gm_E m_s}{r^2}$$

$$\frac{(2\pi r)^2}{T^2} = \frac{Gm_E}{r}$$

$$r = \sqrt[3]{\frac{Gm_E T^2}{4\pi^2}} = \sqrt[3]{\frac{(6.67 \times 10^{-11})(5.98 \times 10^{24})(24 \times 60 \times 60)^2}{4\pi^2}}$$

$r = 4.23 \times 10^7$ m

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9 **a**

$$r = 2.43 \times 10^{8} \text{ m}$$

b

$T = 5.07 \times 10^{6}$ s $\quad v = \dfrac{2\pi r}{T} = \dfrac{2\pi(2.43 \times 10^{8})}{(5.07 \times 10^{6})}$

$r = 2.43 \times 10^{8}$ m $\quad v = 3.01 \times 10^{2}$ m s^{-1}

c

$v = 3.01 \times 10^{2}$ m s^{-1} $\quad a = \dfrac{v^2}{r} = \dfrac{(3.01 \times 10^{2})^2}{(2.43 \times 10^{8})}$

$r = 2.43 \times 10^{8}$ m $\quad a = 3.73 \times 10^{-4}$ m s^{-2}

10 **a** The work done to increase the kinetic energy if the rock is equal to the area under the curve from 3.00×10^6 m to 2.50×10^6 m

$$\text{Area} = W_d = \text{approximate number of squares} \times \text{area of 1 square}$$

$$W_d = (5.5)\left[(10)(0.5 \times 10^{6})\right]$$

$$W_d = 2.75 \times 10^{7} \text{ J}$$

b

$u = 1000$ m s^{-1} $\quad E_k = E_{k1} + W_d$

$m = 20.0$ kg $\quad E_k = \frac{1}{2}mv^2 + W_d = \frac{1}{2}(20.0)(1000)^2 + (2.75 \times 10^{7})$

$W_d = 2.75 \times 10^{7}$ J $\quad E_k = 3.75 \times 10^{7}$ J

c

$E_k = 3.75 \times 10^{7}$ J $\quad E_k = \frac{1}{2}mv^2$

$m = 20.0$ kg $\quad v = \sqrt{\dfrac{2E_k}{m}} = \sqrt{\dfrac{2(3.75 \times 10)}{(20.0)}}$

$$v = 1.94 \times 10^{3} \text{ m s}^{-1}$$

d From the graph, at 2.50×10^6 m, $\boldsymbol{F}$ = 70 N

$\boldsymbol{F} = 70$ N $\quad \boldsymbol{F} = mg$

$m = 20.0$ kg $\quad g = \dfrac{\boldsymbol{F}}{m} = \dfrac{(70)}{(20.0)} = 3.50$ N kg^{-1}

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11 a

$$\boldsymbol{F}_{\mathrm{c}} = \boldsymbol{F}_{\mathrm{g}}$$

$$\frac{mv^2}{r} = \frac{Gm_{\mathrm{E}}m}{r^2}$$

$$\frac{m\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{Gm_{\mathrm{E}}m}{r^2}$$

$$T^2 = \frac{4\pi^2 r^3}{Gm_{\mathrm{E}}}$$

$$\frac{T_{s1}^{\ 2}}{T_{s2}^{\ 2}} = \frac{4\pi^2 r_{s1}^{\ 3}}{Gm_{\mathrm{E}}} \times \frac{Gm_{\mathrm{E}}}{4\pi^2 r_{s2}^{\ 3}}$$

$$\frac{T_{s1}^{\ 2}}{T_{s2}^{\ 2}} = \frac{r_{s1}^{\ 3}}{r_{s2}^{\ 3}} = \frac{(R)^3}{(2R)^3} = \frac{R^3}{8R^3}$$

$$\frac{T_{s1}}{T_{s2}} = \sqrt{\frac{1}{8}} = \frac{1}{\sqrt{8}} = \mathrm{C}$$

b

$$\boldsymbol{F}_{\mathrm{c}} = \boldsymbol{F}_{\mathrm{g}}$$

$$\frac{mv^2}{r} = \frac{Gm_{\mathrm{E}}m}{r^2}$$

$$v^2 = \frac{Gm_{\mathrm{E}}}{r}$$

$$\frac{v_{s1}^{\ 2}}{v_{s2}^{\ 2}} = \frac{Gm_{\mathrm{E}}}{r_{s1}} \times \frac{r_{s2}}{Gm_{\mathrm{E}}}$$

$$\frac{v_{s1}^{\ 2}}{v_{s2}^{\ 2}} = \frac{r_{s2}}{r_{s1}} = \frac{(2R)}{(R)}$$

$$\frac{v_{s1}}{v_{s2}} = \sqrt{2} = \mathrm{B}$$

c

$$\boldsymbol{a}_{\mathrm{c}} = \boldsymbol{g}$$

$$\boldsymbol{a} = \frac{Gm_{\mathrm{E}}}{r^2}$$

$$\frac{\boldsymbol{a}_{s1}}{\boldsymbol{a}_{s2}} = \frac{Gm_{\mathrm{E}}}{r_{s1}^{\ 2}} \times \frac{r_{s2}^{\ 2}}{Gm_{\mathrm{E}}}$$

$$\frac{\boldsymbol{a}_{s1}}{\boldsymbol{a}_{s2}} = \frac{r_{s2}^{\ 2}}{r_{s1}^{\ 2}} = \frac{(2R)^2}{(R)^2}$$

$$\frac{\boldsymbol{a}_{s1}}{\boldsymbol{a}_{s2}} = 4 = \mathrm{D}$$

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12

$$\boldsymbol{F}_c = \boldsymbol{F}_g$$

$$\frac{mv^2}{r} = \frac{Gm_S m}{r^2}$$

$$\frac{m\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{Gm_S m}{r^2}$$

$$m_S = \frac{4\pi^2 r^3}{GT^2} = \frac{4\pi^2(1.50\times10^{11})^3}{(6.67\times10^{-11})(365.25\times24\times60\times60)^2}$$

$$m_S = 2.01\times10^{30}\ \text{kg}$$

13 B

14

$$T_C = 6.40\ \text{days} \qquad \frac{r_N^{\ 3}}{T_N^{\ 2}} = \frac{r_C^{\ 3}}{T_C^{\ 2}}$$

$$r_C = 19\,600\ \text{km} \qquad T_N = \sqrt{\frac{T_C^{\ 2} r_N^{\ 3}}{r_C^{\ 3}}} = \sqrt{\frac{(6.40)^2(49\,000)^3}{(19\,600)^3}}$$

$$r_N = 49\,000\ \text{km} \qquad T_N = 25.3\ \text{days}$$

15

$$\boldsymbol{F}_c = \boldsymbol{F}_g$$

$$\frac{mv^2}{r} = \frac{Gm_P m}{r^2}$$

$$\frac{m\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{Gm_P m}{r^2}$$

$$m_P = \frac{4\pi^2 r^3}{GT^2} = \frac{4\pi^2(19\,600\times10^3)^3}{(6.67\times10^{-11})(6.40\times24\times60\times60)^2}$$

$$m_P = 1.46\times10^{22}\ \text{kg}$$

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16

$$r_{\text{ISS}} = (3.80 \times 10^5) + r_{\text{E}} \text{ m}$$

$$r_{\text{ISS}} = 6.75 \times 10^6 \text{ m}$$

$$r_{\text{O2D}} = (3.60 \times 10^7) + r_{\text{E}} \text{ m}$$

$$r_{\text{O2D}} = 4.24 \times 10^7 \text{ m}$$

$$\boldsymbol{F}_{\text{c}} = \boldsymbol{F}_{\text{g}}$$

$$\frac{mv^2}{r} = \frac{Gm_{\text{E}}m}{r^2}$$

$$v^2 = \frac{Gm_{\text{E}}}{r}$$

$$\frac{{v_{\text{ISS}}}^2}{{v_{\text{O2D}}}^2} = \frac{Gm_{\text{E}}}{r_{\text{ISS}}} \times \frac{r_{\text{O2D}}}{Gm_{\text{E}}}$$

$$\frac{{v_{\text{ISS}}}^2}{{v_{\text{O2D}}}^2} = \frac{r_{\text{O2D}}}{r_{\text{ISS}}} = \frac{(4.24 \times 10^7)}{(6.75 \times 10^6)}$$

$$\frac{v_{\text{ISS}}}{v_{\text{O2D}}} = \sqrt{6.28} = 2.51$$

17

$$r_{\text{ISS}} = 6.75 \times 10^6 \text{ m}$$

$$r_{\text{O2D}} = 4.24 \times 10^7 \text{ m}$$

$$\boldsymbol{F}_{\text{c}} = \boldsymbol{F}_{\text{g}}$$

$$\frac{mv^2}{r} = \frac{Gm_{\text{E}}m}{r^2}$$

$$T^2 = \frac{4\pi^2 r^3}{Gm_{\text{E}}}$$

$$\frac{{T_{\text{ISS}}}^2}{{T_{\text{O2D}}}^2} = \frac{4\pi^2 {r_{\text{ISS}}}^3}{Gm_{\text{E}}} \times \frac{Gm_{\text{E}}}{4\pi^2 {r_{\text{O2D}}}^3}$$

$$\frac{{T_{\text{ISS}}}^2}{{T_{\text{O2D}}}^2} = \frac{{r_{\text{ISS}}}^3}{{r_{\text{O2D}}}^3} = \frac{(6.75 \times 10^6)^3}{(4.24 \times 10^7)^3}$$

$$\frac{T_{\text{ISS}}}{T_{\text{O2D}}} = \sqrt{4.04 \times 10^{-3}} = 6.36 \times 10^{-2}$$

18

$$r_{\text{ISS}} = 6.75 \times 10^6 \text{ m}$$

$$r_{\text{O2D}} = 4.24 \times 10^7 \text{ m}$$

$$\boldsymbol{a}_{\text{c}} = \boldsymbol{g}$$

$$\boldsymbol{a} = \frac{Gm_{\text{E}}}{r^2}$$

$$\frac{\boldsymbol{a}_{\text{ISS}}}{\boldsymbol{a}_{\text{O2D}}} = \frac{Gm_{\text{E}}}{{r_{\text{ISS}}}^2} \times \frac{{r_{\text{O2D}}}^2}{Gm_{\text{E}}}$$

$$\frac{\boldsymbol{a}_{\text{ISS}}}{\boldsymbol{a}_{\text{O2D}}} = \frac{{r_{\text{O2D}}}^2}{{r_{\text{ISS}}}^2} = \frac{(4.24 \times 10^7)^2}{(6.75 \times 10^6)^2}$$

$$\frac{\boldsymbol{a}_{\text{ISS}}}{\boldsymbol{a}_{\text{O2D}}} = 39.4$$

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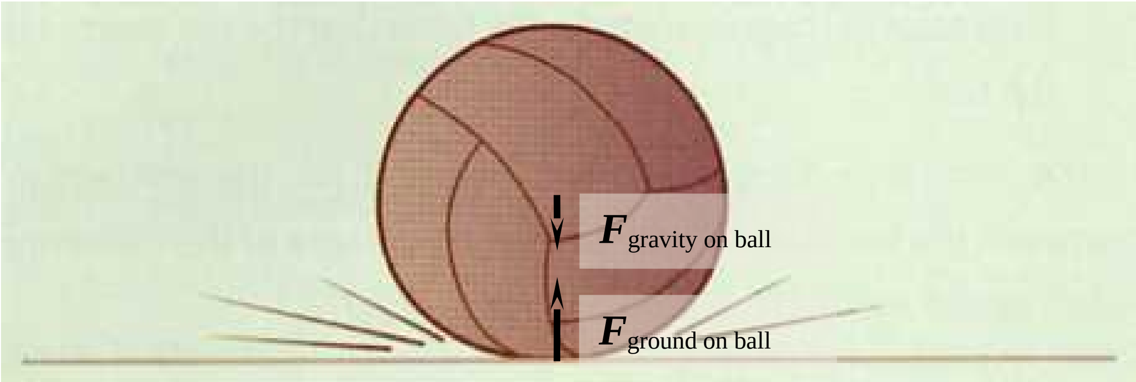
19



20 **a** C

b The forces must be on different objects and be equal in magnitude.

21

$\tau_{cw} = 445$ N m $\tau = Fr_\perp$

$r_{contents} = 1.60$ m $F = \dfrac{\tau}{r_\perp} = \dfrac{(445)}{(1.60)}$

$F = 278$ N up

22

$F = 5.00 \times 10^3$ N $\tau = Fr_\perp = (5.00 \times 10^3)(3.00)$

$r_{contact} = 3.00$ m $\tau = 1.50 \times 10^4$ N m

The wrecker could hit the wall higher up to increase the radius.

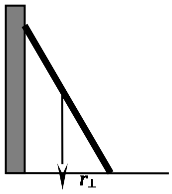
23 E

$r_\perp = (3.00)(\cos 65.0\ )$ $\tau = Fr_\perp = mgr_\perp$

$r_\perp = 1.27$ m $\tau = (7.50)(9.80)(1.27)$

$g = 9.80$ m s^{-2} $\tau = 93.2$ N m

$m = 7.50$ kg



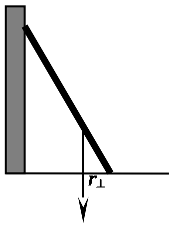
24

$r_\perp = (2.0)(\cos 65.0\ )$ $\tau = Fr_\perp = mgr_\perp$

$r_\perp = 0.85$ m $\tau = (60)(9.80)(0.85)$

$g = 9.80$ m s^{-2} $\tau = 4.99$ N m

$m = 60$ kg



25 B

$m_{load} = 4.50 \times 10^3$ kg $F = mg = (4.50 \times 10^3)(9.80)$

$g = 9.80$ m s^{-2} $F = 4.41 \times 10^4$ N

26 B

27

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$$\boldsymbol{F}_{\text{T1vert}} = m\mathbf{g} = (1.5)(9.80)$$
$$\boldsymbol{F}_{\text{T1vert}} = 14.7\ \text{N}$$

$$\boldsymbol{F}_{\text{T1horiz}} = \boldsymbol{F}_{\text{T1vert}} \tan 50^\circ = (14.7)(1.19)$$
$$\boldsymbol{F}_{\text{T1horiz}} = 17.5\ \text{N}$$

$$\boldsymbol{F}_{\text{T1}}{}^2 = \boldsymbol{F}_{\text{T1vert}}{}^2 + \boldsymbol{F}_{\text{T1horiz}}{}^2$$
$$\boldsymbol{F}_{\text{T1}} = \sqrt{(14.7)^2 + (17.5)^2}$$
$$\boldsymbol{F}_{\text{T1}} = 22.9\ \text{N}$$

$$\boldsymbol{F}_{\text{T2}} = \boldsymbol{F}_{\text{T1horiz}} = 17.4\ \text{N}$$

28

$$F_1 = (6.00 \times 9.80)\ \text{N}$$
$$F_2 = (10.0 \times 9.80)\ \text{N}$$
$$F_3 = (13.0 \times 9.80)\ \text{N}$$
$$F_{\text{beam}} = (2.00 \times 9.80)\ \text{N}$$

taking moments about LHS

$$\Sigma\boldsymbol{\tau}_{\text{cw}} = \Sigma\boldsymbol{\tau}_{\text{acw}}$$
$$\boldsymbol{F}_1 r_{\perp 1} + \boldsymbol{F}_2 r_{\perp 2} + \boldsymbol{F}_3 r_{\perp 3} + \boldsymbol{F}_{\text{beam}} r_{\perp 4} = \boldsymbol{F}_{\text{RHS}} r_{\perp 5}$$
$$\boldsymbol{F}_{\text{RHS}} = \frac{\boldsymbol{F}_1 r_{\perp 1} + \boldsymbol{F}_2 r_{\perp 2} + \boldsymbol{F}_3 r_{\perp 3} + \boldsymbol{F}_{\text{beam}} r_{\perp 4}}{r_{\perp 5}}$$
$$\boldsymbol{F}_{\text{RHS}} = \frac{(58.8)(2.0) + (98.0)(5.0) + (124.4)(7.0) + (19.6)(5.0)}{(10.0)}$$
$$\boldsymbol{F}_{\text{RHS}} = 1.60 \times 10^2\ \text{N upwards}$$

taking moments about RHS

$$\Sigma\boldsymbol{\tau}_{\text{cw}} = \Sigma\boldsymbol{\tau}_{\text{acw}}$$
$$\boldsymbol{F}_1 r_{\perp 1} + \boldsymbol{F}_2 r_{\perp 2} + \boldsymbol{F}_3 r_{\perp 3} + \boldsymbol{F}_{\text{beam}} r_{\perp 4} = \boldsymbol{F}_{\text{LHS}} r_{\perp 5}$$
$$\boldsymbol{F}_{\text{LHS}} = \frac{\boldsymbol{F}_1 r_{\perp 1} + \boldsymbol{F}_2 r_{\perp 2} + \boldsymbol{F}_3 r_{\perp 3} + \boldsymbol{F}_{\text{beam}} r_{\perp 4}}{r_{\perp 5}}$$
$$\boldsymbol{F}_{\text{LHS}} = \frac{(58.8)(8.0) + (98.0)(5.0) + (124.4)(3.0) + (19.6)(5.0)}{(10.0)}$$
$$\boldsymbol{F}_{\text{LHS}} = 1.44 \times 10^2\ \text{N upwards}$$

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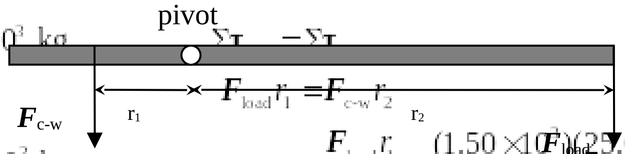
29 **a**



$$m_{load} = 1.50 \times 10^3 \text{ kg}$$
$$r_1 = 25.0 \text{ m}$$
$$m_{load} = 20.0 \times 10^3 \text{ kg}$$

$$\Sigma\tau = \Sigma\tau$$
$$F_{load} r_1 = F_{c\text{-}w} r_2$$
$$r_2 = \frac{F_{load} r_1}{F_{c\text{-}w}} = \frac{(1.50 \times 10^3)(25.0)}{(20.0 \times 10^3)}$$
$$r_2 = 1.88 \text{ m}$$

b This reduces the torque acting on the crane making it less likely that the crane will topple over.

30 **a**

$$F = 250 \text{ N} \qquad \tau = F r_\perp = (250)(1.0)$$
$$r_1 = 1.0 \text{ m} \qquad \tau = 250 \text{ N m}$$

b This torque would cause the barrier to bend slightly to the left causing tension at Y and compression at X, as concrete can withstand more compression than tension it is more likely to crack at position Y.

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Chapter 3 Understanding electromagnetism

3.1 Magnetic fields

1 B

2 C

3 **a** North

b North-east

c East

4 **a** South

b North

c Zero due to the two wires, but the Earth's magnetic field still exists and will be directed north.

5 At point R, but only if the combined field from m and n are balanced by the Earth's field.

6 **a** South

b South

c South, but only if it greater than the Earth's field at that point.

7 **a** $\boldsymbol{B}$, into the page

b 3$\boldsymbol{B}$, into the page

c Zero

8 A

9 South

10 South

3.2 Force on current-carrying conductors

1 **a**

$l = 100.0$ m $\quad\quad \boldsymbol{F} = \boldsymbol{I}l\boldsymbol{B}_{\perp}$

$\boldsymbol{I} = 80.0$ A W → E $\quad\quad \boldsymbol{F} = (80.0)(100.0)(5.34 \times 10^{-5})$

$\boldsymbol{B}_{\perp} = 5.34 \times 10^{-5}$ T $\quad\quad \boldsymbol{F} = 4.27 \times 10^{-1}$ N upwards

b

$l = 100.0$ m $\quad\quad \boldsymbol{F} = \boldsymbol{I}l\boldsymbol{B}_{\perp}$

$\boldsymbol{I} = 50.0$ A E → W $\quad\quad \boldsymbol{F} = (50.0)(100.0)(5.34 \times 10^{-5})$

$\boldsymbol{B}_{\perp} = 5.34 \times 10^{-5}$ T $\quad\quad \boldsymbol{F} = 2.67 \times 10^{-1}$ N downwards

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2

$l = 100.0$ m

$I = 100.0$ A

$B_\perp = 5.34 \times 10^{-5}$ T

$m = 50.0$ kg

$$\frac{F_{wt}}{F_B} = \frac{mg}{IlB_\perp} = \frac{(50.0)(9.80)}{(100.0)(100.0)(5.34 \times 10^{-5})}$$

$$\frac{F_{wt}}{F_B} = 918$$

3 B

4 **a**

$l = 0.0500$ m

$I = 2.00$ A into page

$B_\perp = 2.00 \times 10^{-3}$ T

$F = IlB_\perp$

$F = (2.00)(0.0500)(2.00 \times 10^{-3})$

$F = 2.00 \times 10^{-4}$ N north

b

$l = 0.0500$ m

$I = 1.00$ A out of page

$B_\perp = 2.00 \times 10^{-3}$ T

$F = IlB_\perp$

$F = (1.00)(0.0500)(2.00 \times 10^{-3})$

$F = 1.00 \times 10^{-4}$ N south

5 **a**

$l = 1.00 \times 10^{-3}$ m

$I = 3.00$ A into page

$B_\perp = 0.500$ T

$F = IlB_\perp$

$F = (3.00)(1.00 \times 10^{-3})(0.500)$

$F = 1.50 \times 10^{-3}$ N west

b

$l = 1.00 \times 10^{-3}$ m

$I = 3.00$ A out of page

$B_\perp = 1.00$ T

$F = IlB_\perp$

$F = (3.00)(1.00 \times 10^{-3})(1.00)$

$F = 3.00 \times 10^{-3}$ N east

6 **a**

$l = 2.00 \times 10^{-3}$ m

$F = 8.00 \times 10^{-3}$ N south

$B_\perp = 0.100$ T

$$I = \frac{F}{lB_\perp} = \frac{(8.00 \times 10^{-3})}{(2.00 \times 10^{-3})(0.100)}$$

$I = 40.0$ A into the page

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b

$l = 2.00 \times 10^{-3}$ m

$\boldsymbol{F} = 2.00 \times 10^{-2}$ N north

$\boldsymbol{B}_{\perp} = 0.500$ T

$$\boldsymbol{I} = \frac{\boldsymbol{F}}{l\boldsymbol{B}_{\perp}} = \frac{(2.00 \times 10^{-2})}{(2.00 \times 10^{-3})(0.500)}$$

$\boldsymbol{I} = 20.0$ A out of the page

7 **a**

$I = 5.00$ A

$\boldsymbol{B}_{\perp} = 4.00 \times 10^{-3}$ T south

$$\frac{F}{\ell} = I\boldsymbol{B}_{\perp}$$

$$\frac{F}{\ell} = (5.00)(4.00 \times 10^{-3})$$

$$\frac{F}{\ell} = 2.00 \times 10^{-2} \text{ N m}^{-1} \text{ west}$$

b

$I = 5.00$ A

$\boldsymbol{B}_{\perp} = 4.00 \times 10^{-3}$ T north

$$\frac{F}{\ell} = I\boldsymbol{B}_{\perp}$$

$$\frac{F}{\ell} = (5.00)(4.00 \times 10^{-3})$$

$$\frac{F}{\ell} = 2.00 \times 10^{-2} \text{ N m}^{-1} \text{ east}$$

8 **a**

$I = 2.0$ A

$\boldsymbol{B}_{\perp} = 1.0 \times 10^{-3}$ T north-west

$$\frac{F}{\ell} = I\boldsymbol{B}_{\perp}$$

$$\frac{F}{\ell} = (2.0)(1.0 \times 10^{-3})$$

$$\frac{F}{\ell} = 2.0 \times 10^{-3} \text{ N m}^{-1} \text{ north-east}$$

b

$I = 1.0$ A

$\boldsymbol{B}_{\perp} = 1.0 \times 10^{-3}$ T north-west

$$\frac{F}{\ell} = I\boldsymbol{B}_{\perp}$$

$$\frac{F}{\ell} = (1.0)(1.0 \times 10^{-3})$$

$$\frac{F}{\ell} = 1.0 \times 10^{-3} \text{ N m}^{-1} \text{ south-west}$$

9 Magnetic flux due to wire N at point M is south.

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10 **a**

$\theta = 90.0°$ $\quad$ $\boldsymbol{B}_{\perp} = \boldsymbol{B}\sin\theta = (1.00\times10^{-3})(\sin 90.0) = 1.00\times10^{-3}$ T

$l = 2.00\times10^{-3}$ m $\quad$ $\boldsymbol{F} = \boldsymbol{I}l\boldsymbol{B}_{\perp}$

$\boldsymbol{I} = 1.00\times10^{-3}$ A $\quad$ $\boldsymbol{F} = (1.00\times10^{-3})(2.00\times10^{-3})(1.00\times10^{-3})$

$\boldsymbol{B}_{\perp} = 1.00\times10^{-3}$ T $\quad$ $\boldsymbol{F} = 2.00\times10^{-9}$ N

b

$\theta = 0°$ $\quad$ $\boldsymbol{B}_{\perp} = \boldsymbol{B}\sin\theta = (1.00)(\sin 0) = 0$ T

$l = 5.00\times10^{-2}$ m $\quad$ $\boldsymbol{F} = 0$ N

$\boldsymbol{I} = 1.00$ A

$\boldsymbol{B}_{\perp} = 1.00$ T

c

$\theta = 30.0°$ $\quad$ $\boldsymbol{B}_{\perp} = \boldsymbol{B}\sin\theta = (1.00\times10^{-1})(\sin 30.0) = 5.00\times10^{-2}$ T

$l = 1.00\times10^{-3}$ m $\quad$ $\boldsymbol{F} = \boldsymbol{I}l\boldsymbol{B}_{\perp}$

$\boldsymbol{I} = 5.00$ A $\quad$ $\boldsymbol{F} = (5.00)(1.00\times10^{-3})(5.00\times10^{-2})$

$\boldsymbol{B}_{\perp} = 1.00\times10^{-1}$ T $\quad$ $\boldsymbol{F} = 2.50\times10^{-4}$ N

3.3 Electric motors

1

$\boldsymbol{B}_{\perp} = 0.100$ T $\quad$ $\boldsymbol{F} = Il\boldsymbol{B} = (2.00)(0.05)(0.100)$

$l_{PS} = 0.0500$ m $\quad$ $\boldsymbol{F} = 1.00\times10^{-2}$ N into the page

$I = 2.00$ A

2

$\boldsymbol{B}_{\perp} = 0.100$ T $\quad$ $\boldsymbol{F} = Il\boldsymbol{B} = (2.00)(0.05)(0.100)$

$l_{QR} = 0.0500$ m $\quad$ $\boldsymbol{F} = 1.00\times10^{-2}$ N out of the page

$I = 2.00$ A

3 0 N as the field and current are parallel.

4 Anticlockwise

5 D

6 **a** Down

b Up

7 Anticlockwise

8 **a** Down

b Up

c 0 N m

9 C

10 The commutator reverses the direction of the current through the coil of the motor at a particular

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point. This enables the resultant torque on the coil at that point keep the motor rotating in a constant direction.

3.4 Electric fields in circuits

1 **a** *F* doubles

b *F* quadruples

c *F* becomes attractive

d *F* quadruples

2

$q_1 = 1.00$ C $\quad$ $\boldsymbol{F} = \dfrac{kq_1q_2}{r^2}$

$q_1 = 1.00$ C $\quad$ $\boldsymbol{F} = \dfrac{(9.00\times10^9)(1.00)(1.00)}{(100.0)^2}$

$k = 9.00\times10^9$ N m^2 C^{-2} $\quad$ $\boldsymbol{F} = 9.00\times10^5$ N repulsion

$r = 100$ m

3 **a**

$q_1 = 5.00\times10^{-6}$ C $\quad$ $\boldsymbol{F} = \dfrac{kq_1q_2}{r^2}$

$q_1 = 5.00\times10^{-6}$ C $\quad$ $\boldsymbol{F} = \dfrac{(9.00\times10^9)(5.00\times10^{-6})(5.00\times10^{-6})}{(0.800)^2}$

$k = 9.00\times10^9$ N m^2 C^{-2} $\quad$ $\boldsymbol{F} = 3.52\times10^{-1}$ N repulsion

$r = 0.800$ m

b As the charges on the Van de Graaff machine are mobile, and are of the same sign, they will repel each other so that they move to opposite sides of the dome, this will increase the distance between the 'centre' of the charges.

4 **a**

$\boldsymbol{E} = 5.00\times10^{-3}$ N C^{-1} $\quad$ $\boldsymbol{F}_1 = \boldsymbol{E}q_1 = (5.00\times10^{-3})(+2.00\times10^{-6})$

$q_1 = +2.00\times10^{-6}$ C $\quad$ $\boldsymbol{F}_1 = 1.00\times10^{-8}$ N downwards

$q_2 = -5.00\times10^{-6}$ C

$\boldsymbol{F}_2 = \boldsymbol{E}q_2 = (5.00\times10^{-3})(-5.00\times10^{-6})$

$\boldsymbol{F}_2 = -2.50\times10^{-8}$

$\boldsymbol{F}_2 = 2.50\times10^{-8}$ N upwards

b

$\boldsymbol{E} = 5.00\times10^{-3}$ N C^{-1} $\quad$ $q = \dfrac{\boldsymbol{F}_1}{\boldsymbol{E}} = \dfrac{(-1.00\times10^{-3})}{(5.00\times10^{-3})}$

$\boldsymbol{F} = -1.00\times10^{-3}$ N $\quad$ $q = -2.00\times10^{-1}$ C

5 **a**

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$I = 5 \times 10^{-3}$ A $\qquad q = I\Delta t = (5.00 \times 10^{-3})(10.0 \times 60)$

$\Delta t = (10.0 \times 60) \qquad q = 3$ C

b

$I = 200$ A $\qquad q = I\Delta t = (200)(5.00)$

$\Delta t = 5.00$ s $\qquad q = 1 \times 10^{3}$ C

c

$I = 400 \times 10^{-3}$ A $\qquad q = I\Delta t = (400 \times 10^{-3})(60 \times 60)$

$\Delta t = (60 \times 60)$ s $\qquad q = 1.4 \times 10^{3}$ C

6

$N_e = 50 \times 10^{12} \qquad I = \dfrac{q}{\Delta t} = \dfrac{N_e q_e}{\Delta t}$

$q_e = 1.60 \times 10^{-19}$ C $\qquad I = \dfrac{(50 \times 10^{12})(1.60 \times 10^{-19})}{(3)}$

$\Delta t = 3$ s $\qquad I = 3 \times 10^{-6}$ A

7 The potential difference of a car battery to your hand is 12 V, which causes an insufficient electric field to cause a current to flow through the air to your skin. The spark in a spark plug results from a potential difference of thousands of volts, which will cause current to flow through air to your hand.

8

Assume 100% efficiency

$q = 5.00$ C $\qquad W_d = q\Delta V$

$W_d = 100.0$ J $\qquad \Delta V = \dfrac{W_d}{q} = \dfrac{(100.0)}{(5.00)}$

$\Delta V = 20.0$ V

9

Assume 100% efficiency

$q = 1.00$ C $\qquad W_d = q\Delta V = (9.00)(1.00)$

$\Delta V = 9.00$ V $\qquad W_d = 9.00$ J

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10

Assume 100% efficiency

$W_d = 2.00 \times 10^3$ J $\qquad W_d = q\Delta V$

$\Delta V = 12.0$ V $\qquad q = \frac{W_d}{\Delta V} = \frac{(2.00 \times 10^3)}{(12.0)}$

$q = 1.67 \times 10^2$ C

3.5 Electric circuits

1 Either there is some internal resistance in the battery or there is some form of resistance in the circuit, which may be due to corroded connections.

2

Current in + current out = 0

$(+2.50) + (+1.00) + (-4.20) + I = 0$

$I = +0.70$

$I = 0.70$ A out of the point

3 **a** 0.25 A

b 2.40 V

4 **a** Yes

b If one bulb breaks the other will go out too.

5 **a**

$\Delta V = 5.00$ V $\qquad V = IR$

$R_1 = 400.0\ \Omega$ $\qquad I = \frac{V}{R} = \frac{(5.00)}{(400.0 + 100.0)}$

$R_2 = 100.0\ \Omega$ $\qquad I = 1.00 \times 10^{-2}$ A

b

$I = 1.00 \times 10^{-2}$ A $\qquad V_1 = IR_1 = (1.00 \times 10^{-2})(400.0) = 4.00$ V

$R_1 = 400.0\ \Omega$ $\qquad V_2 = IR_2 = (1.00 \times 10^{-2})(100.0) = 1.00$ V

$R_2 = 100.0\ \Omega$

6 **a** Lamp A gets brighter

b Lamp C turns off

c Current increases

d Potential difference across lamp B increases

e Potential difference across lamp C decreases

f Total power increases

7 **a** R_1, R_4 and R_5

b R_2 and R_3

c R_1, R_4 and R_5

8

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R_1 (Ω)	R_2 (Ω)	V_{out} (V)
1000	1000	10
3000	1000	5.0
400	100	4.0
900	100	2.0
2.0	3.0	12

9 **a** D

b F

c D

d A

10 **a**

$$\frac{1}{R_A} = \frac{1}{(10\times 10^3)} + \frac{1}{(30\times 10^3)} = 1.33\times 10^{-4}$$

$$R_A = 7.5\times 10^3\ \Omega$$

$$R_B = (7.5\times 10^3) + (5\times 10^3) = 1.25\times 10^4\ \Omega$$

$$\frac{1}{R_C} = \frac{1}{(1.25\times 10^4)} + \frac{1}{(30\times 10^3)} = 1.13\times 10^{-4}$$

$$R_C = 8.8\times 10^3\ \Omega$$

$$R_{Total} = (8.8\times 10^3) + (40\times 10^3) = 4.9\times 10^4\ \Omega$$

b

$$\Delta V = I_T R_T$$

$$I_T = \frac{\Delta V}{R_T} = \frac{(10.0)}{(4.9\times 10^4)} = 2.05\times 10^{-4}\ \text{A}$$

$$\Delta V = I_T R_{40} = (2.05\times 10^{-4})(40\times 10^3)$$

$$\Delta V = 8.2\ V$$

c

$$\Delta V = (10) - (8.2) = 1.8\ \text{V}$$

$$I_{30} = \frac{\Delta V}{R_{30}} = \frac{(1.8)}{(30\times 10^3)} = 6.02\times 10^{-5}\ \text{A}$$

$$I_5 = I_T - I_{30} = (2.05\times 10^{-4}) - (6.02\times 10^{-5})$$

$$I_5 = 1.4\times 10^{-4}\ \text{A}$$

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d

$$\Delta V_5 = I_5 R_5 = (1.4 \times 10^{-4})(5 \times 10^3)$$
$$\Delta V_5 = 7.2 \times 10^{-1}\ \text{V}$$

$$\Delta V_{10} = \Delta V - \Delta V_5 = (1.8) - (7.2 \times 10^{-1})$$
$$\Delta V_{10} = 1.1\ \text{V}$$

Chapter 3 Review

1 B, C
2 B
3 A
4 **a** R_4
b R_2 and R_3
c R_4
d E_2
5 **a** All four in series.
b Two in series that are connected to two in parallel.
c All four in parallel.
d One resistor that is connected to three in parallel.
6 **a**

Circuit a:

$$\Delta V = 12.0\ \text{V} \qquad I_T = \frac{\Delta V}{R_T} = \frac{(12.0)}{(16.0)} = 7.50 \times 10^{-1}\ \text{A}$$

Circuit b:

$$I_T = \frac{\Delta V}{R_T} = \frac{(12.0)}{(10.0)} = 1.20\ \text{A}$$

Circuit c:

$$I_T = \frac{\Delta V}{R_T} = \frac{(12.0)}{(1.00)} = 12.0\ \text{A}$$

Circuit d:

$$I_T = \frac{\Delta V}{R_T} = \frac{(12.0)}{(5.33)} = 2.25\ \text{A}$$

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b

Circuit a:

$$I_T = I_1 = I_2 = I_3 = I_4 = 7.50 \times 10^{-1} \text{ A}$$

Circuit b:

$$I_T = I_1 = I_2 = 1.20 \text{ A}, \quad I_3 = I_4 = 0.60 \text{ A}$$

Circuit c:

$$I_1 = I_2 = I_3 = I_4 = \frac{I_T}{4} = \frac{12.0}{4} = 3.00 \text{ A}$$

Circuit d:

$$I_T = I_1 = 2.25 \text{ A}, \quad I_2 = I_3 = I_4 = \frac{I_T}{3} = \frac{2.25}{3} = 7.50 \times 10^{-1} \text{ A}$$

7

$$R_T = R_A + R_B = R + 3R$$
$$R_T = 4R$$

$$I_T = \frac{\Delta V}{R_T} = \frac{\Delta V}{4R}$$

$$V_1 = I_T R_A = \left(\frac{\Delta V}{4R}\right)(R) = \left(\frac{\Delta V}{4}\right)$$
$$V_1 = \tfrac{1}{4}\Delta V$$

8 **a**

$$R_T = \frac{\Delta V}{I_T} = \frac{(12.0)}{(200.0 \times 10^{-3})}$$
$$R_T = 60.0 \ \Omega$$

$$R = \frac{R_T}{4} = \frac{(60.0)}{4}$$
$$R = 15.0 \ \Omega$$

$$R_A = R = 15.0 \ \Omega$$
$$R_B = 3R = 45.0 \ \Omega$$

b

$$P_B = I^2 R_B = (200.0 \times 10^{-3})^2 (45.0)$$
$$P_B = 1.80 \text{ W}$$

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9

$$\Delta V_{\text{Therm}} = \Delta V_{\text{T}} - V_{\text{out}} = (6) - (1)$$
$$\Delta V_{\text{Therm}} = 5 \text{ V}$$

$$I_{\text{T}} = \frac{V_{\text{out}}}{R} = \frac{(1)}{(1 \times 10^{3})}$$
$$I_{\text{T}} = 1 \times 10^{-3} \text{ A}$$

$$R_{\text{Therm}} = \frac{\Delta V_{\text{Therm}}}{I_{\text{T}}} = \frac{(5)}{(1 \times 10^{-3})}$$
$$R_{\text{Therm}} = 5 \times 10^{3} \ \Omega$$

$\therefore$ from graph at $5 \times 10^{3} \ \Omega$ temperature is 20°C

10 a

$$P_{\text{max}} = \frac{\Delta V_{\text{X}}^{2}}{R}$$
$$\Delta V_{\text{X}} = \sqrt{P_{\text{max}} R} = \sqrt{(25)(100)}$$
$$\Delta V_{\text{X}} = 50 \text{ V}$$

$$I_{\text{T}} = \frac{\Delta V_{\text{X}}}{R_{\text{X}}} = \frac{(50)}{(100)} = 0.50 \text{ A}$$
$$I_{\text{Y}} = \frac{I_{\text{T}}}{2} = \frac{(0.50)}{2} = 0.25 \text{ A}$$

$$\Delta V_{\text{Y}} = I_{\text{T}} R_{\text{Y}} = (0.25)(100)$$
$$\Delta V_{\text{Y}} = 25 \text{ V}$$

$$\Delta V_{\text{AB}} = \Delta V_{\text{X}} + \Delta V_{\text{Y}} = (50) + (25)$$
$$\Delta V_{\text{AB}} = 75 \text{ V}$$

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b

$$\frac{1}{R_P} = \frac{1}{R_Y} + \frac{1}{R_Z} = \frac{1}{(100)} + \frac{1}{(100)} = 0.02$$
$$R_P = 50\ \Omega$$

$$R_T = R_X + R_P = (100) + (50\ )$$
$$R_T = 150\ \Omega$$

$$P_T = \frac{\Delta V_{AB}{}^2}{R_T} = \frac{(75)^2}{(150)}$$
$$P_T = 37.5\ \text{W}$$

11

R_1 (Ω)	R_2 (Ω)	Switch	V_{out} (V)
1000	2000	Open	60
2000	4000	Open	60
4000	2000	Open	50
8000	5000	Closed	0

12 **a**

$$\frac{1}{R_P} = \frac{1}{10} + \frac{1}{5} + \frac{1}{(20+5)} = 0.34$$
$$R_P = 2.94\Omega$$

$$R_T = 10 + R_P = (10) + (2.94\ )$$
$$R_T = 12.946\Omega$$

$$I_T = \frac{\Delta V}{R_T} = \frac{(25)}{(12.94)}$$
$$I_T = 1.93\ \text{A}$$

$$\Delta V_{10} = I_T R_{10} = (1.94)(10)$$
$$\Delta V_{10} = 19.3\ \text{V}$$

$$\Delta V_P = \Delta V - \Delta V_{10} = (25) - (19.3)$$
$$\Delta V_P = 5.68\ \text{V}$$

$$I_{20} = \frac{\Delta V_P}{R_{20+5}} = \frac{(5.55)}{(25)}$$
$$I_{20} = 0.23\ \text{A}$$

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b

$$\Delta V_P = \Delta V - \Delta V_{10} = (25) - (19.3)$$
$$\Delta V_P = 5.7 \text{ V}$$

13 **a** Y

b

$$\text{slope} = \frac{(y_2 - y_1)}{(x_2 - x_1)} = \frac{(39 \times 10^{-3} - 0)}{(75 - 0)}$$
$$\text{slope} = 5.2 \times 10^{-4} \text{ A V}^{-1}$$

$$R = \frac{V}{I} = \frac{1}{\text{slope}} = \frac{1}{(5.2 \times 10^{-4})}$$
$$R = 1.9 \times 10^3 \ \Omega$$

c When $V = 60$ V then from the graph $I_Y = I_T = 40 \times 10^{-3}$ A

d

$$R_P = \frac{1}{R_X} + \frac{1}{R_X} = \frac{1}{(1.9 \times 10^3)} + \frac{1}{(1.9 \times 10^3)} = 1.04 \times 10^{-3}$$
$$R_P = 9.6 \times 10^2 \ \Omega$$

$$V_P = IR_P = (40 \times 10^{-3})(9.6 \times 10^2)$$
$$V_P = 38 \text{ V}$$

$$V_{Battery} = V_Y + V_P = (60) + (38)$$
$$V_{Battery} = 98 \text{ V}$$

e

$$P_T = V_T I_T = (98)(40 \times 10^{-3})$$
$$P_T = 3.9 \text{ W}$$

14 **a** Into the page

b Out of the page

c Out of the page

d Out of the page

15 5.00×10^{-5} T south

16 Into the page

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17

$\updownarrow\ {}^{+}_{-}$

$$\boldsymbol{B}_{T} = \boldsymbol{B}_{E} + \boldsymbol{B}_{C} = (+5.00 \times 10^{-5}) + (+50 \times 10^{-6})$$

$$\boldsymbol{B}_{T} = 1.00 \times 10^{-4} \text{ T north}$$

18

$$\boldsymbol{B}_{T} = \sqrt{\boldsymbol{B}_{E}^{2} + \boldsymbol{B}_{C}^{2}} = \sqrt{(+5.00 \times 10^{-5})^{2} + (+50 \times 10^{-6})^{2}}$$

$$\boldsymbol{B}_{T} = 7.07 \times 10^{-5} \text{ T}$$

19 North-west

20 C

21 **a**

$$\boldsymbol{F} = \boldsymbol{I}l\boldsymbol{B} = (1.00 \times 10^{-3})(5.00 \times 10^{-3})(1.00 \times 10^{-3})$$

$$\boldsymbol{F} = 5.00 \times 10^{-9} \text{ N into the page}$$

b

$$\boldsymbol{F} = \boldsymbol{I}l\boldsymbol{B} = (2.00)(1.00 \times 10^{-2})(0.100)$$

$$\boldsymbol{F} = 2.00 \times 10^{-3} \text{ N into the page}$$

c

$$\boldsymbol{F} = \boldsymbol{I}l\boldsymbol{B} = (5.00)(10.0 \times 10^{-3})(1.00)$$

$$\boldsymbol{F} = 5.00 \times 10^{-2} \text{ N into the page}$$

22 **a** Out of the page

b Into the page

23 Zero

24 **a** Attraction

b Attraction

c Repulsion

25 Zero

26

$$\frac{\boldsymbol{F}_{c}}{l} = \boldsymbol{I}\boldsymbol{B}_{\perp} = (1.00)(2.00) = 2.00 \text{ N m}^{-1}$$

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27

$\boldsymbol{I} = 1.0$ A $\qquad$ $\boldsymbol{F} = \boldsymbol{I}l\boldsymbol{B} = (1.0)(0.50)(0.20)$

$l = 0.50$ m $\qquad$ $\boldsymbol{F} = 0.10$ N

$\boldsymbol{B}_{\perp} = 0.20$ T

28 Anticlockwise

29 D

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Chapter 4 Generating electricity

4.1 Magnetic flux and induced currents

1

$$\Phi_{0.00} = \boldsymbol{B}A\cos\theta = (2.00\times10^{-3})(0.0400\times0.0400)(\cos 0.00^\circ)$$
$$\Phi_{0.00} = 3.20\times10^{-6}\ \text{Wb}$$

$$\Phi_{45.0} = \boldsymbol{B}A\cos\theta = (2.00\times10^{-3})(0.0400\times0.0400)(\cos 45.0^\circ)$$
$$\Phi_{45.0} = 2.26\times10^{-6}\ \text{Wb}$$

$$\Phi_{60.0} = \boldsymbol{B}A\cos\theta = (2.00\times10^{-3})(0.0400\times0.0400)(\cos 60.0^\circ)$$
$$\Phi_{60.0} = 1.60\times10^{-6}\ \text{Wb}$$

$$\Phi_{90.0} = \boldsymbol{B}A\cos\theta = (2.00\times10^{-3})(0.0400\times0.0400)(\cos 90.0^\circ)$$
$$\Phi_{90.0} = 0\ \text{Wb}$$

2

$$\Delta\Phi_{0\text{ to }45} = \Phi_{45.0} - \Phi_{0.00} = (2.26\times10^{-6}) - (3.20\times10^{-6})$$
$$\Delta\Phi_{0\text{ to }45} = -9.37\times10^{-7}\ \text{Wb}$$

$$\Delta\Phi_{0\text{ to }60} = \Phi_{60.0} - \Phi_{0.00} = (1.60\times10^{-6}) - (3.20\times10^{-6})$$
$$\Delta\Phi_{0\text{ to }60} = -1.60\times10^{-6}\ \text{Wb}$$

$$\Delta\Phi_{45\text{ to }90} = \Phi_{90.0} - \Phi_{45.0} = (0) - (2.26\times10^{-6})$$
$$\Delta\Phi_{45\text{ to }90} = -2.26\times10^{-6}\ \text{Wb}$$

$$\Delta\Phi_{0\text{ to }90} = \Phi_{90.0} - \Phi_{0.00} = (0) - (3.20\times10^{-6})$$
$$\Delta\Phi_{0\text{ to }90} = -3.20\times10^{-6}\ \text{Wb}$$

3 **a**

$$\Delta\Phi = \Phi_f - \Phi_i = \boldsymbol{B}A\cos\theta_f - \boldsymbol{B}A\cos\theta_i$$
$$\Delta\Phi = (0)(0.0400\times0.0400)(\cos 0.00^\circ) - (3.20\times10^{-6})$$
$$\Delta\Phi = -3.20\times10^{-6}\ \text{Wb}$$

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b

$$\Delta\Phi = \Phi_f - \Phi_i = BA\cos\theta_f - BA\cos\theta_i$$
$$\Delta\Phi = (-3.20\times10^{-6}) - (3.20\times10^{-6})$$
$$\Delta\Phi = -6.40\times10^{-6}\ \text{Wb}$$

c

$$\Delta\Phi = \Phi_f - \Phi_i = BA\cos\theta_f - BA\cos\theta_i$$
$$\Delta\Phi = (4.00\times10^{-3})(0.0400\times0.0400)(\cos0.00) - (3.20\times10^{-6})$$
$$\Delta\Phi = (6.40\times10^{-6}) - (3.20\times10^{-6})$$
$$\Delta\Phi = 3.20\times10^{-6}\ \text{Wb}$$

d

$$\Delta\Phi = \Phi_f - \Phi_i = BA\cos\theta_f - BA\cos\theta_i$$
$$\Delta\Phi = (1.00\times10^{-3})(0.0400\times0.0400)(\cos0.00) - (3.20\times10^{-6})$$
$$\Delta\Phi = (1.60\times10^{-6}) - (3.20\times10^{-6})$$
$$\Delta\Phi = -1.60\times10^{-6}\ \text{Wb}$$

4 **a** Zero
b Negative
c Positive
d Negative

5 There must be a changing magnetic flux in the conductor that makes the coil, and the coil must be part of a complete circuit.

6 As S is closed a current in Y grows, which deflects the galvanometer needle to the right, and then drops to zero.
While S is closed, no current flows.
As S is opened a larger current in Y grows, which deflects the galvanometer needle to the left, and then drops to zero.

7 As the current in X steadily decreases the current in Y is constant and deflects the galvanometer needle to the left.
As the current in X steadily increases the current in Y is constant and deflects the galvanometer needle to the right.

8 **a**

$r = 4.00\times10^{-2}\ \text{m}$ $\qquad \Phi = BA = B\pi r^2 = (2.00\times10^{-3})\pi(4.00\times10^{-2})^2$

$B = 2.00\times10^{-3}\ \text{T}$ $\qquad \Phi = 1.01\times10^{-5}\ \text{Wb}$

b Zero

9 **a**

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$$\Delta\Phi = \Phi_f - \Phi_i = (0) - (1.01\times10^{-5})$$
$$\Delta\Phi = -1.01\times10^{-5}\ \text{Wb}$$

b

$$\frac{\Delta\Phi}{\Delta t} = \frac{(-1.01\times10^{-5})}{(1.00\times10^{-3})}$$
$$\frac{\Delta\Phi}{\Delta t} = -1.01\times10^{-2}\ \text{Wb s}^{-1}$$

c 4.00 mA flowing from Y to X through the milliammeter.

10 a

$$\Delta\Phi = \Phi_f - \Phi_i = (-1.01\times10^{-5}) - (1.01\times10^{-5})$$
$$\Delta\Phi = -2.02\times10^{-5}\ \text{Wb}$$

$$\frac{\Delta\Phi}{\Delta t} = \frac{(-2.02\times10^{-5})}{(1.00\times10^{-3})}$$
$$\frac{\Delta\Phi}{\Delta t} = -2.02\times10^{-2}\ \text{Wb s}^{-1}$$

This is double the change of flux

$\therefore$ induced current is 8.00 mA from X to Y

b

$r = 2.00\times10^{-2}$ m $\qquad \Phi = \boldsymbol{B}A = \boldsymbol{B}\pi r^2 = (2.00\times10^{-3})\pi(2.00\times10^{-2})^2$

$\boldsymbol{B} = 2.00\times10^{-3}$ T $\qquad \Phi = 2.51\times10^{-6}$ Wb

$$\Delta\Phi = \Phi_f - \Phi_i = (0) - (2.51\times10^{-6})$$
$$\Delta\Phi = -2.51\times10^{-6}\ \text{Wb}$$

$$\frac{\Delta\Phi}{\Delta t} = \frac{(-2.51\times10^{-6})}{(1.00\times10^{-3})}$$
$$\frac{\Delta\Phi}{\Delta t} = -2.51\times10^{-3}\ \text{Wb s}^{-1}$$

This is one-quarter the change of flux

$\therefore$ induced current is 1.00 mA from X to Y

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c

$\Delta\Phi = \Phi_f - \Phi_i = (0) - (1.01\times10^{-5})$

$\Delta\Phi = -1.01\times10^{-5}$ Wb

$\frac{\Delta\Phi}{\Delta t} = \frac{(-1.01\times10^{-5})}{(2.00\times10^{-3})}$

$\frac{\Delta\Phi}{\Delta t} = -5.03\times10^{-3}$ Wb s^{-1}

This is half the change of flux

$\therefore$ induced current is 2.00 mA from X to Y

4.2 Induced EMF: Faraday's law

1 a

$B_\perp = 2.00\times10^{-3}$ T

$\Phi = B_\perp A = (2.00\times10^{-3})(0.02\times0.03)$

$\Phi = 1.2\times10^{-6}$ Wb

b Zero

c

$\Phi_i = 1.2\times10^{-6}$ Wb

$\Phi_f = 0$ Wb

$\Delta t = 40\times10^{-3}$ s

$\text{EMF} = -\frac{\Delta\Phi}{\Delta t} = -\frac{(0)-(1.2\times10^{-6})}{(40\times10^{-3})}$

$\text{EMF} = 3.0\times10^{-5}$ V

d

$\text{EMF} = 3.0\times10^{-5}$ V

$R = 1.50\ \Omega$

$I = \frac{\Delta V}{R} = \frac{(3.0\times10^{-5})}{(1.50)}$

$I = 2.0\times10^{-5}$ A

2 a

$B_{\perp i} = 80.0\times10^{-3}$ T

$B_{\perp f} = 0$ T

$A = 10.0$ cm^2

$A = 10.0\times10^{-4}$ m^2

$\Delta\Phi = \Phi_f - \Phi_i = B_{\perp f}A - B_{\perp i}A$

$\Delta\Phi = (0)(10.0\times10^{-4}) - (80.0\times10^{-3})(10.0\times10^{-4})$

$\Delta\Phi = -8.00\times10^{-5}$ Wb

b

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$\Delta\Phi = -8.00\times10^{-5}$ Wb $\quad \text{EMF} = -\dfrac{\Delta\Phi}{\Delta t} = -\dfrac{(-8.00\times10^{-5})}{(20\times10^{-3})}$

$\Delta t = 20\times10^{-3}$ s $\quad \text{EMF} = 4.00\times10^{-3}$ V

c

$\Delta\Phi = -8.00\times10^{-5}$ Wb $\quad \text{EMF} = -N\dfrac{\Delta\Phi}{\Delta t} = -(500)\dfrac{(-8.00\times10^{-5})}{(20\times10^{-3})}$

$\Delta t = 20\times10^{-3}$ s $\quad \text{EMF} = 2.00$ V

$N = 500$

3 **a**

$\boldsymbol{B}_\perp = 5.00\times10^{-3}$ T $\quad \Delta\Phi = \Phi_f - \Phi_i = \boldsymbol{B}_\perp A_f - \boldsymbol{B}_\perp A_i$

$A_i = 50.0$ cm^2 $\quad \Delta\Phi = (5.00\times10^{-3})(250.0\times10^{-4}) - (5.00\times10^{-3})(50.0\times10^{-4})$

$A_i = 50.0\times10^{-4}$ m^2 $\quad \Delta\Phi = (1.25\times10^{-4}) - (2.50\times10^{-5})$

$A_f = 250.0$ cm^2 $\quad \Delta\Phi = 1.00\times10^{-4}$ Wb

$A_f = 250.0\times10^{-4}$ m^2

b

$\Delta\Phi = 1.00\times10^{-4}$ Wb $\quad \text{EMF} = -N\dfrac{\Delta\Phi}{\Delta t} = -(30)\dfrac{(1.00\times10^{-4})}{(0.500)}$

$\Delta t = 0.500$ s $\quad \text{EMF} = -6.00\times10^{-3}$ V

$N = 30$

4 **a**

$\boldsymbol{B}_\perp = 4.42\times10^{-5}$ T $\quad \Phi = \boldsymbol{B}_\perp A = (4.42\times10^{-5})\pi(4.00)^2$

$r = 4.00$ m $\quad \Phi = 2.22\times10^{-3}$ Wb

b

$\Delta\Phi = 2.22\times10^{-3}$ Wb $\quad \text{EMF} = -N\dfrac{\Delta\Phi}{\Delta t} = -(1)\dfrac{(2.22\times10^{-3})}{(0.125)}$

$f = 8.00$ Hz $\quad \text{EMF} = -1.78\times10^{-2}$ V

$\Delta t = 0.125$ s

5 D

6

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$A = 1.60 \times 10^{-3}\ \text{m}^2$ $\qquad l = \sqrt{A} = \sqrt{(1.60 \times 10^{-3})} = 4.00 \times 10^{-2}\ \text{m}$

$v = 2.5\ \text{m s}^{-1}$

$\text{EMF} = 5.0 \times 10^{-3}\ \text{V}$ $\qquad \Delta t = \dfrac{s}{v} = \dfrac{(4.00 \times 10^{-2})}{(2.5)} = 1.60 \times 10^{-2}\ \text{s}$

$$\text{EMF} = -N\frac{\Delta\Phi}{\Delta t}$$

$$\Delta\Phi = \frac{EMF\,\Delta t}{-N} = \frac{(5.0 \times 10^{-3})(1.60 \times 10^{-2})}{-1}$$

$$\Delta\Phi = -8.00 \times 10^{-5}\ \text{Wb}$$

$$\boldsymbol{B} = \frac{\Phi_f}{A} = \frac{(8.00 \times 10^{-5})}{(1.60 \times 10^{-3})}$$

$$\boldsymbol{B} = 5.00 \times 10^{-2}\ \text{T}$$

7 C

8 **a** Out of the page

b Into the page

c Out of the page

9 **a** Positive

b Positive

c Negative

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4.3 Electric power generation

1

$B = 5.00 \times 10^{-3}$ T

$A = 20.0 \times 10^{-4}$ m^2

$\Phi_{0.00} = BA\cos\theta = (5.00 \times 10^{-3})(20.0 \times 10^{-4})(\cos 0.00)$

$\Phi_{0.00} = 1.00 \times 10^{-5}$ Wb

$\Phi_{15.0} = BA\cos\theta = (5.00 \times 10^{-3})(20.0 \times 10^{-4})(\cos 15.0)$

$\Phi_{15.0} = 9.66 \times 10^{-6}$ Wb

$\Phi_{30.0} = BA\cos\theta = (5.00 \times 10^{-3})(20.0 \times 10^{-4})(\cos 30.0)$

$\Phi_{30.0} = 8.66 \times 10^{-6}$ Wb

$\Phi_{45.0} = BA\cos\theta = (5.00 \times 10^{-3})(20.0 \times 10^{-4})(\cos 45.0)$

$\Phi_{45.0} = 7.07 \times 10^{-6}$ Wb

$\Phi_{60.0} = BA\cos\theta = (5.00 \times 10^{-3})(20.0 \times 10^{-4})(\cos 60.0)$

$\Phi_{60.0} = 5.00 \times 10^{-6}$ Wb

$\Phi_{75.0} = BA\cos\theta = (5.00 \times 10^{-3})(20.0 \times 10^{-4})(\cos 75.0)$

$\Phi_{75.0} = 2.590 \times 10^{-6}$ Wb

$\Phi_{90.0} = BA\cos\theta = (5.00 \times 10^{-3})(20.0 \times 10^{-4})(\cos 90.0)$

$\Phi_{90.0} = 0$ Wb

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2

$\boldsymbol{B} = 5.00 \times 10^{-3}$ T

$A = 20.0 \times 10^{-4}$ m^2

$\Delta t = 1.00 \times 10^{-3}$ s

$$\frac{\Delta\Phi_{0-15}}{\Delta t} = \frac{\Phi_{15.0} - \Phi_{0.00}}{\Delta t} = \frac{(9.66 \times 10^{-6}) - (1.00 \times 10^{-5})}{(1.00 \times 10^{-3})}$$

$$\frac{\Delta\Phi_{0-15}}{\Delta t} = -3.41 \times 10^{-4} \text{ Wb s}^{-1}$$

$$\frac{\Delta\Phi_{15-30}}{\Delta t} = \frac{\Phi_{30.0} - \Phi_{15.0}}{\Delta t} = \frac{(8.66 \times 10^{-6}) - (9.66 \times 10^{-6})}{(1.00 \times 10^{-3})}$$

$$\frac{\Delta\Phi_{15-30}}{\Delta t} = -9.99 \times 10^{-4} \text{ Wb s}^{-1}$$

$$\frac{\Delta\Phi_{30-45}}{\Delta t} = \frac{\Phi_{45.0} - \Phi_{30.0}}{\Delta t} = \frac{(7.07 \times 10^{-6}) - (8.66 \times 10^{-6})}{(1.00 \times 10^{-3})}$$

$$\frac{\Delta\Phi_{30-45}}{\Delta t} = -1.59 \times 10^{-3} \text{ Wb s}^{-1}$$

$$\frac{\Delta\Phi_{45-60}}{\Delta t} = \frac{\Phi_{60.0} - \Phi_{45.0}}{\Delta t} = \frac{(5.00 \times 10^{-6}) - (7.07 \times 10^{-6})}{(1.00 \times 10^{-3})}$$

$$\frac{\Delta\Phi_{45-60}}{\Delta t} = -2.07 \times 10^{-3} \text{ Wb s}^{-1}$$

$$\frac{\Delta\Phi_{60-75}}{\Delta t} = \frac{\Phi_{75.0} - \Phi_{60.0}}{\Delta t} = \frac{(2.59 \times 10^{-6}) - (5.00 \times 10^{-6})}{(1.00 \times 10^{-3})}$$

$$\frac{\Delta\Phi_{60-75}}{\Delta t} = -2.41 \times 10^{-3} \text{ Wb s}^{-1}$$

$$\frac{\Delta\Phi_{75-90}}{\Delta t} = \frac{\Phi_{90.0} - \Phi_{75.0}}{\Delta t} = \frac{(0) - (2.59 \times 10^{-6})}{(1.00 \times 10^{-3})}$$

$$\frac{\Delta\Phi_{75-90}}{\Delta t} = -2.59 \times 10^{-3} \text{ Wb s}^{-1}$$

3 The rate of change of flux increases as the angle increases.

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4

$$\text{EMF} = -N\frac{\Delta\Phi_{0-15}}{\Delta t} = -(100)(-3.41\times10^{-4}) = 3.41\times10^{-2}\text{ V}$$

$N = 100$

$$\text{EMF} = -\frac{\Delta\Phi_{15-30}}{\Delta t} = -(100)(-9.99\times10^{-4}) = 9.99\times10^{-2}\text{ V}$$

$$\text{EMF} = -\frac{\Delta\Phi_{30-45}}{\Delta t} = -(100)(-1.59\times10^{-3}) = 1.59\times10^{-1}\text{ V}$$

$$\text{EMF} = -\frac{\Delta\Phi_{45-60}}{\Delta t} = -(100)(-2.07\times10^{-3}) = 2.07\times10^{-1}\text{ V}$$

$$\text{EMF} = -\frac{\Delta\Phi_{60-75}}{\Delta t} = -(100)(-2.41\times10^{-3}) = 2.41\times10^{-1}\text{ V}$$

$$\text{EMF} = -\frac{\Delta\Phi_{75-90}}{\Delta t} = -(100)(-2.59\times10^{-3}) = 2.59\times10^{-1}\text{ V}$$

5 **a** At 90° as the rate of change of flux is maximum at this point, the wire is moving perpendicular to the lines of flux at this point.

b

$A = 20.0\times10^{-4}\text{ m}^2$ $\qquad l = \sqrt{20.0\times10^{-4}} = 4.47\times10^{-2}\text{ m}$

$\boldsymbol{B}_\perp = 5.00\times10^{-3}\text{ T}$ $\qquad r = \frac{l}{2} = 2.236\times10^{-2}\text{ m}$

$T = 24.0\times10^{-3}\text{ s}$ $\qquad v = \frac{2\pi r}{T} = \frac{2\pi(2.236\times10^{-2})}{(24.0\times10^{-3})} = 5.85\times10^{1}\text{ m s}^{-1}$

$N = 100$

$$\text{EMF} = 2Nv\boldsymbol{B}_\perp l = 2(100)(5.85\times10^{1})(5.00\times10^{-3})(4.47\times10^{-2})$$
$$\text{EMF} = 2.62\text{ V}$$

6 B

7 **a** C

b D

c C

d B

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e D

8

$N = 1000$ $\quad T = \dfrac{1}{f} = \dfrac{1}{(50.0)} = 0.0200\ \text{s}$

$f = 50.0\ \text{Hz}$ $\quad \Delta t = \dfrac{T}{4} = \dfrac{(0.0200)}{4} = 5.00\times10^{-3}\ \text{s}$

$r = 10.0\times10^{-2}\ \text{m}$

$V_\text{P} = 8.00\times10^{3}\ \text{V}$ $\quad V_\text{RMS} = \dfrac{V_\text{P}}{\sqrt{2}} = \dfrac{(8000)}{\sqrt{2}} = 5.66\times10^{3}\ \text{V}$

$$\text{EMF} = -N\frac{\Delta\Phi}{\Delta t}$$

$$\Phi_\text{f} - \Phi_\text{i} = \frac{\text{EMF}\Delta t}{-N} = \frac{(5.66\times10^{3})(5.00\times10^{-3})}{-(1000)}$$

$$(0) - \boldsymbol{B}A_\text{i} = -2.83\times10^{-2}$$

$$\boldsymbol{B} = \frac{-2.83\times10^{-2}}{-\pi(10.0\times10^{-2})^2}$$

$$\boldsymbol{B} = 0.900\ \text{T}$$

9 **a**

$$V_\text{P} = \sqrt{2}\times V_\text{RMS} = \sqrt{2}\times(240)$$

$$V_\text{P} = 339\ \text{V}$$

b

$$V_\text{P-P} = 2\times V_\text{P} = 2\times(339)$$

$$V_\text{P-P} = 679\ \text{V}$$

c

$V_\text{RMS} = 240\ \text{V}$ $\quad I_\text{RMS} = \dfrac{V_\text{RMS}}{R} = \dfrac{(240)}{(100)} = 2.40\ \text{A}$

$R = 100\ \Omega$

$$I_\text{P} = \sqrt{2}\times I_\text{RMS} = \sqrt{2}\times(2.40)$$

$$I_\text{P} = 3.39\ \text{A}$$

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d

$$V_{\text{RMS}} = 240 \text{ V} \qquad I_{\text{RMS}} = \frac{V_{\text{RMS}}}{R} = \frac{(240)}{(100)} = 2.40 \text{ A}$$

$$R = 100\ \Omega$$

10 **a**

$$V_{\text{RMS}} = 240 \text{ V} \qquad P = \frac{V_{\text{RMS}}{}^2}{R}$$

$$P = 600 \text{ W} \qquad R = \frac{V_{\text{RMS}}{}^2}{P} = \frac{(240)^2}{(600)}$$

$$R = 96.0\ \Omega$$

b

$$V_{\text{P}} = \sqrt{2} \times V_{\text{RMS}} = \sqrt{2} \times (240)$$

$$V_{\text{P}} = 339 \text{ V}$$

c

$$V_{\text{P}} = 339 \text{ V} \qquad P = \tfrac{1}{2} V_{\text{P}} I_{\text{P}}$$

$$P = 600 \text{ W} \qquad I_{\text{P}} = \frac{2P}{V_{\text{P}}} = \frac{2(600)}{(339)}$$

$$I_{\text{P}} = 3.54 \text{ A}$$

4.4 Transformers

1 **a** $V_{\text{p}} = -N_1 \dfrac{\Delta\Phi_{\text{B}}}{\Delta t}$

b $V_{\text{s}} = -N_2 \dfrac{\Delta\Phi_{\text{B}}}{\Delta t}$

c $\dfrac{V_{\text{p}}}{V_{\text{s}}} = \dfrac{N_1}{N_2}$

2 **a** A, B, D

b A, B, D

3 **a** A

b B, D

4 Power losses occur when electrical energy is converted into heat energy in the copper windings and in the iron core. Energy losses in the core are due to eddy currents.

5 **a** B

b D

c A

6 **a**

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$V_p = 8.00\ \text{V}$ $\qquad \dfrac{V_p}{V_s} = \dfrac{N_p}{N_s}$

$N_p = 20\ \text{turns}$ $\qquad V_s = \dfrac{V_p N_s}{N_p} = \dfrac{(8.00)(200)}{(20)}$

$N_s = 200\ \text{turns}$ $\qquad V_s = 80.0\ \text{V}$

b

Assume 100% efficient

$V_p = 8.00\ \text{V}$ $\qquad V_p I_p = V_s I_s$

$I_p = 2.00\ \text{A}$ $\qquad I_s = \dfrac{V_p I_p}{V_s} = \dfrac{(8.00)(2.00)}{(80.0)}$

$V_s = 80.0\ \text{V}$ $\qquad I_s = 0.200\ \text{A}$

c

Assume 100% efficient

$V_s = 80.0\ \text{V}$ $\qquad P_s = V_s I_s = (80.0)(0.200)$

$I_s = 0.200\ \text{A}$ $\qquad P_s = 16.0\ \text{W}$

7 **a**

$V_p = 240\ \text{V}$ $\qquad \dfrac{V_p}{V_s} = \dfrac{N_p}{N_s}$

$N_p = 800\ \text{turns}$ $\qquad N_s = \dfrac{N_p V_s}{V_p} = \dfrac{(800)(12.0)}{(240)}$

$V_s = 12.0\ \text{V}$ $\qquad V_s = 40.0\ \text{turns}$

b

$V_p = 240\ \text{V}$ $\qquad V_p I_p = V_s I_s$

$I_s = 2.00\ \text{A}$ $\qquad I_p = \dfrac{V_s I_s}{V_p} = \dfrac{(12.0)(2.00)}{(240)}$

$V_s = 12.0\ \text{V}$ $\qquad I_p = 0.100\ \text{A}$

c

$V_p = 240\ \text{V}$ $\qquad P_p = V_p I_p = (240)(0.100)$

$I_p = 0.100\ \text{A}$ $\qquad P_p = 24.0\ \text{W}$

8 The security light would not operate. In order for an EMF to be generated in the secondary coil a changing magnetic flux is required, a constant DC supply will create a constant field, therefore no EMF is induced in the secondary coil.

9 There is no power consumed in the primary coil during this time. This is because the change in flux in the transformer core is not causing any current in the secondary coil, so no energy is lost from the magnetic field. The change in flux in the primary coil will induce a back EMF, which is equal in magnitude and opposite in direction to the applied EMF if it is a perfect transformer. In

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reality there is some energy loss in the eddy currents in the core so some energy is used from the field and less energy is available to create the back EMF in the primary coil. This slight imbalance in the applied EMF and the back EMF results in a small current flowing in the primary coil and therefore some small power consumption occurs. This is why transformers should be unplugged when they are not being used.

Assume 2 W consumed by primary coil:

$$P = \frac{E}{\Delta t}$$

$$E = P\Delta t$$

$$E = (2)(10 \times 60)$$

$$E = 1200\ \text{J}$$

4.5 Distributing electricity

1 **a** By transforming to higher voltages the current decreases, this allows thinner cables to be used. Also the power lost by the cables is reduced significantly as $P_{\text{loss}} = I^2R$

b The corona effect limits the voltage for power transmission. Differences in potential of 1000 V per centimetre will cause current to flow through air, At 500 kV this means that any ground source must be at least 500 cm away from the active wire. This becomes problematic for the design of the transmission towers and insulators used.

2 **a**

$$P_{\text{ps}} = 500 \times 10^6\ \text{W} \qquad I_{\text{tl}} = \frac{P_{\text{ps}}}{V_{\text{ps}}} = \frac{(500 \times 10^6)}{(250 \times 10^3)}$$

$$V_{\text{ps}} = 250 \times 10^3\ \text{V} \qquad I_{\text{tl}} = 2.00 \times 10^3\ \text{A}$$

b

$$P_{\text{ps}} = 500 \times 10^6\ \text{W} \qquad I_{\text{tl}} = \frac{P_{\text{ps}}}{V_{\text{ps}}} = \frac{(500 \times 10^6)}{(500 \times 10^3)}$$

$$V_{\text{ps}} = 500 \times 10^3\ \text{V} \qquad I_{\text{tl}} = 1.00 \times 10^3\ \text{A}$$

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3 **a**

$R_{tl} = 10.0\ \Omega$ $\quad P_{loss} = I_{tl}^{\ 2} R_{tl} = (2.00 \times 10^3)^2 (10.0)$

$I_{tl} = 2.00 \times 10^3\ \text{A}$ $\quad P_{loss} = 4.00 \times 10^7\ \text{W}$

$$\% P_{loss} = \frac{P_{loss}}{P_{ps}} \times 100 = \frac{(4.00 \times 10^7)}{(500 \times 10^6)} \times 100$$

$$\% P_{loss} = 8.00\%$$

b

$R_{tl} = 10.0\ \Omega$ $\quad P_{loss} = I_{tl}^{\ 2} R_{tl} = (1.00 \times 10^3)^2 (10.0)$

$I_{tl} = 1.00 \times 10^3\ \text{A}$ $\quad P_{loss} = 1.00 \times 10^7\ \text{W}$

$$\% P_{loss} = \frac{P_{loss}}{P_{ps}} \times 100 = \frac{(1.00 \times 10^7)}{(500 \times 10^6)} \times 100$$

$$\% P_{loss} = 2.00\%$$

4

$I_{tl} = 1.00 \times 10^3\ \text{A}$ $\quad R_1 = \frac{\rho \ell}{A} = \frac{\rho \ell_1}{\pi r_1^2}$

$$R_2 = \frac{\rho \ell_2}{\pi r_2^{\ 2}} = \frac{\rho 2 \ell_1}{\pi (2 r_1)^2} = \frac{2}{4} \frac{\rho \ell_1}{\pi r_1^2} = 0.5 \times R_1$$

$$P_{loss} = I_{tl}^{\ 2} R_{tl} = (1.00 \times 10^3)^2 (5.0)$$

$$P_{loss} = 5.00 \times 10^6\ \text{W}$$

$$\% P_{loss} = \frac{P_{loss}}{P_{ps}} \times 100 = \frac{(5.00 \times 10^6)}{(500 \times 10^6)} \times 100$$

$$\% P_{loss} = 1.00\%$$

5 **a**

$P_{spg} = 5.00 \times 10^3\ \text{W}$ $\quad I_{tl} = \frac{P_{spg}}{V_{spg}} = \frac{(5.00 \times 10^3)}{(500)}$

$V_{spg} = 500\ \text{V}$ $\quad I_{tl} = 10.0\ \text{A}$

b

$R_{tl} = 4.00\ \Omega$ $\quad P_{loss} = I_{tl}^{\ 2} R_{tl} = (10.0)^2 (4.00)$

$I_{tl} = 10.0\ \text{A}$ $\quad P_{loss} = 4.00 \times 10^2\ \text{W}$

c

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$$\%P_{\text{loss}} = \frac{P_{\text{loss}}}{P_{\text{spg}}} \times 100 = \frac{(4.00 \times 10^{2})}{(5.00 \times 10^{3})} \times 100$$
$$\%P_{\text{loss}} = 8.00\%$$

d

$I_{\text{tl}} = 10.0\ \text{A}$ $\qquad$ $\Delta V_{\text{tl}} = IR = (10.0)(4.00)$

$R = 4.00\ \Omega$ $\qquad$ $\Delta V_{\text{tl}} = 40.0\ \text{V}$

$$V_{\text{house}} = V_{\text{spg}} - \Delta V_{\text{tl}}$$
$$V_{\text{house}} = (5.00 \times 10^{2}) - (40.0)$$
$$V_{\text{house}} = 4.60 \times 10^{2}\ \text{V}$$

6 **a**

$P_{\text{spg}} = 5.00 \times 10^{3}\ \text{W}$ $\qquad$ $I_{\text{tl}} = \dfrac{P_{\text{spg}}}{V_{\text{spg}}} = \dfrac{(5.00 \times 10^{3})}{(5.00 \times 10^{3})}$

$V_{\text{spg}} = 5.00 \times 10^{3}\ \text{V}$ $\qquad$ $I_{\text{tl}} = 1.00\ \text{A}$

b

$R_{\text{tl}} = 4.00\ \Omega$ $\qquad$ $P_{\text{loss}} = I_{\text{tl}}^{\ 2} R_{\text{tl}} = (1.00)^{2}(4.00)$

$I_{\text{tl}} = 1.00\ \text{A}$ $\qquad$ $P_{\text{loss}} = 4.00\ \text{W}$

$$\%P_{\text{loss}} = \frac{P_{\text{loss}}}{P_{\text{spg}}} \times 100 = \frac{(4.00)}{(5.00 \times 10^{3})} \times 100$$
$$\%P_{\text{loss}} = 0.0800\%$$

c

$I_{\text{tl}} = 1.00\ \text{A}$ $\qquad$ $\Delta V_{\text{tl}} = IR = (1.00)(4.00)$

$R = 4.00\ \Omega$ $\qquad$ $\Delta V_{\text{tl}} = 4.0\ \text{V}$

$$V_{\text{house}} = V_{\text{spg}} - \Delta V_{\text{tl}}$$
$$V_{\text{house}} = (5.00 \times 10^{3}) - (4.0)$$
$$V_{\text{house}} = 4.996 \times 10^{3}\ \text{V}$$

7 **a**

$P = 1.00\ \text{kW}$ $\qquad$ $E = P\Delta t = (1.00)(2.00) = 2.00\ \text{kW h}$

$\Delta t = 2.00\ \text{h}$ $\qquad$ $\text{cost} = E \times \text{rate} = (2.00)(0.14) = \$0.28$

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b

$$P = 80.0 \times 10^{-3}\ \text{kW} \qquad E = P\Delta t = (80.0 \times 10^{-3})(0.500) = 4.00 \times 10^{-2}\ \text{kW h}$$
$$\Delta t = 0.500\ \text{h} \qquad \text{cost} = E \times \text{rate} = (4.00 \times 10^{-2})(0.14) = \$0.0056$$

c

$$P = 250.0 \times 10^{-3}\ \text{kW} \qquad E = P\Delta t = (250.0 \times 10^{-3})(12.0) = 3.00\ \text{kW h}$$
$$\Delta t = 12.0\ \text{h} \qquad \text{cost} = E \times \text{rate} = (3.00)(0.14) = \$0.42$$

d

$$P = 6.00 \times 10^{-3}\ \text{kW} \qquad E = P\Delta t = (6.00 \times 10^{-3})(7 \times 24) = 1.01\ \text{kW h}$$
$$\Delta t = 7 \times 24\ \text{h} \qquad \text{cost} = E \times \text{rate} = (1.01)(0.14) = \$0.14$$

e

$$P = 3.00 \times 10^{-3}\ \text{kW} \qquad E = P\Delta t = (3.00 \times 10^{-3})(365.25 \times 24) = 26.3\ \text{kW h}$$
$$\Delta t = 365.25 \times 24\ \text{h} \qquad \text{cost} = E \times \text{rate} = (26.3)(0.14) = \$3.68$$

8 a

$$P_{\text{town}} = 500.0 \times 10^{6}\ \text{W} \qquad I_{\text{tl}} = \frac{P_{\text{town}}}{V_{\text{town}}} = \frac{(500.0 \times 10^{6})}{(250.0)}$$
$$V_{\text{town}} = 250.0\ \text{V} \qquad I_{\text{tl}} = 2.00 \times 10^{6}\ \text{A}$$

$$\Delta V = I_{\text{tl}}R_{\text{tl}} = (2.00 \times 10^{6})(2.00)$$
$$\Delta V = 4.00 \times 10^{6}\ \text{V}$$

This would be impossible.

b

$$P_{\text{town}} = 500.0 \times 10^{6}\ \text{W} \qquad I_{\text{tl}} = \frac{P_{\text{town}}}{V_{\text{town}}} = \frac{(500.0 \times 10^{6})}{(100.0 \times 10^{3})}$$
$$V_{\text{town}} = 100.0 \times 10^{3}\ \text{V} \qquad I_{\text{tl}} = 5.00 \times 10^{3}\ \text{A}$$

$$\Delta V = I_{\text{tl}}R_{\text{tl}} = (5.00 \times 10^{3})(2.00)$$
$$\Delta V = 1.00 \times 10^{4}\ \text{V}$$

$$V_{\text{ps}} = \Delta V + V_{\text{town}} = (1.00 \times 10^{4}) + (100.0 \times 10^{3})$$
$$V_{\text{ps}} = 1.10 \times 10^{5}\ \text{V}$$

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c

$I_{t1} = 5.00 \times 10^3$ A $\qquad P_{loss} = I_{t1}{}^2 R_{t1} = (5.00 \times 10^3)^2 (1.00)$

$R_{t1} = 1.00\ \Omega$ $\qquad P_{loss} = 2.50 \times 10^7$ W

9 a

$P_{wt} = 150.0 \times 10^3$ W $\qquad I_{t1} = \dfrac{P_{spg}}{V_{t1}} = \dfrac{(150.0 \times 10^3)}{(10\ 000)}$

$V_{t1} = 10\ 000$ V $\qquad I_{t1} = 15.0$ A

b

$$\Delta V = I_{t1} R_{tl} = (15.0)(2.00)$$
$$\Delta V = 30.0 \text{ V}$$

$$V_{t2} = V_{t1} - \Delta V = (10\ 000) - (30.0)$$
$$V_{t2} = 9.97 \times 10^3 \text{ V}$$

c

$I_{t1} = 15.0$ A $\qquad P_{loss} = I_{t1}{}^2 R_{tl} = (15.0)^2 (2.00)$

$R_{t1} = 2.00\ \Omega$ $\qquad P_{loss} = 4.50 \times 10^2$ W

This would not be a great problem.

10 a

$P_{wt} = 150.0 \times 10^3$ W $\qquad I_{t1} = \dfrac{P_{spg}}{V_{t1}} = \dfrac{(150.0 \times 10^3)}{(1000)}$

$V_{t1} = 1000$ V $\qquad I_{t1} = 150.0$ A

b

$$\Delta V = I_{t1} R_{tl} = (150.0)(2.00)$$
$$\Delta V = 300.0 \text{ V}$$

$$V_{t2} = V_{t1} - \Delta V = (1000) - (300.0)$$
$$V_{t2} = 7.00 \times 10^2 \text{ V}$$

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c

$I_{tl} = 150.0 \text{ A}$ $\quad P_{loss} = I_{tl}^{2} R_{tl} = (150.0)^2(2.00)$

$R_{tl} = 2.00\ \Omega$ $\quad P_{loss} = 4.50 \times 10^{4} \text{ W}$

$$P_{town} = P_{wt} - P_{loss}$$
$$P_{town} = (150.0 \times 10^{3}) - (4.50 \times 10^{4})$$
$$P_{town} = 1.05 \times 10^{5} \text{ W}$$

d No, as this results in a significant loss of power over the length of the transmission line (30%).

Chapter 4 Review

1 a

$A = 40.0 \times 10^{-4} \text{ m}^2$ $\quad \text{EMF} = -\dfrac{\Delta\Phi}{\Delta t}$

$B_{\perp 1} = 8.00 \times 10^{-4} \text{ T}$ $\quad \text{EMF} = -\dfrac{(16.0 \times 10^{-4})(40.0 \times 10^{-4}) - (8.00 \times 10^{-4})(40.0 \times 10^{-4})}{(1.00 \times 10^{-3})}$

$B_{\perp 2} = 16.0 \times 10^{-4} \text{ T}$ $\quad \text{EMF} = -3.20 \times 10^{-3} \text{ V}$

$\Delta t = 1.00 \times 10^{-3} \text{ s}$

$R = 1.00\ \Omega$ $\quad I = \dfrac{\Delta V}{R} = \dfrac{(3.20 \times 10^{-3})}{1.00} = 3.20 \times 10^{-3} \text{ A}$ clockwise

b

$A = 40.0 \times 10^{-4} \text{ m}^2$ $\quad \text{EMF} = -\dfrac{\Delta\Phi}{\Delta t}$

$B_{\perp 1} = 8.00 \times 10^{-4} \text{ T}$ $\quad \text{EMF} = -\dfrac{(-8.00 \times 10^{-4})(40.0 \times 10^{-4}) - (8.00 \times 10^{-4})(40.0 \times 10^{-4})}{(2.00 \times 10^{-3})}$

$B_{\perp 2} = -8.00 \times 10^{-4} \text{ T}$ $\quad \text{EMF} = 3.20 \times 10^{-3} \text{ V}$

$\Delta t = 2.00 \times 10^{-3} \text{ s}$

$R = 1.00\ \Omega$ $\quad I = \dfrac{\Delta V}{R} = \dfrac{(3.20 \times 10^{-3})}{1.00} = 3.20 \times 10^{-3} \text{ A}$ counterclockwise

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c

$A = 40.0 \times 10^{-4}\ \text{m}^2 \qquad \text{EMF} = -\dfrac{\Delta\Phi}{\Delta t}$

$B_{\perp 1} = 8.00 \times 10^{-4}\ \text{T} \qquad \text{EMF} = -\dfrac{(4.00 \times 10^{-4})(40.0 \times 10^{-4}) - (8.00 \times 10^{-4})(40.0 \times 10^{-4})}{(1.00 \times 10^{-3})}$

$B_{\perp 2} = 4.00 \times 10^{-4}\ \text{T} \qquad \text{EMF} = 1.60 \times 10^{-3}\ \text{V}$

$\Delta t = 1.00 \times 10^{-3}\ \text{s}$

$R = 1.00\ \Omega \qquad I = \dfrac{\Delta V}{R} = \dfrac{(1.60 \times 10^{-3})}{1.00} = 1.60 \times 10^{-3}\ \text{A}$ clockwise

2 **a**

$A = 40.0 \times 10^{-4}\ \text{m}^2 \qquad l = \sqrt{A} = \sqrt{40.0 \times 10^{-4}} = 6.32 \times 10^{-2}\ \text{m}$

$B_{\perp} = 8.00 \times 10^{-4}\ \text{T} \qquad C = 2\pi r = \dfrac{2\pi l}{2} = \pi(6.32 \times 10^{-2}) = 1.99 \times 10^{-1}\ \text{m}$

$f = 100\ \text{Hz} \qquad T = \dfrac{1}{f} = \dfrac{1}{(100)} = 1.00 \times 10^{-2}\ \text{s}$

$v = \dfrac{C}{T} = \dfrac{(1.99 \times 10^{-1})}{(1.00 \times 10^{-2})} = 1.99 \times 10^{1}\ \text{m s}^{-1}$

$\text{EMF} = 2Blv = 2(8.00 \times 10^{-4})(6.32 \times 10^{-2})(1.99 \times 10^{1})$

$\text{EMF} = 2.01 \times 10^{-3}\ \text{V}$

b

$\text{EMF} = 2.01 \times 10^{-3}\ \text{V} \qquad I_{\text{peak}} = \dfrac{\Delta V}{R} = \dfrac{(2.01 \times 10^{-3})}{(1.00)}$

$R = 1.00\ \Omega \qquad I_{\text{peak}} = 2.01 \times 10^{-3}\ \text{A}$

3 **a** current halved to 1.00 mA, period doubled to 20 ms = A

b current same as 2.01 mA, period halved to 5 ms = C

c current halved to 1.00 mA, period same as 10 ms = B

4 **a** To the left, as the soft iron core is induced to become a temporary magnet by the permanent magnet's field.

b To the left, attraction.

c To the right, repulsion.

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5

$$r = 4.00 \times 10^{-2}\ \text{m} \qquad \text{EMF} = -N\frac{\Delta\Phi}{\Delta t}$$

$$B_{\perp} = 20.0 \times 10^{-3}\ \text{T} \qquad \text{EMF} = -(40)\frac{(0) - (20.0 \times 10^{-3})\left(\pi \times (4.00 \times 10^{-2})^{2}\right)}{(0.100)}$$

$$N = 40\ \text{turns} \qquad \text{EMF} = 4.02 \times 10^{-2}\ \text{V}$$

$$\Delta t = 0.100\ \text{s}$$

$$R = 2.00\ \Omega \qquad I = \frac{\Delta V}{R} = \frac{(4.02 \times 10^{-2})}{(2.00)} = 2.01 \times 10^{-2}\ \text{A} \quad \text{from Y to X}$$

6 A, C

7 The direction would be from X to Y as according to Lenz's law the EMF will be induced in a direction that causes a current that creates a magnetic field that opposes the change that is causing the current. Current from X to Y will cause a north pole at the top and a south at the bottom of the coil, which will oppose the north at the top of and the south at the bottom of the permanent magnet.

8 **a**

$$B_{\perp} = 10.0 \times 10^{-3}\ \text{T} \qquad \text{EMF} = Blv = (10.0 \times 10^{-3})(20.0 \times 10^{-2})(2.00)$$

$$l = 20.0 \times 10^{-2}\ \text{m} \qquad \text{EMF} = 4.00 \times 10^{-3}\ \text{V}$$

$$v = 2.00\ \text{m s}^{-1}$$

$$R = 1.00\ \Omega \qquad I = \frac{\Delta V}{R} = \frac{(4.00 \times 10^{-3})}{(1.00)} = 4.00 \times 10^{-3}\ \text{A} \quad \text{from X to Y}$$

b

$$B_{\perp} = 10.0 \times 10^{-3}\ \text{T} \qquad \boldsymbol{F} = IlB = (4.00 \times 10^{-3})(20.0 \times 10^{-2})(10.0 \times 10^{-3})$$

$$l = 20.0 \times 10^{-2}\ \text{m} \qquad \boldsymbol{F} = 8.00 \times 10^{-6}\ \text{N to the left}$$

$$I = 4.00 \times 10^{-3}\ \text{A}$$

9 There is no induced current as there isn't a complete circuit, as the switch is open.

10

$$B_{\perp} = 1.00\ \text{T} \qquad \boldsymbol{F} = IlB_{\perp} = (1.00)(5.00 \times 10^{-2})(1.00)$$

$$l = 5.00 \times 10^{-2}\ \text{m} \qquad \boldsymbol{F} = 5.00 \times 10^{-2}\ \text{N}$$

$$I = 1.00\ \text{A}$$

11 To the right

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12

$B_\perp = 1.00 \text{ T}$ $\quad$ $\boldsymbol{F} = IlB_\perp = (1.00)(1.00\times10^{-2})(1.00)$

$l = 1.00\times10^{-2} \text{ m}$ $\quad$ $\boldsymbol{F} = 1.00\times10^{-2} \text{ N}$

$I = 1.00 \text{ A}$

13 To the left

14 **a**

$B_\perp = 5.00\times10^{-5} \text{ T}$ $\quad$ $\text{EMF} = Blv = (5.00\times10^{-5})(8.00)(4.00)$

$l = 8.00 \text{ m}$ $\quad$ $\text{EMF} = 1.60\times10^{-3} \text{ V}$

$v = 4.00 \text{ m s}^{-1} \text{ W}$

b Zero current is induced in the loop, as both vertical sides of the loop have an EMF induced in the same direction (downwards). This means that each side produces equal and opposing EMFs so no current flows in the loop.

15

$A = 40.0 \text{ m}^2$ $\quad$ $\text{EMF} = -N\dfrac{\Delta\Phi}{\Delta t}$

$B_\perp = 1.00\times10^{-5} \text{ T s}^{-1}$ $\quad$ $\text{EMF} = -(1)\dfrac{(1.00\times10^{-5})(40.0)}{(1.00)}$

$N = 1 \text{ turn}$ $\quad$ $\text{EMF} = -4.00\times10^{-4} \text{ V}$

$R = 8.00\ \Omega$

$$I = \frac{\Delta V}{R} = \frac{(4.00\times10^{-4})}{(8.00)} = 5.00\times10^{-5} \text{ A}$$

16 **a**

$l = 100.0\times10^{-3} \text{ m}$ $\quad$ $\Delta\Phi_i = B_\perp A = (1.00\times10^{-3})(100.0\times10^{-3})(50.0\times10^{-3})$

$w = 50.0\times10^{-3} \text{ m}$ $\quad$ $\Delta\Phi_i = 5.00\times10^{-6} \text{ Wb}$

$B_\perp = 1.00\times10^{-3} \text{ T}$

b

$l = 100.0\times10^{-3} \text{ m}$ $\quad$ $\Delta\Phi_f = B_\perp A = (1.00\times10^{-3})(0)$

$w = 50.0\times10^{-3} \text{ m}$ $\quad$ $\Delta\Phi_f = 0 \text{ Wb}$

$B_\perp = 1.00\times10^{-3} \text{ T}$

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c

$\Phi_i = 5.00 \times 10^{-6}$ Wb $\qquad$ $\text{EMF} = -N\dfrac{\Delta\Phi}{\Delta t}$

$\Phi_f = 0$ Wb $\qquad$ $\text{EMF} = -(1)\dfrac{(0) - \left(5.00 \times 10^{-6}\right)}{(2.00 \times 10^{-3})}$

$N = 1$ $\qquad$ $\text{EMF} = 2.50 \times 10^{-3}$ V

$\Delta t = 2.00 \times 10^{-3}$ s

d

$\Delta V = 2.50 \times 10^{-3}$ V $\qquad$ $I = \dfrac{\Delta V}{R} = \dfrac{(2.50 \times 10^{-3})}{(2.00)}$

$R = 2.00\ \Omega$ $\qquad$ $I = 1.25 \times 10^{-3}$ A

e No the current will stop. For an EMF to be induced, the flux must be changing in the loop, if it is not changing then no EMF is induced and therefore no current will flow.

17 **a** This is a quarter of the time so the EMF and therefore the current will increase by a factor of four = 2.00 × 10^{-4} A.

b

$R_{meter} = 595\ \Omega$ $\qquad$ $\Delta V = IR_{total} = (50.0 \times 10^{-6})(595 + 5.00)$

$R_{coil} = 5.00\ \Omega$ $\qquad$ $\Delta V = 3.00 \times 10^{-2}$ V

$I = 50.0 \times 10^{-6}$ A

$N = 100$ $\qquad$ $\text{EMF} = -N\dfrac{\Delta\Phi}{\Delta t} = -N\dfrac{(0) - (B \times \pi r^2)}{\Delta t}$

$r = 3.00 \times 10^{-2}$ m $\qquad$ $B = \dfrac{\text{EMF}\Delta t}{N \times \pi r^2}$

$\Delta t = 2.00$ s $\qquad$ $B = \dfrac{(3.00 \times 10^{-2})(2.00)}{(100) \times \pi(3.00 \times 10^{-2})^2}$

$B = 2.12 \times 10^{-1}$ T

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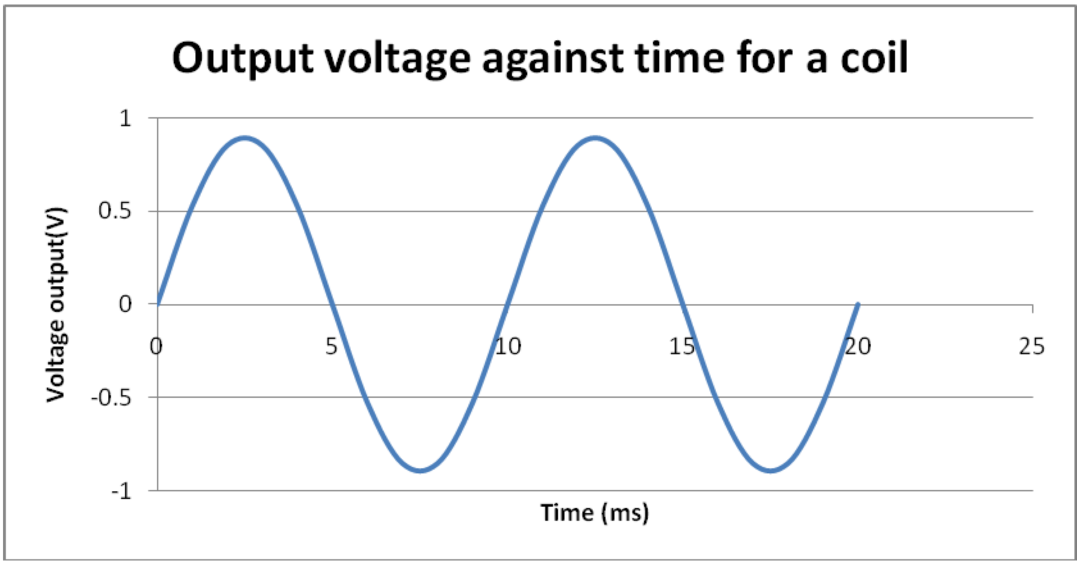
18 **a**



b

$V_{peak} = 0.900$ V $\qquad V_{RMS} = \dfrac{V_{peak}}{\sqrt{2}} = \dfrac{(0.900)}{\sqrt{2}}$

$V_{RMS} = 0.636$ V

c Period halved to 5 ms, V_{peak} doubles to 1.8 V, V_{RMS} becomes 1.3 V.

19 **a**

$V_{RMS\ p} = 14.0$ V $\qquad V_{RMS\ p} I_{RMS\ p} = V_{RMS\ s} I_{RMS\ s}$

$I_{RMS\ p} = 3.00$ A $\qquad I_{RMS\ s} = \dfrac{V_{RMS\ p} I_{RMS\ p}}{V_{RMS\ s}} = \dfrac{(14.0)(3.00)}{(42.0)}$

$V_{RMS\ s} = 42.0$ V $\qquad I_{RMS\ s} = 1.00$ A

b

$V_{RMS\ p} = 14.0$ V $\qquad \dfrac{V_{RMS\ p}}{V_{RMS\ s}} = \dfrac{N_p}{N_s}$

$N_s = 30$ $\qquad N_p = \dfrac{V_{RMS\ p} N_s}{V_{RMS\ s}} = \dfrac{(14.0)(30)}{(42.0)}$

$V_{RMS\ s} = 42.0$ V $\qquad N_p = 10$ turns

c

$V_{RMS\ p} = 14.0$ V $\qquad P_s = P_p = V_{RMS\ p} I_{RMS\ p} = (14.0)(3.00)$

$I_{RMS\ p} = 3.00$ A $\qquad P_s = 42.0$ W

20 **a** C
b A
c B

21 C

22 C

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23 **a**

$$T = 2.0 \times 10^{-3}\ \text{s} \qquad f = \frac{1}{T} = \frac{1}{(2.0 \times 10^{-3})} = 5.0 \times 10^{2}\ \text{Hz}$$

b

$$V_{\text{peak}} = 25\ \text{V} \qquad V_{\text{RMS}} = \frac{V_{\text{peak}}}{\sqrt{2}} = \frac{(25)}{\sqrt{2}}$$

$$V_{\text{RMS}} = 17.7\ \text{V}$$

c

$$V_{\text{peak}} = 25\ \text{V} \qquad V_{\text{p-p}} = 2 \times V_{\text{peak}} = 2(25)$$

$$V_{\text{p-p}} = 50\ \text{V}$$

24 **a**

$$I_{\text{peak}} = 15\ \text{A} \qquad I_{\text{RMS}} = \frac{I_{\text{peak}}}{\sqrt{2}} = \frac{(15)}{\sqrt{2}}$$

$$V_{\text{RMS}} = 17.7\ \text{V} \qquad I_{\text{RMS}} = 10.6\ \text{A}$$

$$P_{\text{RMS}} = V_{\text{RMS}} I_{\text{RMS}} = (17.7)(10.6)$$

$$P_{\text{RMS}} = 188\ \text{W}$$

b

$$I_{\text{peak}} = 15\ \text{A} \qquad P_{\text{peak}} = V_{\text{peak}} I_{\text{peak}} = (15)(25)$$

$$V_{\text{peak}} = 25\ \text{V} \qquad P_{\text{peak}} = 375\ \text{W}$$

c

$$I_{\text{RMS}} = 10.6\ \text{A} \qquad R = \frac{V_{\text{RMS}}}{I_{\text{RMS}}} = \frac{(17.7)}{(10.6)}$$

$$V_{\text{RMS}} = 17.7\ \text{V} \qquad R = 1.67\ \Omega$$

25 C

26

$$R = 15\ \Omega \qquad P = \frac{V^2}{R} = \frac{(30)^2}{(15)}$$

$$V = 30\ \text{V} \qquad P = 60\ W$$

Set C is equivalent to 60 W.

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27 **a**

$V_{\text{peak}} = 12.6\ \text{V}$

$$V_{\text{p-p}} = 2 \times V_{\text{peak}} = 2(12.6)$$
$$V_{\text{p-p}} = 25.2\ \text{V}$$

$$V_{\text{RMS}} = \frac{V_{\text{peak}}}{\sqrt{2}} = \frac{(12.6)}{\sqrt{2}}$$
$$V_{\text{RMS}} = 8.91\ \text{V}$$

b

$V_{\text{peak}} = 25.2\ \text{V}$

$$V_{\text{RMS}} = \frac{V_{\text{peak}}}{\sqrt{2}} = \frac{(25.2)}{\sqrt{2}}$$
$$V_{\text{RMS}} = 17.8\ \text{V}$$

c

$V_{\text{RMS}} = 16.0\ \text{V}$

$$V_{\text{peak}} = \sqrt{2} \times V_{\text{RMS}} = \sqrt{2} \times (16.0)$$
$$V_{\text{peak}} = 22.6\ \text{V}$$

$$\frac{V_{\text{peak 2}}}{V_{\text{peak 1}}} = \frac{f_2}{f_1}$$
$$f_2 = \frac{f_1 \times V_{\text{peak 2}}}{V_{\text{peak 1}}} = \frac{(50.0)(22.6)}{(12.6)}$$
$$f_2 = 89.8\ \text{Hz}$$

d

$V_{\text{peak}} = 12.6\ \text{V}$

$$\frac{V_{\text{peak 2}}}{V_{\text{peak 1}}} = \frac{B_2}{B_1}$$
$$V_{\text{peak 2}} = \frac{B_2 \times V_{\text{peak 1}}}{B_1} = \frac{(60.0 \times 10^{-3})(12.6)}{(80.0 \times 10^{-3})}$$
$$V_{\text{peak 2}} = 9.45\ \text{V}$$

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28 **a**

$P = 480.0\ W$ $\quad$ $P = \Delta VI$

$\Delta V = 240.0\ \text{V}$ $\quad$ $I = \dfrac{P}{\Delta V} = \dfrac{(480.0)}{(240.0)} = 2.00\ \text{A}$

$$\Delta V = IR = (2.00)(2.00) = 4.00\ \text{V}$$

$$\Delta V_{tr} = (240.0) - (4.00) = 236.0\ \text{V}$$

The machine should work satisfactorily.

b By dropping the voltage by a factor of 10 the current is increased by a factor of 10. This would result in a significant power loss over the cable.

c

$I = 20.0\ A$ $\quad$ $\Delta V = IR = (20.0)(2.00) = 40.0\ \text{V}$

$R = 2.00\ \Omega$

$$\Delta V_{\text{trans out}} = \Delta V_{\text{machine}} + \Delta V_{\text{cable}} = (24.0) + (40.0) = 64.0\ \text{V}$$

$$\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{(64.0)}{(240.0)} = 0.267$$

d

$I = 20.0\ A$ $\quad$ $P_{\text{loss}} = \Delta VI = (40.0)(20.0) = 800.0\ \text{W}$

$\Delta V = 40.0\ \text{V}$

29 Appliances with built-in transformers or motors that require AC will not function correctly and could burn out. At full load there would be a power loss of about 555 W, or about 66 V difference in potential which would only leave about 173 V potential at the farmhouse.

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30 He needs a step-down transformer with a turns ratio of 5 : 1.

$P_{\text{low}} = 500\ \text{W}$

$$I = \frac{P}{V} = \frac{(500)}{(1200)} = 0.417\ \text{A}$$

$$\Delta V_{\text{cable}} = IR = (0.417)(8.00) = 3.33\ \text{V}$$

$$V_{\text{p}} = V_{\text{gen}} - \Delta V_{\text{cable}} = (1200) - (3.33) = 1197\ \text{V}$$

$$V_{\text{s}} = \frac{1}{5}V_{\text{p}} = \frac{1}{5}(1197) = 239\ \text{V}$$

$P_{\text{half}} = 1000\ \text{W}$

$$I = \frac{P}{V} = \frac{(1000)}{(1200)} = 0.917\ \text{A}$$

$$\Delta V_{\text{cable}} = IR = (0.917)(8.00) = 7.33\ \text{V}$$

$$V_{\text{p}} = V_{\text{gen}} - \Delta V_{\text{cable}} = (1200) - (7.33) = 1193\ \text{V}$$

$$V_{\text{s}} = \frac{1}{5}V_{\text{p}} = \frac{1}{5}(1193) = 239\ \text{V}$$

$P_{\text{full}} = 2000\ \text{W}$

$$I = \frac{P}{V} = \frac{(2000)}{(1200)} = 1.67\ \text{A}$$

$$\Delta V_{\text{cable}} = IR = (1.67)(8.00) = 13.3\ \text{V}$$

$$V_{\text{p}} = V_{\text{gen}} - \Delta V_{\text{cable}} = (1200) - (13.3) = 1187\ \text{V}$$

$$V_{\text{s}} = \frac{1}{5}V_{\text{p}} = \frac{1}{5}(1187) = 237\ \text{V}$$

This set-up would suit his purposes well.

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