Physics N – Mechanics

Chapter 1 One-Dimensional Motion

Section 1.2 Displacement versus Distance

(1) **1. [G]** a. The total distance travelled by the car is:
d = (12 m – 5.0 m) + 1.0 m = 8.0 m
b. Initially, the car was 5.0 m from the origin and reaches a point 11 m away from the origin. The net displacement of the toy car is 6.0 m.

Section 1.3 Average Velocity and Average Speed

(2) **2. [G]**

a. The speed of the box is:

$$\text{speed} = \frac{d}{t}$$

$$\text{speed} = \frac{5.0 \text{ m}}{2.0 \text{ s}} = 2.5 \text{ m/s}$$

b. The velocity of the box is 2.5 m/s due East.

Section 1.6 Velocity and Average Velocity from Position-Time Graph

(3) **3. [G]** The velocity of the cyclist at t = 4 s is:

$$v = \frac{\Delta s}{\Delta t}$$

$$v = \frac{(8 \text{ m} - 24 \text{ m})}{6.0 \text{ s} - 0 \text{ s}} = -2.7 \text{ m/s}$$

Section 1.7 Acceleration

(4) **4. [G]** The acceleration of the car is:

$$a = \frac{\Delta v}{\Delta t}$$

$$a = \frac{12\ \text{m/s} - 20\ \text{m/s}}{2.0\ \text{s}} = -4.0\ \text{m/s}^2$$

Section 1.8 Velocity-Time Graphs

(5) **5. [G]**

a. The acceleration at t = 30 s is:

$$a = \frac{\Delta v}{\Delta t}$$

$$a = \frac{21\ \text{m/s} - 0\ \text{m/s}}{60\ \text{s} - 0\ \text{s}} = 0.35\ \text{m/s}^2$$

b. The magnitude of the acceleration is greatest in the time interval where the slope of the graph is greatest (in magnitude). This takes place at t between 90 s and 120 s

(6) **6. [G]** Draw a line tangent to the v-t curve at t = 10 s.
Draw a right triangle for which the tangent line is a hypotenuse
The acceleration is the slope of the tangent line = rise over run in the triangle.

Section 1.10 Displacement as the Area under the *v*-*t* Graph

(7) **7. [G]** The total displacement of the cyclist is the area under the *v*-*t* graph:

$$d = A_{[0,\,15\text{ s}]} + A_{[15\text{ s},\,20\text{ s}]}$$

$$d = \frac{1}{2}(15\text{ s} + 10\text{ s})(6\text{ m/s}) + \frac{1}{2}(5\text{ s})(6\text{ m/s}) = 90\text{ m}$$

Section 1.11 Motion with Constant Acceleration

(8) **8. [G]** The displacement of the car is given by:

$$x = \frac{1}{2}at^2 + v_0 t + x_0$$

$$x = \frac{1}{2}\left(0.20\text{ m/s}^2\right)\left(6.0\text{ s}\right)^2 + \left(0.50\text{ m/s}\right)\left(6.0\text{ s}\right) = 6.6\text{ m}$$

Section 1.12 Free Fall

(9) **9. [G]** 9.8 m/s^2

Section 1.13 One-Dimensional Relative Motion

(10) **10. [G]** The speed of the motorboat relative to a stationary observer is:

$$v = \sqrt{\left(6.0\text{ m/s}\right)^2 + \left(2.0\text{ m/s}\right)^2} = 6.3\text{ m/s}$$

Section 1.14 Integration and Differentiation: Beyond URM and UARM

(11) **11. [T]**

a. Step 1 The initial distance separating the carts is 6 m – 2 m = 4 m.

b. Step 1 Cart 1 is moving at constant speed, then its speed is the slope of the *x*-*t* graph.
Step 2 As a result, $u = 1.0$ m/s.

c. Step 1 The carts pass each other at the instant when the graphs meet, that is at $T = 2.0$ s.

d.Step 1 When the carts pass each other, they have the same position, then:

$$x_{\text{cart 1}} = x_{\text{cart 2}}$$

$$v_{\text{cart 1}}T + \left(x_{\text{cart 1}}\right)_0 = \frac{1}{2}a_{\text{cart 2}}T^2 + \left(v_{\text{cart 2}}\right)_0 T + \left(x_{\text{cart 2}}\right)_0$$

$$\left(1.0 \text{ m/s}\right)T + 2.0 \text{ m} = \frac{1}{2}a_{\text{cart 2}}T^2 + 6.0 \text{ m}$$

Step 2 Solving for T = 2.0 s yields: $a = -1 \text{ m/s}^2$

e.

Step 1 The speed of cart 2 is given by:

$$v^2 - v_0^2 = 2da$$

$$v^2 = 2da$$

Step 2

$$v = \sqrt{2da}$$

$$v = \sqrt{2\left(-6.0 \text{ m}\right)\left(-1.0 \text{ m/s}^2\right)} = 3.5 \text{ m/s}$$

Chapter 2 Motion in Two and Three Dimensions

Section 2.3 Ideal Projectile Motion

(12) 1. [G]

a. 11.5 m
b. 20 m/s
c. 61.2 m

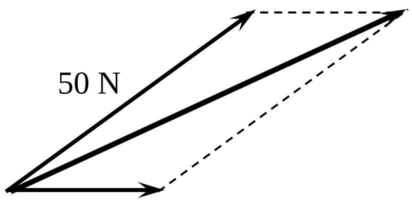
Chapter 3 Newton's Laws of Motion

Section 3.1 Describing Forces

(13) **1. [G]** No. The weight depends on the gravitational strength near a planet's surface. Since the gravitational field strength on the moon is different, so is the weight of the apple.

Section 3.3 Superposition of Forces

(14) **2. [G]** a.



b. The x-component of the resultant force is given by:

$$F_x = 20\ \text{N} + (50\ \text{N})\cos 37^\circ = 60\ \text{N}$$

The y-component of the resultant force is given by:

$$F_y = (50\ \text{N})\sin 37^\circ = 30\ \text{N}$$

The magnitude of the resultant force is then:

$$F = \sqrt{F_x^2 + F_y^2}$$

$$F = \sqrt{(60\ \text{N})^2 + (30\ \text{N})^2} = 67\ \text{N}$$

Section 3.5 Newton's Second Law of Motion

(15) **3. [G]** Applying Newton's second law of motion:

$$F = ma$$

$$F = m\frac{\Delta v}{\Delta t}$$

$$F = (800\ \text{kg})\left(\frac{0\ \text{m/s} - 20\ \text{m/s}}{4.0\ \text{s}}\right) = -4{,}000\ \text{N}$$

(16) **4. [G]** Inertia is the tendency of a moving body to carry on moving. The quantitative measure of inertia is mass.

Section 3.6 Newton's Third Law of Motion

(17) **5. [G]** Based on Newton's third law of motion, the magnitude of the force exerted by the ground on the person is equal to 500 N.

Section 3.8 Application of Newton's Second Law

(18) **6. [T]**

a. **Step 1** When a zero net force acts on an object, then the object moves linearly at a constant speed.

b.i
Step 1 The acceleration of the cyclist is the slope of the tangent to the *v*-*t* graph at the indicated instant.
Step 2 Then, $a = \frac{7.6 \text{ m/s} - 4 \text{ m/s}}{18 \text{ s} - 15 \text{ s}} = 1.2 \text{ m/s}^2$

b.ii
Step 1 The total displacement of the cyclist is the area under its *v*-*t* graph.
Step 2
$$s = A_{[0\text{ s}, 15\text{ s}]} + A_{[15\text{ s}, 20\text{ s}]}$$
$$s = (4 \text{ m/s})(20 \text{ s}) + \frac{1}{2}(6 \text{ m/s})(5 \text{ s}) = 95 \text{ m}$$

b.iii
Step 1 The change in the kinetic energy of the cyclist is positive as the final speed is greater than the initial speed.
Step 2 Based on the work-energy theorem, the work done on the cyclist is then positive.

b.iv.1
Step 1 The forces on the cyclist that are perpendicular to the slope are balanced, then:
$$N - w\cos 15^\circ = 0$$
Step 2
$$N = w\cos 15^\circ$$
$$N = (800 \text{ N})\cos 15^\circ = 773 \text{ N}$$

b.iv.2

Step 1 The cyclist is accelerating down the slope: $w\sin 15^\circ - f = ma$

Step 2

$$f = w\sin 15^\circ - ma$$

$$f = w\sin 15^\circ - \frac{w}{g}a$$

$$f = w\left(\sin 15^\circ - \frac{a}{g}\right)$$

$$f = (800\ \text{N})\left(\sin 15^\circ - \frac{1.2\ \text{m/s}^2}{9.80\ \text{m/s}^2}\right) = 109\ \text{N}$$

Chapter 4 Work, energy, and Power

Section 4.1 Work Done by a Force

[19] **1. [G]**

a. Since the normal reaction is perpendicular to the displacement of the box, then its work is 0 J.

b. The work done by the weight on the box is:

$$W = wd\cos\left(90^\circ - 30^\circ\right)$$

$$W = \left(40\ \text{N}\right)\left(10\ \text{m}\right)\cos\left(60^\circ\right) = 200\ \text{J}$$

Section 4.2 Work-Energy Theorem

[20] **2. [G]** The kinetic energy of the car is:

$$KE = \frac{1}{2}mv^2$$

Then,

$$v = \sqrt{\frac{2KE}{m}}$$

$$v = \sqrt{\frac{2\left(20\times10^3\ \text{J}\right)}{500\ \text{kg}}} = 8.9\ \text{m/s}$$

Section 4.3 Potential energy

[21] **3. [G]** The gravitational potential energy of the bird relative to the ground is:

$$GPE = mgh$$

$$h = \frac{GPE}{mg}$$

$$h = \frac{25\ \text{J}}{\left(0.8\ \text{kg}\right)\left(9.8\ \text{m/s}^2\right)} = 3.2\ \text{m}$$

[22] **4. [G]** The elastic potential energy stored in a spring is given by:

$$E = \frac{1}{2}kx^2$$

$$x = \sqrt{\frac{2E}{k}}$$

$$x = \sqrt{\frac{2(0.10\ \text{J})}{250\ \text{N/m}}} = 2.8\ \text{cm}$$

Section 4.4 Mechanical Energy

[23] **5. [G]**The speed of the bob is greatest at the lowest point that the bob passes through, where the height is zero.

Based on the principle of conservation of energy, we have:

$$(GPE)_{\text{highest point}} = (KE)_{\text{lowest point}}$$

$$mgh_i = \frac{1}{2}mv_{\max}^2$$

$$v_{\max} = \sqrt{2gh_i}$$

$$v_{\max} = \sqrt{2(9.8\ \text{m/s}^2)(0.050\ \text{m})} = 0.99\ \text{m/s}$$

[24] **6. [T]**

a. Step 1 Inertia is a measure of how difficult it is to change the velocity of an object, or change its speed or direction. it is a measure of the mass of an object.

b. Step 1 The initial speed of the parcel is equal to the speed of the helicopter, that is

$$v_0 = (260\ \text{km/h})\left(\frac{1\ \text{m/s}}{3.6\ \text{km/h}}\right) = 72.2\ \text{m/s}$$

c. Step 1 The parcel is in uniform motion along the *x*-axis and in uniformly accelerated rectilinear motion along the *y*-axis. Then the parcel describes a parabola (projectile motion) as it falls.

d. **Step 1** The parcel is in UARM along the y-axis, and taking the positive direction to be downward, we get:

$$\Delta y = \frac{1}{2}gt^2 + v_{0y}t$$

$$h = \frac{1}{2}gt^2$$

Step 2 Then,

$$t = \sqrt{\frac{2h}{g}}$$

$$t = \sqrt{\frac{2(200\ \text{m})}{9.8\ \text{m/s}^2}} = 6.4\ \text{s}$$

e. **Step 1** Since the parcel is in URM along the x-axis, then:

$$v_x = v_{0x} = 72.2\ \text{m/s}$$

Step 2 Since the parcel is in UARM along the y-axis, then:

$$v_y = gt + v_{0y}$$

$$v_y = (9.80\ \text{m/s}^2)(6.4\ \text{s}) = 62.7\ \text{m/s}$$

Step 3 The speed of the parcel just before hitting the ground is:

$$v = \sqrt{v_x^2 + v_y^2}$$

$$v = \sqrt{(72.2\ \text{m/s})^2 + (62.7\ \text{m/s})^2} = 95.6\ \text{m/s}$$

f. **Step 1** When the parcel is moving with terminal speed, the forces on it are balanced, then

$kv_T = mg$

Step 2

$$v_T = \frac{mg}{k}$$

$$v_T = \frac{(15\ \text{kg})(9.80\ \text{m/s}^2)}{12\ \text{N.s/m}} = 12.3\ \text{m/s}$$

g. **Step 1** As the parcel reached the ground, its mechanical energy is in the kinetic form, that is:

$$ME_f = KE_f$$

$$ME_f = \frac{1}{2} m v_T^2$$

$$ME_f = \frac{1}{2}(15\text{ kg})(12.3\text{ m/s})^2 = 1.13\text{ kJ}$$

Step 2 The initial mechanical energy of the parcel, as it is released from rest, is:

$$ME_i = GPE_i$$

$$ME_i = mgh_i$$

$$ME_i = (15\text{ kg})(9.80\text{ m/s}^2)(200\text{ m}) = 29.4\text{ kJ}$$

Step 3 The percentage of energy lost as heat is:

$$\%E_{\text{lost}} = \left|\frac{1.13\text{ kJ} - 29.4\text{ kJ}}{29.4\text{ kJ}}\right| \times 100\% = 96\%$$

(25) 7. [T]

a.

Step 1 A body is said to be in translational equilibrium when the sum of all forces acting on it is zero.

b.i

Step 1 The condition for equilibrium for the block:

$mg - T_1 = 0$

$T_1 = 20$ N

b.ii

Step 1 By Newton's third law of motion: $T_1 = T_2 = 20$ N

b.iii

Step 1 The condition for equilibrium for the ball along the horizontal axis is:

$$T_2 \cos 53^\circ = T_3 \cos 37^\circ$$

Step 2

$$T_3 = \frac{T_2 \cos 53^\circ}{\cos 37^\circ}$$

$$T_3 = (20\text{ N})\left(\frac{0.60}{0.80}\right) = 15\text{ N}$$

b.iv Step 1 The condition for equilibrium for the ball along the vertical axis is:

$$T_2 \sin 53^\circ + T_3 \sin 37^\circ - mg = 0$$

Step 2

$$m = \frac{T_2 \sin 53^\circ + T_3 \sin 37^\circ}{g}$$

$$m = \frac{(20\text{ N})(0.80) + (15\text{ N})(0.60)}{9.80\text{ m/s}^2} = 2.6\text{ kg}$$

c.i Step 1 The initial gravitational potential energy of the ball relative to the ceiling is:

$$GPE_1 = -mgh_1$$

$$GPE_1 = -mgl \sin 37^\circ$$

$$GPE_1 = -(2.6\text{ kg})(9.80\text{ m/s}^2)(1.0\text{ m})(0.60) = -15.3\text{ J}$$

c.ii Step 1 The equilibrium position of the ball is attained when the string is vertical.
Step 2 The gravitational potential energy of the ball at the new equilibrium position is then:

$$GPE_2 = -mgh_2$$

$$GPE_2 = -(2.6\text{ kg})(9.80\text{ m/s}^2)(1.0\text{ m}) = -25.5\text{ J}$$

$$U_2 = mgh_2;\ U_2 = -2.6\text{ kg} \times 9.8\text{ N/kg} \times (-1.0\text{ m}) = -25.5\text{ J}$$

c.iii Step 1 Based on the principle of conservation of mechanical energy:

$$GPE_2 + KE_2 = GPE_1 + KE_1$$

$$GPE_2 + KE_2 = GPE_1$$

Step 2

$$\frac{1}{2} m v_2^2 = GPE_1 - GPE_2$$

$$v_2 = \sqrt{\frac{2(GPE_1 - GPE_2)}{m}}$$

$$v_2 = \sqrt{\frac{2[-15.3\text{ J} - (-25.5\text{ J})]}{2.6\text{ kg}}} = 2.8\text{ m/s}$$

Section 4.6 Power

(26) **8. [G]**

$$\text{efficiency} = \frac{\text{useful output energy}}{\text{total input energy}} \times 100\%$$

$$\text{efficiency} = \frac{(100 \text{ kJ} - 75 \text{ kJ})}{100 \text{ kJ}} \times 100\% = 25\%$$

(27) **9. [G]** The power of the motor is given by:

$$P = \frac{W}{t}$$

$$P = \frac{mgh}{t}$$

$$P = \frac{(40 \text{ kg})(9.8 \text{ m/s}^2)(2.0 \text{ m})}{5.0 \text{ s}} = 157 \text{ W}$$

(28) **10. [T]**

a.Step 1 Velocity is speed in a given direction.

b.Step 1 $w_{par} = mg\sin 10^{o}$; $w_{par} = 6.0 \text{ kg} \times 9.8 \text{ m/s}^2 \times 0.17 = 10 \text{ N}$.

c.(i)

Step 1 Not constant

Step 2 The net force on the sleigh up the hill is not zero (20 N – f – 10 N = 10 N – f)

Step 3 Thus the speed of the sleigh changes, resulting in the change in the resistance force and, hence the change in the net force on the sleigh and consequently its acceleration.

c.ii

Step 1 $\sum F_{par} = ma_{par}$; $a_{par} = \dfrac{20 \text{ N} - 2 \text{ N} - 10 \text{ N}}{6.0 \text{ kg}} = 1.3 \text{ m/s}^2$

c.iii

Step 1 $P = F_{par}v$; $P = 8 \text{ N} \times 0.8 \text{ m/s} = 6.4 \text{ W}$

Chapter 5 Momentum and Collisions

Section 5.1 Linear Momentum and Impulse

(29) **1. [G]** The linear momentum of the vehicle is given by:

$$p = mv$$

Then,

$$v = \frac{p}{m}$$

$$v = \frac{4\times10^3 \text{ kg.m/s}}{500 \text{ kg}} = 8 \text{ m/s}$$

(30) **2. [G]** The force exerted by the wall on the ball is given by:

$$F = \frac{\Delta p}{\Delta t}$$

Taking the final direction of motion as positive and knowing that the collision is perfectly elastic, we get:

$$F = \frac{(0.15 \text{ kg})\left[(5.0 \text{ m/s}) - (-5.0 \text{ m/s})\right]}{0.20 \text{ s}} = 7.5 \text{ N}$$

(31) **3. [T]**

a. **Step 1** The displacement of the dart is the area below the graph (a trapezoid) and equal to:

$$d = \frac{1}{2}(v_0 + v)t$$

Step 2 The average velocity is given by:

$$v_{\text{av}} = \frac{d}{t}$$

$$v_{\text{av}} = \frac{1}{2}\frac{(v_0 + v)t}{t}$$

$$v_{\text{av}} = \frac{v_0 + v}{2}$$

b. **Step 1** The dart is in UARM along the vertical axis. Taking the origin of the axes to be on the ground (below the dart) and the *y*-axis directed upward, then

$$y = -\frac{1}{2}gt^2 + v_{0y}t + y_0$$

$$y = -\frac{1}{2}gt^2 + y_0$$

Step 2

$$t = \sqrt{\frac{2(y_0 - y)}{g}}$$

$$t = \sqrt{\frac{2(1.60\ \text{m} - 1.20\ \text{m})}{9.80\ \text{m/s}^2}} = 0.286\ \text{s}$$

c.

Step 1 The dart is in URM along the horizontal axis, Then,

$$d = v_{0x}t$$

Step 2 $d = (2.00\ \text{m/s})(0.286\ \text{s}) = 0.572\ \text{m}$

d.

Step 1 Since the dart is in URM along the *x*-axis, then:

$$v_x = v_{0x} = 2.00\ \text{m/s}$$

Step 2 Since the dart is in UARM along the *y*-axis, then:

$$v_y = -gt + v_{0y}$$

$$v_y = -(9.80\ \text{m/s}^2)(0.286\ \text{s}) = -2.80\ \text{m/s}$$

Step 3 The speed of the dart just before hitting the board is:

$$v = \sqrt{v_x^2 + v_y^2}$$

$$v = \sqrt{(2.00\ \text{m/s})^2 + (-2.80\ \text{m/s})^2} = 3.44\ \text{m/s}$$

e.i

Step 1 The acceleration (deceleration) of the dart as it hits the board is:

$$v_f^2 - v_i^2 = 2ax$$

Step 2

$$a = \frac{v_f^2 - v_i^2}{2x}$$

$$a = \frac{0^2 - \left(3.44\ \text{m/s}\right)^2}{2\left(11.0\times10^{-3}\ \text{m}\right)} = -538\ \text{m/s}^2$$

Step 3 Applying Newton's second law of motion:

$$F = ma$$

$$F = \left(50.0\times10^{-3}\ \text{kg}\right)\left(-538\ \text{m/s}^2\right) = -26.9\ \text{N}$$

e.ii

Step 1 Newton's second law in terms of the change in momentum is expressed as:

$$F = \frac{\Delta p}{\Delta t}$$

Step 2

$$\Delta t = \frac{mv_f - mv_i}{F}$$

$$\Delta t = \frac{0 - \left(50.0\times10^{-3}\ \text{kg}\right)\left(3.44\ \text{m/s}\right)}{-26.9\ \text{N}} = 6.4\times10^{-3}\ \text{s}$$

(32) **4. [T]**

a.i Step 1 The initial length of the spring is 15 cm.

a.ii

Step 1 Based on Hooke's law:

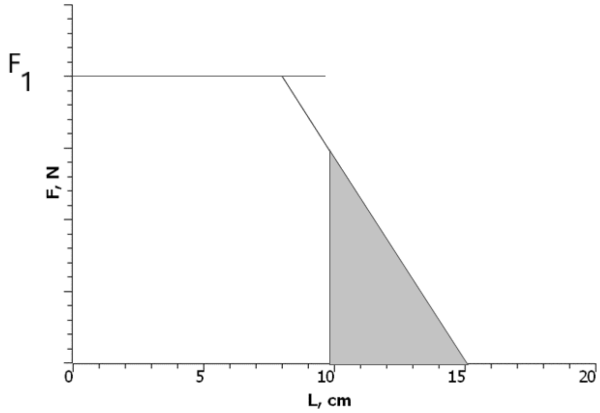
$$F_1 = kx$$

$$F_1 = k\left(L - L_0\right)$$

$$F_1 = \left(450\ \text{N/m}\right)\left|0.15\ \text{m} - 0.08\ \text{m}\right| = 32\ \text{N}$$

a.iii

Step 1 Area under *F*-*x* graph.



a.iv

Step 1 The energy stored in the spring is given by:

$$U_{el} = \frac{1}{2}kx^2$$

$$U_{el} = \frac{1}{2}(450\text{ N/m})(0.15\text{ m} - 0.08\text{ m})^2 = 1.1\text{ J}$$

b.i

Step 1 Since 95% of the spring's elastic potential energy is converted into kinetic energy, then:

$$KE = 0.95U_{el}$$

Step 2 In addition, $KE = \frac{1}{2}mv^2$

Step 3 As a result:

$$v = \sqrt{\frac{2 \times 0.95U_{el}}{m}}$$

$$v = \sqrt{\frac{2(0.95)(1.0\text{ J})}{0.10\text{ kg}}} = 4.4\text{ m/s}$$

b.ii

Step 1 The initial mechanical energy of the ball is:

$ME_i = GPE_i + KE_i$

$ME_i = mgh_i + 0.95U_{\text{el}}$

$ME_i = (0.10\text{ kg})(9.80\text{ m/s}^2)(0.80\text{ m}) + 0.95\text{ J} = 1.73\text{ J}$

Step 2 Eventually, all mechanical energy of the ball is converted into heat energy since it comes to rest at ground level. Then, E_{lost} = 1.73 J.

b.iii

Step 1 Since the ball is in URM along the *x*-axis, then its range in case there is no drag:

$d = v_0 t$

Step 2 Along the *y*-axis, the ball is in UARM, then:

$h = \frac{1}{2}gt^2$

$t = \sqrt{\frac{2h}{g}}$

Step 2 The range of the projectile is expressed as:

$d = v\sqrt{\frac{2h}{g}}$

$d = (4.3\text{ m/s})\sqrt{\frac{2(0.80\text{ m})}{9.8\text{ m/s}^2}} = 1.74\text{ m}$

Step 3 The range is about 10% smaller, thus there is drag.

b.iv

Step 1 Applying Newton's second law in terms of momentum:

$F = \frac{\Delta p}{\Delta t}$

$F = \frac{0.53\text{ kg.m/s}}{0.42\text{ s}} = 1.3\text{ N}$

(33) 5. [T]

a. **Step 1** The ball is in UARM along the *y*-axis. Taking the origin of the axes system at the initial position of the ball and the *y*-axis to be directed upwards, we can write:

$y = -\frac{1}{2}gt^2 + v_0 \sin 30^\circ t$

Step 2

$$1.00\text{ m} = -\frac{1}{2}\left(9.80\text{ m/s}^2\right)t^2 + \left[\left(12.0\text{ m/s}\right)\sin 30^\circ\right]t$$

$$-\left(4.90\text{ m/s}^2\right)t^2 + \left(6.00\text{ m/s}\right)t - 1.00\text{ m} = 0$$

t = 1.03 s or t = 0.20 s

b. **Step 1** The ball is in URM along the x-axis, then

$$D = \left(v_0 \cos 30^\circ\right)t$$

$$D = \left(12.0\text{ m/s}\right)\cos 30^\circ\left(1.03\text{ s}\right) = 10.7\text{ m}$$

c.

c.i Step 1 The ball is in URM along the horizontal:

$$v_x = v_0 \cos 30^\circ$$

$$v_x = \left(12.0\text{ m/s}\right)\cos 30^\circ = 10.4\text{ m/s}$$

c.ii Step 1 The ball is in UARM along the vertical:

$$v_y = -gt + v_0 \sin 30^\circ$$

$$v_x = -\left(9.80\text{ m/s}^2\right)\left(1.03\text{ s}\right)^2 + \left(12.0\text{ m/s}\right)\sin 30^\circ = -4.1\text{ m/s}$$

d.Step 1 The horizontal component of the momentum is conserved:

$$m_{\text{ball}}v_x = \left(m_{\text{ball}} + m_{\text{cart}}\right)v'$$

Step 2 $v' = \dfrac{m_{\text{ball}}v_x}{m_{\text{ball}} + m_{\text{cart}}}$

$$v' = \frac{\left(0.05\text{ kg}\right)\left(10.4\text{ m/s}\right)}{0.05\text{ kg} + 0.300\text{ kg}} = 1.49\text{ m/s}$$

e.

Step 1 The initial momentum of the ball is not equal to the final momentum of the ball-cart system because

Step 2 the vertical component of the momentum was disregarded when studying the collision.

Section 5.2 Conservation of Momentum

(34) **6. [G]** Based on the principle of conservation of momentum, and taking the direction of motion of the lighter cart to be positive, we get:

$$m_1v_1 - m_2v_2 = -m_1v_1' + m_2v_2'$$

$$m(5.0\text{ m/s}) - 2m(6.0\text{ m/s}) = -m(3.0\text{ m/s}) + 2mv_2'$$

$$v_2' = \frac{5.0\text{ m/s} - 12\text{ m/s} + 3.0\text{ m/s}}{2} = -2.0\text{ m/s}$$

That is the heavier cart moves at 2.0 m/s in its original direction

Section 5.5 Problems Involving Linear Momentum and Energy

(35) **7. [T] a.Step 1** Based on Newton's third law of motion, the forces between interacting objects are equal in magnitude and opposite in directions, that is $\mathbf{F}_{12} = -\mathbf{F}_{21}$.

Step 2 By Newton's second law of motion in terms of momentum:

$$\mathbf{F}_{12} = \frac{\Delta\mathbf{p}_1}{\Delta t} \text{ and } \mathbf{F}_{21} = \frac{\Delta\mathbf{p}_2}{\Delta t}$$

Step 3 Combining the equations we get:

$$\Delta\mathbf{p}_1 = -\Delta\mathbf{p}_2$$

$$\mathbf{p}_{1f} - \mathbf{p}_{1i} = -(\mathbf{p}_{2f} - \mathbf{p}_{2i})$$

$$\mathbf{p}_{1i} + \mathbf{p}_{2i} = \mathbf{p}_{1f} + \mathbf{p}_{2f}$$

The last equation describes the principle of conservation of momentum.

b.

Step 1 Based on the principle of conservation of momentum and taking the direction to the right to be positive:

$$M(2.0\text{ m/s}) + 2M(-4.0\text{ m/s}) = M(-3.0\text{ m/s}) + 2MV$$

Step 2 Solving for V yields: $V = -1.5\text{ m/s}$.

c.i

Step 1 The kinetic energy of the system before the collision is:

$$KE_i = \frac{1}{2}M(2.0\text{ m/s})^2 + \frac{1}{2}(2M)(-4.0\text{ m/s})^2$$

$$KE_i = 2M + 16M = 18M\text{ J}$$

c.ii

Step 1 The kinetic energy of the system after the collision is:

$$KE_f = \frac{1}{2}M\left(-3.0 \text{ m/s}\right)^2 + \frac{1}{2}\left(2M\right)\left(-1.5 \text{ m/s}\right)^2$$
$$KE_f = 6.8M \text{ J}$$

d.
Step 1 Since some of the kinetic energy is lost in the collision, then the collision is not elastic.

e.
Step 1 Another method is to compare the relative speeds of approach and separation.
Step 2 If their magnitudes are equal, it is a perfectly elastic collision; otherwise collision is inelastic.

Section 5.6 Collisions in Two Dimensions

(36) 8. [G] Applying the principle of conservation of momentum along the *x*-axis:
$$m\left(20 \text{ m/s}\right) = m\left(0 \text{ m/s}\right) + \left(5m\right)v_x$$
$$v_x = \frac{20 \text{ m/s}}{5} = 4 \text{ m/s}$$
Applying the principle of conservation of momentum along the *y*-axis:
$$m\left(0 \text{ m/s}\right) = m\left(2 \text{ m/s}\right) - \left(5m\right)v_y$$
$$v_y = \frac{2 \text{ m/s}}{5} = 0.4 \text{ m/s}$$
The speed of the heavier ball is then:
$$v = \sqrt{v_x^2 + v_y^2}$$
$$v = \sqrt{\left(4 \text{ m/s}\right)^2 + \left(0.4 \text{ m/s}\right)^2} = 4.02 \text{ m/s}$$

(37) 9. [T] a.i Step 1 Applying the principle of conservation of momentum along the *x*-axis and along the *y*-axis:
$$\begin{cases} x: \left(4.0 \text{ m/s}\right)M = \left[\left(1.0 \text{ m/s}\right)\cos 60^\circ\right]M + \left(v\cos\theta\right)\left(10M\right) \\ y: 0 = \left[\left(1.0 \text{ m/s}\right)\sin 60^\circ\right]M + \left(v\sin\theta\right)\left(10M\right) \end{cases}$$
Step 2
$$\begin{cases} 10v\cos\theta = 3.5 \\ 10v\sin\theta = -0.866 \end{cases}$$

Step 3 Dividing both equations, we get:

$$\tan\theta = -\frac{0.866}{3.5}$$

$$\theta = -13.9^{\circ}$$

Or θ = 13.9° below the *x*-axis.

a.ii

Step 1 Using the conservation of momentum along the *y*-axis, we get:

$$0 = \left[(1.0\ \text{m/s})\sin 60^{\circ}\right]M + (v\sin\theta)(10M)$$

Step 2

$$10v\sin\theta = -(1.0\ \text{m/s})\sin 60^{\circ}$$

$$v = \frac{-(1.0\ \text{m/s})\sin 60^{\circ}}{10\sin\left(-13.9^{\circ}\right)} = 0.36\ \text{m/s}$$

b.

Step 1 The kinetic energy of the system before the collision is:

$$KE_i = \frac{1}{2}M\,(4.0\ \text{m/s})^2 = 8M\ \text{J}$$

Step 2 The kinetic energy of the system after the collision is:

$$KE_f = \frac{1}{2}M\,(1.0\ \text{m/s})^2 + \frac{1}{2}(10M)(0.36\ \text{m/s})^2 = 1.15M\ \text{J}$$

Step 3 Since the final kinetic energy is different from the initial one, then the collision is not perfectly elastic.

Chapter 6 Torque and Equilibrium

Section 6.1 Torque

(38) **1. [G]** The moment of the force is given by:

$$\text{moment} = Fd\sin 45^\circ$$

$$\text{moment} = (10\ \text{N})(2.5\ \text{m})\sin 45^\circ = 17.7\ \text{N.m}$$

(39) **2. [G]** The torque of a couple is given by:

$$\text{torque of couple} = Fd$$

$$\text{torque of couple} = (50\ \text{N})(0.20\ \text{m}) = 10\ \text{N.m}$$

Section 6.3 Equilibrium of Extended Bodies

(40) **3. [G]**

a. The two conditions for equilibrium are:
   The sum of all forces is zero ad the sum of all torques about an arbitrary point is zero.
b. Applying the second condition for equilibrium about the pivot, and taking counterclockwise moment to be positive, we can write:

$$(50\ \text{N})(0.30\ \text{m}) = w(0.50\ \text{m} - 0.30\ \text{m}) + (20\ \text{N})(0.70\ \text{m})$$

$$w = 5.0\ \text{N}$$

(41) **4. [T]**

a. Step 1 $w = mg = \rho\left(\frac{\pi d^3}{6}\right)g$

Step 2 $w = 7200\ \text{kg/m}^3\left(\frac{3.14\times(4.2\times10^{-2}\ \text{m})^3}{6}\right)9.8\ \text{m/s}^2 = 2.7\ \text{N}$

b.i

Step 1 Gravitational field is uniform, g is the same everywhere

Step 2 So $\frac{\sum r_i m_i g}{\sum m_i g} = \frac{\sum r_i m_i}{\sum m_i}$ and the expressions for the center of gravity and the center of mass are identical

b.ii

Step 1 Rotational equilibrium condition: $\sum \tau_i = 0$

Step 2 Taking torques about P: $(60\ \text{cm})(2.7\ \text{N})+(30\ \text{cm})(4.6\ \text{N})=(10\ \text{cm})w$

Step 3 $w=\dfrac{(60\ \text{cm})(2.7\ \text{N})+(30\ \text{cm})(4.6\ \text{N})}{10\ \text{cm}}=30\ \text{N}$

c.i

Step 1 The pressure on the bottom of the ball is greater than the pressure on the top of the ball, resulting in an upward thrust.

Step 2 The upward force on the sphere decreases the tension in the string connecting it to the bar, thus decreasing the downward pull by the string on the bar.

c.ii

Step 1 Since the anticlockwise moment was reduced, the clockwise moment must also be reduced

Step 2 If the distance to the pivot remains unchanged, then the weight of *X* must be decreased.

Physics N – Electricity and Waves

Chapter 1 Current, Resistance, and Electromotive Force

Section 1.2 Electric Potential and Potential Difference

(42) **1. [G]** The potential difference across an electric component represents the energy transferred to the component per unit of charge.

Section 1.3 Electric Current

(43) **2. [G]** The current flowing through the circuit is:

$$I = \frac{Q}{t}$$

$$I = \frac{5.0\ \text{C}}{60\ \text{s}} = 83\ \text{mA}$$

(44) **3. [G]** The current in the wire is given by:

$$I = nAvq$$

$$I = \left(5.86\times10^{28}\ \text{m}^{-3}\right)\left(2.0\times10^{-6}\ \text{m}^2\right)\left(0.11\times10^{-3}\ \text{m/s}\right)\left(1.6\times10^{-19}\ \text{C}\right) = 2.06\ \text{A}$$

Section 1.4 Ohm's Law

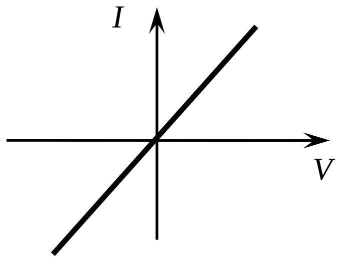
(45) **4. [G]** The resistance of the element is given by:

$$R = \frac{V}{I}$$

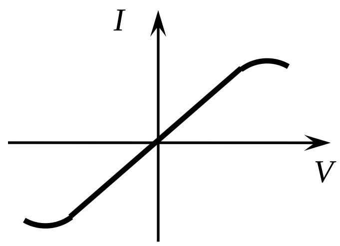
$$R = \frac{12\ \text{V}}{0.30\ \text{A}} = 40\ \Omega$$

(46) **5. [G]**

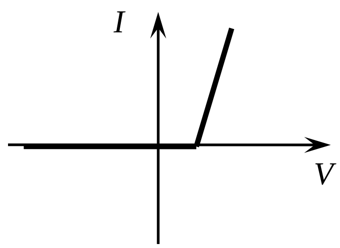
a.



b.



c.



(47) **6. [G]** Any electric component, for which the ratio of the potential difference across it and the current through it is constant, obeys Ohm's law.

Section 1.5 Resistance and Resistors

(48) **7. [G]** The resistance of the copper wire is:

$$R = \frac{\rho L}{A}$$

$$R = \frac{(1.69\times10^{-8}\ \Omega\text{.m})(3.0\ \text{m})}{1.00\times10^{-6}\ \text{m}^2} = 5.1\times10^{-2}\ \Omega$$

Section 1.6 Voltage and Electromotive Force

(49) **8. [G]** The current flowing through the circuit is given by:

$$I = \frac{E}{R + r}$$

$$I = \frac{12.0\ V}{20\ \Omega + 1.0\ \Omega} = 0.57\ \text{A}$$

The terminal potential difference across the battery is then:

$$V = E - rI$$

$$V = 12.0\ \text{V} - (1.0\ \Omega)(0.57\ \text{A}) = 11.4\ \text{V}$$

Chapter 2 DC Circuits

Section 2.2 Electrical Energy and Power

(50) **1. [G]** The power output of the heating element is given by:

$$P = \frac{V^2}{R}$$

$$P = \frac{(120\ \text{V})^2}{20\ \Omega} = 720\ \text{W}$$

Section 2.4 Resistors in Series and in Parallel

(51) **2. [G]** Since the resistors are connected in series, then:

$$R_{eq} = 15\ \Omega + 5\ \Omega + X\ \ \Omega$$

$$X = R_{eq} - 15\ \Omega - 5\ \Omega$$

$$X = 50\ \Omega - 15\ \Omega - 5\ \Omega = 30\ \Omega$$

(52) **3. [G]** The equivalent resistance of resistors in parallel is given by:

$$\frac{1}{R_{eq}} = \frac{1}{80\ \Omega} + \frac{1}{20\ \Omega} + \frac{1}{10\ \Omega} = \frac{13}{80}\ \Omega^{-1}$$

$$\rightarrow R_{eq} = \frac{80}{13}\ \Omega = 6.2\ \Omega$$

(53) **4. [T]**

a. Step 1 An ohmic conductor is a conductor that obeys Ohm's law where the resistance of the conductor is independent of both the current and the potential difference.

b. Step 1 The resistors in the lower branch are connected in series and both are connected in parallel with the resistor in the upper branch, then:

$$\frac{1}{R_{eq}} = \frac{1}{2R} + \frac{1}{R}$$

Step 2 (1) $R_{eq} = \frac{2R}{3}$

$$R_{eq} = \frac{2(60\ \Omega)}{3} = 40\ \Omega$$

c. Step 1 Applying Ohm's law across the equivalent resistor, we can write:

$$V = IR_{eq}$$

$V = (0.25\ \text{A})(40\ \Omega) = 10\ \text{V}$

d. **Step 1** The potential difference across the power supply is given by:

$V = E - Ir$

$r = \dfrac{E - V}{I}$

$r = \dfrac{12\ \text{V} - 10\ \text{V}}{0.25\ \text{A}} = 8\ \Omega$

e. **Step 1** The electric current is expressed as:

$I = envA$

Step 2 The current through both faces is the same, and the number of free carriers and their charges are also the same

Step 3 Then,

$I_A = I_B$

$env_A \pi R_A^2 = env_B \pi R_B^2$

$v_A R_A^2 = v_B R_B^2$

$\dfrac{v_A}{v_B} = \dfrac{R_B^2}{R_A^2}$

$\dfrac{v_A}{v_B} = \dfrac{(2.0\ \text{mm})^2}{(4.5\ \text{mm})^2} = 0.2$

Section 2.6 Multiloop Circuits

(54) **5. [G]** Applying Kirchhoff's first law, the current flowing through resistor 2 is equal to that through resistor 1, then, I_2 = 0.5A.

Applying Kirchhoff's second law, we can write:

$V = V_1 + V_2$

$V_2 = V - V_1$

$V_2 = 12\ \text{V} - 8\ \text{V} = 4\ \text{V}$

(55) **6. [G]** a. Taking the loop containing I_1 and working anticlockwise around the loop:

$+4.5\ \text{V} - 1.5\ \text{V} - (10\ \Omega) I' = 0$

where I' is the current flowing through the 10 Ω resistor.

Then,

$$I' = \frac{3.0\ \text{V}}{10\ \Omega} = 0.3\ \text{A}$$

Taking the loop containing I_2 and working anticlockwise around the loop:

$$+1.5\ \text{V} - (50\ \Omega + 40\ \Omega)I_2 + (10\ \Omega)I' = 0$$

$$+1.5\ \text{V} - (90\ \Omega)I_2 + (10\ \Omega)(0.30\ \text{A}) = 0$$

$$I_2 = 0.050\ \text{A}$$

b. Current I_1 is given by:

$$I_1 = I' + I_2$$

$$I_1 = 0.30\ \text{A} + 0.050\ \text{A} = 0.35\ \text{A}$$

Section 2.7 Practical Electric Circuits

(56) **7. [G]**

a. The resistance of a PTC thermistor increases with increasing temperature.
b. The resistance of an NTC thermistors decreases with increasing temperature.

(57) **8. [G]** The value of the output voltage across resistance *X* is:

$$V_{\text{out}} = \left(\frac{R_X}{R_X + R_Y}\right)V_{\text{in}}$$

$$V_{\text{out}} = \left(\frac{50\ \Omega}{50\ \Omega + 100\ \Omega}\right)(24\ \text{V}) = 8\ \text{V}$$

(58) **9. [G]**

a. As the intensity of the ambient light increases, the resistance of the LDR will decrease and so does the p.d. across it.
b. As the temperature increases, the resistance of the NTC will decrease and so does the p.d. across it.

(59) **10. [G]** The ratio of the emfs of the two cells is given by:

$$\frac{E_x}{E_y} = \frac{AC}{AD}$$

$$\frac{E_x}{E_y} = \frac{15 \text{ cm}}{20 \text{ cm}} = 0.75$$

(60) **11. [T]**

a. Step 1 The resistance of a wire is given by:

$$R = \frac{\rho l}{A}$$

$$R = \frac{\left(1.7\times10^{-8}\ \Omega.\text{m}\right)\times\left(29\ \text{m}\right)}{3.2\times10^{-7}\ \text{m}^2} = 1.54\ \Omega$$

b. Step 1 Applying Ohm's law:

$$V_{\text{wire}} = IR_{\text{wire}}$$

$$V_{\text{wire}} = \left(0.20\ \text{A}\right)\left(1.54\ \Omega\right) = 0.31\ \text{V}$$

c. Step 1 The power dissipated in the wire is:

$$P_{\text{wire}} = I^2R_{\text{wire}}$$

$$P_{\text{wire}} = \left(0.20\ \text{A}\right)^2\left(1.54\ \Omega\right) = 0.062\ \text{W}$$

d. Step 1 The current flowing through the wire can be expressed as:

$$I = neAv$$

Step 2 $n = \frac{I}{eAv}$

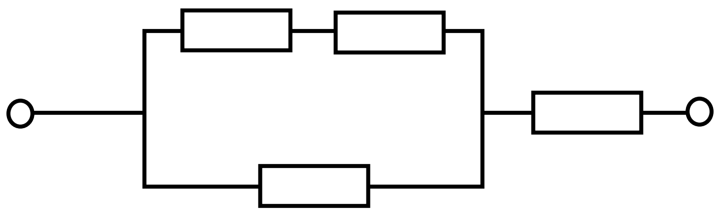
$$n = \frac{0.20\ \text{A}}{\left(1.60\times10^{-19}\ \text{C}\right)\left(3.2\times10^{-7}\ \text{m}^2\right)\left(4.6\times10^{-5}\ \text{m/s}\right)} = 8.5\times10^{28}\ \text{m}^{-3}$$

f. Step 1 The power dissipated in the wire is proportional to the resistance of the wire and the square of the current which remains the same.

Step 2 The resistance of the wire is inversely proportional to the cross-sectional area. At the fault, the cross-sectional area decreases and hence the resistance increases.

Step 3 As the resistance increases, the power (or energy) dissipated as heat increases as well.

f.i Step 1 One resistor in series with a parallel combination of three resistors (two in series connected in parallel to a third one).



f.ii. Step 1 The resistance of the parallel branch in the circuit is:

$$\frac{1}{R'}=\frac{1}{R}+\frac{1}{2R}=\frac{3}{2R}$$

$$R'=\frac{2R}{3}$$

Step 2 The equivalent resistance of the circuit is then:

$$R_{eq}=R+R'$$

$$R_{eq}=R+\frac{2R}{3}$$

$$R_{eq}=\frac{5R}{3}$$

$$R_{eq}=\frac{5(60\ \Omega)}{3}=100\ \Omega$$

f.iii. Step 1 The output voltage across the arrangement (100 Ω) of the resistors is:

$$V_{out}=V_{in}\frac{R_{eq}}{R_{eq}+R_2}$$

$$V_{out}=(15\ \text{V})\frac{100\ \Omega}{100\ \Omega+25\ \Omega}=12\ \text{V}$$

(61) 12. [T]

a.Step 1 The resistance of any component is defined as the ratio of the potential difference across the component to the current through it.

b.
Step 1 The resistance of the wire is expressed as:

$$R = \frac{\rho l}{A}$$

Step 2

$$A = \frac{\rho l}{R}$$

$$A = \frac{\left(1.68\times10^{-8}\ \Omega.\text{m}\right)\left(0.25\ \text{m}\right)}{3.0\ \Omega} = 1.4\times10^{-9}\ \text{m}^2$$

c.i
Step 1 The current through a branch is proportional to the charge flowing through it.
Step 2 Due to the conservation of charges, only some of the charges that flow through the battery flow also through resistor *X*; the rest flows through resistor *Y*.

c.ii
Step 1 The p.d. across the battery is equal to the p.d. across each element as they are connected in parallel with the battery.
Step 2 Applying Ohm's law across resistor *X*, we can write:

$$I_X = \frac{\varepsilon}{R_X}$$

$$I_X = \frac{12\ \text{V}}{20\ \Omega} = 0.60\ \text{A}$$

d.i
Step 1 The p.d. across resistor X will decrease since the batteries are connected in opposite directions.

d.ii
Step 1 The p.d. across B_1 remain unchanged.

e.i.
Step 1 Resistors *L* and *M* are connected in series, then:
$R' = R_L + R_M$

$R' = 20\ \Omega + 10\ \Omega = 30\ \Omega$

Step 2 Resistors N and R' are connected in parallel:

$$\frac{1}{R_{eq}} = \frac{1}{30\ \Omega} + \frac{1}{50\ \Omega} = \frac{4}{75}\ \Omega^{-1}$$

$$R_{eq} = 18.8\ \Omega$$

e.ii

Step 1 The p.d. across branch ML is 15 V, so

$$V_M + V_L = 15\ \text{V} \qquad (1)$$

Step 2 Within the branch, the current is the same, then by applying Ohm's law across each resistor of the branch:

$$\frac{V_M}{R_M} = \frac{V_L}{R_L}$$

$$V_L = \frac{R_L}{R_M} V_M$$

$$V_L = \left(\frac{20\ \Omega}{10\ \Omega}\right) V_M = 2V_M$$

Step 3 Replacing the expression of V_L in (1), we get:

$$V_M + 2V_M = 15\ \text{V}$$

$$V_M = 5\ \text{V}$$

(62) **13. [T]**

a.

Step 1 Using Kirchhoff's first law, we get:

$I_3 = I_2 - I_1$

b.

Step 1 Using Kirchhoff's second law in the loop to the left:

$$\varepsilon_1 - R_1 I_1 - \varepsilon_3 + R_3 I_3 = 0$$

c.

Step 1 Using Kirchhoff's second law all the way around the circuit:

$$\varepsilon_1 - R_1 I_1 - \varepsilon_3 + \varepsilon_2 - R_2 I_2 = 0$$

(63) **14.[T]**

a.Step 1 Energy released in a circuit per unit charge

b.Step 1 As the temperature decreases, the resistance of *Y* and thus the equivalent resistance of the circuit will increase
Step 2 the current decreases (as resistance of *Y* increases)
Step 3 lost volts go down (as resistance of *Y* increases)
Step 4 p.d. *AB* increases (as resistance of *Y* increases)

c.i
Step 1 4.5 = 0.22 (8 + 0.5 + R)
Step 2 *R* = 12 Ω

c.ii
Step 1 V = 4.50 V – 0.22 A × 0.5 Ω
Step 2 V = 4.39 V

c.iii
Step 1 Wasted energy in one second = energy input – energy output = $I(\varepsilon - V)$ in one second
Step 2 Wasted energy in one second = 0.02 J

Chapter 3 Mechanical Waves and Sound

Section 3.1 Types of Mechanical Waves

(64)**1. [G]** a. In a longitudinal wave, the particles of a medium vibrate parallel to the direction of the wave velocity.

b. In a transverse wave, the particles of a medium vibrate at right angles to the direction of the wave velocity.

Section 3.2 Mathematical Description of Periodic Waves

(65)**2. [G]** The period of the wave is given by:

$$T = \frac{1}{f}$$

$$T = \frac{1}{120\text{ Hz}} = 8.3\text{ ms}$$

(66)**3. [G]** The phase difference between two consecutive troughs is given by:

$$\phi = \frac{x}{\lambda} \times 360^\circ$$

$$\phi = \frac{\lambda}{\lambda} \times 360^\circ = 360^\circ$$

(67)**4.[G]** The speed of the wave is given by:

$$v = \lambda f$$

$$v = \frac{\lambda}{T}$$

$$v = \frac{30.0 \times 10^{-2}\text{ m}}{2.00 \times 10^{-3}\text{ s}} = 150\text{ m/s}$$

Section 3.4 Sound Waves

(68)5.[G]

$$I = \frac{P}{4\pi r^2}$$

$$I = \frac{20\ \text{W}}{4\pi(0.5\ \text{m})^2}$$

$$I = 6.4\ \text{W/m}^2$$

(69)6. [G] The detected intensity will decrease and becomes equal to 10 mW/m^2.

Section 3.5 Doppler Effect

(70)7. [G] The observed frequency is given by:

$$f_{\text{observer}} = \frac{f_{\text{source}}v}{v + v_{\text{source}}}$$

$$f_{\text{observer}} = \frac{(900\ \text{Hz})(340\ \text{m/s})}{(340\ \text{m/s} + 25\ \text{m/s})} = 838\ \text{Hz}$$

(71)8. [T] a. Step 1 Applying Doppler effect:

$$f_{\text{detected}} = f_{\text{source}}\frac{v + v_{\text{observer}}}{v}$$

Step 2 $$f_{\text{source}} = \frac{f_{\text{detected}}v}{v + v_{\text{observer}}}$$

$$f_{\text{source}} = (600\ \text{Hz})\frac{340\ \text{m/s}}{340\ \text{m/s} + 4.0\ \text{m/s}} = 590\ \text{Hz}$$

b. Step 1 The jumper is in UARM along the vertical with an acceleration equal to $-g$:

$$v^2 - v_0^2 = -2gh$$

Step 2 $$h = \frac{v^2 - v_0^2}{-2g}$$

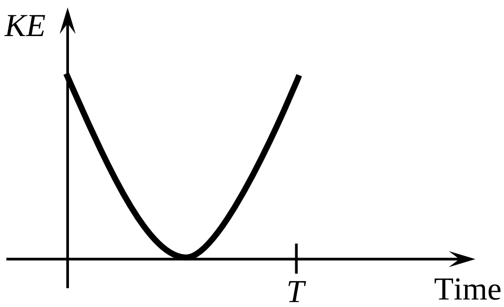
$$h = \frac{(0\ \text{m/s})^2 - (6.4\ \text{m/s})^2}{-2(9.80\ \text{m/s}^2)} = 2.1\ \text{m}$$

c. Step 1 The greatest gravitational potential energy acquired by the jumper is:

$GPE = mgh$

$$GPE = (50\ \text{kg})(2.1\ \text{m})(9.80\ \text{m/s}^2) = 1.0\ \text{kJ}$$

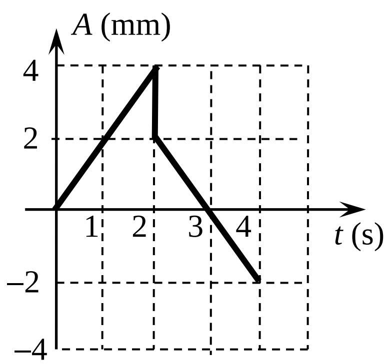
d. **Step 1 a parabola with *KE* = 0, at *t* = *T*/2.**



e. **Step 1** As the jumper jumps (t = 0 s), she moves at the highest velocity.
Step 2 (1) Since the drag is directly proportional to the speed of a body, then the drag force is the highest at the moment when the jumper leaves the ground
Step 3 As some of her initial kinetic energy will be lost as heat.

Section 3.6 Wave interference

(72)9. [G]



Section 3.7 Standing Waves

(73)**10. [G]** a. The point on a stationary wave that does not move at all times.
b. The point on a stationary wave that vibrates with the highest amplitude.

(74)**11. [G]** Two progressive waves, with the same amplitude and wavelength, travel in opposite directions. As they superimpose, constructive interference is observed periodically at certain positions.

(75)**12. [G]** The frequencies of harmonics are the same in the string of fixed length and the air column open at both ends.

The condition for the stationary waves is the same: an integer number of half-waves must fit the resonator.

The condition for stationary waves in an air column open at one end only is different: an odd number of quarter wavelength must fit the resonator.

(76)**13. [T]**

a. Step 1 The power is the rate of doing work, that is:

$$P = \frac{W}{t}$$

$$P = \frac{Fd}{t}$$

Step 2 $[P] = \frac{[F][d]}{[t]}$

$$[P] = \frac{\left(\frac{\text{kg.m}}{\text{s}^2}\right)(\text{m})}{\text{s}} = \text{kg.m}^2/\text{s}^3$$

b. Step 1 Extracting the constant from the given expression, we get:

$$f^2 = \left(\frac{1}{2L}\right)^2\left(\frac{T}{\mu}\right)$$

$$\mu = \frac{T}{(2Lf)^2}$$

Step 2

$$[\mu] = \frac{[T]}{[L]^2[f]^2}$$

$$[\mu] = \frac{\text{kg.m/s}^2}{(\text{m}^2)\left(\frac{1}{\text{s}}\right)^2} = \text{kg/m}$$

c.i Step 1 They obtain a reading/result to several decimal places, but their reading is far from the actual value of the current in the wire.

c.ii Step 1 Although the actual value of the current in the wire is found within the confidence interval, the absolute uncertainty of the measurement is very high.

(77)14. [T]

a. Step 1 A stationary waves is a stable wave pattern produced from the superposition of two progressive waves of the same frequency and travelling in opposite directions.

b.i Step 1 The period of the wave is:

$$T + \frac{T}{4} = 0.78\ \text{s}$$

$$\frac{5}{4}T = 0.78\ \text{s}$$

$$T = 0.62\ \text{s}$$

b.ii Step 1 The frequency of the wave is given by:

$$f = \frac{1}{T}$$

$$f = \frac{1}{0.62\ \text{s}} = 1.6\ \text{Hz}$$

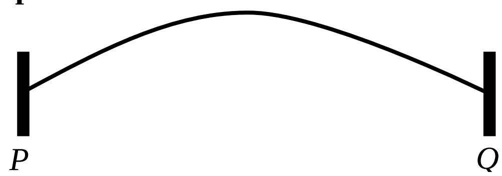
b.iii Step 1 The phase difference between instants *M* and *L* is half a wavelength, that is $\Phi = 180°$.

b.iv Step 1 The wavelength of the wave is:

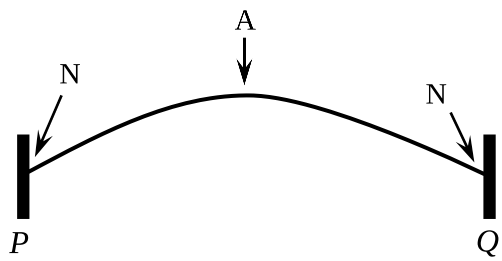
$$\lambda = \frac{v}{f}$$

$$\lambda = \frac{12\ \text{m/s}}{1.6\ \text{Hz}} = 7.5\ \text{m}$$

c.i Step 1



c.ii Step 1



c.iii.1 Step 1 The fundamental frequency of the standing wave is:

$$f_0 = \frac{v}{2L}$$

$$f_0 = \frac{250 \text{ m/s}}{2(1.20 \text{ m})} = 104 \text{ Hz}$$

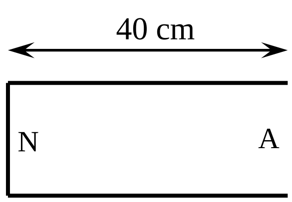
c.iii.2 Step 1 The fourth harmonic of the standing wave is:

$$f_4 = 4f_0$$

$$f_4 = 4(104 \text{ Hz}) = 416 \text{ Hz}$$

(78)15. [T] a.Step 1 A stationary wave forms by the superposition of two progressive waves – an incident and a reflected one.

b.Step 1 Node at the closed end and an antinode at the open end



c.

Step 1 The distance between a node and an antinode is $\frac{\lambda}{4}$.

Step 2 Then, the phase difference between these points is

$$\phi = \left(\frac{x}{\lambda}\right)360^\circ$$

$$\phi = \left(\frac{\lambda/4}{\lambda}\right)360^\circ = 90^\circ$$

d.i

Step 1 The lowest possible harmonic corresponds to $L = \frac{\lambda}{4}$.

Step 2 In addition, $f_0 = \frac{v}{\lambda}$

Step 3 Then,

$$f_0 = \frac{v}{4L}$$

$$f_0 = \frac{340\ \text{m/s}}{4(0.40\ \text{m})} = 213\ \text{Hz}$$

d.ii

Step 1 The next possible harmonic corresponds to $L = \frac{3\lambda}{4}$.

Step 2 Then,

$$f_1 = \frac{3v}{4L}$$

$$f_1 = \frac{3(340\ \text{m/s})}{4(0.40\ \text{m})} = 638\ \text{Hz}$$

e.

Step 1 A stationary wave will not form.

Step 2 The conditions for the formation of stationary waves are different / the resonator must fit not odd number of quarter-wavelengths, but any number of half-wavelengths = even number of quarter wavelengths.

(79) 16. [T]

a.

Step 1 Result of the superposition of two coherent travelling waves travelling in opposite directions.

b.

Step 1 L = 3 wavelengths of the wave; $\lambda = \frac{120\text{ cm}}{3} = 40\text{ cm}$

Step 2 $f = \frac{c}{\lambda}$; $f = \frac{40\text{ m/s}}{0.40\text{ m}} = 100\text{ Hz}$

c.i

Step 1 Period of the wave = 1/100 = 10 ms.

Step 2 At t = 5 ms the displacement is 0 mm

c.ii

Step 1 At t = 2.5 ms the displacement is +3.0 mm

Chapter 4 Light Interference and Diffraction

Section 4.1 Electromagnetic Waves

(80)**1. [G]** The frequency of the light wave is given by:

$$f = \frac{c}{\lambda}$$

$$f = \frac{3.00\times10^{8}\ \text{m/s}}{650\times10^{-9}\ \text{m}} = 4.62\times10^{14}\ \text{Hz}$$

Section 4.2 Light Polarization

(81)**2. [G]** Light polarization represents the process of transforming unpolarized light into polarized light.

(82)**3. [G]** The intensity of the transmitted light through the polarizing film is given by:

$$I = I_0\cos^2\theta$$

$$I = \left(1.6\ \text{mW.m}^{-2}\right)\cos^2 30^\circ = 1.2\ \text{mW.m}^{-2}$$

(83)**4. [T]**

a. **Step 1** Longitudinal waves oscillate along the direction of wave propagation, so no matter what the orientation of the slit, the waves will be able to get through.

b.i Step 1 Applying Malus's law:

$$I = I_0\cos^2\theta$$

$$I = \left(60.0\ \text{mW/m}^2\right)\cos^2 25^\circ = 49.3\ \text{mW/m}^2$$

b.ii Step 1 The intensity of a wave is proportional to the square of its amplitude, then

$$\frac{A_0}{A} = \sqrt{\frac{I_0}{I}} = \sqrt{\frac{1}{\cos^2\theta}}$$

Step 2 $\frac{A_0}{A} = \frac{1}{\cos 25^\circ} = 1.1$

Section 4.3 Diffraction of Waves

(84)**5. [G]** The water waves will spread out more and more as the gap decreases

Section 4.4 Interference of Waves

(85)**6. [G]**

a. For constructive interference to occur, the path difference between the waves should be a whole number of wavelength. The smallest path difference is zero.
b. For destructive interference to occur, the path difference between the waves should be an odd number of half wavelength. The smallest path difference is then 20 cm

(86)**7. [G]** Two light sources are said to be coherent when they have the same frequency and a constant phase difference between the emitted waves.

(87)**8. [G]** The distance between two consecutive bright fringes can be found as follows:

$$\lambda = \frac{ax}{D}$$

$$x = \frac{\lambda D}{a}$$

$$x = \frac{(632\times10^{-9}\ \text{m})(2.20\ \text{m})}{1.50\times10^{-3}\ \text{m}} = 9.27\times10^{-4}\ \text{m} = 0.927\ \text{mm}$$

(88)**9. [T]**

a. Step 1 The amplitude of both waves is the same.

c. Step 1 The wavelength or initial phase of the waves is different.

d. Step 1 Since the two waves do not have the same frequency or wavelength, then they are not coherent.

d.i Step 1 The waves interfere constructively at the position where the phase difference is zero, that is at *d* = 1.8 m.

d.ii Step 1 The amplitude of the resultant wave is the sum of the amplitude of each wave, that is *A* = 4 mm.

e. Step 1 The frequency of the wave is given by:

$f = \frac{v}{\lambda}$

Step 2 Graphically, the wavelength is about 0.63 m

Step 3 $f = \frac{200\ \text{m/s}}{0.63\ \text{m}} = 317\ \text{Hz}$

f. Step 1 The intensity of a wave is proportional to the square of its amplitude.
Step 2 Since the waves have the same amplitude, then their intensities are equal.

Section 4.5 Diffraction Grating

(89)10. [G] The wavelength of the laser light can be found as follows:

$$d \sin\theta = n\lambda$$

$$\lambda = \frac{d \sin\theta}{n}$$

$$\lambda = \frac{\left(\frac{1}{150\ \text{lines/mm}}\right)\sin 12^\circ}{2} = 6.93\times10^{-4}\ \text{mm} = 693\ \text{nm}$$

(90)11. [T]

a. Step 1 The double-slit equation is given by:

$$\lambda = \frac{ax}{D}$$

Step 2 $\lambda = \frac{(0.20\times10^{-3}\ \text{m})(3.4\times10^{-3}\ \text{m})}{1.50\ \text{m}} = 453\ \text{nm}$

b.
Step 1 At point *P*, a dark spot is located which is the first minimum, then the path difference is:

$$d = \frac{\lambda}{2}$$

Step 2 $d = \frac{453\ \text{nm}}{2} = 227\ \text{nm}$

c.
Step 1 At point *Q*, the central maximum is located, then there is no phase difference.

d.i
Step 1 If a laser of lower intensity is used then the obtained fringes are less bright / smaller number of fringes is visible.

d.ii
Step 1 Slits with smaller diameter results in a wider central fringe.

d.iii
Step 1 The fringes become sharp and very bright.
Step 2 The maxima become widely separated.

(91) 12. [T] a.
Step 1 A transverse wave is a wave in which the particles of a medium oscillate are right angles to the direction of wave propagation.

b.Step 1 An electromagnetic wave is a transverse wave traveling through space as vibrations of electric and magnetic fields.

c. Step 1 A diffraction grating is a glass or plastic slide that consists of a large number of equally spaced slits.

d.
Step 1 The wavelength of the equation is expressed by:
$$d\sin\theta = n\lambda$$

Step 2 The maxima are symmetrical with respect of the central spot, then, $\theta = \frac{40^\circ}{2} = 20^\circ$

Step 3 $\lambda = \frac{d\sin\theta}{n}$

$$\lambda = \frac{\left(\frac{1.0\times10^{-3}\ \text{m}}{400}\right)\sin 20^\circ}{2} = 428\ \text{nm}$$

e.i
Step 1 The number of maxima obtained in a diffraction grating is given by:
$$n = \frac{d\sin\theta}{\lambda}$$
Step 2 The greatest number of maxima corresponds to the greatest value of sin θ =1, that is
$$n_{\max} = \frac{d}{\lambda}$$

Step 3 A longer wavelength results in a smaller order of maxima.

e.ii

Step 1 The greatest order of maxima does not depend on the distance between the screen and the grating. Then, changing the distance does not affect the order of maxima.

Chapter 5 Atomic Physics

Section 5.1 The Atomic Model

(92)**1. [G]** According to Rutherford's model of the atom, charged protons and neutral neutrons make up the nucleus of the atom, whereas electrons move around the nucleus in a cloud.

Section 5.2 The Atom

(93)**2. [G]**

a. Number of protons = $Z = 26$

b. Number of neutrons = $A - Z$

Number of neutrons = $56 - 26 = 30$

c. Number of electrons = $Z = 26$

(94)**3. [G]**

a. They have the same proton number.

b. They have different nucleon number.

Section 5.3 Radioactivity

(95)**4. [G]**

a. 4 proton masses, +2 elementary charges, about 10^6 m/s

b. About 1/2000 proton mass, −1 elementary charge, about 10^8 m/s

c. Zero mass, zero charge, speed of light

(96)**5. [G]**

a. Alpha decay of gadolinium into samarium: ${}^{149}_{64}\text{Gd} \rightarrow {}^{145}_{62}\text{Sm} + {}^{4}_{2}\alpha$

b. Beta-minus decay of technetium into ruthenium: ${}^{99}_{43}\text{Tc} \rightarrow {}^{99}_{44}\text{Ru} + {}^{0}_{-1}\beta^{-}$

c. Beta-plus decay of nitrogen into carbon: ${}^{12}_{7}\text{N} \rightarrow {}^{12}_{6}\text{C} + {}^{0}_{1}\beta^{+}$

(97)**6. [T]**

a.

Step 1 Proton number: 80; nucleon number: 175.

b.

Step 1 $\lambda = \dfrac{c}{f}$; $\lambda = \dfrac{3\times10^{8}\,\text{m/s}}{2.2\times10^{20}\,\text{Hz}} = 1.4\times10^{-12}\,\text{m} = 1.4\text{ pm}$

c.

Step 1 Alpha particles are deviated by an electric or a magnetic field. Gamma rays are unaffected by both.

d.

Step 1 Converting eV into joules: $33\text{ eV} = 33 \times 1.6 \times 10^{-19}\text{ J} = 53 \times 10^{-19}\text{ J}$

Step 2 Maximum number of atoms that can be ionized: $\dfrac{7.8 \times 10^{-13}}{53 \times 10^{-19}} = 1.5 \times 10^{5}$

Section 5.4 Families of Particles

(98)7. [G]

a. protons and neutrons
b. electrons and neutrinos

(99)8. [G]

a. A proton is made up of two up quarks and one down quark.
b. A neutron is made up of two down quarks and one up quark.

(100)9. [G]

The six types or flavors of quarks are:
up, down, charm, strange, top, bottom

(101)10. [G] One of the down quarks decays into an up quark.

(102)11. [T] a. Step 1 A fundamental particle is a particle that does not consist of other types of particles / cannot be subdivided further.

b.i

Step 1 Any charged particle will change its motion in the presence of a charged object; examples of charged particles include protons, electrons, positrons.

b.ii

Step 1 Any neutral particle, such as a neutron, will maintain its motion in the presence of a charged object.

c.i

Step 1 baryon

c.ii

Step 1 The charge of an up quark is $+\frac{2}{3}e$ and that of a down quark is $-\frac{1}{3}e$.

Step 2 To make the particle neutral, it requires one more down quark (accept strange/bottom).

(103)**12. [T]**

a.

Step 1 The quark composition of an antiproton is $\bar{u}\,\bar{u}\,\bar{d}$, thus the charge is $-\frac{2}{3}e-\frac{2}{3}e+\frac{1}{3}e=-e$

b.

Step 1 The strong force

c. i

Step 1

	nucleus formed after $^{112}_{53}I$ decay	nucleus formed after $^{140}_{54}Xe$ decay
proton number	**52**	**55**
neutron number	**60**	**85**

c.ii

Step 1 positron, lepton

c.iii

Step 2 anti-neutrino, lepton

Chapter 6 Fluids and Properties of Materials

Section 6.1 Density

(104)**1. [G]** The density is given by:

$$\rho = \frac{m}{V}$$

$$\rho = \frac{m}{\frac{4}{3}\pi R^3}$$

$$\rho = \frac{90\times10^{-3}\ \text{kg}}{\frac{4}{3}\pi\left(2.0\times10^{-2}\ \text{m}\right)^3} = 2687\ \text{kg/m}^3$$

Section 6.2 Pressure

(105)**2. [G]** The pressure due to water on the box is given by:

$$p = \rho_{\text{water}} gh$$

$$p = \left(1{,}000\ \text{kg/m}^3\right)\left(9.8\ \text{m/s}^2\right)\left(0.30\ \text{m}\right) = 2.94\ \text{kPa}$$

(106)**3. [T] a. Step 1** Since the curling stone is moving at constant velocity, then by applying Newton's first law of motion:

$f = F \sin 60°$

Step 2 $f = (10.0\ \text{N})\sin 60^\circ = 8.66\ \text{N}$

b. Step 1 The power developed by the athlete is given by:

$P = Fv\sin 60^\circ$

$P = (10.0\ \text{N})(1.2\ \text{m/s})\sin 60^\circ = 10.4\ \text{W}$

c.Step 1 The pressure exerted by the curling stone on the ground is:

$$p = \frac{F_\perp}{A}$$

Step 2 The normal force exerted by the stone is:

$F_\perp = mg + F\cos 60^\circ$

Step 3 Then,

$$p=\frac{mg+F\cos 60^{\circ}}{A}$$

$$p=\frac{(19\ \text{kg})(9.80\ \text{m/s}^2)+(10.0\ \text{N})\cos 60^{\circ}}{615\times10^{-4}\ \text{m}^2}=3.11\ \text{kPa}$$

d.i

Step 1 The force by the stone on the ground directed parallel to the stone's direction of motion.

d.ii

Step 1 **the** upward pull by the stone on Earth.

Section 6.3 Buoyancy

(107)**4. [G]** The magnitude of the upthrust is given by:

$$\text{upthrust}=\rho V g$$

$$\text{upthrust}=\rho\left(\frac{4}{3}\pi R^3\right)g$$

$$\text{upthrust}=\left(1,020\ \text{kg/m}^3\right)\left[\frac{4}{3}\pi\left(4.0\times10^{-2}\ \text{m}\right)^3\right]\left(9.8\ \text{m/s}^2\right)=2.68\ \text{N}$$

Section 6.4 Mechanical Properties of Materials

(108)**5. [G]** The force applied on the spring is given by:

$$F=kx$$

$$F=(250\ \text{N/m})\left(5.0\times10^{-2}\ \text{m}\right)=12.5\ \text{N}$$

(109)**6. [G]** a. The stress in the rod is given by:

$$\text{stress}=\frac{F}{A}$$

$$\text{stress}=\frac{1,200\ \text{N}}{2.4\times10^{-5}\ \text{m}^2}=50\ \text{MPa}$$

b. The strain in the rod is given by:

$$\text{strain} = \frac{x}{L}$$

$$\text{strain} = \frac{0.50\times10^{-3}\ \text{m}}{2.0\ \text{m}} = 2.5\times10^{-4}$$

c. The Young modulus of the alloy is:

$$E = \frac{\text{stress}}{\text{strain}}$$

$$E = \frac{50\times10^{6}\ \text{Pa}}{2.5\times10^{-4}} = 200\ \text{GPa}$$

(110)7. [T]

a. Step 1 Since the length versus force graph of the spring is a straight line, then the spring obeys Hooke's law.

b. Step 1 By Hooke's law:

$$F = k\left(l - l_0\right)$$

Then, $l = l_0 + \dfrac{F}{k}$

Step 2 The slope of the *l*-*F* graph is:

$$\text{slope} = \frac{1}{k}$$

$$\frac{1}{k} = \frac{16\times10^{-2}\ \text{m} - 10\times10^{-2}\ \text{m}}{4\ \text{N}} = 1.5\times10^{-2}\ \text{m/N}$$

Step 3 $k = \dfrac{1}{1.5\times10^{-2}\ \text{m/N}} = 67\ \text{N/m}$

c. Step 1 The work done on the spring to stretch it is given by:

$$W = \frac{1}{2}kx^2$$

$$W = \frac{1}{2}\left(67\ \text{N/m}\right)\left(0.02\ \text{m}\right)^2 = 13\ \text{mJ}$$

d. Step 1 Applying Hooke's law:

$$x = \frac{F}{k}$$

$$x = \frac{mg}{k}$$

$$x = \frac{(0.12\ \text{kg})(9.80\ \text{m/s}^2)}{67\ \text{N/m}} = 1.8\ \text{cm}$$

e.i

Step 1 The pressure in the liquid is proportional to the depth below the surface
Step 2 Then, the pressure of the liquid on the bottom face of the block is greater than the pressure on the top face of the block
Step 3 The difference in the pressure results in an upward force decreasing the net downward pull on the spring.

e.ii

Step 1 Inside the liquid, the block is in equilibrium:

$$mg = kx_2 + \rho_{\text{liquid}} Vg$$

$$mg = kx_2 + \rho_{\text{liquid}} \frac{m}{\rho_{\text{block}}} g$$

Step 2

$$\rho_{\text{liquid}} = (mg - kx_2)\left(\frac{\rho_{\text{block}}}{mg}\right)$$

$$\rho_{\text{liquid}} = \left[(0.12\ \text{kg})(9.80\ \text{m/s}^2) - (67\ \text{N/m})(0.011\ \text{m})\right]\left[\frac{2,700\ \text{kg/m}^3}{(0.12\ \text{kg})(9.80\ \text{m/s}^2)}\right]$$

$$\rho_{\text{liquid}} = 1,008\ \text{kg/m}^3$$

(111)8. [T]

a. **Step 1** The principle of moments states that for any object in equilibrium, the sum of clockwise moments about a point is equal to the sum of anticlockwise moments about the same point.

b. **Step 1** Since the tweezers are in equilibrium, we apply the principle of moments:

$$-Fl_1 \sin 60^\circ + N(l_1 + l_2) = 0$$

Step 2

$$N=\frac{Fl_1\sin 60^\circ}{l_1+l_2}$$

$$N=\frac{(2.0\ \text{N})(4.2\times10^{-2}\ \text{m})\sin 60^\circ}{4.2\times10^{-2}\ \text{m}+5.9\times10^{-2}\ \text{m}}=0.72\ \text{N}$$

c.i. Step 1 The mass of the wire can be expressed as:

$$m=\rho V$$

$$m=\rho LA$$

$$A=\frac{m}{\rho L} \qquad (1)$$

Step 2 Knowing that $m=\frac{w}{g}$, equation (1) becomes

$$A=\frac{w}{\rho Lg}$$

$$A=\frac{0.011\ \text{N}}{(8,730\ \text{kg/m}^3)(6.0\times10^{-3}\ \text{m})(9.80\ \text{m/s}^2)}=21.4\times10^{-6}\ \text{m}^2$$

c.ii Step 1 The stress on the wire is:

$$\sigma=\frac{F}{A}$$

$$\sigma=\frac{0.72\ \text{N}}{21.4\times10^{-6}\ \text{m}^2}=3.36\times10^{4}\ \text{Pa}$$

(112)9 .[T]

a.i
Step 1 Hooke's law states that the absolute extension of an elastic object is directly proportional to the stretching force acting on it.

a.ii
Step 1 The strain is directly proportional to stress on an object.

b.i
Step 1 Young modulus is given by:

$$E = \frac{\sigma}{\varepsilon}$$
$$\sigma = E\varepsilon$$

$$\frac{F}{A} = E\frac{x}{L} \qquad (1)$$

Step 2 In addition, the slope of the graph is $\text{slope} = \frac{F}{x}$ (2).

Step 3 Combining equations (1) and (2) we get:

$$E = \frac{\text{slope} \times L}{A}$$

b.ii
Step 1 The slope of the graph is 600 N/mm = 6.0×10^5 N/m
Step 2 The Young modulus of tin is:

$$E = \frac{\left(6.0\times10^5\ \text{N/m}\right)\left(1.0\ \text{m}\right)}{12\times10^{-6}\ \text{m}^2} = 50\ \text{GPa}$$

b.iii
Step 1 The work done on the rod is the area under the *F*-*x* graph.
Step 2 $W = \frac{1}{2}(240\ \text{N})\left(0.4\times10^{-3}\ \text{m}\right) = 48\ \text{mJ}$

b.iv
Step 1 Tin has a low elastic limit.
Step 2 When deformation exceeds the elastic limit and deformations become plastic, the object does not return to its original shape.

c.i Step 1 Inaccurate, does not coincide with the reference value within experimental error.

c.ii Step 1 Precise, more s.f. than in the reference value.

(113)10. [T]
a.Step 1 Newton's third law of motion states that when two bodies interact, the forces they exert on each other are equal in magnitude and opposite in direction.

b.i Step 1 The acceleration is equal to the slope of the *v*-*t* graph.

Step 2 Then, $a = \dfrac{6.2\ \text{m/s} - 0\ \text{m/s}}{10\ \text{s} - 0\ \text{s}} = 0.62\ \text{m/s}^2$

b.ii.1
Step 1 The displacement is the area under the *v*-*t* graph in a certain time interval.

Step 2 Between $t = 0$ s and $t = 10$ s:
$$d_1 = \frac{1}{2}(6.2\ \text{m/s})(10\ \text{s}) = 31\ \text{m}$$

b.ii.2
Step 1 Between $t = 10$ s and $t = 20$ s:
$$d_2 = (6.2\ \text{m/s})(10\ \text{s}) = 62\ \text{m}$$

b.iii.1
Step 1 For $t > 10$ s, the tractor is in URM, then the forces on the car are balanced.
Step 2 $T - f_{\text{car}} = 0$
$T = 400$ N

b.iii.2
Step 1 Applying Newton's first law of motion on the tractor:
$$F - T - f_{\text{tractor}} = 0$$
$$F = T + f_{\text{tractor}}$$
Step 2 By Newton's third law, the tensile force on the tractor is also 400 N.
Step 3 Then,
$$F = 400\ \text{N} + 550\ \text{N} = 950\ \text{N}$$

b.iii.3
Step 1 The work done by the engine is given by:
$$W = Fd$$
$$W = (950\ \text{N})(62\ \text{m}) = 58.9\ \text{kJ}$$

c.
Step 1 Young modulus is expressed by:
$$E = \frac{\sigma}{\varepsilon}$$
Step 2 $E = \dfrac{1.8 \times 10^9\ \text{Pa}}{0.03} = 60 \times 10^9\ \text{Pa}$

d.

Step 1 Applying Doppler effect:

$$f_{\text{detected}} = f_{\text{source}} \frac{v}{v - v_{\text{source}}}$$

Step 2

$$f_{\text{detected}} = (700\ \text{Hz}) \frac{340\ \text{m/s}}{340\ \text{m/s} - 6.2\ \text{m/s}} = 713\ \text{Hz}$$

(114) 11. [T]

a.

Step 1

Quantity	Scalar	Vector
displacement		√
potential energy	√	
strain	√	
velocity		√

b.i

Step 1 $w = mg = \rho \pi r^2 hg$

Step 2 $w = 0.50\ \text{kg/m}^3 \left(3.14 \times (4.0 \times 10^{-2}\ \text{m})^2 \times 0.25\ \text{m}\right) 9.8\ \text{m/s}^2 = 6.1\ \text{mN}$

b.ii

Step 1 Applying the equilibrium condition for the vertical components: $U - w - T\sin 80^{\circ} = 0$

Step 2 $U = w + T\sin 80^{\circ}$; $U = 6.1\ \text{mN} + 8.7\ \text{mN} = 14.8\ \text{mN}$

b.iii

Step 1 The density of air is greater than the density of the helium balloon

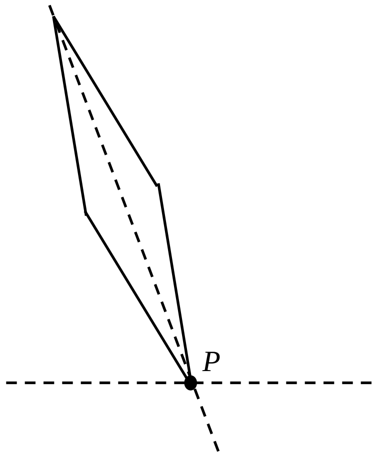
Step 2 Otherwise, the upthrust could not exceed the weight of the balloon and the balloon would sink to the ground.

(115)**12. [T]**

a.Step 1 An object is said to be in rotational equilibrium when the net torques on the object is zero, that is the object is either not rotating or rotating at a constant angular velocity.

b.i

Step 1 The other force acting on the crane's arm is the reaction of the hinge.



b.ii

Step 1 Applying Newton's first law for rotational motion, and taking the moments about the hinge, we get:

$$w\frac{l}{2}\sin 37^\circ + w_{\text{load}} l \sin 37^\circ - Tl\sin\left(53^\circ - 37^\circ\right) = 0$$

Step 2

$$w = \frac{2\left[T\sin\left(53^\circ - 37^\circ\right) - w_{\text{load}}\sin 37^\circ\right]}{\sin 37^\circ}$$

$$w = \frac{2\left[(9{,}900\ \text{N})\sin 16^\circ - (2{,}500\ \text{N})\sin 37^\circ\right]}{\sin 37^\circ} = 4.07\times 10^3\ \text{N}$$

c.i

Step 1 Hooke's law states that the extension of an object is proportional to the applied force or the strain is directly proportional to stress.

c.ii

Step 1 Young Modulus is given by:

$$E = \frac{\sigma}{\varepsilon}$$

$$\varepsilon = \frac{1}{E}\sigma$$

Step 2

$$E = \frac{1}{\text{slope}}$$

$$E = \frac{1}{5.0 \times 10^{-12}\ \text{Pa}^{-1}} = 200\ \text{GPa}$$

c.iii

Step 1 The additional quantities needed are the initial length of the cable and its cross-sectional area / diameter / radius.