Answers

N.B. — All numerical answers here have been rounded to the same number of significant figures as the given data value with the least number of significant figures (see page 1).

Section 1 — Forces and Motion

Page 2 — Speed, Displacement and Velocity

1 speed = distance ÷ time = 1500 ÷ 210 = 7.142...
= **7.1 ms^{-1} (to 2 s.f.)**

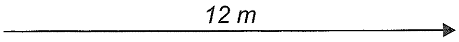
2 distance = speed × time = $(3.0 \times 10^8) \times (8.3 \times 60)$
= 1.494×10^{11}
= **1.5×10^{11} m (to 2 s.f.)**

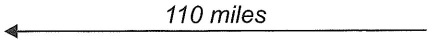
3 time = distance ÷ speed. 1.5 m = 150 cm,
so time = 150 ÷ 0.24 = 625 = **620 seconds (to 2 s.f.)**

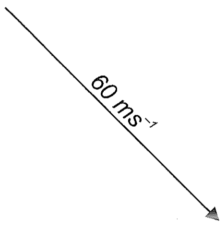
4 t = s ÷ v = (1 × 1000) ÷ 50 = **20 s**

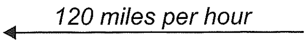
5 s = v × t = 7.50 × 15.0 = 112.5
= **113 m south (to 3 s.f.)**

Page 3 — Drawing Displacements and Velocities

1 a) 

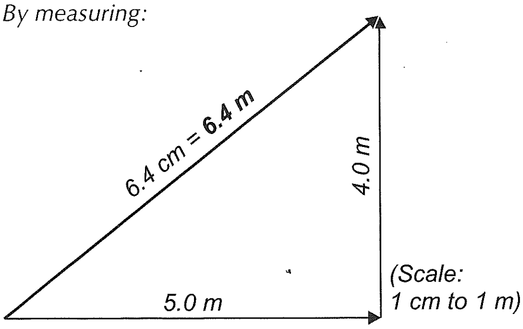
b) 

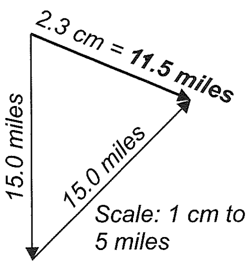
2 a) 

b) 

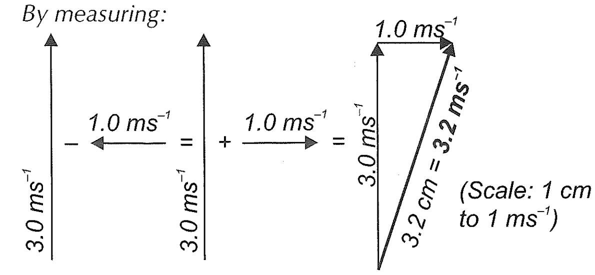
Page 4 — Combining Displacements and Velocities

1 a) By measuring:



b) 

2 By measuring:



Or by Pythagoras: $\Delta v = \sqrt{3.0^2 + 1.0^2} = 3.162...$
= 3.2 m (to 2 s.f.)

Page 5 — Resolving Vectors

1 Horizontal component = $v_x = v \cos\theta = 12 \times \cos 68$
$= 4.495... =$ **4.5 ms^{-1} (to 2 s.f.)**
Vertical component = $v_y = v \sin\theta = 12 \times \sin 68$
$= 11.128... =$ **11 ms^{-1} (to 2 s.f.)**

2 $\cos\theta = \frac{v_x}{v}$. Rearranging for θ gives:
$\theta = \cos^{-1}\left(\frac{v_x}{v}\right) = \cos^{-1}\frac{67}{98} = 46.868...$
= 47° (to 2 s.f.)

3 Vertical velocity = $v_y = v \sin\theta = 5.9 \times \sin 23$
$= 2.305...$ ms^{-1}
Time taken to descend 150 m = $\frac{s}{v_y} = \frac{150}{2.305...}$
$= 65.067...$
= 65 s (to 2 s.f.)

Page 6 — Acceleration

1 u = 12.8 ms^{-1} to the left = −12.8 ms^{-1}
v = 18.3 ms^{-1} to the right = +18.3 ms^{-1}
$a = \frac{v-u}{t} = \frac{18.3-(-12.8)}{22.0} = 1.4136...$
= 1.41 ms^{-2} to the right (to 2 s.f.)

2 $t = \frac{v-u}{a} = \frac{4.5-1.5}{0.18} = 16.66...$ **= 17 s (to 2 s.f.)**

3 u = v − (a × t) = 0 − (−0.41 × 3.7) = 1.517
= 1.5 ms^{-1} (to 2 s.f.)

Page 7 — Acceleration Due To Gravity

1 $t = \frac{v-u}{a} = \frac{-4.9-0}{-9.81} = 0.4994...$ = **0.50 s (to 2 s.f.)**

2 u = v − (a × t) = −26.5 − (−9.81 × 2.15) = −5.4085
= 5.41 ms^{-1} downwards (to 3 s.f.)

3 v = u + (a × t) = 0 + (−9.81 × 10.0) = −98.1
= 98.1 ms^{-1} down

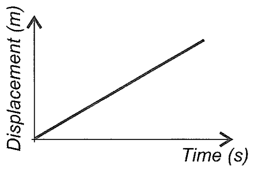
4 $t = \frac{v-u}{a} = \frac{-24.5-0}{-9.81} = 2.4974...$ = **2.50 s (to 3 s.f.)**

5 u = v − (a × t) = −10.7 − (−9.81 × 1.90) = 7.939
= 7.94 ms^{-1} up (to 3 s.f.)

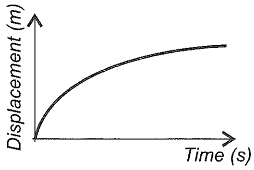
Answers

Page 8 — Displacement-Time Graphs

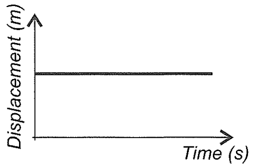
1 E.g.



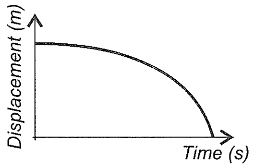
2 E.g.



3 E.g.



4 E.g.



Page 9 — Displacement-Time Graphs

1 a) *It is accelerating (towards the start line).*

b) *Between 3 and 4 seconds it is moving towards the start line and decelerating until it is stationary. It travels 20 metres in this time. Between 4 and 6 seconds it remains stationary zero metres from the start line.*

c) *Velocity = (160 – 40) ÷ (10 – 8)*
= 120 ÷ 2 = **60 ms^{-1}**

d) *Average velocity = (180 – 80) ÷ 14 = 100 ÷ 14*
= 7.1428... = **7 ms^{-1} (to 1 s.f.)**

e) *Average speed = (80 + 180) ÷ 14 = 260 ÷ 14*
= 18.571... = **20 ms^{-1} (to 1 s.f.)**

Page 11 — Velocity-Time Graphs

1 a) A (0 s-10 s), acceleration = $\frac{10-6}{10-0}$ = **0.4 ms^{-2}**,

B (10 s-20 s), acceleration = $\frac{10-10}{20-10}$ = **0 ms^{-2}**,

C (20 s-30 s), acceleration = $\frac{2-10}{30-20}$ = **–0.8 ms^{-2}**

b) A (0 s-10 s), area = ½(6 + 10) × 10 = 80 m
B (10 s-20 s), area = 10 × 10 = 100 m
C (20 s-30 s), area = ½(10 + 2) × 10 = 60 m
Total distance travelled = 80 + 100 + 60 = **240 m**

2 a) A (0 s-3 s), acceleration = $\frac{15-0}{3-0}$ = **5 ms^{-2}**

B (3 s-4 s), acceleration = $\frac{10-15}{4-3}$ = **–5 ms^{-2}**

C (4 s-6 s), acceleration = $\frac{20-10}{6-4}$ = **5 ms^{-2}**

b) A (0 s-3 s), area = ½ × 15 × 3 = 22.5 m
B (3 s-4 s), area = ½(15 + 10) × 1 = 12.5 m
C (4 s-6 s), area = ½(10 + 20) × 2 = 30 m
Total distance travelled = 22.5 + 12.5 + 30 = **65 m**

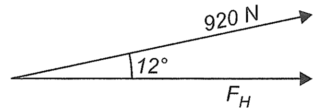
Page 12 — Adding and Resolving Forces

1 a) 8 – 5 = **3 N to the right, forces are unbalanced.**

b) 700 – 200 = **500 N to the left, forces are unbalanced.**

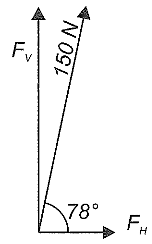
c) 2 – 2 = **0 N, forces are balanced.**

2



$F_H = F\cos\theta = 920 \times \cos 12 = 899.89...$
= **900 N (to 2 s.f.)**

3 $F_V = F\sin\theta = 150 \times \sin 78 = 146.72...$
= **150 N (to 2 s.f.)**



Page 14 — Forces and Acceleration

1 F = m × a = 840 × 0.50 = **420 N**

2 F = m × a = 0.120 × 9.81 = 1.1772
= **1.18 N (to 3 s.f.)**

3 a = F ÷ m = 250 ÷ 0.5 = **500 N**

4 m = F ÷ a = 55 000 ÷ 0.275 = **200 000 kg**

5 a = F ÷ m = 8600 ÷ 15 000 = 0.573... ms^{-2}
$a = \frac{v-u}{t}$, so v = u + (a × t) = 0 + (0.573... × 25)
= 14.333... = **14 ms^{-1} (to 2 s.f.)**

Answers

Section 2 — Energy

Page 15 — Kinetic Energy

1 $E_k = ½ \times m \times v^2 = ½ \times 0.125 \times 72.0^2 =$ **324 J**

2 $E_k = ½ \times m \times v^2$ so $m = \frac{2 \times E_k}{v^2} = \frac{2 \times 5.4 \times 10^7}{15^2}$ **= 4.8 × 10⁵ kg**

3 $v = \sqrt{\frac{2 \times E_k}{m}} = \sqrt{\frac{2 \times 1.0 \times 10^{-6}}{0.057}} = 5.9234... \times 10^{-3}$
$=$ **5.9×10^{-3} ms⁻¹** (or 0.59 cms⁻¹) **(to 2 s.f.)**

Page 16 — Gravitational Potential Energy

1 $E_p = m \times g \times h = 750 \times 9.81 \times 350 = 2\ 575\ 125$
= 2.6×10^6 J (to 2 s.f.)

2 $m = \frac{E_p}{g \times h} = \frac{1715}{9.81 \times 7.00} = 24.974... =$ **25.0 kg (to 3 s.f.)**

3 $h = \frac{E_p}{m \times g} = \frac{24\ 700}{65.0 \times 9.81} = 38.735... =$ **38.7 m (to 3 s.f.)**

Page 17 — Conservation of Energy

1 E_k lost = E_p gained = 2850 J
So $E_p = m \times g \times h = 2850$ J
$m = \frac{E_p}{g \times h} = \frac{2850}{9.81 \times 5.10} = 56.964... =$ **57.0 kg (to 3 s.f.)**

2 E_p lost $= m \times g \times h = 0.475 \times 9.81 \times 0.920 = 4.28697$ J
E_p lost = E_k gained, so $E_k = ½ \times m \times v^2 = 4.28697$ J
$v = \sqrt{\frac{2 \times E_k}{m}} = \sqrt{\frac{2 \times 4.28697}{0.475}} = 4.2485...$
= 4.25 ms⁻¹ (to 3 s.f.)

3 E_k lost $= ½ \times m \times v^2 = ½ \times 0.015 \times 420^2 = 1323$ J
E_p gained = E_k lost, so $E_p = m \times g \times h = 1323$ J
$h = \frac{E_p}{m \times g} = \frac{1323}{0.015 \times 9.81} = 8990.8...$
= 9000 m (to 2 s.f.)

Page 18 — Work

1 $W = F \times s = 25 \times 44 =$ **1100 J**

2 $W = F\cos\theta \times s = 17 \times \cos 35 \times 2.5 = 34.81...$
= 35 J (to 2 s.f.)

Page 19 — Work

1 a) $W = F \times s = 125 \times 2.50 = 312.5 =$ **313 J (to 3 s.f.)**

b) $E_p = m \times g \times h = 5.75 \times 9.81 \times 2.50 = 141.01...$
= 141 J (to 3 s.f.)

c) Work done = increase in E_k + increase in E_p so:
$E_k = W - E_p = 312.5 - 141.01... = 171.48...$
= 171 J (to 3 s.f.)

d) $v = \sqrt{\frac{2 \times E_k}{m}} = \sqrt{\frac{2 \times 171.48...}{5.75}} = 7.7230...$
= 7.72 ms⁻¹ (to 3 s.f.)

Page 20 — Power

1 $P = \frac{W}{t} = \frac{250}{4.0} = 62.5 =$ **63 W (to 2 s.f.)**

2 $t = \frac{W}{P} = \frac{91 \times 1000}{14 \times 1000} = \frac{91\ 000}{14\ 000} =$ **6.5 s**

3 $W = F \times s = 276 \times (1.25 \times 1000) = 345\ 000$ J
$P = \frac{W}{t} = \frac{345\ 000}{2.5 \times 60} =$ **2300 W**

Page 21 — Power

1 $P = F \times v = 1.80 \times 10^5 \times 40.0$
= 7.20×10^6 W (or 7.20 MW)

2 The skydiver's weight is equal to the force, F, exerted by gravity on her mass, so:
$F = \frac{P}{v} = \frac{31\ 500}{45} =$ **700 N**

3 $v = \frac{P}{F} = \frac{5.20 \times 10^4}{1650} = 31.515... =$ **31.5 ms⁻¹ (to 3 s.f.)**

Page 22 — Efficiency

1 Useful energy out $= E_p = m \times g \times h$
$= 12.9 \times 9.81 \times 2.50 = 316.3725$ J
$\text{Efficiency} = \frac{\text{useful energy out}}{\text{total energy in}} \times 100\%$
$= \frac{316.3725}{375} \times 100\% = 84.366 =$ **84.4%**

2 a) $E_k = ½ \times m \times v^2 = ½ \times 560 \times 25^2 = 1.75 \times 10^5$
= 1.8×10^5 J (or 180 kJ) **(to 2 s.f.)**

b) $\text{Efficiency} = \frac{\text{useful energy out}}{\text{total energy in}} \times 100\%$
$= \frac{1.75 \times 10^5}{1.4 \times 10^6} \times 100\% = 12.5$
= 13% (to 2 s.f.)

Section 3 — Materials

Page 24 — Forces and Springs

1 $F = k \times \Delta l = 64.1 \times 0.245 = 15.7045$
= 15.7 N (to 3 s.f.)

2 $\Delta l = \frac{F}{k} = \frac{378}{84.0} =$ **4.50 m**

3 a) $F = m \times g = 7.4 \times 9.81 = 72.594$ N
$k = \frac{F}{\Delta l} = \frac{72.594}{0.084} = 864.214... =$ **860 Nm⁻¹ (to 2 s.f.)**

b) $F = k \times \Delta l = 864.214... \times 0.095 = 82.100...$ N
$m = \frac{F}{g} = \frac{82.100...}{9.81} = 8.369... =$ **8.4 kg (to 2 s.f.)**
Yes, the bag can be taken on the flight.

4 a) The maximum force at which an object's extension is still proportional to the force applied to it.

b) It could have been stretched beyond its elastic limit.

Answers

Section 4 — Electricity

Page 25 — Current and Potential Difference

1 $I = \frac{Q}{t}$, so $t = \frac{Q}{I} = \frac{12}{3.0} = \mathbf{4.0\ s}$

2 $V = \frac{W}{Q}$, so $W = V \times Q = 1.5 \times 9.2 = \mathbf{13.8\ V}$

3 $I = \frac{Q}{t}$, so $Q = I \times t = 3.80 \times 275 = 1045\ C$

$V = \frac{W}{Q} = \frac{9540}{1045} = 9.129... = \mathbf{9.13\ V\ (to\ 3\ s.f.)}$

Page 26 — Current in Electric Circuits

1 $0.5 = I_1 + 0.2 + 0.05$
$0.5 = I_1 + 0.25$
$I_1 = 0.5 - 0.25$
$I_1 = \mathbf{0.25\ A}$

2 $0.4 + 0.3 + I_2 = 1.3$
$0.7 + I_2 = 1.3$
$I_2 = 1.3 - 0.7$
$I_2 = \mathbf{0.6\ A}$

Page 27 — Potential Difference in Electric Circuits

1 a) $12 = V_M + 3$
$V_M = 12 - 3$
$= \mathbf{9\ V}$

b) $12 = 6 + 2 + V_S$
$V_S = 12 - 6 - 2$
$= \mathbf{4\ V}$

2 **12 V**

Page 28 — Resistance

1 $V = I \times R$, so $V = 2.5 \times 15 = 37.5 = \mathbf{38\ V\ (to\ 2\ s.f.)}$

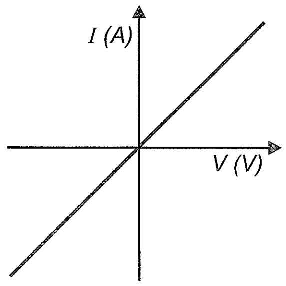
2 $I = \frac{V}{R} = \frac{6.0}{2500} = \mathbf{0.0024\ A}$ (or 2.4 mA)

3 $R = \frac{V}{I} = \frac{1.5}{0.024} = 62.5 = \mathbf{63\ \Omega\ (to\ 2\ s.f.)}$

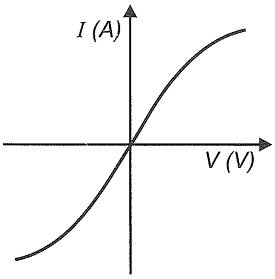
Page 29 — I-V Graphs

1 Provided the temperature is constant, the current though an ohmic component is directly proportional to the potential difference across it ($V = IR$).

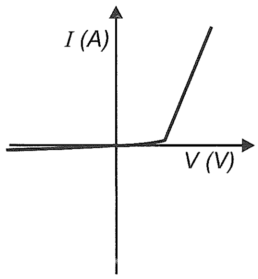
2 a)



b)



c)



Page 30 — Power in Circuits

1 $P = V \times I = 6.5 \times 0.12 = \mathbf{0.78\ W}$

2 a) $I = \frac{P}{V} = \frac{45}{14} = 3.214... = \mathbf{3.2\ A\ (to\ 2\ s.f.)}$

b) $W = P \times t = 45 \times 12 = \mathbf{540\ J}$

Page 31 — Power in Circuits

1 $P = I^2R = 1.2^2 \times 2400 = 3456 = \mathbf{3500\ W\ (to\ 2\ s.f.)}$

2 $P = \frac{V^2}{R} = \frac{6^2}{100} = \frac{36}{100} = 0.36\ W$

$W = P \times t = 0.36 \times 60 = 21.6 = \mathbf{20\ J\ (to\ 1\ s.f.)}$

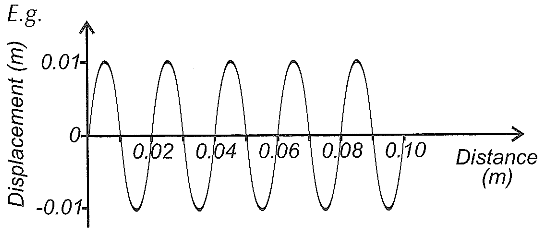
3 $R = \frac{P}{I^2} = \frac{6.0}{0.50^2} = \mathbf{24\ \Omega}$

Answers

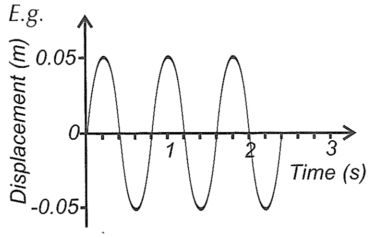
Section 5 — Waves

Page 32 — Waves

1 E.g.



2 E.g.



Page 33 — Frequency and the Wave Equation

1 $T = \frac{1}{f} = \frac{1}{6.25 \times 10^5} = \mathbf{1.60 \times 10^{-6}}$ **s**

2 $f = \frac{1}{T} = \frac{1}{0.0012} = 833.33... =$ **830 Hz (to 2 s.f.)**

3 $v = f \times \lambda = 3.5 \times 1.4 =$ **4.9 ms^{-1}**

4 a) $f = \frac{1}{T} = \frac{1}{7.1} = 0.1408... =$ **0.14 Hz (to 2 s.f.)**

b) $v = f \times \lambda$, so $\lambda = \frac{v}{f} = \frac{180}{0.1408...} = 1278$

$=$ **1300 m (to 2 s.f.)**

Page 34 — Superposition of Waves

1 a) If two waves meet they will briefly combine and become one single wave, with a displacement equal to the displacement of each individual wave added together.

b) When the amplitude of the combined wave is larger than the amplitude of the individual waves.

c) When the amplitude of the combined wave is smaller than the amplitude of the individual waves.

2 Amplitude = 0.67 + 0.67 = **1.34 mm**

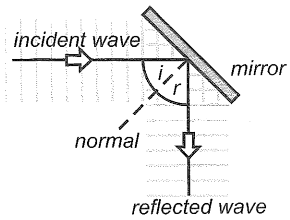
3 The waves will cancel each other out completely, so the amplitude will be **0 m**.

4 Amplitude = 35 + 41 = **76 cm**

Page 35 — Reflection and Diffraction

1 Angle of incidence (i) = angle of reflection (r)

2 E.g.



3 When the gap is about the same size as the wavelength, there will be a lot of diffraction. When the gap is made slightly larger, the amount of diffraction will decrease.

4 Light diffracts as it passes through the slit and forms a diffraction pattern of light and dark fringes.

Page 36 — Refraction

1 The wave slows down without changing direction.

2 The wave slows down and changes direction.

3 $n = \frac{\sin i}{\sin r} = \frac{\sin 72}{\sin 39} = 1.511... =$ **1.5**

4 $n = \frac{\sin i}{\sin r}$ so $\sin r = \frac{\sin i}{n} = \frac{\sin 23}{1.3} = 0.3005...$

so $r = \sin^{-1} 0.3005... = 17.49... =$ **17° (to 2 s.f.)**

Section 6 — Atoms and Radioactivity

Page 37 — Atomic Structure

1 a) 95 protons, 146 neutrons

b) 94 protons, 145 neutrons

c) 38 protons, 52 neutrons

d) 27 protons, 33 neutrons

e) 88 protons, 138 neutrons

2 An isotope is a different form of the same element. It has the same number of protons but a different number of neutrons.

Page 38 — Nuclear Radiation

1 An alpha particle is made up of two protons and two neutrons.

2 In beta radiation a neutron in the nucleus turns into a proton and an electron. The electron is emitted from the nucleus.
In gamma radiation high-energy electromagnetic radiation is emitted from the nucleus. There is no change to the number of protons and neutrons.

3 a) ${}^{242}_{94}Pu \rightarrow {}^{238}_{92}U + {}^{4}_{2}\alpha$

b) ${}^{40}_{19}K \rightarrow {}^{40}_{20}Ca + {}^{0}_{-1}\beta$

c) ${}^{222}_{86}Rn \rightarrow {}^{218}_{84}Po + {}^{4}_{2}\alpha$

d) ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta$

Answers

Section 7 — Investigating and Interpreting

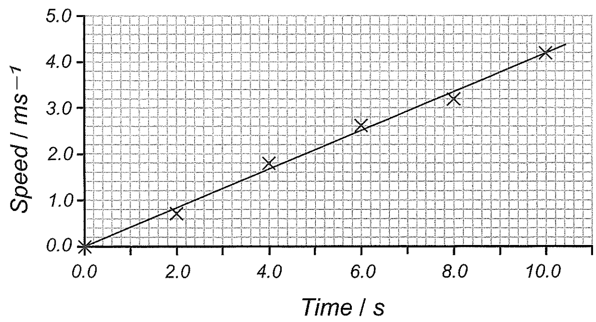
Page 39 — Planning an Experiment and Collecting Data

1 a) *Independent variable: potential difference across the component.*
Dependent variable: current through the component.

b) *(0.13 + 0.17 + 0.12) ÷ 3 = 0.14 A*

Page 40 — Analysing Your Data

1



Page 41 — Conclusions and Uncertainty

1 a) *0.001 s (or 1 ms)*

b) *No. There will be some human error in the result caused by the student's reaction time.*

Index

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