Physics Units 1 & 2

Practice Examinations — Units 1 & 2

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Contents

Practice Exam 1 — Easier

Physics Units 1 & 2 — Practice Examination 1

Reading time: 15 minutes

Writing time: 2 hours 30 minutes

- Section A: 20 questions, 20 marks
- Section B: 18 questions, 100 marks
- Total: 120 marks

There is no VCAA examination for VCE Physics Units 1 & 2; all assessment at Units 1 & 2 is school-based. This practice examination, its conditions, its structure and its mark totals are house convention only — they mirror the format of the family's Units 3 & 4 examination and are not a VCAA requirement.

Approved materials

- One scientific calculator
- Pre-written notes (one folded A3 sheet or two A4 sheets bound together by tape)

A formula sheet is provided at the end of this examination.

Students are **not** permitted to bring mobile phones and/or any unauthorised electronic devices into the examination room.

Section A — Multiple-choice questions (20 marks)

*Answer **all** questions. Choose the response that is **correct** or that **best answers** the question.*

*A correct answer scores 1; an incorrect answer scores 0. Marks will **not** be deducted for incorrect answers.*

No marks will be given if more than one answer is completed for any question.

*Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.*

Where required, take the gravitational field strength to be $g = 9.8\ \mathrm{N\ kg^{-1}}$.

Question 1

A sound wave of frequency $170\ \mathrm{Hz}$ travels through air at $340\ \mathrm{m\ s^{-1}}$. Which one of the following is closest to the wavelength of the wave?

A. $0.50\ \mathrm{m}$

B. $2.0\ \mathrm{m}$

C. $5.8 \times 10^{4}\ \mathrm{m}$

D. $0.20\ \mathrm{m}$

Question 2

Which one of the following lists the regions of the electromagnetic spectrum in order of increasing frequency?

A. radio, infrared, visible, ultraviolet

B. ultraviolet, visible, infrared, radio

C. infrared, radio, ultraviolet, visible

D. radio, ultraviolet, visible, infrared

Question 3

Light signals are sent along an optical fibre to carry information. The signal stays inside the core of the fibre because of

A. continuous refraction as the light passes through the core.

B. total internal reflection at the boundary between the core and the cladding.

C. dispersion of the different colours of light inside the core.

D. diffraction of the light at the ends of the fibre.

Question 4

The temperature of a room is $27\,°\mathrm{C}$. Which one of the following is closest to this temperature on the kelvin scale?

A. $246\,\mathrm{K}$

B. $273\,\mathrm{K}$

C. $27\,\mathrm{K}$

D. $300\,\mathrm{K}$

Question 5

Which one of the following correctly describes an alpha particle?

A. It is a helium nucleus; it is highly ionising and is stopped by a sheet of paper.

B. It is a high-speed electron; it is moderately ionising and is stopped by a few mm of aluminium.

C. It is a high-frequency electromagnetic wave; it is weakly ionising and is reduced by thick lead.

D. It is a helium nucleus; it is weakly ionising and is highly penetrating.

Question 6

Carbon-14, ${}^{14}_{6}C$, decays by β^- emission. Which one of the following is the daughter nucleus produced?

A. ${}^{14}_{5}B$

B. ${}^{10}_{6}C$

C. ${}^{13}_{6}C$

D. ${}^{14}_{7}N$

Question 7

A radioactive sample has an initial mass of $80\,\mathrm{g}$. Which one of the following is closest to the mass of the original radioactive isotope remaining after three half-lives?

A. $10\,\mathrm{g}$

B. $20\,\mathrm{g}$

C. $27\,\mathrm{g}$

D. $40\,\mathrm{g}$

Question 8

A current of $2.0\ \mathrm{A}$ flows through a wire for $30\ \mathrm{s}$. Which one of the following is closest to the charge that passes through the wire?

A. $15\ \mathrm{C}$

B. $0.067\ \mathrm{C}$

C. $60\ \mathrm{C}$

D. $6.0\ \mathrm{C}$

Question 9

A $12\ \mathrm{V}$ battery supplies a current of $0.50\ \mathrm{A}$ to a small motor. Which one of the following is closest to the electrical power delivered to the motor?

A. $24\ \mathrm{W}$

B. $0.042\ \mathrm{W}$

C. $12.5\ \mathrm{W}$

D. $6.0\ \mathrm{W}$

Question 10

Two resistors, each of resistance $6.0\ \Omega$, are connected in parallel. Which one of the following is closest to their combined resistance?

A. $12\ \Omega$

B. $3.0\ \Omega$

C. $6.0\ \Omega$

D. $0.33\ \Omega$

Question 11

A voltage divider is made from two equal resistors connected in series across a $12\ \mathrm{V}$ supply. The output voltage is taken across one of the resistors. Which one of the following is closest to the output voltage?

A. $6.0\ \mathrm{V}$

B. $3.0\ \mathrm{V}$

C. $12\ \mathrm{V}$

D. $24\ \mathrm{V}$

Question 12

Which one of the following safety devices protects a person by detecting a difference between the current in the active wire and the current in the neutral wire?

A. a fuse

B. a circuit breaker

C. a residual current device (RCD)

D. an earth wire

Question 13

Which one of the following quantities is a vector?

A. kinetic energy

B. speed

C. mass

D. force

Question 14

A car starts from rest and accelerates uniformly at $2.0\,\mathrm{m\ s^{-2}}$ for $5.0\,\mathrm{s}$. Which one of the following is closest to the speed of the car at the end of this time?

A. $10\,\mathrm{m\ s^{-1}}$

B. $25\,\mathrm{m\ s^{-1}}$

C. $2.5\,\mathrm{m\ s^{-1}}$

D. $0.40\,\mathrm{m\ s^{-1}}$

Question 15

A net force of $12\,\mathrm{N}$ acts on an object of mass $4.0\,\mathrm{kg}$. Which one of the following is closest to the acceleration of the object?

A. $48\,\mathrm{m\ s^{-2}}$

B. $0.33\,\mathrm{m\ s^{-2}}$

C. $3.0\,\mathrm{m\ s^{-2}}$

D. $12\,\mathrm{m\ s^{-2}}$

Question 16

A mechanic applies a force of $20\,\mathrm{N}$ at right angles to the end of a spanner, $30\,\mathrm{cm}$ from the centre of the nut. Which one of the following is closest to the torque applied to the nut?

A. $6.0\,\mathrm{N\ m}$

B. $600\,\mathrm{N\ m}$

C. $67\,\mathrm{N\ m}$

D. $0.60\,\mathrm{N\ m}$

Question 17

A thermometer always reads $0.5\,^\circ\mathrm{C}$ higher than the true temperature, no matter what temperature is being measured. The readings from this thermometer are affected mainly by

A. random error.

B. a mistake.

C. the resolution of the thermometer.

D. systematic error.

Question 18

A student measures the acceleration due to gravity five times and obtains the values 8.9, 9.0, 8.8, 8.9 and $9.0\,\mathrm{m\,s^{-2}}$. The accepted value is $9.8\,\mathrm{m\,s^{-2}}$. These measurements are best described as

A. accurate but not precise.

B. precise but not accurate.

C. both accurate and precise.

D. neither accurate nor precise.

Question 19

A student plots a graph of current I (on the vertical axis) against potential difference V (on the horizontal axis) for a resistor. The gradient of the line represents

A. the resistance of the resistor, R.

B. the power dissipated by the resistor.

C. the reciprocal of the resistance, $\frac{1}{R}$.

D. the charge passing through the resistor.

Question 20

A length is measured to be $2.6 \pm 0.2\,\mathrm{cm}$. Which one of the following readings is consistent with this measurement?

A. $2.2\,\mathrm{cm}$

B. $2.7\,\mathrm{cm}$

C. $2.9\,\mathrm{cm}$

D. $3.0\,\mathrm{cm}$

End of Section A

Practice Exam 1 — Section B

*Answer **all** questions in the spaces provided. Write your responses in English.*

Where an answer box is provided, write your final answer in the box. If an answer box has a unit printed in it, give your answer in that unit.

*In questions where more than one mark is available, appropriate working **must** be shown.*

*Unless otherwise indicated, the diagrams in this book are **not** drawn to scale. Take the gravitational field strength to be* $g = 9.8\,\mathrm{N\ kg^{-1}}$.

Question 1 (6 marks)

A vibrating source in a ripple tank produces water waves of frequency $5.0\,\mathrm{Hz}$. The waves travel across the surface of the tank at $0.40\,\mathrm{m\ s^{-1}}$.

a. Calculate the wavelength of the waves. Give your answer in m. 2 marks

b. State the period of the waves. Give your answer in s. 1 mark

c. The waves pass into a shallower part of the tank, where they travel more slowly. State what happens to the frequency of the waves and what happens to their wavelength, and explain your answer for the frequency. 2 marks

d. Water waves are mechanical waves. State one difference between a mechanical wave and an electromagnetic wave. 1 mark

Question 2 (5 marks)

A ray of light travelling through air strikes a flat block of glass. The angle of incidence is 45°. The refractive index of air is 1.00 and the refractive index of the glass is 1.50.

a. Calculate the angle of refraction of the ray in the glass. Give your answer in degrees. 2 marks

b. The ray travels through the glass until it reaches a glass–air boundary. Show that the critical angle for the glass–air boundary is 41.8°. 2 marks

c. Explain why the ray bends towards the normal as it passes from air into the glass. 1 mark

Question 3 (6 marks)

A $0.200\,\mathrm{kg}$ block of aluminium, of specific heat capacity $900\,\mathrm{J\ kg^{-1}\,K^{-1}}$, is heated from $20\,°\mathrm{C}$ to $80\,°\mathrm{C}$.

a. Calculate the thermal energy absorbed by the block. Give your answer in J. 2 marks

b. State the final temperature of the block on the kelvin scale. 1 mark

c. The hot block is placed against $0.100\,\mathrm{kg}$ of ice at $0\,°\mathrm{C}$. Calculate the energy required to melt all of the ice. The specific latent heat of fusion of ice is $3.34 \times 10^{5}\,\mathrm{J\ kg^{-1}}$. Give your answer in J. 2 marks

d. Name the process by which thermal energy is transferred through the solid aluminium block. 1 mark

Question 4 (5 marks)

The heating elements of an electric oven glow at a temperature of $1450\,\mathrm{K}$.

a. Calculate the peak wavelength of the electromagnetic radiation emitted by the elements. Give your answer in m. 2 marks

b. A second object has a surface temperature of $2900\,\mathrm{K}$. State, giving a reason, how the peak wavelength of the radiation emitted by this object compares with the peak wavelength of the radiation from the oven elements. No further calculation is required. 1 mark

c. Earth's surface re-emits the solar energy it absorbs mainly as infrared radiation. Greenhouse gases in the atmosphere absorb some of this infrared radiation and re-emit it in all directions. Explain how this process raises the temperature of Earth's surface. 2 marks

Question 5 (5 marks)

a. Radium-226, $^{226}_{88}Ra$, decays by alpha emission to an isotope of radon, Rn. Complete the decay equation below, showing the mass number and the atomic number of the radon isotope. 2 marks

$^{226}_{88}Ra \rightarrow$ —__Rn + $^{4}_{2}\alpha$

b. Iodine-131, $^{131}_{53}I$, decays by beta-minus emission to an isotope of xenon, Xe. Complete the decay equation below, showing the mass number and the atomic number of the xenon isotope. 2 marks

$^{131}_{53}I \rightarrow$ —__Xe + $^{0}_{-1}\beta$

c. Gamma radiation often accompanies radioactive decay. State what gamma radiation is. 1 mark

Question 6 (4 marks)

A sample of technetium-99m has an activity of $640\,\mathrm{Bq}$ (640 decays per second). The half-life of technetium-99m is $6.0\,\mathrm{h}$.

a. Calculate the activity of the sample after $18\,\mathrm{h}$. Give your answer in Bq. 2 marks

b. Calculate the time taken for the activity of the sample to fall from $640\,\mathrm{Bq}$ to $40\,\mathrm{Bq}$. Give your answer in h. 1 mark

c. Explain why it is not possible to predict when one particular nucleus in the sample will decay. 1 mark

Question 7 (3 marks)

A small sample of tissue receives an absorbed dose of $0.040\,\mathrm{Gy}$ from an alpha radiation source. The radiation weighting factor, w_R, for alpha radiation is 20. The equivalent dose is given by $H = w_R \times D$, where D is the absorbed dose.

a. Calculate the equivalent dose received by the tissue. Give your answer in Sv. 2 marks

b. Explain why an alpha-emitting source inside the body is more dangerous than the same source just outside the body. 1 mark

Question 8 (4 marks)

a. Distinguish between nuclear fission and nuclear fusion. 2 marks

b. Use the idea of mass being converted into energy to explain why fission releases energy. 2 marks

Question 9 (6 marks)

A torch bulb is rated at $6.0\,\mathrm{V}$. When the bulb is connected to a battery, the current in the bulb is $0.50\,\mathrm{A}$.

a. Calculate the charge that passes through the bulb in 2.0 minutes. Give your answer in C. 2 marks

b. Calculate the energy transferred to the bulb by this charge. Give your answer in J. 2 marks

c. Calculate the power of the bulb. Give your answer in W. 1 mark

d. State what a potential difference of $6.0\,\mathrm{V}$ across the bulb means in terms of energy and charge. 1 mark

Question 10 (5 marks)

A $12\,\mathrm{V}$ battery of negligible internal resistance is connected in series with a $4.0\,\Omega$ resistor and a parallel combination of a $6.0\,\Omega$ resistor and a $3.0\,\Omega$ resistor.

a. Calculate the combined resistance of the parallel combination. Give your answer in Ω. 1 mark

b. Calculate the total resistance of the circuit. Give your answer in Ω. 1 mark

c. Calculate the current supplied by the battery. Give your answer in A. 1 mark

d. Calculate the potential difference across the parallel combination. Give your answer in V. 1 mark

e. Calculate the current in the $3.0\,\Omega$ resistor. Give your answer in A. 1 mark

Question 11 (4 marks)

A voltage divider circuit consists of a $2.0\,\mathrm{k}\,\Omega$ resistor, R_1, connected in series with a $1.0\,\mathrm{k}\,\Omega$ resistor, R_2, across a $9.0\,\mathrm{V}$ supply. The output voltage, V_{out}, is taken across R_2.

a. Show that $V_{\text{out}} = 3.0\,\mathrm{V}$. 1 mark

b. Resistor R_2 is replaced by an NTC thermistor, a component whose resistance decreases as its temperature increases. State and explain what happens to V_{out} as the temperature of the thermistor decreases. 2 marks

c. State one practical use of this type of circuit. 1 mark

Question 12 (3 marks)

A $2.0\,\mathrm{kW}$ electric heater operates for $3.0\,\mathrm{h}$.

a. Calculate the energy used by the heater. Give your answer in kW h. 1 mark

b. Convert this energy into joules. 1 mark

c. Explain why the circuits in a home are wired in parallel rather than in series. 1 mark

Question 13 (4 marks)

a. Explain how a fuse protects a household circuit. 2 marks

b. State one advantage of a residual current device (RCD) over a fuse for protecting a person from electric shock. 1 mark

c. State one factor that determines how dangerous an electric shock is to a person. 1 mark

Question 14 (6 marks)

A cyclist starts from rest on a straight, level road and accelerates uniformly at $1.5\,\mathrm{m\,s^{-2}}$ for $8.0\,\mathrm{s}$.

a. Calculate the speed of the cyclist at the end of the $8.0\,\mathrm{s}$. Give your answer in $\mathrm{m\,s^{-1}}$. 2 marks

b. Calculate the distance travelled by the cyclist during the $8.0\,\mathrm{s}$. Give your answer in m. 2 marks

c. The quantities distance, speed, velocity, acceleration and time are used to describe this motion. Classify these five quantities as vectors or scalars. 2 marks

Question 15 (5 marks)

A box of mass $5.0\,\mathrm{kg}$ is pulled along a rough horizontal floor by a horizontal force of $20\,\mathrm{N}$. A friction force of $8.0\,\mathrm{N}$ opposes the motion.

a. Calculate the force due to gravity acting on the box and state its direction. Give your answer in N. 1 mark

b. Calculate the acceleration of the box. Give your answer in $\mathrm{m\,s^{-2}}$. 2 marks

c. The floor exerts a normal force on the box. Identify the Newton's third-law pair partner of this force, using the $F_{\text{on A by B}}$ convention, and state its magnitude and direction. 2 marks

Question 16 (5 marks)

A trolley of mass $2.0\,\text{kg}$ is released from rest at the top of a frictionless ramp that is $1.2\,\text{m}$ above the floor, measured vertically.

a. Show that the gravitational potential energy of the trolley at the top of the ramp is about $24\,\text{J}$. 1 mark

b. Calculate the speed of the trolley at the bottom of the ramp. Give your answer in m s^{-1}. 2 marks

c. In an actual trial the speed of the trolley at the bottom is found to be less than your answer to part **b**. Explain why. 1 mark

d. After reaching the floor, a student pushes the trolley with a constant horizontal force of $6.0\,\text{N}$ over a distance of $2.0\,\text{m}$. Calculate the work done on the trolley by this force. Give your answer in J. 1 mark

Question 17 (4 marks)

A ball of mass $0.60\,\text{kg}$ rolls along a smooth, straight track at $4.0\,\text{m s}^{-1}$ and collides with a stationary ball of mass $0.20\,\text{kg}$. After the collision, the two balls stick together and move off as one.

a. Calculate the total momentum of the two balls before the collision. Give your answer in N s. 1 mark

b. Calculate the speed of the two balls immediately after the collision. Give your answer in m s^{-1}. 2 marks

c. This collision is inelastic. State what happens to the total kinetic energy of the two balls during the collision. 1 mark

Question 18 (20 marks)

A student determines the specific heat capacity of water using an electrical method. A $100\,\text{W}$ immersion heater is placed completely below the surface of $0.50\,\text{kg}$ of water in a beaker. The water is stirred throughout the investigation, and its temperature is recorded every $60\,\text{s}$. The results are shown in the table. The uncertainty in each temperature reading is $\pm 0.5\,°\text{C}$.

t (s)	0	60	120	180	240	300
T (°C)	20.0	22.9	25.7	28.6	31.4	34.3

a. For this investigation, identify the independent variable, the dependent variable and one controlled variable. 3 marks

b. Explain why the water is stirred throughout the investigation. 2 marks

c. State one change the student could make to reduce the energy transferred from the water to the surroundings, and explain why this change works. 2 marks

d. The student repeats the whole investigation two more times and averages the temperatures at each time. State the purpose of taking these repeat measurements. 1 mark

e. On the grid provided, plot the temperature of the water against time, including an uncertainty bar of $\pm 0.5\,°\text{C}$ on each point, and draw the line of best fit. 5 marks

f. Using two well-separated points on your line of best fit, determine the gradient of the line. Give your answer in °C s^{-1}. 2 marks

g. The energy supplied by the heater is $E = P\,t$, and the energy gained by the water is $Q = m\,c\,\Delta T$. Assuming that no energy is lost to the surroundings, use your gradient to determine the specific heat capacity of the water. Give your answer in J kg^{-1} K^{-1}. 3 marks

h. A second student repeats the investigation using a $200\,\mathrm{W}$ heater and the same mass of water. Predict how the gradient of the temperature–time graph would change, and justify your answer. 2 marks

End of Section B

Practice Exam 1 — Formula Sheet

This formula sheet is provided for use with all practice examinations in this booklet. Part 1 reproduces, unaltered and with attribution, the items of the official VCE Physics Formula Sheet (© VCAA 2026) that lie within the Units 1 & 2 study design; items that belong to Units 3 & 4 only are omitted. Part 2 is a house supplement drawn from the key knowledge of the Units 1 & 2 study design (2023–2027): it carries the relationships that Units 1 & 2 students apply which the official sheet does not give.

Part 1 — VCE Physics Formula Sheet: Units 1 & 2 items

Motion and related energy transformations

velocity	$v=\frac{\Delta s}{\Delta t}$
acceleration	$a=\frac{\Delta v}{\Delta t}$
constant acceleration	$v=u+at$
	$s=ut+\frac{1}{2}at^2$
	$s=vt-\frac{1}{2}at^2$
	$v^2=u^2+2as$
	$s=\frac{1}{2}(u+v)t$
Newton's second law	$\Sigma F=ma$
Hooke's law	$F=-kx$
elastic potential energy	$E_s=\frac{1}{2}kx^2$
gravitational potential energy	$E_g=mg\Delta h$
kinetic energy	$E_k=\frac{1}{2}mv^2$
impulse	$F\Delta t=m\Delta v$
momentum	$p=mv$

Generation and transmission of electricity

current	$I=\frac{V}{R}$
power	$P=VI$
resistors in series	$R_T=R_1+R_2+\ldots$
resistors in parallel	$\frac{1}{R_T}=\frac{1}{R_1}+\frac{1}{R_2}+\ldots$

Waves

wave equation	$v=f\lambda$

Part 2 — Units 1 & 2 supplement

Waves and light

wavelength, frequency, period and speed	$\lambda=\frac{v}{f}=vT$

refraction (Snell's Law) $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$n_1 v_1 = n_2 v_2$

critical angle $n_1 \sin\theta_c = n_2 \sin 90^\circ$

Thermal energy

Celsius–kelvin conversion $T(\mathrm{K}) = T(°\mathrm{C}) + 273.15$

raising temperature $Q = m c \Delta T$

change of state $Q = m L$

Wien's Law $\lambda_{\max} T = \text{constant}$

Radiation from the nucleus

Provenance note (TOC §2.7): D = E/m, H = w_R × D and E = mc² do not appear on the official Units 1 & 2 formula sheet; they are included in this supplement because the Units 1 & 2 key knowledge requires dose calculations and treats mass–energy conversion qualitatively.

radioactive decay (whole half-lives) $N = N_0 \left(\frac{1}{2}\right)^n$

$n = \frac{t}{t_{1/2}}$

absorbed dose $D = \frac{E}{m}$ (unit: Gy)

equivalent dose $H = w_R \times D$ (unit: Sv)

effective dose $\Sigma\, w_T H_T$ over tissues T (unit: Sv)

Nuclear energy

mass–energy conversion $E = m c^2$

Electricity

current and charge $I = \frac{Q}{t}$

potential difference $V = \frac{E}{Q}$

power and energy $P = \frac{E}{t}$

voltage divider $V_{\text{out}} = V_{\text{in}} \times \frac{R_2}{R_1 + R_2}$

Forces, work and energy

work done by a constant force $W = F s \cos\theta$

work done: area under a force–distance graph

torque $\tau = r_\perp F$

force due to gravity $F_{\text{on body by Earth}} = m g$

Newton's third law $F_{\text{on A by B}} = -F_{\text{on B by A}}$

change in momentum $\Delta p = F_{\text{net}} \Delta t$

efficiency $\eta = \frac{\text{useful energy out}}{\text{total energy in}}$

Data

acceleration due to gravity at Earth's surface	$g = 9.8$ m s^{-2} (9.8 N kg^{-1})
speed of light in a vacuum	$c = 3.00 \times 10^{8}$ m s^{-1}
Wien's Law constant	2.9×10^{-3} m K

The Units 1 & 2 study design gives the gravitational field strength near Earth's surface as g = 9.8 N kg^{-1} (9.8 m s^{-2}), and this is the value used throughout this booklet. The official VCE Physics Formula Sheet gives g = 9.81 m s^{-2} for Units 3 & 4.

Metric (SI) multipliers

pico (p)	10^{-12}	kilo (k)	10^{3}
nano (n)	10^{-9}	mega (M)	10^{6}
micro (μ)	10^{-6}	giga (G)	10^{9}
milli (m)	10^{-3}	tera (T)	10^{12}

Unit conversions

1 tonne (t)	$= 10^{3}$ kg
1 kilowatt hour (kW h)	$= 3.6 \times 10^{6}$ J

Nomenclature

force due to gravity	F_{g}
force on A by B	$F_{\text{on A by B}}$
normal force	F_{N}

End of Formula Sheet

Practice Exam 1 — solutions

Section A — answer key

Question	Answer	Question	Answer
1	B	11	A
2	A	12	C
3	B	13	D
4	D	14	A
5	A	15	C
6	D	16	A
7	A	17	D
8	C	18	B
9	D	19	C
10	B	20	B

Question 1 — B. The wave equation gives $\lambda = \frac{v}{f} = \frac{340}{170} = 2.0\,\mathrm{m}$. **A** inverts the ratio (f / v); **C** multiplies $v \times f$; **D** is a decimal-place slip on the correct division.

Question 2 — A. Frequency increases through the spectrum in the order radio, microwave, infrared, visible, ultraviolet, X-ray, gamma ray; the list in **A** follows this order. **B** lists the regions in decreasing frequency; **C** and **D** place at least one region out of order.

Question 3 — B. The light striking the core–cladding boundary at an angle greater than the critical angle undergoes total internal reflection, so it reflects repeatedly along the fibre without escaping. **A** misidentifies the mechanism (refraction would bend the light out of the core); **C** and **D** name wave effects that do not keep the signal confined.

Question 4 — D. $T = 27 + 273 = 300\,\mathrm{K}$. **A** subtracts 273 instead of adding it; **B** is $0\,°\mathrm{C}$ in kelvin; **C** leaves the number unchanged.

Question 5 — A. An alpha particle is a helium nucleus (two protons and two neutrons). It is the most ionising and the least penetrating of the three common radiations, and is stopped by a sheet of paper or a few cm of air. **B** describes a beta particle; **C** describes gamma radiation; **D** keeps the correct identity but assigns beta/gamma properties to it.

Question 6 — D. In β^- decay a neutron changes into a proton, so the mass number stays at 14 while the atomic number rises from 6 to 7: the daughter is ${}^{14}{}_{7}\mathrm{N}$. **A** lowers the atomic number (β^+ behaviour); **B** reduces the mass number by 4 (alpha behaviour); **C** leaves both numbers wrong.

Question 7 — A. Each half-life halves the remaining mass: $80 \to 40 \to 20 \to 10\,\mathrm{g}$ after three half-lives. **D** applies only one half-life; **B** applies two; **C** divides by 3 instead of halving repeatedly.

Question 8 — C. $Q = I\,t = 2.0 \times 30 = 60\,\mathrm{C}$. **A** computes t / I; **B** computes I / t; **D** is a decimal-place slip.

Question 9 — D. $P = V\,I = 12 \times 0.50 = 6.0\,\mathrm{W}$. **A** computes V / I; **B** computes I / V; **C** adds the two values.

Question 10 — B. $\frac{1}{R_T} = \frac{1}{6.0} + \frac{1}{6.0} = \frac{2}{6.0}$, so $R_T = 3.0\,\Omega$. **A** adds the resistors as if they were in series; **C** uses only one resistor; **D** leaves the sum of the reciprocals un-inverted (0.33).

Question 11 — A. With two equal resistors, $V_{\text{out}} = V_{\text{in}} \times \frac{R_2}{R_1 + R_2} = 12 \times \frac{R}{2R} = 6.0\,\mathrm{V}$. **B** halts the halving once too often; **C** takes the full supply voltage; **D** doubles the supply voltage.

Question 12 — C. An RCD continuously compares the current in the active wire with the current in the neutral wire; any difference (a residual current, such as current passing through a person) makes it cut the circuit within milliseconds. A fuse (**A**) and a circuit breaker (**B**) respond only to excess current, and the earth wire (**D**) provides a low-resistance path to ground rather than detecting an imbalance.

Question 13 — D. A vector has both magnitude and direction: force qualifies. Kinetic energy, speed and mass all have magnitude only, so they are scalars.

Question 14 — A. $v = u + at = 0 + 2.0 \times 5.0 = 10\,\mathrm{m\ s^{-1}}$. **B** computes the distance travelled ($s = 1/2\,at^2 = 25\,\mathrm{m}$); **C** halves the correct answer; **D** inverts the ratio ($t\,/\,a$).

Question 15 — C. $a = \dfrac{F_{\mathrm{net}}}{m} = \dfrac{12}{4.0} = 3.0\,\mathrm{m\ s^{-2}}$. **A** multiplies $F \times m$; **B** inverts the ratio ($m\,/\,F$); **D** ignores the mass.

Question 16 — A. $\tau = r_{\perp} F = 0.30 \times 20 = 6.0\,\mathrm{N\ m}$ (the $30\,\mathrm{cm}$ must be converted to metres). **B** forgets the conversion and gets $600\,\mathrm{N\ m}$; **C** computes $F\,/\,r$; **D** is a decimal-place slip.

Question 17 — D. An error that shifts every reading by the same fixed amount is a systematic error. **A** describes random error, which varies from reading to reading; **B** describes a mistake (blunder); **C** describes resolution, which limits the detail of a reading but does not produce a fixed offset.

Question 18 — B. The five values cluster tightly around one another, so the measurements are precise; but they are all well below the accepted value of $9.8\,\mathrm{m\ s^{-2}}$, so they are not accurate. **A** reverses the two terms; **C** and **D** are inconsistent with the values given.

Question 19 — C. The gradient of an I–V graph is $\dfrac{I}{V} = \dfrac{1}{R}$ by Ohm's law. **A** applies only to a V–I graph (with V vertical); **B** is $V\,I$, the product rather than the ratio; **D** confuses the gradient with charge.

Question 20 — B. The measurement is consistent with any value in the range $2.6 - 0.2 = 2.4\,\mathrm{cm}$ to $2.6 + 0.2 = 2.8\,\mathrm{cm}$; only $2.7\,\mathrm{cm}$ lies inside this range. **A**, **C** and **D** all fall outside it.

Section B — worked solutions

Question 1

(a) From the wave equation $v = f\,\lambda$:

$$\lambda = \frac{v}{f} = \frac{0.40}{5.0} = 0.080\,\mathrm{m}.$$

(1 mark $v = f\,\lambda$ rearranged correctly; **1 mark** value $0.080\,\mathrm{m}$.)

(b) $T = \dfrac{1}{f} = \dfrac{1}{5.0} = 0.20\,\mathrm{s}$. **(1 mark:** $0.20\,\mathrm{s}$**.)**

(c) The **frequency is unchanged** — the frequency of a wave is set by the source (the vibrating dipper), not by the medium, so the shallower water cannot change it. The speed decreases and $\lambda = \dfrac{v}{f}$, so the **wavelength decreases** as well. **(1 mark** frequency unchanged, with the source-set explanation; **1 mark** wavelength decreases.)

(d) A mechanical wave needs a material medium to travel through (and cannot travel through a vacuum), whereas an electromagnetic wave can travel through a vacuum. Equivalently: a mechanical wave is a vibration of matter, while an electromagnetic wave is a travelling oscillation of electric and magnetic fields. **(1 mark: any one correct difference.)**

Question 2

(a) Snell's Law: $n_1 \sin\theta_1 = n_2 \sin\theta_2$.

$$\sin\theta_2 = \frac{n_1 \sin\theta_1}{n_2} = \frac{1.00 \times \sin 45^\circ}{1.50} = \frac{0.707}{1.50} = 0.471$$

$$\theta_2 = \sin^{-1}(0.471) = 28.1^\circ.$$

(1 mark correct use of Snell's Law; **1 mark** value 28.1°.)

(b) At the critical angle the refracted ray emerges at 90°, with the glass as the denser medium ($n_1 = 1.50$):

$$n_1 \sin\theta_c = n_2 \sin 90^\circ \Rightarrow 1.50 \sin\theta_c = 1.00 \times 1$$

$$\sin\theta_c = 0.667 \Rightarrow \theta_c = \sin^{-1}(0.667) = 41.8^\circ,$$

as required. **(1 mark** correct set-up with $n_1 = 1.50$ and $\sin 90^\circ = 1$; **1 mark** value 41.8°.)

(c) Light travels more slowly in glass than in air. When a wave enters a medium in which it travels more slowly, at an angle, it bends towards the normal. **(1 mark: the wave slows down in the glass, so it bends towards the normal.)**

Question 3

(a) $Q = m c \Delta T$, with $\Delta T = 80 - 20 = 60\,°\mathrm{C} = 60\,\mathrm{K}$:

$$Q = 0.200 \times 900 \times 60 = 10\,800\,\mathrm{J} = 1.08 \times 10^4\,\mathrm{J}.$$

(1 mark $Q = m c \Delta T$ with the correct temperature change; **1 mark** value $10\,800\,\mathrm{J}$.)

(b) $T = 80 + 273 = 353\,\mathrm{K}$. **(1 mark:** $353\,\mathrm{K}$**.)**

(c) Melting occurs at constant temperature, so $Q = m L$:

$$Q = 0.100 \times 3.34 \times 10^5 = 3.34 \times 10^4\,\mathrm{J}.$$

(1 mark $Q = m L$; **1 mark** value $3.34 \times 10^4\,\mathrm{J}$.)

(d) Conduction. **(1 mark: conduction.)**

Question 4

(a) Wien's Law: $\lambda_{max} T = 2.9 \times 10^{-3}\,\mathrm{m\,K}$.

$$\lambda_{max} = \frac{2.9 \times 10^{-3}}{1450} = 2.0 \times 10^{-6}\,\mathrm{m}.$$

(1 mark Wien's Law applied; **1 mark** value $2.0 \times 10^{-6}\,\mathrm{m}$.)

(b) The peak wavelength is **half** that of the oven elements, $\lambda_{max} = 1.0 \times 10^{-6}\,\mathrm{m}$. The temperature has doubled ($1450\,\mathrm{K} \rightarrow 2900\,\mathrm{K}$) and λ_{max} is inversely proportional to T, so the peak wavelength halves. **(1 mark: half, justified by the inverse proportionality in Wien's Law.)**

(c) The greenhouse gases absorb the infrared radiation re-emitted by Earth's surface and re-emit it in all directions — including back towards the surface. This returns energy to the surface, so the surface receives energy from the Sun **and** from the atmosphere; it warms until the rate at which it loses energy again balances this larger rate of energy input. **(1 mark** absorption and re-emission, including back towards the surface; **1 mark** the surface gains net energy and its temperature rises.)

Question 5

(a) In alpha emission the mass number drops by 4 and the atomic number drops by 2: $^{226}_{88}\mathrm{Ra} \rightarrow {}^{222}_{86}\mathrm{Rn} + {}^{4}_{2}\alpha$. **(1 mark** mass number 222; **1 mark** atomic number 86.)

(b) In beta-minus emission the mass number is unchanged and the atomic number rises by 1: ${}^{131}_{53}I \rightarrow {}^{131}_{54}Xe + {}^{0}_{-1}\beta$. **(1 mark** mass number 131; **1 mark** atomic number 54.)

(c) Gamma radiation is electromagnetic radiation — high-frequency photons. It has no mass and no charge. **(1 mark: electromagnetic radiation / photons.)**

Question 6

(a) $18\,\mathrm{h}$ is three half-lives ($18 \div 6.0 = 3$). The activity halves three times:

$$640 \rightarrow 320 \rightarrow 160 \rightarrow 80\,\mathrm{Bq}.$$

(1 mark three half-lives identified; **1 mark** value $80\,\mathrm{Bq}$.)

(b) From $640\,\mathrm{Bq}$ to $40\,\mathrm{Bq}$ is four halvings ($640 \rightarrow 320 \rightarrow 160 \rightarrow 80 \rightarrow 40$), i.e. four half-lives:

$$t = 4 \times 6.0 = 24\,\mathrm{h}.$$

(1 mark: $24\,\mathrm{h}$**.)**

(c) Radioactive decay is random (spontaneous): it is impossible to predict which particular nucleus will decay next, or when. Only the average behaviour of a large number of nuclei — expressed through the half-life — can be predicted. **(1 mark: decay is random / spontaneous, so individual decays cannot be predicted.)**

Question 7

(a) $H = w_R \times D = 20 \times 0.040 = 0.80\,\mathrm{Sv}$. **(1 mark** $H = w_R \times D$; **1 mark** value $0.80\,\mathrm{Sv}$.)

(b) Alpha radiation is highly ionising but very poorly penetrating. Outside the body it is stopped by the outer layer of dead skin and never reaches living cells; inside the body, with no such barrier, it deposits all of its energy in nearby living tissue and causes far more cell damage. **(1 mark: highly ionising / stopped by dead skin outside, but deposits its energy in living tissue inside.)**

Question 8

(a) **Fission** is the splitting of a heavy nucleus into two lighter nuclei (usually with the release of neutrons). **Fusion** is the joining of two light nuclei to form a heavier nucleus. **(1 mark** fission described; **1 mark** fusion described.)

(b) In fission, the total mass of the product nuclei is slightly less than the mass of the original nucleus (and the neutron that triggered the split). This 'lost' mass is converted into energy and released — as kinetic energy of the products and as radiation. Equivalently, the product nuclei are more tightly bound than the original heavy nucleus, and the increase in binding energy is released. **(1 mark** total mass of products is less / products more tightly bound; **1 mark** the missing mass is converted into energy and released.)

Question 9

(a) $t = 2.0\,\mathrm{min} = 120\,\mathrm{s}$. From $I = \dfrac{Q}{t}$:

$$Q = I\,t = 0.50 \times 120 = 60\,\mathrm{C}.$$

(1 mark $Q = I\,t$ with $t = 120\,\mathrm{s}$; **1 mark** value $60\,\mathrm{C}$.)

(b) From $V = \dfrac{E}{Q}$:

$$E = Q\,V = 60 \times 6.0 = 360\,\mathrm{J}.$$

(1 mark $E = Q\,V$; **1 mark** value $360\,\mathrm{J}$.)

(c) $P = V\,I = 6.0 \times 0.50 = 3.0\,\mathrm{W}$. **(1 mark:** $3.0\,\mathrm{W}$**.)**

(d) A potential difference of $6.0\ \text{V}$ means that $6.0\ \text{J}$ of energy is transferred for each coulomb of charge that passes through the bulb. **(1 mark: energy transferred per unit charge, $6.0\ \text{J}$ per C.)**

Question 10

(a) $\frac{1}{R_T} = \frac{1}{6.0} + \frac{1}{3.0} = \frac{1}{6.0} + \frac{2}{6.0} = \frac{3}{6.0}$, so $R_T = 2.0\ \Omega$. **(1 mark: $2.0\ \Omega$.)**

(b) $R_{\text{total}} = 4.0 + 2.0 = 6.0\ \Omega$. **(1 mark: $6.0\ \Omega$.)**

(c) $I = \frac{V}{R} = \frac{12}{6.0} = 2.0\ \text{A}$. **(1 mark: $2.0\ \text{A}$.)**

(d) The same $2.0\ \text{A}$ flows through the equivalent $2.0\ \Omega$ parallel combination: $V = I\,R = 2.0 \times 2.0 = 4.0\ \text{V}$. **(1 mark: $4.0\ \text{V}$.)**

(e) Both resistors of the parallel combination have $4.0\ \text{V}$ across them, so the current in the $3.0\ \Omega$ resistor is

$$I = \frac{V}{R} = \frac{4.0}{3.0} = 1.3\ \text{A}.$$

(1 mark: $1.3\ \text{A}$.)

Question 11

(a) $V_{\text{out}} = V_{\text{in}} \times \frac{R_2}{R_1 + R_2} = 9.0 \times \frac{1.0}{2.0 + 1.0} = 9.0 \times \frac{1}{3} = 3.0\ \text{V}$, as required. **(1 mark: correct substitution giving $3.0\ \text{V}$.)**

(b) As the temperature of the NTC thermistor decreases, its resistance **increases**. Since $V_{\text{out}} = V_{\text{in}} \times \frac{R_2}{R_1 + R_2}$ grows as R_2 grows, V_{out} **increases**. (**1 mark** resistance of the thermistor increases as it cools; **1 mark** V_{out} increases, justified through the divider equation.)

(c) Any one valid use, e.g. a temperature-sensing circuit: a thermostat, a temperature-operated switch, or a fire alarm. **(1 mark: one valid use.)**

Question 12

(a) $E = P\,t = 2.0 \times 3.0 = 6.0\ \text{kW h}$. **(1 mark: $6.0\ \text{kW h}$.)**

(b) $E = 6.0 \times 3.6 \times 10^6 = 2.16 \times 10^7\ \text{J}$ (about $2.2 \times 10^7\ \text{J}$). **(1 mark: $2.16 \times 10^7\ \text{J}$.)**

(c) In a parallel circuit each appliance receives the full supply voltage and operates independently of the others, so appliances can be switched on and off separately. In a series circuit the appliances would share the supply voltage (each receiving too little), and a fault in one appliance would break the whole circuit. **(1 mark: full voltage / independent operation in parallel, or the corresponding series drawback.)**

Question 13

(a) A fuse contains a wire that melts when the current in it exceeds the fuse's rated current. Melting breaks (opens) the circuit, cutting off the current before the wiring can overheat and start a fire. (**1 mark** the fuse wire melts and breaks the circuit when the current exceeds its rating; **1 mark** this prevents overheating / fire.)

(b) An RCD detects a very small imbalance between the active and neutral currents — such as the tiny current passing through a person — and cuts the circuit within milliseconds, whereas a fuse responds only to currents far larger than a dangerous shock current. **(1 mark: RCD detects small leakage currents through a person / responds much faster than a fuse.)**

(c) Any one: the size of the current passing through the body; the duration of the shock; the path the current takes through the body (a path across the chest is the most dangerous). **(1 mark: one valid factor.)**

Question 14

(a) $v = u + at = 0 + 1.5 \times 8.0 = 12\,\mathrm{m\ s^{-1}}$. **(1 mark** $v = u + at$ with $u = 0$; **1 mark** value $12\,\mathrm{m\ s^{-1}}$.)

(b) $s = ut + 1/2\,at^2 = 0 + 1/2 \times 1.5 \times 8.0^2 = 48\,\mathrm{m}$. **(1 mark** $s = ut + 1/2\,at^2$ (or $s = 1/2(u+v)t$); **1 mark** value $48\,\mathrm{m}$.)

(c) **Vectors:** velocity, acceleration. **Scalars:** distance, speed, time. **(1 mark** vectors correctly identified; **1 mark** scalars correctly identified.)

Question 15

(a) $F_g = mg = 5.0 \times 9.8 = 49\,\mathrm{N}$, directed vertically downwards (towards the centre of the Earth). **(1 mark: $49\,\mathrm{N}$, downwards.)**

(b) The net horizontal force is $F_{\text{net}} = 20 - 8.0 = 12\,\mathrm{N}$, so

$$a = \frac{F_{\text{net}}}{m} = \frac{12}{5.0} = 2.4\,\mathrm{m\ s^{-2}}.$$

(1 mark $F_{\text{net}} = 12\,\mathrm{N}$; **1 mark** $a = 2.4\,\mathrm{m\ s^{-2}}$.)

(c) The box has no vertical acceleration, so the normal force of the floor on the box balances the force due to gravity: $F_{\text{on box by floor}} = 49\,\mathrm{N}$, upwards. Its Newton's third-law partner is $F_{\text{on floor by box}}$: the box pushes down on the floor with a force of $49\,\mathrm{N}$, vertically downwards — equal in magnitude and opposite in direction. **(1 mark** identifies $F_{\text{on floor by box}}$; **1 mark** $49\,\mathrm{N}$, vertically downwards.)

Question 16

(a) $E_g = mg\Delta h = 2.0 \times 9.8 \times 1.2 = 23.5\,\mathrm{J} \approx 24\,\mathrm{J}$, as required. **(1 mark: correct substitution giving about $24\,\mathrm{J}$.)**

(b) With no friction, the gravitational potential energy converts entirely to kinetic energy:

$$\frac{1}{2}mv^2 = mg\Delta h \Rightarrow v = \sqrt{2g\Delta h} = \sqrt{2 \times 9.8 \times 1.2} = \sqrt{23.5} = 4.8\,\mathrm{m\ s^{-1}}.$$

(1 mark energy conservation set up; **1 mark** value $4.8\,\mathrm{m\ s^{-1}}$.)

(c) In a real trial, friction (and air resistance) converts some of the gravitational potential energy into thermal energy and sound, so less energy reaches the trolley as kinetic energy and its final speed is lower. **(1 mark: some energy is converted to thermal energy / sound by friction.)**

(d) The force and the displacement are in the same direction, so $W = Fs = 6.0 \times 2.0 = 12\,\mathrm{J}$. **(1 mark: $12\,\mathrm{J}$.)**

Question 17

(a) Before the collision only the $0.60\,\mathrm{kg}$ ball is moving:

$$p = mv = 0.60 \times 4.0 = 2.4\,\mathrm{N\ s}.$$

(1 mark: $2.4\,\mathrm{N\ s}$.)

(b) Momentum is conserved. After the collision the combined mass is $0.60 + 0.20 = 0.80\,\mathrm{kg}$, so

$$2.4 = 0.80\,v \Rightarrow v = \frac{2.4}{0.80} = 3.0\,\mathrm{m\ s^{-1}}.$$

(1 mark conservation of momentum with the combined mass; **1 mark** value $3.0\,\mathrm{m\ s^{-1}}$.)

(c) The total kinetic energy decreases: some of it is converted into thermal energy, sound and deformation of the balls. Kinetic energy is not conserved in an inelastic collision (although momentum still is). **(1 mark: kinetic energy decreases / is converted to other forms.)**

Question 18

The electrical energy supplied by the heater, $E = P\,t$, is absorbed by the water as thermal energy, $Q = m\,c\,\Delta T$. With no losses, $P\,t = m\,c\,\Delta T$, so $\Delta T = \frac{P}{m\,c}\,t$: a graph of T against t is a straight line of gradient $\frac{P}{m\,c}$.

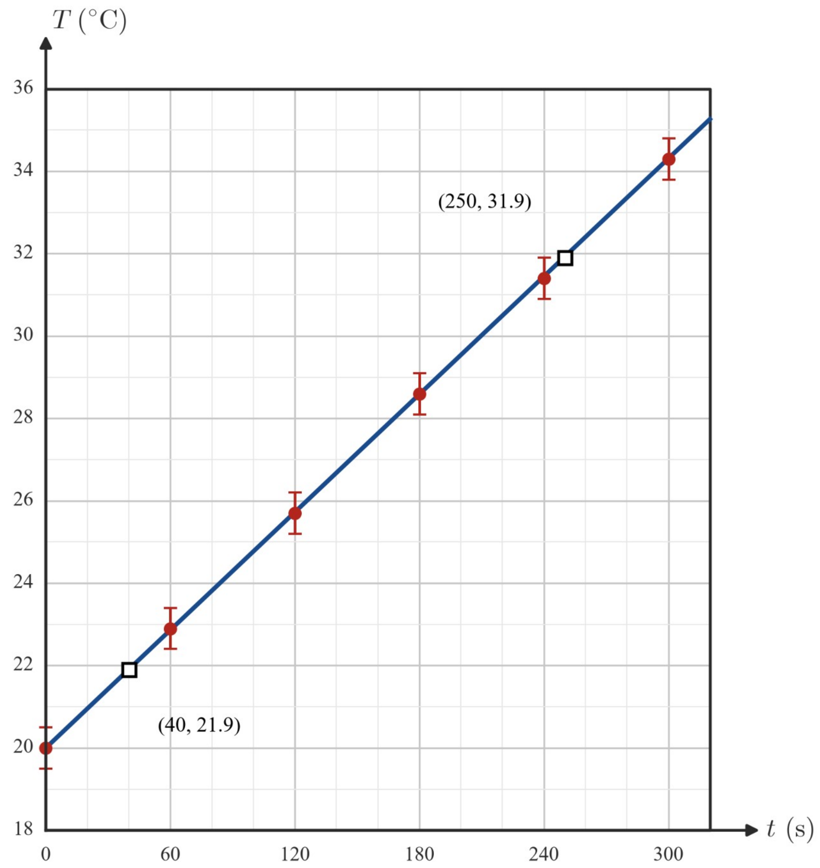
(a) **Independent variable:** the heating time t (set by the student). **Dependent variable:** the temperature T of the water (measured). **Controlled variable (any one):** the mass of the water / the power of the heater / the same beaker and starting temperature. **(1 mark each: IV = t; DV = T; one valid controlled variable.)**

(b) Stirring spreads the thermal energy evenly through the water, preventing hot water from collecting around the heater. The thermometer then reads the average temperature of the whole sample rather than the temperature of the water just beside the heater. (**1 mark** stirring distributes the thermal energy evenly; **1 mark** the thermometer reading is then representative of the whole water sample.)

(c) Any one valid change with a matching explanation, e.g.: place a lid on the beaker — this reduces energy loss by evaporation and by convection of warm air from the surface. Or: wrap the beaker in insulating material — this reduces energy transfer to the surroundings by conduction and convection. (**1 mark** one valid change; **1 mark** correct explanation of how it reduces energy loss.)

(d) Repeating the investigation and averaging reduces the effect of random errors, giving a more reliable (more precise) mean temperature at each time. **(1 mark: repeats reduce the effect of random error / improve the reliability of the mean.)**

(e) A correct plot shows: T (°C) on the vertical axis and t (s) on the horizontal axis, each labelled with quantity and unit; scales chosen so the points fill most of the grid; the six points plotted correctly; a vertical uncertainty bar of $\pm 0.5\,°\mathrm{C}$ on each point; and a single straight line of best fit drawn through the scatter.



(**1 mark** axes correct (quantity + unit, correct way round); **1 mark** suitable scales filling the grid; **1 mark** all six points plotted correctly; **1 mark** uncertainty bars drawn; **1 mark** a single straight line of best fit weighing all the points.)

The line shown has equation $T = 20.0 + 0.0477\,t$.

(f) Reading two well-separated points **on the line of best fit** (not the data-table points) — for example $(40\,\text{s}, 21.9\,°\text{C})$ and $(250\,\text{s}, 31.9\,°\text{C})$:

$$\text{gradient} = \frac{\Delta T}{\Delta t} = \frac{31.9 - 21.9}{250 - 40} = \frac{10.0}{210} = 0.048\,°\text{C s}^{-1}.$$

(1 mark two well-separated on-line points used (not raw data points); **1 mark** gradient $\approx 0.048\,°\text{C s}^{-1}$, accept $0.047–0.049$ from the student's line.)

(g) Since $\Delta T = \frac{P}{mc}t$, the gradient of the T–t graph equals $\frac{P}{mc}$. Rearranging:

$$c = \frac{P}{m \times \text{gradient}} = \frac{100}{0.50 \times 0.0477} = 4.2 \times 10^3\,\text{J kg}^{-1}\text{K}^{-1}.$$

(1 mark $c = \frac{P}{m \times \text{gradient}}$ derived from $Pt = mc\Delta T$; **1 mark** correct substitution; **1 mark** value $\approx 4.2 \times 10^3\,\text{J kg}^{-1}\text{K}^{-1}$, accept $4.1–4.3 \times 10^3$ with the student's gradient.)

(h) The gradient would **double** (to about $0.095\,°\text{C s}^{-1}$). From gradient $= \frac{P}{mc}$, the gradient is directly proportional to the heater power P when the mass of water and its specific heat capacity are unchanged; doubling P from $100\,\text{W}$ to $200\,\text{W}$ therefore doubles the gradient. **(1 mark** gradient doubles; **1 mark** justified because gradient $= \frac{P}{mc}$ is directly proportional to P.)

End of solutions

Practice Exam 2 — Easier

- Reading time: **15 minutes**
- Writing time: **2 hours 30 minutes**
- Section A: 20 questions, 20 marks
- Section B: 16 questions, 100 marks
- Total: 120 marks

Approved materials

- One scientific calculator
- Pre-written notes (one folded A3 sheet or two A4 sheets bound together by tape)

A formula sheet is provided at the end of this examination.

House note: there is no VCAA examination for Physics Units 1 and 2 — assessment at these units is school-based. This practice paper is a ClassBasics house convention: it mirrors the shape of the Units 3 & 4 examination (reading time, two sections, mark allocation) so that practice here builds directly toward the assessed Units 3 & 4 papers.

Students are **not** permitted to bring mobile phones and/or any unauthorised electronic devices into the examination room.

Section A — Multiple-choice questions (20 marks)

- Answer **all** questions. Choose the response that is **correct** or that **best answers** the question.
- A correct answer scores 1; an incorrect answer scores 0. Marks will **not** be deducted for incorrect answers.
- No marks will be given if more than one answer is completed for any question.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- Where required, take the gravitational field strength at Earth's surface to be $g = 9.8\,\mathrm{N\ kg^{-1}}$.

Question 1

A sound wave travels through air at $340\,\mathrm{m\ s^{-1}}$ with a frequency of $850\,\mathrm{Hz}$. Which one of the following is the wavelength of this wave?

A. $0.20\,\mathrm{m}$

B. $0.40\,\mathrm{m}$

C. $2.9 \times 10^{5}\,\mathrm{m}$

D. $2.5\,\mathrm{m}$

Question 2

Which one of the following lists regions of the electromagnetic spectrum in order of **increasing** frequency?

A. ultraviolet, visible, infrared, radio

B. gamma, X-ray, ultraviolet, visible

C. radio, infrared, visible, ultraviolet

D. infrared, radio, visible, X-ray

Question 3

A ray of light passes from air into a block of glass. Which one of the following best describes what happens to the light as it enters the glass?

A. Its frequency is unchanged and its speed decreases.

B. Its frequency decreases and its speed is unchanged.

C. Its speed and its wavelength are both unchanged.

D. Its frequency and its speed both decrease.

Question 4

A camp stove heats $0.50\,\mathrm{kg}$ of water in a metal can from $20\,°\mathrm{C}$ to $30\,°\mathrm{C}$. The specific heat capacity of water is $4180\,\mathrm{J\,kg^{-1}\,K^{-1}}$. Which one of the following is closest to the energy transferred to the water?

A. $2.1\,\mathrm{kJ}$

B. $4.2\,\mathrm{kJ}$

C. $42\,\mathrm{kJ}$

D. $21\,\mathrm{kJ}$

Question 5

A piece of glowing steel is heated so that its temperature in kelvin **doubles**. According to Wien's Law, what happens to the peak wavelength λ_{max} of the radiation it emits?

A. It doubles.

B. It halves.

C. It quarters.

D. It is unchanged.

Question 6

Which one of the following types of radiation from a radioactive source is the **most penetrating**?

A. alpha particles

B. beta-minus particles

C. gamma rays

D. All three are equally penetrating.

Question 7

Iodine-131, ${}^{131}_{53}\mathrm{I}$, decays by beta-minus emission. Which one of the following is the daughter nucleus?

A. ${}^{131}_{52}\mathrm{Te}$

B. ${}^{131}_{54}\mathrm{Xe}$

C. ${}^{127}_{51}\mathrm{Sb}$

D. ${}^{131}_{53}\mathrm{I}$

Question 8

A radioisotope has a half-life of $20\,\mathrm{min}$. What fraction of a sample of this radioisotope remains after $1.0\,\mathrm{h}$?

A. $1/2$

B. $1/4$

C. $1/8$

D. $1/16$

Question 9

A current of $3.0\,\mathrm{A}$ flows through a wire for $40\,\mathrm{s}$. Which one of the following is the charge that passes a point in the wire in this time?

A. $13\,\mathrm{C}$

B. $0.075\,\mathrm{C}$

C. $12\,\mathrm{C}$

D. $120\,\mathrm{C}$

Question 10

A $6\,\Omega$ resistor and a $3\,\Omega$ resistor are connected in **parallel**. Which one of the following is the equivalent resistance of the pair?

A. $9\,\Omega$

B. $2\,\Omega$

C. $4.5\,\Omega$

D. $18\,\Omega$

Question 11

A $1.2\,\mathrm{kW}$ portable heater runs for $2.5\,\mathrm{h}$. Which one of the following is the energy it uses, in kilowatt hours?

A. $0.48\,\mathrm{kW\,h}$

B. $2.1\,\mathrm{kW\,h}$

C. $3.0\,\mathrm{kW\,h}$

D. $3.0 \times 10^3\,\mathrm{kW\,h}$

Question 12

Which one of the following devices opens a circuit when it detects a difference between the current in the active wire and the current in the neutral wire?

A. a fuse

B. a circuit breaker

C. a residual current device (RCD)

D. a surge diverter

Question 13

Which one of the following is a **scalar** quantity?

A. displacement

B. velocity

C. momentum

D. distance

Question 14

A car starts from rest and accelerates uniformly at $3.0\,\mathrm{m\ s^{-2}}$ for $4.0\,\mathrm{s}$. Which one of the following is its speed at the end of the $4.0\,\mathrm{s}$?

A. $24\,\mathrm{m\ s^{-1}}$

B. $12\,\mathrm{m\ s^{-1}}$

C. $3.0\,\mathrm{m\ s^{-1}}$

D. $0.75\,\mathrm{m\ s^{-1}}$

Question 15

A book rests on a table. The table pushes up on the book with a normal force. Which one of the following is the Newton's-third-law partner of this force?

A. the force due to gravity on the book from Earth

B. the force on the table from the book

C. the force due to gravity on Earth from the book

D. the normal force on the table from the floor

Question 16

Which one of the following is closest to the kinetic energy of a $2.0\,\mathrm{kg}$ object moving at $3.0\,\mathrm{m\ s^{-1}}$?

A. $9.0\,\mathrm{J}$

B. $6.0\,\mathrm{J}$

C. $18\,\mathrm{J}$

D. $3.0\,\mathrm{J}$

Question 17

A student investigates how the resistance of a wire depends on its length, using wires of the same material and thickness at room temperature. Which one of the following is the **dependent** variable?

A. the length of the wire

B. the material of the wire

C. the temperature of the wire

D. the resistance of the wire

Question 18

A student repeats a measurement several times. The readings differ slightly from one another, scattered above and below the true value. This variation is best described as

A. random error

B. systematic error

C. a mistake

D. a resolution limit

Question 19

Four students each measure the resistance of the same resistor. One student's readings are tightly clustered about their mean, but the mean is far from the accepted value. These readings are best described as

A. accurate but not precise

B. both accurate and precise

C. precise but not accurate

D. neither accurate nor precise

Question 20

To test the relationship $E_k = 1/2\, m v^2$ for a fixed mass, a student plots E_k against v^2, obtaining a straight line through the origin. Which one of the following is the gradient of this line?

A. m

B. $2m$

C. m^2

D. $m/2$

Record your answers here.

Question	Answer	Question	Answer
1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
10		20	

Practice Exam 2 — Section B

- Answer **all** questions in the spaces provided.
- Write your responses in English.
- In questions where more than one mark is available, appropriate working **must** be shown.
- Give each final answer in the unit indicated.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- Take the gravitational field strength at Earth's surface to be $g = 9.8\ \text{N kg}^{-1}$.

Question 1 (6 marks)

Optical fibres carry light for the internet and for medical instruments. The core of a fibre has refractive index $n = 1.50$ and is surrounded by a cladding layer of refractive index $n = 1.45$. A light ray travelling in air strikes the flat end of the core at an angle of incidence of 30°.

a. Calculate the angle of refraction as the light enters the core. Give your answer in degrees. 2 marks

b. The light now travels through the glass core. Explain why the frequency of the light is the same in the core as in air, but the wavelength is shorter. 2 marks

c. Calculate the critical angle at the core–cladding boundary, and use your answer to explain how the fibre keeps the light inside the core. 2 marks

Question 2 (6 marks)

A school canteen kettle heats $0.80\ \text{kg}$ of water from $20\ °\text{C}$ to $100\ °\text{C}$, and then keeps it at the boil. The specific heat capacity of water is $4180\ \text{J kg}^{-1}\ \text{K}^{-1}$ and the specific latent heat of vaporisation of water is $2.26 \times 10^{6}\ \text{J kg}^{-1}$.

a. Show that the energy required to raise the water from $20\ °\text{C}$ to $100\ °\text{C}$ is approximately $2.7 \times 10^{5}\ \text{J}$. 1 mark

b. Once the water is at $100\ °\text{C}$, the kettle supplies a further $4.52 \times 10^{5}\ \text{J}$. Calculate the mass of water that is vaporised by this energy. Give your answer in kg. 2 marks

c. Name the main method of energy transfer: i. through the metal base of the kettle; ii. around the kettle as warmer water rises and cooler water sinks. 2 marks

d. State the temperature of the water while it boils, and explain briefly why the temperature does not rise even though energy is still being supplied. 1 mark

Question 3 (5 marks)

The element of a bar radiator glows dull red when the heater is on. Its surface reaches a temperature of about $900\ °\text{C}$.

Source: International Astronomical Union, IAU 2015 Resolution B3 — Recommended Nominal Units for Stellar & Planetary Astronomy (nominal solar effective temperature $5772\ \text{K}$*), retrieved 2026-08-18.*

a. Convert $900\ °\text{C}$ to kelvin. 1 mark

b. Calculate the peak wavelength λ_{max} of the radiation emitted by the element at this temperature. Give your answer in m. 2 marks

c. The surface of the Sun is at about $5800\ \text{K}$. Without calculating, use Wien's Law to explain why the Sun's peak wavelength lies in the visible region of the spectrum while the radiator element's peak lies in the infrared. 2 marks

Question 4 (5 marks)

Earth's climate can be studied with an energy budget: energy reaches Earth from the Sun and is absorbed, and Earth radiates infrared energy back to space.

a. State the main method of energy transfer by which energy from the Sun reaches Earth. 1 mark

b. State what must be true of the energy absorbed from the Sun and the energy radiated to space for Earth's average temperature to stay approximately constant. 1 mark

c. The atmosphere slows the outward transfer of infrared energy from the surface. Explain, in terms of energy absorbed and energy radiated, why a stronger slowing effect makes Earth's surface warmer. 2 marks

d. Some of the extra stored energy melts ice on land. The melting ice stays at $0\,°\mathrm{C}$ while it melts. Explain why its temperature does not rise even though it is absorbing energy. 1 mark

Question 5 (5 marks)

Americium-241 is a radioisotope used in household smoke detectors. It decays by emitting an alpha particle.

a. Complete the decay equation by writing the daughter nucleus and the alpha particle with their mass and charge numbers, and show that both numbers are conserved: ${}^{241}_{95}\mathrm{Am} \rightarrow ?$ 2 marks

b. State the number of protons and the number of neutrons in an americium-241 nucleus. 1 mark

c. Compare alpha particles and gamma rays in terms of their ionising power and their ability to penetrate materials. 2 marks

Question 6 (5 marks)

Fluorine-18 is a radioisotope used for medical imaging in Australian hospitals. Its half-life is $110\,\mathrm{min}$. A freshly prepared sample has an activity of $800\,\mathrm{MBq}$.

Source: IAEA Nuclear Data Section, LiveChart of Nuclides, retrieved 2026-08-18.

a. Define the half-life of a radioisotope. 1 mark

b. Calculate the activity of the sample after $330\,\mathrm{min}$. Give your answer in MBq. 2 marks

c. The sample should not be used once its activity falls below $25\,\mathrm{MBq}$. Calculate the time from preparation until the activity first reaches $25\,\mathrm{MBq}$. 2 marks

Question 7 (6 marks)

In a laboratory study, a $0.20\,\mathrm{kg}$ tissue sample absorbs $0.010\,\mathrm{J}$ of energy from alpha radiation. The radiation weighting factor for alpha particles is $w_R = 20$.

a. Show that the absorbed dose in the tissue is $0.050\,\mathrm{Gy}$. 1 mark

b. Calculate the equivalent dose received by the tissue. Give your answer in Sv. 2 marks

c. Calculate the equivalent dose the tissue would receive from the same absorbed dose delivered by gamma radiation, for which $w_R = 1$. 1 mark

d. Explain why the radiation weighting factor is larger for alpha particles than for gamma rays. 2 marks

Question 8 (5 marks)

An LED torch runs from a $3.0\,\mathrm{V}$ battery, and the current in its LEDs is $0.20\,\mathrm{A}$. The torch is switched on for $150\,\mathrm{s}$.

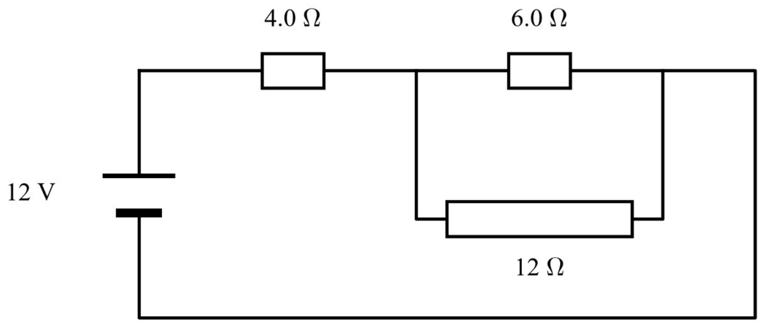
a. Calculate the charge that passes through the LEDs in $150\,\mathrm{s}$. Give your answer in C. 2 marks

b. Calculate the energy the battery delivers to this charge. Give your answer in J. 2 marks

c. Calculate the power of the torch. Give your answer in W. 1 mark

Question 9 (6 marks)

A $12\,\mathrm{V}$ battery is connected to a $4.0\,\Omega$ resistor in series with a parallel pair of resistors: $6.0\,\Omega$ and $12\,\Omega$.



a. Show that the equivalent resistance of the parallel pair is $4.0\,\Omega$. 1 mark

b. Calculate the total current drawn from the battery. Give your answer in A. 2 marks

c. Calculate the potential difference across the $4.0\,\Omega$ resistor. Give your answer in V. 1 mark

d. Of the $6.0\,\Omega$ resistor and the $12\,\Omega$ resistor, which one transforms energy to the surroundings at the greater rate? Justify your answer with a calculation or a proportionality argument. 2 marks

Question 10 (6 marks)

In a Victorian home, the supply to the power points is $230\,\mathrm{V}$. A $2400\,\mathrm{W}$ electric heater and a $120\,\mathrm{W}$ globe are both plugged in and running, connected in parallel across the supply.

a. Calculate the current in the heater. Give your answer in A. 2 marks

b. Calculate the energy used by the heater in $3.0\,\mathrm{h}$. Give your answer in kW h. 2 marks

c. Explain why the appliances in a home are connected in parallel rather than in series. Give two reasons. 2 marks

Question 11 (5 marks)

A designer builds a temperature sensor from a voltage divider: a $12\,\mathrm{V}$ supply, a fixed resistor $R_1 = 10\,\mathrm{k}\,\Omega$, and a thermistor R_2, with the output voltage V_{out} taken across the thermistor. The thermistor is an NTC type: at $20\,°\mathrm{C}$ its resistance is $20\,\mathrm{k}\,\Omega$, and its resistance decreases as its temperature increases.

a. Calculate V_{out} at $20\,°\mathrm{C}$. Give your answer in V. 2 marks

b. The temperature of the thermistor rises. State and explain what happens to V_{out}. 2 marks

c. Name one device in a home or school that could use a circuit like this as a sensor. 1 mark

Question 12 (5 marks)

A car starts from rest at traffic lights and accelerates uniformly, reaching $20\,\mathrm{m\,s^{-1}}$ in $8.0\,\mathrm{s}$.

a. Show that the acceleration of the car is $2.5\,\mathrm{m\,s^{-2}}$. 1 mark

b. Calculate the distance the car travels during these $8.0\,\mathrm{s}$. Give your answer in m. 2 marks

c. The driver then brakes, and the car comes to rest over a distance of $50\,\mathrm{m}$ from $20\,\mathrm{m\,s^{-1}}$. Calculate the magnitude of the car's acceleration while braking. Give your answer in m s^{-2}. 2 marks

Question 13 (5 marks)

A crane lifts a $120\,\mathrm{kg}$ crate vertically with a cable.

a. Calculate the force due to gravity on the crate. Give your answer in N. 1 mark

b. The tension in the cable is 1500 N, directed upward. Calculate the acceleration of the crate, including its direction. Give the magnitude in m s^{-2}. 2 marks

c. State the Newton's-third-law partner of the force on the crate from Earth, and give two features of a Newton's-third-law pair. 2 marks

Question 14 (5 marks)

In a railway yard, a $40\,\mathrm{kg}$ railway truck rolls along a straight, level track at $3.0\,\mathrm{m\ s^{-1}}$ and collides with a stationary $20\,\mathrm{kg}$ truck. The two trucks couple together and move off as one.

a. Show that the common speed of the coupled trucks immediately after the collision is $2.0\,\mathrm{m\ s^{-1}}$. 1 mark

b. The collision lasts $0.50\,\mathrm{s}$. Calculate the magnitude of the average force on the $20\,\mathrm{kg}$ truck during the collision. Give your answer in N. 2 marks

c. Explain, with reference to the kinetic energy before and after, why this collision is inelastic, and state where the difference in kinetic energy goes. 2 marks

Question 15 (5 marks)

A mechanic uses a spanner of length $0.40\,\mathrm{m}$ to loosen a nut, pushing at the end of the handle with a force of $50\,\mathrm{N}$, at right angles to the handle.

a. Calculate the torque the mechanic applies to the nut. Give your answer in N m. 2 marks

b. Explain why pushing at right angles to the handle gives the largest torque for the same force. 1 mark

c. A uniform seesaw is balanced on a pivot at its centre. A child whose force due to gravity is $300\,\mathrm{N}$ sits $1.2\,\mathrm{m}$ to the left of the pivot. Calculate how far to the right of the pivot a second child, whose force due to gravity is $400\,\mathrm{N}$, must sit to keep the seesaw balanced. Ignore the force due to gravity on the plank. Give your answer in m. 2 marks

Question 16 (20 marks)

A student investigates how the extension of a spring depends on the force applied to it. The spring hangs vertically from a clamp stand; the student adds $100\,\mathrm{g}$ slotted masses one at a time (each mass applies a force of $0.98\,\mathrm{N}$, taking $g = 9.8\,\mathrm{N\ kg^{-1}}$) and reads the extension from a ruler beside the spring. Each force is measured three times and the readings are averaged. The uncertainty in each mean extension is $\pm 0.005\,\mathrm{m}$. The results are:

Force F (N)	Mean extension x (m)
0.98	0.040
1.96	0.082
2.94	0.118
3.92	0.161
4.90	0.202
5.88	0.238

a. Complete the table of variables for this investigation.

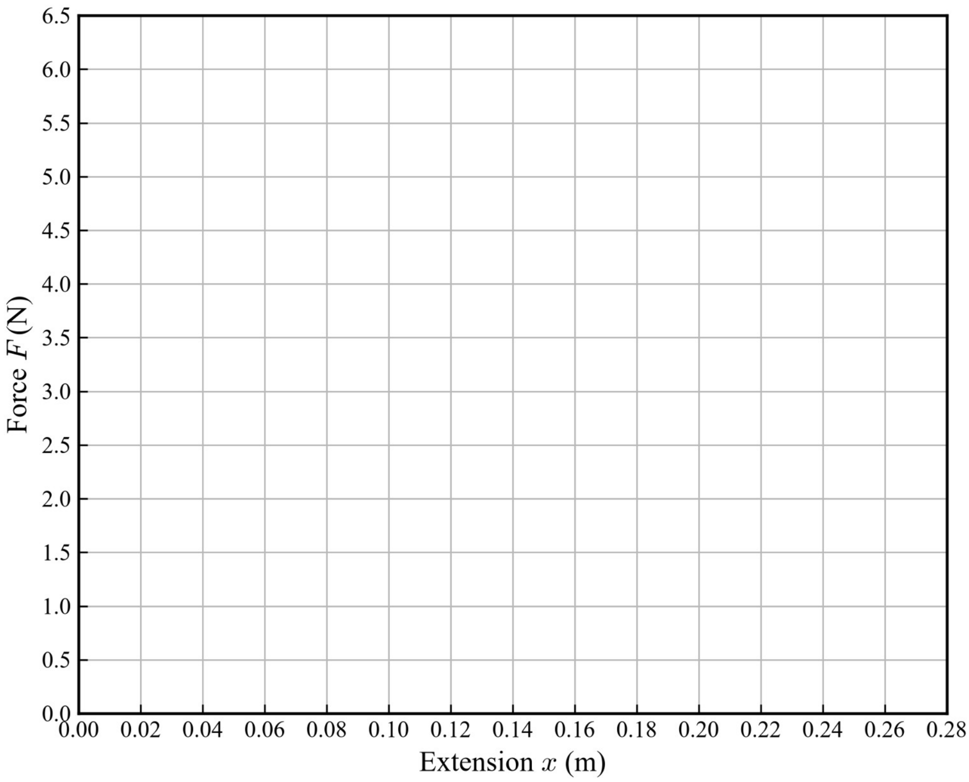
Variable	Name it
Independent variable	
Dependent variable	
One controlled variable	

3 marks

b. State the purpose of repeating each measurement three times and averaging. 1 mark

c. Identify one source of **random** error and one source of **systematic** error in this setup. 2 marks

d. On the grid below, plot the six data points with their $\pm 0.005\,\mathrm{m}$ uncertainty bars, and draw a straight line of best fit. 5 marks



e. Using two well-separated points **on your line of best fit**, calculate the gradient of the line. Include the unit. 2 marks

f. The student hypothesised that the extension of the spring is proportional to the force applied. State whether the graph supports this hypothesis and justify your answer. 2 marks

g. The relationship between force and extension is $F = k\,x$, where k is the spring constant. Use your gradient to determine k for this spring. Give your answer in N m^{-1}. 2 marks

h. Predict, with a reason, how the graph would differ if the experiment were repeated with a stiffer spring (a larger spring constant). 2 marks

i. State one safety precaution the student should follow in this experiment, and the reason for it. 1 mark

Practice Exam 2 — Formula Sheet

This formula sheet is provided for use with all practice examinations in this booklet. Part 1 reproduces, unaltered and with attribution, the items of the official VCE Physics Formula Sheet (© VCAA 2026) that lie within the Units 1 & 2 study design; items that belong to Units 3 & 4 only are omitted. Part 2 is a house supplement drawn from the key knowledge of the Units 1 & 2 study design (2023–2027): it carries the relationships that Units 1 & 2 students apply which the official sheet does not give.

Part 1 — VCE Physics Formula Sheet: Units 1 & 2 items

Motion and related energy transformations

velocity	$v = \frac{\Delta s}{\Delta t}$
acceleration	$a = \frac{\Delta v}{\Delta t}$
constant acceleration	$v = u + at$
	$s = ut + \frac{1}{2}at^2$
	$s = vt - \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
	$s = \frac{1}{2}(u + v)t$
Newton's second law	$\Sigma F = ma$
Hooke's law	$F = -kx$
elastic potential energy	$E_s = \frac{1}{2}kx^2$
gravitational potential energy	$E_g = mg\Delta h$
kinetic energy	$E_k = \frac{1}{2}mv^2$
impulse	$F\Delta t = m\Delta v$
momentum	$p = mv$

Generation and transmission of electricity

current	$I = \frac{V}{R}$
power	$P = VI$
resistors in series	$R_T = R_1 + R_2 + \ldots$
resistors in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

Waves

wave equation	$v = f\lambda$

Part 2 — Units 1 & 2 supplement

Waves and light

wavelength, frequency, period and speed	$\lambda = \frac{v}{f} = vT$

refraction (Snell's Law)	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
	$n_1 v_1 = n_2 v_2$
critical angle	$n_1 \sin\theta_c = n_2 \sin 90^\circ$

Thermal energy

Celsius–kelvin conversion	$T(\mathrm{K}) = T(°\mathrm{C}) + 273.15$
raising temperature	$Q = mc\Delta T$
change of state	$Q = mL$
Wien's Law	$\lambda_{\max} T = \text{constant}$

Radiation from the nucleus

Provenance note (TOC §2.7): D = E/m, H = w_R × D and E = mc² do not appear on the official Units 1 & 2 formula sheet; they are included in this supplement because the Units 1 & 2 key knowledge requires dose calculations and treats mass–energy conversion qualitatively.

radioactive decay (whole half-lives)	$N = N_0 \left(\frac{1}{2}\right)^n$
	$n = \frac{t}{t_{1/2}}$
absorbed dose	$D = \frac{E}{m}$ (unit: Gy)
equivalent dose	$H = w_R \times D$ (unit: Sv)
effective dose	$\Sigma\, w_T H_T$ over tissues T (unit: Sv)

Nuclear energy

mass–energy conversion	$E = mc^2$

Electricity

current and charge	$I = \frac{Q}{t}$
potential difference	$V = \frac{E}{Q}$
power and energy	$P = \frac{E}{t}$
voltage divider	$V_{\text{out}} = V_{\text{in}} \times \frac{R_2}{R_1 + R_2}$

Forces, work and energy

work done by a constant force	$W = Fs\cos\theta$
work done	area under a force–distance graph
torque	$\tau = r_\perp F$
force due to gravity	$F_{\text{on body by Earth}} = mg$
Newton's third law	$F_{\text{on A by B}} = -F_{\text{on B by A}}$
change in momentum	$\Delta p = F_{\text{net}} \Delta t$
efficiency	$\eta = \frac{\text{useful energy out}}{\text{total energy in}}$

Data

acceleration due to gravity at Earth's surface	$g = 9.8\ \text{m s}^{-2}$ ($9.8\ \text{N kg}^{-1}$)
speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
Wien's Law constant	$2.9 \times 10^{-3}\ \text{m K}$

The Units 1 & 2 study design gives the gravitational field strength near Earth's surface as g = 9.8 N kg^{-1} (9.8 m s^{-2}), and this is the value used throughout this booklet. The official VCE Physics Formula Sheet gives g = 9.81 m s^{-2} for Units 3 & 4.

Metric (SI) multipliers

pico (p)	10^{-12}	kilo (k)	10^{3}
nano (n)	10^{-9}	mega (M)	10^{6}
micro (μ)	10^{-6}	giga (G)	10^{9}
milli (m)	10^{-3}	tera (T)	10^{12}

Unit conversions

1 tonne (t)	$= 10^{3}$ kg
1 kilowatt hour (kW h)	$= 3.6 \times 10^{6}$ J

Nomenclature

force due to gravity	F_{g}
force on A by B	$F_{\text{on A by B}}$
normal force	F_{N}

End of Formula Sheet

Practice Exam 2 — solutions

Section A — answer key

Question	Answer	Question	Answer
1	B	11	C
2	C	12	C
3	A	13	D
4	D	14	B
5	B	15	B
6	C	16	A
7	B	17	D
8	C	18	A
9	D	19	C
10	B	20	D

Question 1 — B. $\lambda = \frac{v}{f} = \frac{340}{850} = 0.40\,\mathrm{m}$. **A** halves the wavelength; **C** multiplies ($v \times f$); **D** inverts the ratio ($\frac{f}{v}$).

Question 2 — C. Frequency rises in the order radio < infrared < visible < ultraviolet. **A** and **D** both run part of the list in decreasing order; **B** runs the whole list in decreasing order.

Question 3 — A. The frequency of a wave is set by its source and does not change at a boundary; in glass the speed decreases, and since $v = f\,\lambda$, the wavelength decreases too. **B**, **C** and **D** each change the frequency or keep the speed fixed, contrary to this.

Question 4 — D. $Q = m\,c\,\Delta T = 0.50 \times 4180 \times 10 = 20\,900\,\mathrm{J} \approx 21\,\mathrm{kJ}$. **A** divides by ten twice; **B** omits the mass; **C** uses twice the correct energy.

Question 5 — B. Wien's Law gives $\lambda_{\mathrm{max}} \propto \frac{1}{T}$, so doubling T halves λ_{max}. **A** inverts the proportion; **C** squares it; **D** ignores the law.

Question 6 — C. Gamma rays pass through many materials that stop alpha and beta-minus particles; alpha particles are the least penetrating. **D** contradicts the measured penetrating powers.

Question 7 — B. Beta-minus emission raises the charge number by one at the same mass number: $53 + 1 = 54$ (xenon-131). **A** is beta-plus ($Z - 1$); **C** is alpha emission ($A - 4$, $Z - 2$); **D** changes nothing.

Question 8 — C. $1.0\,\mathrm{h} = 60\,\mathrm{min}$ is three half-lives of $20\,\mathrm{min}$: $(1/2)^3 = 1/8$ remains. **A** is one half-life; **B** two; **D** four.

Question 9 — D. $Q = I\,t = 3.0 \times 40 = 120\,\mathrm{C}$. **A** divides the time by the current ($40/3.0 = 13$); **B** divides the current by the time ($3.0/40 = 0.075$); **C** drops a factor of ten.

Question 10 — B. $\frac{1}{R_T} = \frac{1}{6} + \frac{1}{3} = \frac{1}{2}$, so $R_T = 2\,\Omega$. **A** adds the resistances (series); **C** averages them; **D** multiplies them.

Question 11 — C. $E = P\,t = 1.2\,\mathrm{kW} \times 2.5\,\mathrm{h} = 3.0\,\mathrm{kW\,h}$. **A** uses $\frac{P}{t}$ ($\frac{1.2}{2.5} = 0.48$); **B** inverts this ($\frac{t}{P}$: $\frac{2.5}{1.2} = 2.1$); **D** converts the power to watts ($1200 \times 2.5 = 3.0 \times 10^3$) but still labels the result in kW h.

Question 12 — C. An RCD compares the active and neutral currents and opens when they differ (a residual current). **A** and **B** respond to overcurrent only; **D** protects appliances against voltage surges, not people.

Question 13 — D. Distance has magnitude only; displacement, velocity and momentum all carry a direction.

Question 14 — B. $v=u+at=0+3.0\times4.0=12\,\mathrm{m\,s^{-1}}$. **A** is the distance $1/2\,at^2=24\,\mathrm{m}$, not the speed; **C** simply quotes the acceleration; **D** divides the acceleration by the time ($\frac{3.0}{4.0}=0.75$).

Question 15 — B. A third-law pair is the mutual force between two objects: the force on the table from the book. **A** is the classic trap — the force due to gravity on the book balances the normal force on the book, but both act on the same object, so they are not a third-law pair; **C** pairs with the force due to gravity on the book; **D** involves a third object.

Question 16 — A. $E_k=1/2\,mv^2=1/2\times2.0\times3.0^2=9.0\,\mathrm{J}$. **B** is mv; **C** is mv^2; **D** is $1/2\,mv$.

Question 17 — D. The resistance is what the student measures as the length changes; the material and temperature are held fixed (controlled), and the length is the independent variable.

Question 18 — A. Scatter in both directions about the true value is random error. **B** shifts every reading the same way; **C** is a one-off blunder; **D** limits the finest readable division but does not by itself scatter readings.

Question 19 — C. Tightly clustered readings are precise; a mean far from the accepted value is not accurate. **A** reverses the terms; **B** and **D** contradict the clustering and the offset.

Question 20 — D. $E_k=1/2\,mv^2=(m/2)\,v^2$, so with m fixed the gradient of E_k against v^2 is $m/2$. **A, B** and **C** misplace the factor of a half.

Section B — worked solutions

Question 1 $n_1=1.00$ (air), $n_2=1.50$ (core), $\theta_1=30^\circ$.

(a) Snell's Law: $n_1\sin\theta_1=n_2\sin\theta_2$, so

$$\sin\theta_2=\frac{n_1\sin\theta_1}{n_2}=\frac{1.00\times\sin30^\circ}{1.50}=\frac{0.50}{1.50}=0.333\,,$$

$$\theta_2=\sin^{-1}(0.333)=19.47^\circ\approx19^\circ.$$

(2 marks: 1 correct substitution into Snell's Law; **1** answer $\approx19^\circ$.)

(b) The frequency of a wave is set by the source, and a boundary cannot change how many wave crests arrive per second, so f is the same in the core as in air. Light travels more slowly in glass than in air; from $v=f\lambda$, with f fixed and v smaller, λ must be smaller too — the wavelength is shorter in the core. **(1 mark** frequency set by source / unchanged at a boundary; **1 mark** v decreases with f fixed, so $v=f\lambda$ gives a shorter λ.)

(c) At the critical angle the refracted ray would run along the boundary ($\theta_2=90^\circ$):

$$n_1\sin\theta_c=n_2\sin90^\circ\Rightarrow1.50\sin\theta_c=1.45\times1\,,$$

$$\sin\theta_c=\frac{1.45}{1.50}=0.967\Rightarrow\theta_c=\sin^{-1}(0.967)=75.2^\circ\approx75^\circ.$$

Light that strikes the core–cladding boundary at an angle of incidence greater than 75° cannot refract into the cladding; it is totally internally reflected, so it stays inside the core and travels along the fibre. **(1 mark** correct substitution giving $\theta_c\approx75^\circ$; **1 mark** links total internal reflection at angles beyond θ_c to guiding the light along the core.)

Question 2 $m=0.80\,\mathrm{kg}$, $c=4180\,\mathrm{J\,kg^{-1}K^{-1}}$, $\Delta T=100-20=80\,\mathrm{K}$, $L_v=2.26\times10^6\,\mathrm{J\,kg^{-1}}$.

(a) $Q=mc\Delta T=0.80\times4180\times80=267\,520\,\mathrm{J}\approx2.7\times10^5\,\mathrm{J}$, as required. **(1 mark: correct substitution giving $\approx2.7\times10^5$ J.)**

(b) $Q = m L_v \Rightarrow m = \frac{Q}{L_v} = \frac{4.52 \times 10^5}{2.26 \times 10^6} = 0.20\,\text{kg}$. **(1 mark** rearranges $Q = m L_v$ and substitutes; **1 mark** 0.20 kg.)

(c)

i. conduction (through the solid metal base). ii. convection (circulation of the water). **(1 mark each.)**

(d) The water stays at $100\,°\text{C}$ while it boils. The supplied energy goes into changing the state of the water ($Q = m L_v$) — breaking the bonds between particles rather than raising their average kinetic energy — so the temperature does not rise. **(1 mark: energy goes into the change of state / latent heat at constant temperature.)**

Question 3

(a) $T = 900 + 273.15 = 1173.15\,\text{K} \approx 1173\,\text{K}$. **(1 mark.)**

(b) Wien's Law: $\lambda_{\text{max}} T = 2.9 \times 10^{-3}\,\text{m K}$, so

$$\lambda_{\text{max}} = \frac{2.9 \times 10^{-3}}{T} = \frac{2.9 \times 10^{-3}}{1173} = 2.47 \times 10^{-6}\,\text{m} \approx 2.5 \times 10^{-6}\,\text{m}.$$

(1 mark correct substitution; **1 mark** $\approx 2.5 \times 10^{-6}$ m.)

(c) Wien's Law says the hotter the object, the shorter the peak wavelength. The Sun's surface (5800 K) is about five times hotter than the element (1173 K), so its peak wavelength is about five times shorter — in the visible region — while the element's peak (2.5×10^{-6} m) lies in the infrared. **(1 mark** hotter object → shorter λ_{max}; **1 mark** applies the comparison: Sun hotter, visible peak; element cooler, infrared peak.)

Question 4

(a) Radiation (electromagnetic radiation from the Sun). **(1 mark.)**

(b) The energy absorbed from the Sun must equal (balance) the energy radiated to space. **(1 mark.)**

(c) If the atmosphere slows the outward transfer more strongly, then for a time the energy absorbed from the Sun exceeds the energy radiated to space. The climate system stores the difference, and stored energy raises the temperature of the surface; the surface keeps warming until the energy radiated again balances the energy absorbed, at a higher average temperature. **(1 mark** energy in exceeds energy out while the slowing is stronger; **1 mark** the stored difference raises the temperature until a new balance is reached.)

(d) The absorbed energy goes into changing the state of the ice (solid to liquid), $Q = m L_f$, at constant temperature, rather than into raising the temperature of the ice–water mixture. **(1 mark.)**

Question 5

(a) ${}^{241}_{95}\text{Am} \rightarrow {}^{237}_{93}\text{Np} + {}^{4}_{2}\text{He}$. Mass numbers: $241 = 237 + 4$ ✓. Charge numbers: $95 = 93 + 2$ ✓. The daughter nucleus is neptunium-237. **(1 mark** correct daughter and alpha with mass and charge numbers; **1 mark** shows both numbers conserved.)

(b) Protons: 95 (the charge number). Neutrons: $241 - 95 = 146$. **(1 mark.)**

(c) Alpha particles are the most strongly ionising of the two but the least penetrating — stopped by paper or a few cm of air. Gamma rays are weakly ionising but the most penetrating — reduced only by thick lead or concrete. **(1 mark** correct ionising-power comparison; **1 mark** correct penetrating-power comparison.)

Question 6

(a) The half-life is the time taken for half of the nuclei in a sample to decay (equivalently, for the activity of the sample to halve). **(1 mark.)**

(b) $330\,\text{min} \div 110\,\text{min} = 3$ half-lives. Activity: $800 \rightarrow 400 \rightarrow 200 \rightarrow 100\,\text{MBq}$. **(1 mark** three half-lives identified; **1 mark** 100 MBq.)

(c) 25 MBq needs two more halvings: 800 → 400 → 200 → 100 → 50 → 25, that is five half-lives. $t = 5 \times 110 = 550\,\text{min}$. **(1 mark** five half-lives to reach 25 MBq; **1 mark** 550 min.)

Question 7 $E = 0.010\,\text{J}$, $m = 0.20\,\text{kg}$.

(a) $D = \frac{E}{m} = \frac{0.010}{0.20} = 0.050\,\text{Gy}$, as required. **(1 mark.)**

(b) $H = w_R \times D = 20 \times 0.050 = 1.0\,\text{Sv}$. **(1 mark** correct substitution into $H = w_R D$; **1 mark** 1.0 Sv.)

(c) $H = 1 \times 0.050 = 0.050\,\text{Sv}$. **(1 mark.)**

(d) Alpha particles ionise much more densely along their path than gamma rays, so for the same absorbed dose they cause more damage to living tissue. The larger weighting factor accounts for this greater biological effect. **(1 mark** alpha causes more ionisation/damage per gray; **1 mark** the weighting factor reflects the greater biological effect.)

Question 8 $V = 3.0\,\text{V}$, $I = 0.20\,\text{A}$, $t = 150\,\text{s}$.

(a) $I = \frac{Q}{t} \Rightarrow Q = I\,t = 0.20 \times 150 = 30\,\text{C}$. **(1 mark** rearranges and substitutes; **1 mark** 30 C.)

(b) $V = \frac{E}{Q} \Rightarrow E = V\,Q = 3.0 \times 30 = 90\,\text{J}$. **(1 mark** rearranges and substitutes; **1 mark** 90 J.)

(c) $P = V\,I = 3.0 \times 0.20 = 0.60\,\text{W}$. **(1 mark.)**

Question 9

(a) $\frac{1}{R_p} = \frac{1}{6.0} + \frac{1}{12} = \frac{2}{12} + \frac{1}{12} = \frac{3}{12} = \frac{1}{4.0}$, so $R_p = 4.0\,\Omega$, as required. **(1 mark.)**

(b) Total resistance: $R_T = 4.0 + R_p = 4.0 + 4.0 = 8.0\,\Omega$. Current from the battery:

$$I = \frac{V}{R_T} = \frac{12}{8.0} = 1.5\,\text{A}.$$

(1 mark adds series resistance to the parallel pair; **1 mark** 1.5 A.)

(c) The full battery current flows through the series resistor: $V = I\,R = 1.5 \times 4.0 = 6.0\,\text{V}$. **(1 mark.)**

(d) The parallel pair share the same potential difference, $12 - 6.0 = 6.0\,\text{V}$. With V the same, $P = \frac{V^2}{R}$ is larger for the smaller resistance: $P_6 = \frac{6.0^2}{6.0} = 6.0\,\text{W}$ and $P_{12} = \frac{6.0^2}{12} = 3.0\,\text{W}$. The $6.0\,\Omega$ resistor transforms energy to the surroundings at the greater rate. **(1 mark** same V across the pair with $P = V^2 / R$ (or correct powers 6.0 W vs 3.0 W); **1 mark** concludes the $6.0\,\Omega$ resistor dissipates more.)

Question 10 $V = 230\,\text{V}$, $P_{\text{heater}} = 2400\,\text{W}$.

(a) $P = V\,I \Rightarrow I = \frac{P}{V} = \frac{2400}{230} = 10.4\,\text{A}$. **(1 mark** rearranges and substitutes; **1 mark** 10.4 A (10 A to 2 s.f.).)

(b) $E = P\,t = 2.4\,\text{kW} \times 3.0\,\text{h} = 7.2\,\text{kW h}$. **(1 mark** converts to kW and multiplies by hours; **1 mark** 7.2 kW h.)

(c) In parallel, every appliance has the full 230 V across it, so each runs at its rated power; and each appliance can be switched on or off independently — switching one off (or one failing) does not break the circuit for the others, as it would in series. **(1 mark** full supply pd across each appliance; **1 mark** independent switching / one failure does not stop the others.)

Question 11 $V_{\text{in}} = 12\,\text{V}$, $R_1 = 10\,\text{k}\Omega$, $R_2 = 20\,\text{k}\Omega$ at 20 °C.

(a) $V_{out} = V_{in} \times \frac{R_2}{R_1 + R_2} = 12 \times \frac{20}{10+20} = 12 \times \frac{20}{30} = 8.0\,\text{V}$. **(1 mark** correct substitution into the divider rule; **1 mark** 8.0 V.)

(b) As the temperature rises, the thermistor's resistance falls (NTC). The thermistor then takes a smaller share of the supply potential difference, so V_{out} decreases. **(1 mark** resistance falls with rising temperature; **1 mark** smaller share of the supply pd, so V_{out} falls.)

(c) Any one of: a thermostat for a heater or air conditioner; a fire alarm; an oven over-temperature cut-out. **(1 mark.)**

Question 12 $u = 0$, $v = 20\,\text{m s}^{-1}$, $t = 8.0\,\text{s}$.

(a) $a = \frac{v-u}{t} = \frac{20-0}{8.0} = 2.5\,\text{m s}^{-2}$, as required. **(1 mark.)**

(b) $s = 1/2(u+v)t = 1/2(0+20) \times 8.0 = 80\,\text{m}$. **(1 mark** correct equation and substitution; **1 mark** 80 m.)

(c) $v^2 = u^2 + 2as$ with $v = 0$, $u = 20\,\text{m s}^{-1}$, $s = 50\,\text{m}$:

$$0 = 20^2 + 2a(50) \Rightarrow a = -\frac{400}{100} = -4.0\,\text{m s}^{-2},$$

so the magnitude of the acceleration is $4.0\,\text{m s}^{-2}$. **(1 mark** correct substitution into $v^2 = u^2 + 2as$; **1 mark** magnitude 4.0 m s^{-2}.)

Question 13 $m = 120\,\text{kg}$, $g = 9.8\,\text{N kg}^{-1}$.

(a) $F_g = mg = 120 \times 9.8 = 1176\,\text{N} \approx 1.2 \times 10^3\,\text{N}$. **(1 mark.)**

(b) Taking up as positive: $F_{net} = F_T - F_g = 1500 - 1176 = 324\,\text{N}$ (upward).

$$a = \frac{F_{net}}{m} = \frac{324}{120} = 2.7\,\text{m s}^{-2}, \text{directed upward.}$$

(1 mark correct net force 324 N upward; **1 mark** 2.7 m s^{-2} upward.)

(c) The partner is the force on Earth from the crate (the gravitational pull of the crate on Earth). Features of a third-law pair (any two): equal in magnitude; opposite in direction; the same type of force; acting on different objects. **(1 mark** correct partner force; **1 mark** two correct features.)

Question 14

(a) Momentum is conserved in the collision: $m_1 u_1 = (m_1 + m_2)v$, so

$$v = \frac{40 \times 3.0}{40+20} = \frac{120}{60} = 2.0\,\text{m s}^{-1},$$

as required. **(1 mark.)**

(b) For the 20 kg truck, $\Delta p = m \Delta v = 20 \times (2.0 - 0) = 40\,\text{N s}$.

$$F = \frac{\Delta p}{\Delta t} = \frac{40}{0.50} = 80\,\text{N}.$$

(1 mark correct impulse 40 N s; **1 mark** 80 N.)

(c) Before: $E_k = 1/2 \times 40 \times 3.0^2 = 180\,\text{J}$. After: $E_k = 1/2 \times 60 \times 2.0^2 = 120\,\text{J}$. Kinetic energy is not conserved (60 J less after), so the collision is inelastic; the 60 J is transformed to heat, sound and the deformation of the coupling. **(1 mark** correct before/after kinetic energies showing a loss; **1 mark** names where the difference goes.)

Question 15 $r = 0.40\,\text{m}$, $F = 50\,\text{N}$.

(a) $\tau = r_{\perp} F = 0.40 \times 50 = 20\,\text{N m}$. **(1 mark** correct substitution; **1 mark** 20 N m.)

(b) At right angles, the perpendicular distance $r_{\perp}$ equals the full length of the handle, its largest possible value; at any other angle $r_{\perp} = r \sin\theta < r$, so the same force gives a smaller torque. **(1 mark.)**

(c) Balance requires equal and opposite torques about the pivot:

$$300 \times 1.2 = 400 \times d \Rightarrow d = \frac{360}{400} = 0.90\,\text{m}.$$

(1 mark sets the two torques equal; **1 mark** 0.90 m.)

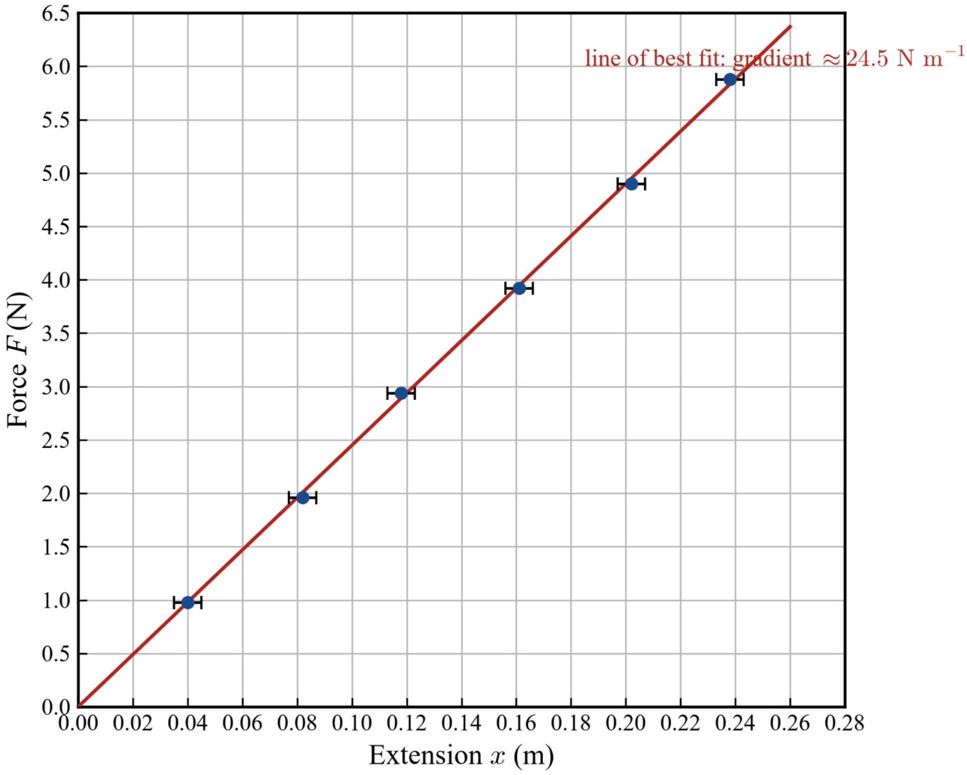
Question 16

(a) Independent: the force applied to the spring (the hanging mass). Dependent: the extension of the spring. Controlled (any one): the same spring; the same ruler read the same way; room temperature. **(1 mark per correct row.)**

(b) Repeating and averaging reduces the effect of random error, giving a more reliable (more precise) value of the extension at each force. **(1 mark.)**

(c) Random (any one): parallax when reading the ruler, or judging the exact position of the bottom of the spring — readings scatter either side of the true value. Systematic (any one): the zero of the ruler not level with the original bottom of the spring (or a tilted ruler) — every reading shifted by the same amount in the same direction. **(1 mark** plausible random source; **1 mark** plausible systematic source.)

(d) The plotted points, with horizontal uncertainty bars of $\pm 0.005\,\text{m}$, and a straight line of best fit drawn close to all points with the scatter balanced on either side, are shown below.



(2 marks points plotted correctly; **1 mark** uncertainty bars of the stated size on each point; **2 marks** single straight line of best fit, not forced through particular points, scatter balanced.)

(e) Reading two well-separated points on the line, $(0, 0)$ and $(0.24, 5.88)$:

$$\text{gradient} = \frac{5.88 - 0}{0.24 - 0} = 24.5\,\text{N m}^{-1}.$$

(Accept $24–25\,\text{N m}^{-1}$ from a correctly drawn line.) **(1 mark** uses two points on the line, not data points; **1 mark** gradient ≈ 24.5 N m^{-1} with unit.)

(f) Supported. The line of best fit is straight and passes through the origin (within the uncertainty bars), which is exactly what proportionality ($x \propto F$) requires. **(1 mark** states supported; **1 mark** straight line through the origin within uncertainty.)

(g) $F = k\,x$ has the form $y = (\text{gradient})\,x$ with F on the vertical axis, so k equals the gradient: $k \approx 24.5 \approx 25\,\text{N m}^{-1}$. **(1 mark** identifies k with the gradient; **1 mark** value with unit.)

(h) A stiffer spring extends less for the same force, so each plotted point moves to a smaller extension; the line of best fit is steeper (a larger gradient, equal to the larger k). **(1 mark** smaller extension at each force / steeper line; **1 mark** links the steeper gradient to the larger spring constant.)

(i) Any one of: keep feet clear and wear closed shoes, because the masses can fall if the spring slips; wear safety glasses, because an over-stretched spring can snap back; do not over-stretch the spring past its limit, because it may break or drop the masses. **(1 mark: sensible precaution with matching reason.)**

End of examination

Practice Exam 3 — Medium

Physics — Units 1 & 2 — Practice Examination 3

- Reading time: **15 minutes**
- Writing time: **2 hours 30 minutes**
- Section A: 20 questions, 20 marks
- Section B: 18 questions, 100 marks
- Total: 120 marks

Approved materials

- One scientific calculator
- Pre-written notes (one folded A3 sheet or two A4 sheets bound together by tape)

A formula sheet is provided at the end of this examination. Answer multiple-choice questions in this book.

Students are **not** permitted to bring mobile phones and/or any unauthorised electronic devices into the examination room.

There is no VCAA examination at Units 1 & 2. This paper mirrors the house examination profile, and its mark allocations are house convention only — they are not a VCAA requirement.

Section A — Multiple-choice questions (20 marks)

- Answer **all** questions.
- Choose the response that is **correct** or that **best answers** the question.
- A correct answer scores 1; an incorrect answer scores 0.
- Marks will **not** be deducted for incorrect answers.
- No marks will be given if more than one answer is completed for any question.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Where required, take the magnitude of the gravitational field strength at Earth's surface to be $g = 9.8\,\text{N kg}^{-1}$*, the speed of light in a vacuum to be* $c = 3.00 \times 10^{8}\,\text{m s}^{-1}$*, and the constant in Wien's Law to be* $2.9 \times 10^{-3}\,\text{m K}$.

Question 1

In a ripple tank, water waves travel at $0.30\,\text{m s}^{-1}$ with a frequency of $2.0\,\text{Hz}$. Which one of the following is closest to the wavelength of these waves?

A. $0.60\,\text{m}$

B. $6.7\,\text{m}$

C. $0.15\,\text{m}$

D. $0.30\,\text{m}$

Question 2

Which one of the following statements about electromagnetic waves is correct?

A. Electromagnetic waves need a material medium, such as air, to propagate.

B. Higher-frequency electromagnetic waves travel faster than lower-frequency ones in a vacuum.

C. Electromagnetic waves are longitudinal waves.

D. All electromagnetic waves are transverse and travel at the same speed in a vacuum.

Question 3

A ray of light passes from air into a glass block. Which one of the following correctly describes what happens to the light as it enters the glass?

A. Its speed decreases, its frequency decreases and its wavelength is unchanged.

B. Its speed decreases, its wavelength decreases and its frequency is unchanged.

C. Its speed is unchanged, its wavelength decreases and its frequency increases.

D. Its speed decreases, its wavelength increases and its frequency is unchanged.

Question 4

A heated metal surface in a kiln is at a temperature of $2900\,\mathrm{K}$. Which one of the following is closest to the peak wavelength of the electromagnetic radiation it emits?

A. $1.0 \times 10^{-3}\,\mathrm{m}$

B. $1.0 \times 10^{6}\,\mathrm{m}$

C. $1.0 \times 10^{-6}\,\mathrm{m}$

D. $1.0 \times 10^{-9}\,\mathrm{m}$

Question 5

A shallow dish of water cools as some of the water evaporates. Which one of the following best explains the cooling?

A. The water particles with the greatest kinetic energy escape from the surface, so the average kinetic energy of the particles that remain decreases.

B. The escaping water particles carry the coldest particles away with them, leaving warmer particles behind.

C. The water reacts chemically with the air, and the reaction absorbs energy from the dish.

D. The dish absorbs coldness from the surroundings as the water leaves.

Question 6

Which one of the following lists α, β and γ radiation in order of **increasing** penetrating power?

A. γ, β, α

B. β, α, γ

C. α, γ, β

D. α, β, γ

Question 7

A sample of a radioisotope has a half-life of $2.0\,\text{h}$. Which one of the following is closest to the fraction of the original undecayed nuclei remaining after $10\,\text{h}$?

A. $\frac{1}{16}$

B. $\frac{1}{4}$

C. $\frac{1}{32}$

D. $\frac{1}{8}$

Question 8

In a nuclear fission reactor, a moderator surrounds the fuel. Which one of the following best describes the role of the moderator?

A. It slows down the neutrons released in fission, so they are more likely to cause further fissions.

B. It absorbs all of the neutrons, so the chain reaction cannot occur.

C. It speeds up the neutrons so that they split nuclei more easily.

D. It absorbs the γ radiation produced by the fuel so that no radiation leaves the reactor.

Question 9

A current of $2.5\,\text{A}$ flows through a torch bulb for 4.0 minutes. Which one of the following is closest to the charge that passes through the bulb in this time?

A. $10\,\text{C}$

B. $600\,\text{C}$

C. $150\,\text{C}$

D. $0.10\,\text{C}$

Question 10

A $1.5\,\text{kW}$ microwave oven runs for 20 minutes. Which one of the following is closest to the energy it transfers in this time?

A. $500\,\text{J}$

B. $9.0\times10^{4}\,\text{J}$

C. $1.08\times10^{8}\,\text{J}$

D. $1.8\times10^{6}\,\text{J}$

Question 11

A $12\,\Omega$ resistor and a $4.0\,\Omega$ resistor are connected in parallel. Which one of the following is closest to their equivalent resistance?

A. $16\,\Omega$

B. $8.0\,\Omega$

C. $3.0\,\Omega$

D. $0.33\,\Omega$

Question 12

The lighting and power circuits in Australian homes are wired in parallel rather than in series. Which one of the following is the main reason for this?

A. Each appliance receives the full supply potential difference and can operate independently of the others.

B. A parallel circuit has a greater total resistance, so it draws less current.

C. A parallel circuit prevents the current from ever becoming too large.

D. Each appliance receives an equal share of the supply potential difference, whatever its resistance.

Question 13

A device is ohmic. Which one of the following best describes its current–potential difference (I–V) graph?

A. A straight line through the origin.

B. A curve that flattens out at higher potential differences.

C. A horizontal line.

D. A straight line that does not pass through the origin.

Question 14

Which one of the following contains one vector quantity and one scalar quantity?

A. Velocity and momentum

B. Displacement and speed

C. Distance and mass

D. Acceleration and force

Question 15

A car travelling in a straight line at $5.0\,\mathrm{m\ s^{-1}}$ accelerates uniformly at $2.0\,\mathrm{m\ s^{-2}}$ for $6.0\,\mathrm{s}$. Which one of the following is closest to the car’s speed at the end of this time?

A. $12\,\mathrm{m\ s^{-1}}$

B. $7.0\,\mathrm{m\ s^{-1}}$

C. $60\,\mathrm{m\ s^{-1}}$

D. $17\,\mathrm{m\ s^{-1}}$

Question 16

A $2.0\,\mathrm{kg}$ cart moving at $3.0\,\mathrm{m\ s^{-1}}$ collides with a stationary $1.0\,\mathrm{kg}$ cart. The two carts stick together and move off as one. Which one of the following is closest to their speed immediately after the collision?

A. $3.0\,\mathrm{m\ s^{-1}}$

B. $1.5\,\mathrm{m\ s^{-1}}$

C. $2.0\,\mathrm{m\ s^{-1}}$

D. $1.0\,\mathrm{m\ s^{-1}}$

Question 17

A person pulls a sled along level snow with a constant force of $50\,\mathrm{N}$ directed at 60° to the direction of motion. The sled moves $4.0\,\mathrm{m}$. Which one of the following is closest to the work done on the sled by this force?

A. $200\,\mathrm{J}$

B. $100\,\mathrm{J}$

C. $173\,\mathrm{J}$

D. $0\,\mathrm{J}$

Question 18

A student's digital scale reads $0.4\,\mathrm{kg}$ when nothing is placed on it. The student uses the scale for a series of mass measurements without resetting it. This is an example of

A. a random error; averaging repeated measurements will remove it.

B. a mistake; the affected measurements should simply be discarded.

C. a systematic error; repeating the measurements will not reduce its effect.

D. a loss of precision; the readings will become more widely scattered.

Question 19

A ball dropped from a height of $2.0\,\mathrm{m}$ is predicted, from the constant-acceleration equations, to take $0.64\,\mathrm{s}$ to reach the ground. A student measures the fall time four times and records $0.71\,\mathrm{s}$, $0.72\,\mathrm{s}$, $0.71\,\mathrm{s}$ and $0.72\,\mathrm{s}$. These measurements are best described as

A. accurate but not precise.

B. precise but not accurate.

C. both accurate and precise.

D. neither accurate nor precise.

Question 20

An object is dropped from rest and falls a distance s in a time t. For constant acceleration g, the model is $s=\frac{1}{2}gt^2$.

To obtain a straight-line graph from which g can be determined, a student should plot

A. s against t; the gradient equals g.

B. s against t^2; the gradient equals $\frac{1}{2}g$.

C. t against s; the gradient equals $\frac{1}{g}$.

D. s against t^2; the gradient equals $2g$.

End of Section A

Practice Exam 3 — Section B

*Answer **all** questions in the spaces provided. Write your responses in English. In questions where more than one mark is available, appropriate working **must** be shown. Where a final answer requires a particular unit, that unit is stated in the question; give your answer in that unit. Unless otherwise indicated, the diagrams in this book are **not** drawn to scale. Take the magnitude of the gravitational field strength at Earth's surface to be* $g = 9.8\,\mathrm{N\,kg^{-1}}$.

Question 1 (5 marks)

A coastal radio station in Victoria broadcasts radio waves at a frequency of $1.5 \times 10^{6}\,\mathrm{Hz}$.

a. Calculate the wavelength of these radio waves in a vacuum. Give your answer in m. 2 marks

b. State the region of the electromagnetic spectrum to which these waves belong, and one use of this region in society. 1 mark

c. Radio waves and microwaves have very different wavelengths, yet both travel at the same speed in a vacuum. Explain why. 2 marks

Question 2 (5 marks)

An underwater lamp in a swimming pool directs a ray of light upwards towards the water's surface. The refractive index of water is 1.33 and the refractive index of air is 1.00.

a. Show that the speed of light in the water is $2.26 \times 10^{8}\,\mathrm{m\,s^{-1}}$. 1 mark

b. Calculate the critical angle for the water–air boundary. Give your answer in degrees. 2 marks

c. The ray strikes the water surface from below at an angle of incidence of 55°. State, with a reason that uses your answer to part **b.**, whether the ray emerges from the water into the air. 1 mark

d. When light does pass from water into air, it refracts away from the normal. Explain why. 1 mark

Question 3 (6 marks)

A $2.0\,\mathrm{kW}$ electric kettle is used to heat $0.50\,\mathrm{kg}$ of water from $20\,°\mathrm{C}$ to its boiling point at $100\,°\mathrm{C}$. The specific heat capacity of water is $4200\,\mathrm{J\,kg^{-1}\,K^{-1}}$.

a. Calculate the energy required to raise the temperature of the water from $20\,°\mathrm{C}$ to $100\,°\mathrm{C}$. Give your answer in J. 2 marks

b. Calculate the minimum time the kettle takes to deliver this energy. Give your answer in s. 2 marks

c. In practice the time taken is longer than your answer to part **b.** Explain why, with reference to energy transfers. 2 marks

Question 4 (6 marks)

The surface of the Sun is at a temperature of about $5800\,\mathrm{K}$. Earth's surface has an average temperature of about $288\,\mathrm{K}$.

a. Show that the peak wavelength of the radiation emitted by the Sun is $5.0 \times 10^{-7}\,\mathrm{m}$. 1 mark

b. Calculate the peak wavelength of the radiation emitted by Earth's surface, and state the region of the electromagnetic spectrum in which this wavelength lies. Give your answer in m. 2 marks

c. State which of the Sun and Earth radiates more total energy across the electromagnetic spectrum, and explain why. 1 mark

d. Most of the radiation arriving from the Sun passes through the atmosphere and is absorbed by Earth's surface, which re-emits it. Explain how an increase in the concentration of greenhouse gases, such as carbon dioxide, leads to an increase in Earth's average surface temperature. 2 marks

Question 5 (4 marks)

Carbon-14 is a radioactive isotope that decays by β^- emission.

a. Write the complete decay equation for the β^- decay of carbon-14, showing the daughter nucleus with its proton number and nucleon number. 2 marks

b. Describe the change that takes place inside the nucleus during this decay. 1 mark

c. Compare the penetrating power of β^- radiation with that of α radiation, and relate the difference to their ionising power. 1 mark

Question 6 (5 marks)

A hospital prepares a sample of a radioisotope used in therapy. At the time of preparation the sample contains 8.0×10^{10} undecayed nuclei. The half-life of the isotope is $8.0\,\mathrm{h}$.

a. Calculate the number of undecayed nuclei remaining in the sample after $32\,\mathrm{h}$. 2 marks

b. Explain why an isotope used in therapy should have a half-life of hours rather than years. 2 marks

c. Radioactive decay is modelled as a random process. Explain what is meant by this, and how the half-life can still be used to make reliable predictions. 1 mark

Question 7 (4 marks)

A patient's thyroid gland, of mass $0.025\,\mathrm{kg}$, absorbs $5.0\times10^{-3}\,\mathrm{J}$ of energy from a β-emitting radioisotope. For β radiation the radiation weighting factor is $w_R=1$.

a. Calculate the absorbed dose received by the thyroid. Give your answer in Gy. 2 marks

b. Calculate the equivalent dose received by the thyroid. Give your answer in Sv. 1 mark

c. For α radiation the radiation weighting factor is $w_R=20$. Explain why α radiation has a much larger weighting factor than β radiation. 1 mark

Question 8 (3 marks)

The binding energy per nucleon of uranium-235 is about $7.6\,\mathrm{MeV}$, while the binding energy per nucleon of the medium-mass nuclei produced when it fissions is about $8.5\,\mathrm{MeV}$.

a. Use these values to explain why the fission of uranium-235 releases energy. 2 marks

b. State how a chain reaction is maintained in a fission reactor. 1 mark

Question 9 (6 marks)

A $12\,\mathrm{V}$ battery powers a lamp. In 5.0 minutes, a charge of $90\,\mathrm{C}$ passes through the lamp.

a. Calculate the current in the lamp. Give your answer in A. 2 marks

b. Calculate the energy transferred to the lamp in this time. Give your answer in J. 2 marks

c. Calculate the power of the lamp. Give your answer in W. 1 mark

d. To measure the current in the lamp, an ammeter must be connected in series with it. Explain why the ammeter is connected in series rather than in parallel. 1 mark

Question 10 (6 marks)

A $12\,\mathrm{V}$ battery of negligible internal resistance is connected in series with a $6.0\,\Omega$ resistor and a parallel combination of two $8.0\,\Omega$ resistors.

a. Show that the equivalent resistance of the whole circuit is $10\,\Omega$. 1 mark

b. Calculate the current supplied by the battery. Give your answer in A. 1 mark

c. Calculate the potential difference across the parallel combination. Give your answer in V. 2 marks

d. Calculate the current in one of the $8.0\,\Omega$ resistors. Give your answer in A. 1 mark

e. Calculate the power dissipated in the $6.0\,\Omega$ resistor. Give your answer in W. 1 mark

Question 11 (5 marks)

A voltage divider is built from a $9.0\,\text{V}$ supply, a $10\,\text{k}\,\Omega$ resistor (R_1) and a $5.0\,\text{k}\,\Omega$ resistor (R_2) connected in series. The output potential difference is measured across R_2.

a. Calculate the output potential difference of the divider. Give your answer in V. 2 marks

b. The $5.0\,\text{k}\,\Omega$ resistor is replaced with a light dependent resistor (LDR). The resistance of the LDR increases when the light level falls. State and explain the effect on the output potential difference when the light level falls. 2 marks

c. A device that draws current is connected in parallel with R_2. Explain why the output potential difference falls when the device is connected. 1 mark

Question 12 (5 marks)

A Victorian household is supplied with $230\,\text{V}$, $50\,\text{Hz}$ alternating current. A $2400\,\text{W}$ portable heater is plugged into a power point.

a. Calculate the current drawn by the heater. Give your answer in A. 2 marks

b. The heater runs for $5.0\,\text{h}$. Calculate the energy it transfers in this time. Give your answer in kW h. 1 mark

c. The household switchboard contains both circuit breakers and residual current devices (RCDs). State the condition each device responds to, and explain why an RCD gives protection against electric shock that a circuit breaker alone does not. 2 marks

Question 13 (5 marks)

A tram in Melbourne travels along a straight, level track at $15\,\text{m s}^{-1}$. The driver applies the brakes and the tram decelerates uniformly, coming to rest in $5.0\,\text{s}$.

a. Calculate the acceleration of the tram while it is braking. Give your answer in m s^{-2}. 1 mark

b. Calculate the distance the tram travels while braking. Give your answer in m. 2 marks

c. A second tram is following the first at the same speed of $15\,\text{m s}^{-1}$. Its driver has a reaction time of $0.80\,\text{s}$ before the brakes are applied. Calculate the distance the second tram travels during this reaction time. Give your answer in m. 1 mark

d. The second tram then brakes with the same acceleration as the first. Calculate the total stopping distance of the second tram, measured from the point where its driver first saw the need to brake. Give your answer in m. 1 mark

Question 14 (5 marks)

In a backyard test, a $0.15\,\text{kg}$ cricket ball moving horizontally at $30\,\text{m s}^{-1}$ is caught by a player, whose hands bring the ball to rest.

a. Show that the magnitude of the change in momentum of the ball is $4.5\,\text{N s}$. 1 mark

b. The player brings the ball to rest in $0.50\,\text{s}$. Calculate the average force exerted on the ball by the hands during the catch. Give your answer in N. 2 marks

c. A skilled fielder moves their hands backward with the ball while catching it. Explain, in terms of impulse, why this reduces the force on the hands. 2 marks

Question 15 (4 marks)

A box of mass $8.0\,\mathrm{kg}$ rests on a horizontal floor. A person pushes the box horizontally with a force of $30\,\mathrm{N}$, and the friction force opposing the motion is $6.0\,\mathrm{N}$.

a. Calculate the acceleration of the box. Give your answer in $\mathrm{m\,s^{-2}}$. 2 marks

b. State the magnitude of the normal force on the box by the floor. Give your answer in N. 1 mark

c. The force due to gravity on the box is $F_{\text{on box by Earth}}$. State the Newton's third law pair-partner of this force, using the $F_{\text{on A by B}}$ convention. 1 mark

Question 16 (3 marks)

A mechanic loosens a bolt using a spanner of length $0.30\,\mathrm{m}$. The mechanic applies a force of $80\,\mathrm{N}$ at the end of the spanner.

a. The force is applied perpendicular to the spanner. Calculate the torque applied to the bolt. Give your answer in N m. 1 mark

b. The mechanic now applies the same $80\,\mathrm{N}$ force at an angle of 60° to the spanner instead of perpendicular to it. Calculate the new torque applied to the bolt. Give your answer in N m. 2 marks

Question 17 (3 marks)

A $60\,\mathrm{kg}$ athlete runs up a flight of stairs, gaining a vertical height of $3.0\,\mathrm{m}$ in $4.0\,\mathrm{s}$.

a. Calculate the gain in gravitational potential energy of the athlete. Give your answer in J. 1 mark

b. Calculate the useful power output of the athlete during the climb. Give your answer in W. 1 mark

c. The athlete's body converts $1.5 \times 10^{4}\,\mathrm{J}$ of chemical energy during the climb. Calculate the efficiency of the athlete's body for this climb. Give your answer as a percentage. 1 mark

Question 18 (20 marks)

A student investigates how the current in a fixed resistor changes as the potential difference across it changes. The resistor is connected in series with a variable resistor and a $6.0\,\mathrm{V}$ battery. An ammeter in the circuit measures the current in the resistor, and a voltmeter connected across the resistor measures the potential difference across it. The student adjusts the variable resistor to obtain the readings shown in the table. Each current reading is repeated three times and averaged, and each averaged reading has an uncertainty of $\pm 0.05\,\mathrm{A}$.

Potential difference V (V)	1.0	2.0	3.0	4.0	5.0	6.0
Current I (A)	0.20	0.41	0.59	0.80	1.01	1.19

a. State the independent variable, the dependent variable, and **one** variable that should be controlled in this investigation. 3 marks

b. The student repeats each current reading three times and averages the results. State the purpose of repeating the measurements. 2 marks

c. The model for the resistor is $I = \frac{V}{R}$, where R is constant. Explain why, if this model holds, the line of best fit on an I–V graph should pass through the origin. 2 marks

d. Explain why the voltmeter is connected in parallel across the resistor rather than in series with it. 1 mark

e. On the grid provided, plot a graph of current I (vertical axis) against potential difference V (horizontal axis). Include uncertainty bars of $\pm 0.05\,\mathrm{A}$ on each point and draw a line of best fit. 5 marks

f. Using two well-separated points on your line of best fit, determine the gradient of the graph. Give your answer in $\mathrm{A\,V^{-1}}$. 2 marks

g. The model for the resistor is $I = \dfrac{V}{R}$, where R is the resistance.

(i) State what physical quantity the gradient of your graph represents.

(ii) Using your gradient, calculate the resistance R of the resistor. Give your answer in Ω.

(iii) Using the model, predict the current in the resistor when the potential difference across it is $4.5\,\mathrm{V}$. Give your answer in A. 3 marks

h. After taking the readings, the student leaves the circuit connected for some time, and the resistor becomes noticeably warm. Later current readings are lower than the model predicts. Explain, with reference to the model $I = \dfrac{V}{R}$, why the model no longer describes the resistor's behaviour. 2 marks

End of Section B

Practice Exam 3 — Formula Sheet

This formula sheet is provided for use with all practice examinations in this booklet. Part 1 reproduces, unaltered and with attribution, the items of the official VCE Physics Formula Sheet (© VCAA 2026) that lie within the Units 1 & 2 study design; items that belong to Units 3 & 4 only are omitted. Part 2 is a house supplement drawn from the key knowledge of the Units 1 & 2 study design (2023–2027): it carries the relationships that Units 1 & 2 students apply which the official sheet does not give.

Part 1 — VCE Physics Formula Sheet: Units 1 & 2 items

Motion and related energy transformations

velocity	$v=\frac{\Delta s}{\Delta t}$
acceleration	$a=\frac{\Delta v}{\Delta t}$
constant acceleration	$v=u+at$
	$s=ut+\frac{1}{2}at^2$
	$s=vt-\frac{1}{2}at^2$
	$v^2=u^2+2as$
	$s=\frac{1}{2}(u+v)t$
Newton's second law	$\Sigma F=ma$
Hooke's law	$F=-kx$
elastic potential energy	$E_s=\frac{1}{2}kx^2$
gravitational potential energy	$E_g=mg\Delta h$
kinetic energy	$E_k=\frac{1}{2}mv^2$
impulse	$F\Delta t=m\Delta v$
momentum	$p=mv$

Generation and transmission of electricity

current	$I=\frac{V}{R}$
power	$P=VI$
resistors in series	$R_T=R_1+R_2+\ldots$
resistors in parallel	$\frac{1}{R_T}=\frac{1}{R_1}+\frac{1}{R_2}+\ldots$

Waves

wave equation	$v=f\lambda$

Part 2 — Units 1 & 2 supplement

Waves and light

wavelength, frequency, period and speed	$\lambda=\frac{v}{f}=vT$

refraction (Snell's Law) $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$n_1 v_1 = n_2 v_2$

critical angle $n_1 \sin\theta_c = n_2 \sin 90^\circ$

Thermal energy

Celsius–kelvin conversion $T(\mathrm{K}) = T(^\circ\mathrm{C}) + 273.15$

raising temperature $Q = m c \Delta T$

change of state $Q = m L$

Wien's Law $\lambda_{\max} T = \text{constant}$

Radiation from the nucleus

Provenance note (TOC §2.7): D = E/m, H = w_R × D and E = mc² do not appear on the official Units 1 & 2 formula sheet; they are included in this supplement because the Units 1 & 2 key knowledge requires dose calculations and treats mass–energy conversion qualitatively.

radioactive decay (whole half-lives) $N = N_0 \left(\frac{1}{2}\right)^n$

$n = \frac{t}{t_{1/2}}$

absorbed dose $D = \frac{E}{m}$ (unit: Gy)

equivalent dose $H = w_R \times D$ (unit: Sv)

effective dose $\Sigma\, w_T H_T$ over tissues T (unit: Sv)

Nuclear energy

mass–energy conversion $E = m c^2$

Electricity

current and charge $I = \frac{Q}{t}$

potential difference $V = \frac{E}{Q}$

power and energy $P = \frac{E}{t}$

voltage divider $V_{\text{out}} = V_{\text{in}} \times \frac{R_2}{R_1 + R_2}$

Forces, work and energy

work done by a constant force $W = F s \cos\theta$

work done area under a force–distance graph

torque $\tau = r_\perp F$

force due to gravity $F_{\text{on body by Earth}} = m g$

Newton's third law $F_{\text{on A by B}} = -F_{\text{on B by A}}$

change in momentum $\Delta p = F_{\text{net}} \Delta t$

efficiency $\eta = \frac{\text{useful energy out}}{\text{total energy in}}$

Data

acceleration due to gravity at Earth's surface	$g = 9.8\ \text{m s}^{-2}$ ($9.8\ \text{N kg}^{-1}$)
speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
Wien's Law constant	$2.9 \times 10^{-3}\ \text{m K}$

The Units 1 & 2 study design gives the gravitational field strength near Earth's surface as g = 9.8 N kg⁻¹ (9.8 m s⁻²), and this is the value used throughout this booklet. The official VCE Physics Formula Sheet gives g = 9.81 m s⁻² for Units 3 & 4.

Metric (SI) multipliers

pico (p)	10^{-12}	kilo (k)	10^{3}
nano (n)	10^{-9}	mega (M)	10^{6}
micro (μ)	10^{-6}	giga (G)	10^{9}
milli (m)	10^{-3}	tera (T)	10^{12}

Unit conversions

1 tonne (t)	$= 10^{3}$ kg
1 kilowatt hour (kW h)	$= 3.6 \times 10^{6}$ J

Nomenclature

force due to gravity	F_{g}
force on A by B	$F_{\text{on A by B}}$
normal force	F_{N}

End of Formula Sheet

Practice Exam 3 — solutions

Section A — answer key

Question	Answer	Question	Answer
1	C	11	C
2	D	12	A
3	B	13	A
4	C	14	B
5	A	15	D
6	D	16	C
7	C	17	B
8	A	18	C
9	B	19	B
10	D	20	B

Question 1 — C. $\lambda = \frac{v}{f} = \frac{0.30}{2.0} = 0.15\,\text{m}$. **A** multiplies $v \times f$ instead of dividing; **B** inverts the expression (f / v); **D** quotes the wave speed as if it were the wavelength.

Question 2 — D. All electromagnetic waves are transverse and travel at the same speed c in a vacuum; only mechanical waves require a medium. **A** describes mechanical waves; **B** wrongly makes the speed depend on frequency — in a vacuum all electromagnetic waves travel at c; **C** names the wrong wave type.

Question 3 — B. The frequency is set by the source and does not change at the boundary. In glass the wave speed is lower, so since $v = f\lambda$ with f fixed, the wavelength is also lower. **A** wrongly changes the frequency; **C** wrongly keeps the speed unchanged; **D** wrongly increases the wavelength.

Question 4 — C. Wien's Law: $\lambda_{\max} = \frac{2.9 \times 10^{-3}}{T} = \frac{2.9 \times 10^{-3}}{2900} = 1.0 \times 10^{-6}\,\text{m}$. **A** slips a factor of 10^3 (as if the temperature were $2.9\,\text{K}$); **B** inverts the expression ($T / \text{constant}$); **D** slips a further factor of 10^3.

Question 5 — A. In the kinetic energy model, the particles with the greatest kinetic energy are the ones that escape the surface. They take their energy with them, so the average kinetic energy of the particles that remain is lower, which corresponds to a lower temperature. **B** reverses the idea; **C** invents a chemical reaction; **D** treats coldness as a substance that flows in.

Question 6 — D. α radiation is stopped by paper or a few centimetres of air, β by a few millimetres of aluminium, and γ is reduced by thick lead or concrete — so penetrating power increases in the order α, β, γ. **A** gives the order of decreasing penetrating power; **B** and **C** misorder the three.

Question 7 — C. $10\,\text{h}$ is five half-lives ($10 \div 2.0 = 5$), so the fraction remaining is $\left(\frac{1}{2}\right)^5 = \frac{1}{32}$. **A** counts only four half-lives; **B** counts only two; **D** counts only three.

Question 8 — A. The moderator slows the neutrons released in fission, because slow neutrons are more likely to cause further fissions of uranium-235 nuclei and so sustain the chain reaction. **B** describes the role of the control rods (neutron absorption), and absorbing all neutrons would stop the reaction; **C** reverses the effect — fast neutrons are less likely to cause fission of ^{235}U; **D** confuses the moderator with radiation shielding.

Question 9 — B. $Q = It = 2.5 \times (4.0 \times 60) = 2.5 \times 240 = 600\,\text{C}$. **A** uses the time in minutes without converting to seconds (2.5 × 4.0); **C** converts only one minute (2.5 × 60); **D** divides the current by the time.

Question 10 — D. 20 minutes is $1/3$ of an hour, so $E=Pt=1.5\,\text{kW}\times1/3\,\text{h}=0.50\,\text{kW h}$, and $0.50\times3.6\times10^{6}=1.8\times10^{6}\,\text{J}$. **A** treats the kilowatt-hour as $1000\,\text{J}$ (0.50×1000); **B** uses a time of 1.0 minute ($1.5\,\text{kW}\times60\,\text{s}=9.0\times10^{4}\,\text{J}$); **C** treats 20 minutes as 20 hours ($1.5\times20=30\,\text{kW h}$).

Question 11 — C. $\frac{1}{R}=\frac{1}{12}+\frac{1}{4.0}=\frac{1}{12}+\frac{3}{12}=\frac{4}{12}$, so $R=3.0\,\Omega$. **A** adds the resistances as if they were in series; **B** averages them; **D** stops at the sum of reciprocals ($1/R=0.33$) without inverting back to the resistance.

Question 12 — A. In a parallel circuit every appliance is connected across the full supply potential difference ($230\,\text{V}$) and can be switched independently. **B** is false — adding parallel branches lowers the total resistance; **C** is false — parallel branches add current, which is why fuses and circuit breakers are still needed; **D** describes a series circuit.

Question 13 — A. An ohmic device has a constant resistance ($R=V/I$), so its I–V graph is a straight line through the origin. **B** describes a non-ohmic device such as a globe or diode; **C** would mean the current never changes; **D** would mean there is current at zero potential difference.

Question 14 — B. Displacement has magnitude and direction (a vector); speed has magnitude only (a scalar). **A** is two vectors; **C** is two scalars; **D** is two vectors.

Question 15 — D. $v=u+at=5.0+2.0\times6.0=17\,\text{m s}^{-1}$. **A** gives only the gain in speed at, omitting u; **B** adds the acceleration once without multiplying by the time; **C** multiplies $u\times a\times t$.

Question 16 — C. Momentum is conserved: total momentum before $=2.0\times3.0=6.0\,\text{kg m s}^{-1}$; after the collision the combined mass is $3.0\,\text{kg}$, so $v=\frac{6.0}{3.0}=2.0\,\text{m s}^{-1}$. **A** leaves the speed unchanged; **B** averages the two speeds; **D** divides the momentum by the wrong mass.

Question 17 — B. $W=Fs\cos\theta=50\times4.0\times\cos60^{\circ}=50\times4.0\times0.50=100\,\text{J}$. **A** ignores the angle ($\cos0^{\circ}$); **C** uses $\sin60^{\circ}$ instead of $\cos60^{\circ}$; **D** treats the force as perpendicular to the motion.

Question 18 — C. A reading of $0.4\,\text{kg}$ with nothing on the scale is a constant offset (a zeroing fault): every measurement is shifted by the same amount. That is a systematic error, and repeating the measurements will not reduce it. **A** describes scatter, not a fixed offset; **B** wrongly treats a repeatable offset as a one-off mistake; **D** describes precision.

Question 19 — B. The four readings are closely grouped (a spread of only $0.01\,\text{s}$), so they are precise, but they all sit about $0.07\,\text{s}$ above the predicted $0.64\,\text{s}$, so they are not accurate. **A** reverses the two ideas; **C** ignores the offset from the predicted value; **D** ignores the tight grouping.

Question 20 — B. Writing $s=\frac{1}{2}gt^{2}$ shows that a graph of s against t^{2} is a straight line through the origin with gradient $\frac{1}{2}g$. **A** gives a curve, not a straight line; **C** also gives a curve; **D** has the correct axes but misreads the gradient as $2g$.

Section B — worked solutions

Question 1 $f=1.5\times10^{6}\,\text{Hz}$; in a vacuum $v=c=3.00\times10^{8}\,\text{m s}^{-1}$.

(a) $\lambda=\frac{v}{f}=\frac{3.00\times10^{8}}{1.5\times10^{6}}=200\,\text{m}$. (**1 mark** correct relationship $\lambda=v/f$; **1 mark** correct value $200\,\text{m}$.)

(b) Region: **radio** (radio waves). One use: broadcasting (radio or television), or communications more generally. **(1 mark: both the region and one valid use.)**

(c) Both radio waves and microwaves are electromagnetic waves. All electromagnetic waves are transverse waves that travel at the same speed c in a vacuum, regardless of their wavelength or frequency — the speed is a property of electromagnetic waves in the medium, not of the particular wavelength. (**1 mark** identifies both as electromagnetic waves; **1 mark** states that all electromagnetic waves travel at the same speed c in a vacuum, independent of wavelength/frequency.)

Question 2 $n_{\text{water}} = 1.33$, $n_{\text{air}} = 1.00$.

(a) $n = \frac{c}{v}$, so $v = \frac{c}{n} = \frac{3.00 \times 10^8}{1.33} = 2.26 \times 10^8\,\text{m s}^{-1}$, as required. **(1 mark: correct substitution and result.)**

(b) At the critical angle the refracted ray emerges at 90°: $n_1 \sin\theta_c = n_2 \sin 90^\circ$ with the water as medium 1, so

$$\sin\theta_c = \frac{n_2}{n_1} = \frac{1.00}{1.33} = 0.752,$$

giving $\theta_c = 48.8^\circ$. **(1 mark** correct use of the critical angle relationship; **1 mark** correct value 48.8°.)

(c) The ray does not emerge. The angle of incidence (55°) is greater than the critical angle (48.8°), so the ray undergoes total internal reflection and stays in the water. **(1 mark: comparison $55^\circ > 48.8^\circ$ linked to total internal reflection / no emergence.)**

(d) Light travels faster in air than in water. By Snell's Law, when light passes into a medium in which it travels faster (a lower refractive index), the ray bends away from the normal. **(1 mark: the speed is greater in air / the refractive index is lower, so the ray bends away from the normal.)**

Question 3 $m = 0.50\,\text{kg}$, $c = 4200\,\text{J kg}^{-1}\text{K}^{-1}$, $\Delta T = 100 - 20 = 80\,\text{K}$, $P = 2.0\,\text{kW} = 2000\,\text{W}$.

(a) $Q = mc\Delta T = 0.50 \times 4200 \times 80 = 1.68 \times 10^5\,\text{J}$. **(1 mark** $Q = mc\Delta T$ with $\Delta T = 80\,\text{K}$; **1 mark** correct value $1.68 \times 10^5\,\text{J}$.)

(b) $P = \frac{E}{t}$, so $t = \frac{E}{P} = \frac{1.68 \times 10^5}{2000} = 84\,\text{s}$. **(1 mark** $t = E/P$; **1 mark** correct value $84\,\text{s}$.)

(c) This is the minimum time because it assumes all of the energy transferred by the element goes into raising the temperature of the water. In practice some energy heats the kettle itself (the element and the body), and some is transferred to the surrounding air by conduction, convection and radiation, so less than $1.68 \times 10^5\,\text{J}$ reaches the water each second and the heating takes longer. **(1 mark** identifies energy transferred to the kettle/surroundings rather than the water; **1 mark** links this to a longer time / names the transfer pathways.)

Question 4 $T_{\text{Sun}} = 5800\,\text{K}$, $T_{\text{Earth}} = 288\,\text{K}$; Wien constant $2.9 \times 10^{-3}\,\text{m K}$.

(a) $\lambda_{\text{max}} = \frac{2.9 \times 10^{-3}}{T} = \frac{2.9 \times 10^{-3}}{5800} = 5.0 \times 10^{-7}\,\text{m}$, as required. **(1 mark: correct substitution and result.)**

(b) $\lambda_{\text{max}} = \frac{2.9 \times 10^{-3}}{288} = 1.0 \times 10^{-5}\,\text{m}$, which lies in the **infrared** region. **(1 mark** correct value $1.0 \times 10^{-5}\,\text{m}$; **1 mark** identifies the infrared region.)

(c) The Sun radiates more total energy across the electromagnetic spectrum. A hotter object emits more radiation overall (at all wavelengths) than a cooler object. **(1 mark: the Sun, because it is the hotter object.)**

(d) Earth's surface re-emits the absorbed energy as infrared radiation (part **b**). Greenhouse gases such as carbon dioxide absorb this outgoing infrared radiation and re-emit it in all directions, including back toward Earth's surface. This returns energy to Earth's surface and lower atmosphere, so the surface must reach a higher temperature to balance the incoming energy from the Sun. **(1 mark** greenhouse gases absorb and re-emit the outgoing infrared radiation; **1 mark** energy is re-emitted back toward Earth, raising the surface temperature.)

Question 5

(a) ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$ (House convention follows the study design: the equations in this course are written without the antineutrino.) **(1 mark** correct daughter nucleus ${}^{14}_{7}N$; **1 mark** correct β^- particle and balanced top and bottom numbers.)

(b) A neutron in the nucleus changes into a proton. The proton number rises from 6 to 7 and the neutron number falls from 8 to 7; the nucleon number stays at 14. **(1 mark: neutron → proton, with the correct change in proton/neutron numbers.)**

(c) β^- radiation is more penetrating than α radiation (α is stopped by paper or a few centimetres of air, while β travels up to about a metre in air and is stopped by a few millimetres of aluminium). α radiation is the more strongly ionising of the two: it loses its energy over a shorter distance, producing denser ionisation along its path. **(1 mark: correct comparison of penetrating power linked to ionising power.)**

Question 6 $N_0 = 8.0 \times 10^{10}$, $t_{1/2} = 8.0\,\text{h}$.

(a) $32\,\text{h}$ is four whole half-lives ($32 \div 8.0 = 4$), so

$$N = N_0 \left(\frac{1}{2}\right)^4 = 8.0 \times 10^{10} \times \frac{1}{16} = 5.0 \times 10^9\,\text{nuclei}.$$

(1 mark correct number of half-lives and the halving model; **1 mark** correct value 5.0×10^9.)

(b) With a half-life of hours, most of the isotope has decayed to stable products within days of the treatment, so the patient's dose is delivered during the therapy and then falls away quickly. An isotope with a half-life of years would keep irradiating the patient's healthy tissue long after the treatment, giving a much larger total dose. **(1 mark** the isotope decays away soon after treatment; **1 mark** links this to a reduced ongoing dose to healthy tissue.)

(c) It is not possible to predict which particular nucleus will decay, or when; each nucleus decays independently and without a trigger. The half-life is still useful because, for a large sample, the fraction of nuclei decaying per half-life is very reliably one half, so the overall behaviour of the sample can be predicted. **(1 mark: individual decays unpredictable, but the half-life gives a reliable statistical prediction for a large sample.)**

Question 7 $E = 5.0 \times 10^{-3}\,\text{J}$, $m = 0.025\,\text{kg}$, $w_R = 1$.

(a) $D = \frac{E}{m} = \frac{5.0 \times 10^{-3}}{0.025} = 0.20\,\text{Gy}$. **(1 mark** $D = E/m$; **1 mark** correct value $0.20\,\text{Gy}$.)

(b) $H = w_R \times D = 1 \times 0.20 = 0.20\,\text{Sv}$. **(1 mark: correct value $0.20\,\text{Sv}$.)**

(c) α radiation is far more densely ionising than β radiation: an α particle is massive and doubly charged, so it deposits its energy in a very short path and causes more cell damage per gray of absorbed dose. The weighting factor of 20 reflects this greater biological damage for the same absorbed dose. **(1 mark: α causes more cell damage per gray because it ionises more densely.)**

Question 8

(a) The fission products have a larger binding energy per nucleon ($8.5\,\text{MeV}$) than the original uranium-235 nucleus ($7.6\,\text{MeV}$), so the nucleons in the products are more tightly bound. Moving to the more tightly bound arrangement releases energy: the products have less mass than the original nucleus, and the lost mass is converted to energy ($E = mc^2$) and carried away as kinetic energy of the fragments and radiation. **(1 mark** the products have greater binding energy per nucleon / are more tightly bound; **1 mark** the difference is released as energy from the conversion of mass.)

(b) Neutrons released in one fission go on to cause further fissions of uranium-235 nuclei, which release more neutrons in turn. (In a reactor the rate is controlled, for example by a moderator that slows the neutrons and control rods that absorb some of them.) **(1 mark: neutrons from one fission cause further fissions.)**

Question 9 $V = 12\,\text{V}$, $Q = 90\,\text{C}$, $t = 5.0\,\text{min} = 300\,\text{s}$.

(a) $I=\frac{Q}{t}=\frac{90}{300}=0.30\,\text{A}$. **(1 mark** $I=Q/t$ with the time in seconds; **1 mark** correct value $0.30\,\text{A}$.)

(b) $V=\frac{E}{Q}$, so $E=V\,Q=12\times 90=1080\,\text{J}$ ($1.1\times 10^3\,\text{J}$ to two significant figures). **(1 mark** $E=V\,Q$; **1 mark** correct value $1080\,\text{J}$.)

(c) $P=\frac{E}{t}=\frac{1080}{300}=3.6\,\text{W}$ (equivalently $P=V\,I=12\times 0.30$). **(1 mark: correct value** $3.6\,\text{W}$**.)**

(d) The ammeter must carry the same current as the lamp so that it measures the current through the lamp; connecting it in series puts it in the same single path. Connected in parallel, the ammeter would measure only the current in its own branch, not the lamp's current. **(1 mark: series connection puts the ammeter in the same path so the same current flows through both.)**

Question 10 $V=12\,\text{V}$; series resistor $6.0\,\Omega$; parallel pair, two $8.0\,\Omega$ resistors.

(a) Parallel combination: $\frac{1}{R_p}=\frac{1}{8.0}+\frac{1}{8.0}=\frac{2}{8.0}=\frac{1}{4.0}$, so $R_p=4.0\,\Omega$. In series with the $6.0\,\Omega$ resistor: $R_{\text{equivalent}}=6.0+4.0=10\,\Omega$, as required. **(1 mark: correct equivalent resistance via the parallel-then-series reduction.)**

(b) $I=\frac{V}{R}=\frac{12}{10}=1.2\,\text{A}$. **(1 mark: correct value** $1.2\,\text{A}$**.)**

(c) The full battery current flows through the equivalent resistance of the parallel combination, so

$$V_p=I\,R_p=1.2\times 4.0=4.8\,\text{V}.$$

(1 mark $V=I\,R$ applied to the parallel combination's equivalent resistance; **1 mark** correct value $4.8\,\text{V}$.)

(d) Each resistor in the parallel combination has the full $4.8\,\text{V}$ across it, so

$$I_8=\frac{V_p}{8.0}=\frac{4.8}{8.0}=0.60\,\text{A}.$$

(1 mark: correct value $0.60\,\text{A}$**.)**

(e) The full battery current of $1.2\,\text{A}$ flows through the series $6.0\,\Omega$ resistor, so

$$P=I^2R=1.2^2\times 6.0=8.6\,\text{W}.$$

(1 mark: correct value $8.6\,\text{W}$**.)**

Question 11 $V_{\text{in}}=9.0\,\text{V}$, $R_1=10\,\text{k}\,\Omega$, $R_2=5.0\,\text{k}\,\Omega$.

(a) $V_{\text{out}}=V_{\text{in}}\frac{R_2}{R_1+R_2}=9.0\times\frac{5.0}{10+5.0}=9.0\times\frac{1}{3}=3.0\,\text{V}$. **(1 mark** correct divider relationship; **1 mark** correct value $3.0\,\text{V}$.)

(b) The output potential difference **increases**. The divider shares the supply potential difference in proportion to the resistances; when the light level falls, the LDR's resistance increases, so the LDR takes a larger share of the $9.0\,\text{V}$ and the output across it rises. **(1 mark** output increases; **1 mark** justification via the LDR's larger share of the supply potential difference.)

(c) Connecting the device in parallel with R_2 lowers the equivalent resistance of the lower arm of the divider (parallel resistances combine to less than the smallest). The lower arm then takes a smaller share of the supply potential difference, so the output potential difference falls. **(1 mark: the parallel load lowers the effective resistance of the lower arm, reducing its share of the supply potential difference.)**

Question 12 Supply $230\,\mathrm{V}$; heater $P=2400\,\mathrm{W}$.

(a) $P=V\,I$, so $I=\frac{P}{V}=\frac{2400}{230}=10.4\,\mathrm{A}$. **(1 mark** $I=P/V$; **1 mark** correct value $10.4\,\mathrm{A}$ ($10\,\mathrm{A}$ to two significant figures).)

(b) $E=P\,t=2.4\,\mathrm{kW}\times5.0\,\mathrm{h}=12\,\mathrm{kW\,h}$. **(1 mark: correct value** $12\,\mathrm{kW\,h}$**.)**

(c) A circuit breaker responds to an overcurrent — a current larger than its rating, such as too many appliances drawing current at once — and opens the circuit to protect the wiring from overheating. An RCD responds to a difference between the current in the active and neutral conductors, which indicates that current is leaking from the circuit, for example through a person to earth. An RCD therefore protects against electric shock: it detects the small leakage current through a body (and trips very quickly), whereas a circuit breaker needs a much larger current and would not trip for the current through a person. **(1 mark** correct triggering condition for each device; **1 mark** explains that the RCD detects leakage current through a person, which a circuit breaker does not.)

Question 13 $u=15\,\mathrm{m\,s^{-1}}$, $v=0$, $t=5.0\,\mathrm{s}$.

(a) $a=\frac{v-u}{t}=\frac{0-15}{5.0}=-3.0\,\mathrm{m\,s^{-2}}$ — a deceleration of $3.0\,\mathrm{m\,s^{-2}}$. **(1 mark: correct value $-3.0\,\mathrm{m\,s^{-2}}$, or magnitude $3.0\,\mathrm{m\,s^{-2}}$ stated as a deceleration.)**

(b) $s=\frac{1}{2}(u+v)t=\frac{1}{2}(15+0)\times5.0=37.5\,\mathrm{m}$. **(1 mark** suitable constant-acceleration relationship; **1 mark** correct value $37.5\,\mathrm{m}$.)

(c) During the reaction time the tram travels at constant speed: $s=v\,t=15\times0.80=12\,\mathrm{m}$. **(1 mark: correct value** $12\,\mathrm{m}$**.)**

(d) The braking distance is the same $37.5\,\mathrm{m}$ as the first tram (same speed, same acceleration), so the total stopping distance is $12+37.5=49.5\,\mathrm{m}$. **(1 mark: correct value** $49.5\,\mathrm{m}$**.)**

Question 14 $m=0.15\,\mathrm{kg}$, $u=30\,\mathrm{m\,s^{-1}}$, brought to rest.

(a) Change in momentum $=m\,\Delta v=0.15\times30=4.5\,\mathrm{kg\,m\,s^{-1}}=4.5\,\mathrm{N\,s}$, as required. **(1 mark: correct change in momentum.)**

(b) $\Delta p=F_{\mathrm{net}}\,\Delta t$, so

$$F=\frac{\Delta p}{\Delta t}=\frac{4.5}{0.50}=9.0\,\mathrm{N}.$$

(1 mark $F=\Delta p/\Delta t$ (or $F\,\Delta t=m\,\Delta v$); **1 mark** correct value $9.0\,\mathrm{N}$.)

(c) The ball undergoes the same change in momentum whatever the catching style, so the impulse $F\,\Delta t=\Delta p$ is fixed. Moving the hands backward with the ball increases the time Δt over which the ball is brought to rest, so the average force $F=\frac{\Delta p}{\Delta t}$ is smaller. **(1 mark** same change in momentum, so the impulse is fixed; **1 mark** a longer stopping time gives a smaller force.)

Question 15 $m=8.0\,\mathrm{kg}$; push $30\,\mathrm{N}$; friction $6.0\,\mathrm{N}$.

(a) The net horizontal force is $\Sigma F=30-6.0=24\,\mathrm{N}$, so by Newton's second law

$$a=\frac{\Sigma F}{m}=\frac{24}{8.0}=3.0\,\mathrm{m\,s^{-2}}$$

in the direction of the push. **(1 mark** correct net force $24\,\mathrm{N}$; **1 mark** correct acceleration $3.0\,\mathrm{m\,s^{-2}}$.)

(b) There is no vertical acceleration, so the vertical forces balance: the normal force on the box by the floor equals the force due to gravity, $F_N = m g = 8.0 \times 9.8 = 78\,\text{N}$. **(1 mark: correct value $78\,\text{N}$.)**

(c) $F_{\text{on Earth by box}}$ — the gravitational force on the Earth by the box, equal in magnitude and opposite in direction to $F_{\text{on box by Earth}}$. **(1 mark: correct third-law partner with the $F_{\text{on A by B}}$ convention.)**

Question 16 $r = 0.30\,\text{m}$, $F = 80\,\text{N}$.

(a) With the force perpendicular to the spanner, $\tau = r_{\perp} F = 0.30 \times 80 = 24\,\text{N m}$. **(1 mark: correct value $24\,\text{N m}$.)**

(b) Only the component of the force perpendicular to the spanner produces torque:

$$\tau = r F \sin\theta = 0.30 \times 80 \times \sin 60^{\circ} = 0.30 \times 80 \times 0.866 = 21\,\text{N m}.$$

(**1 mark** uses the perpendicular component of the force; **1 mark** correct value $21\,\text{N m}$.)

Question 17 $m = 60\,\text{kg}$, $\Delta h = 3.0\,\text{m}$, $t = 4.0\,\text{s}$.

(a) $E_g = m g \Delta h = 60 \times 9.8 \times 3.0 = 1764\,\text{J}$ ($1.8 \times 10^3\,\text{J}$ to two significant figures). **(1 mark: correct value $1764\,\text{J}$.)**

(b) $P = \dfrac{E}{t} = \dfrac{1764}{4.0} = 441\,\text{W}$ ($440\,\text{W}$ to two significant figures). **(1 mark: correct value $441\,\text{W}$.)**

(c) $\eta = \dfrac{\text{useful energy out}}{\text{total energy in}} = \dfrac{1764}{1.5 \times 10^4} = 0.118$, or about 12%. **(1 mark: correct value 12%.)**

Question 18 I–V investigation of a fixed resistor; model $I = V / R$; each current reading uncertain by $\pm 0.05\,\text{A}$.

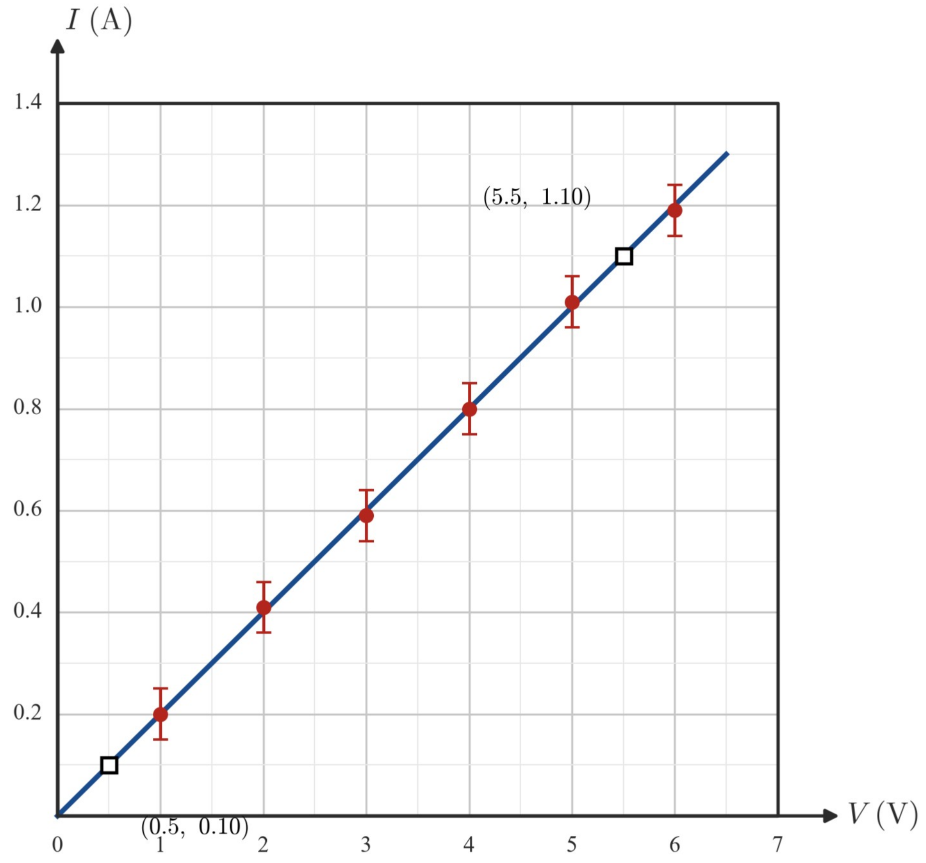
(a) Independent variable: the **potential difference across the resistor** (set by the variable resistor). Dependent variable: the **current in the resistor** (measured). A controlled variable (any one): the same resistor, the same meters, the same battery/supply, or keeping the circuit connected only briefly so the resistor's temperature stays the same. (**1 mark** IV = potential difference; **1 mark** DV = current; **1 mark** one valid controlled variable, taken from the method.)

(b) Repeating each reading and averaging reduces the effect of random errors, giving a more reliable (precise) mean current at each setting, and allows anomalous readings to be identified. (**1 mark** reduces the effect of random errors / gives a more reliable mean; **1 mark** allows anomalous readings to be identified.)

(c) If $I = V / R$ with R constant, then I is proportional to V: when $V = 0$, the equation gives $I = 0$ [1], so the straight line must pass through the origin $(0, 0)$ [1]. (**1 mark** zero potential difference gives zero current; **1 mark** proportionality means a straight line through the origin.)

(d) The voltmeter measures the potential difference **across** the resistor, so it must be connected across its two ends (in parallel). Connected in series, it would not measure the potential difference across the resistor (and its very high resistance would almost stop the current). **(1 mark: parallel connection places the voltmeter across the resistor so it measures the potential difference across it.)**

(e) The completed graph is shown below: I on the vertical axis, V on the horizontal axis; each point carries an uncertainty bar of $\pm 0.05\,\text{A}$; a straight line of best fit is drawn, balancing the scatter of the points. The line shown has equation $I = 0.20\,V$ (I in A, V in V).



(**1 mark** correct axes (I vs V) with sensible scales filling the grid; **1 mark** all six points plotted correctly; **1 mark** uncertainty bars of ± 0.05 A drawn on each point; **1 mark** a single straight line of best fit; **1 mark** the line balances the points and passes near the origin.)

(f) Using two well-separated points **on the line of best fit** — for example $(0.5, 0.10)$ and $(5.5, 1.10)$:

$$\text{gradient} = \frac{\Delta I}{\Delta V} = \frac{1.10 - 0.10}{5.5 - 0.5} = \frac{1.0}{5.0} = 0.20\ \text{A V}^{-1}.$$

Values in the range about 0.19–$0.21\ \text{A V}^{-1}$ are acceptable, depending on the student's line. **(1 mark** two well-separated on-line points used (not raw data points); **1 mark** correct gradient, consistent with the drawn line.)

(g) (i) Comparing $I = \frac{V}{R} = \left(\frac{1}{R}\right)V$ with a straight line through the origin (I plotted against V), the gradient equals the **reciprocal of the resistance**, $1/R$.

(ii) $R = \frac{1}{\text{gradient}} = \frac{1}{0.20} = 5.0\ \Omega$. Values consistent with the student's own gradient are acceptable.

(iii) $I = \frac{V}{R} = \frac{4.5}{5.0} = 0.90$ A. Values consistent with the student's own resistance are acceptable. **(1 mark** identifies the gradient as $1/R$; **1 mark** correct resistance about $5.0\ \Omega$; **1 mark** correct predicted current about 0.90 A.)

(h) The warming of the resistor increases its resistance. The model $I = V/R$ assumes that R is constant, so once the resistance rises with temperature, the current at each potential difference is smaller than the constant-R model predicts, and the value of R found from the graph no longer describes the resistor's behaviour. **(1 mark** identifies that the resistance increases as the temperature rises; **1 mark** states that the model assumes a constant resistance, so it no longer holds once R changes.)

End of solutions

Practice Exam 4 — Medium

Physics — Units 1 & 2 — Practice Examination 4

- Reading time: **15 minutes**
- Writing time: **2 hours 30 minutes**
- Section A: 20 questions, 20 marks
- Section B: 16 questions, 100 marks
- Total: 120 marks

VCE Physics Units 1 & 2 has no external VCAA examination. This practice paper mirrors the structure of the Units 3 & 4 examination as a house convention; the mark allocations and timings are not a VCAA requirement.

Approved materials

- One scientific calculator
- Pre-written notes (one folded A3 sheet or two A4 sheets bound together by tape)

A formula sheet is provided at the end of this examination.

Students are **not** permitted to bring mobile phones and/or any unauthorised electronic devices into the examination room.

Section A — Multiple-choice questions (20 marks)

- Answer **all** questions.
- Choose the response that is **correct** or that **best answers** the question.
- A correct answer scores 1; an incorrect answer scores 0.
- Marks will **not** be deducted for incorrect answers.
- No marks will be given if more than one answer is completed for any question.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Where required, take the magnitude of the gravitational field strength at Earth's surface to be $g = 9.8\,\mathrm{N\ kg^{-1}}$.

Question 1

A water wave in a ripple tank has a wavelength of $0.80\,\mathrm{m}$. A floating cork moves up and down with a period of $0.50\,\mathrm{s}$ as the wave passes. Which one of the following is closest to the speed of the wave?

A. $0.40\,\mathrm{m\ s^{-1}}$

B. $0.63\,\mathrm{m\ s^{-1}}$

C. $1.6\,\mathrm{m\ s^{-1}}$

D. $3.2\,\mathrm{m\ s^{-1}}$

Question 2

Which one of the following correctly compares the ultraviolet radiation and the infrared radiation emitted by the Sun?

A. The ultraviolet radiation has a longer wavelength and a higher frequency than the infrared radiation.

B. The ultraviolet radiation has a shorter wavelength and a higher frequency than the infrared radiation.

C. The ultraviolet radiation has a shorter wavelength and a lower frequency than the infrared radiation.

D. The ultraviolet radiation travels faster through a vacuum than the infrared radiation.

Question 3

A ray of light passes from air, of refractive index 1.00, into a transparent plastic block, of refractive index 1.50. The angle of incidence is 30°. Which one of the following is closest to the angle of refraction?

A. 19°

B. 25°

C. 30°

D. 48°

Question 4

The specific heat capacity of water is $4180\,\mathrm{J\,kg^{-1}\,K^{-1}}$. Which one of the following is closest to the energy required to heat $2.0\,\mathrm{kg}$ of water from $20^\circ\mathrm{C}$ to $70^\circ\mathrm{C}$?

A. $2.1\times10^5\,\mathrm{J}$

B. $5.9\times10^5\,\mathrm{J}$

C. $4.2\times10^5\,\mathrm{J}$

D. $8.4\times10^5\,\mathrm{J}$

Question 5

Which one of the following best explains why many nuclei are stable?

A. The electrostatic attraction between the protons and the neutrons holds the nucleus together.

B. The strong nuclear force attracts all the nucleons to one another over short distances and overcomes the electrostatic repulsion between the protons.

C. The strong nuclear force pushes the neutrons out of the nucleus, leaving only bound protons behind.

D. The neutrons shield the protons from the electrostatic force, so the protons do not repel one another.

Question 6

Carbon-14 decays by beta-minus (β^-) emission. Which one of the following is the daughter nucleus?

A. carbon-13

B. boron-14

C. nitrogen-15

D. nitrogen-14

Question 7

A sample of tissue of mass $0.50\,\mathrm{kg}$ receives an absorbed dose of $0.10\,\mathrm{Gy}$ from alpha radiation. The radiation weighting factor for alpha radiation is 20. Which one of the following is the equivalent dose received by the tissue?

A. $0.0050\,\mathrm{Sv}$

B. $0.10\,\mathrm{Sv}$

C. $2.0\,\mathrm{Sv}$

D. $20\,\mathrm{Sv}$

Question 8

A current of $0.80\,\text{A}$ flows through an LED lamp for 5.0 minutes. Which one of the following is the charge that passes through the lamp in this time?

A. $4.0\,\text{C}$

B. $48\,\text{C}$

C. $2.4 \times 10^{3}\,\text{C}$

D. $240\,\text{C}$

Question 9

A $0.80\,\text{kW}$ electric heater runs for 5.0 hours. Which one of the following is the energy used by the heater, in kW h?

A. 0.16

B. 4.0

C. 1.4×10^{7}

D. 4.0×10^{3}

Question 10

A $5.0\,\Omega$ resistor is connected in series with a parallel combination of a $9.0\,\Omega$ resistor and a $4.5\,\Omega$ resistor. Which one of the following is the total resistance of the combination?

A. $3.0\,\Omega$

B. $18.5\,\Omega$

C. $13.5\,\Omega$

D. $8.0\,\Omega$

Question 11

Two identical lamps, each of resistance $6.0\,\Omega$, are connected in parallel across a $12\,\text{V}$ battery. Which one of the following is the total power delivered to the two lamps?

A. $12\,\text{W}$

B. $24\,\text{W}$

C. $48\,\text{W}$

D. $96\,\text{W}$

Question 12

A thermistor and a fixed resistor are connected in series across a power supply. The output potential difference is measured across the thermistor. The resistance of the thermistor decreases as its temperature increases. As the temperature of the thermistor increases, the output potential difference

A. decreases, because the share of the supply potential difference across the thermistor decreases.

B. decreases, because the current in the circuit decreases.

C. remains the same, because the supply potential difference does not change.

D. increases, because the resistance of the thermistor decreases.

Question 13

Which one of the following pairs contains one vector quantity and one scalar quantity, each correctly identified?

A. momentum (vector) and kinetic energy (scalar)

B. force (vector) and acceleration (vector)

C. speed (vector) and distance (scalar)

D. displacement (scalar) and velocity (vector)

Question 14

A car starts from rest and accelerates uniformly to $20\,\mathrm{m\ s^{-1}}$ in $8.0\,\mathrm{s}$. It then travels at this constant speed for a further $4.0\,\mathrm{s}$. Which one of the following is the total distance travelled by the car in the $12\,\mathrm{s}$?

A. $80\,\mathrm{m}$

B. $160\,\mathrm{m}$

C. $120\,\mathrm{m}$

D. $240\,\mathrm{m}$

Question 15

A large truck and a small car collide head-on. During the collision,

A. the force on the truck by the car is greater than the force on the car by the truck, because the truck has the greater mass.

B. the force on the truck by the car is greater than the force on the car by the truck, because the car undergoes the greater change in motion.

C. the force on each vehicle by the other depends on which vehicle was travelling faster before the collision.

D. the force on the truck by the car and the force on the car by the truck are equal in magnitude and opposite in direction.

Question 16

A mechanic applies a force of $20\,\mathrm{N}$ at right angles to a spanner, at a point $0.25\,\mathrm{m}$ from the centre of a nut. Which one of the following is the torque applied to the nut?

A. $2.5\,\mathrm{N\ m}$

B. $5.0\,\mathrm{N\ m}$

C. $20\,\mathrm{N\ m}$

D. $80\,\mathrm{N\ m}$

Question 17

A measuring cylinder is marked with graduations every $2\,\mathrm{mL}$. A student reads the volume of a liquid from this cylinder. Which one of the following is the uncertainty in this single reading due to the scale divisions?

A. $\pm 1\,\mathrm{mL}$

B. $\pm 2\,\mathrm{mL}$

C. $\pm 0.5\,\mathrm{mL}$

D. $\pm 4\,\mathrm{mL}$

Question 18

A student measures the time for one swing of a pendulum five times and records $2.1\,\text{s}$, $2.2\,\text{s}$, $2.1\,\text{s}$, $3.4\,\text{s}$ and $2.2\,\text{s}$. The best way to treat the $3.4\,\text{s}$ reading is to

A. delete it immediately, because it is different from the other readings.

B. keep it, but give it less influence when calculating the mean.

C. repeat the measurement and investigate how the reading arose before deciding whether to include it.

D. change it to $2.2\,\text{s}$ so that it matches the other readings.

Question 19

Two groups measure the same acceleration. Group X reports $9.5 \pm 0.4\,\text{m s}^{-2}$ and group Y reports $10.2 \pm 0.4\,\text{m s}^{-2}$. Are the two results consistent with one another?

A. Yes, because the uncertainty intervals of the two results overlap.

B. Yes, because both groups measured the same quantity.

C. No, because the mean values reported by the two groups are different.

D. No, because the two results have the same uncertainty.

Question 20

An object accelerates uniformly from rest along a straight line, so that $v^2 = 2as$, where v is its speed, a is its acceleration and s is the distance it has travelled. To obtain a straight-line graph through the origin from which a can be determined, a student should plot

A. v against s; the gradient of the line equals a.

B. v against s^2; the gradient of the line equals $2a$.

C. v^2 against s; the gradient of the line equals $2a$.

D. v^2 against s; the gradient of the line equals $\frac{a}{2}$.

End of Section A

Practice Exam 4 — Section B

*Answer **all** questions in the spaces provided. Write your responses in English. In questions where more than one mark is available, appropriate working **must** be shown. Where a final answer requires a particular unit, that unit is stated in the question; give your answer in that unit. Unless otherwise indicated, the diagrams in this book are **not** drawn to scale. Take the magnitude of the gravitational field strength at Earth's surface to be* $g = 9.8\ \mathrm{N\ kg^{-1}}$.

Question 1 (5 marks)

In a ripple tank, straight water waves travel across the surface. The distance between successive crests is $0.12\ \mathrm{m}$. A small cork floating on the surface takes $0.40\ \mathrm{s}$ to complete one full up-and-down cycle as the waves pass.

a. State the wavelength and the period of the waves. 1 mark

b. Calculate the frequency of the waves. Give your answer in Hz. 1 mark

c. Calculate the speed of the waves. Give your answer in $\mathrm{m\ s^{-1}}$. 2 marks

d. The waves pass into a shallower region of the tank, where they travel more slowly. State and explain what happens to the wavelength of the waves in the shallower region. 1 mark

Question 2 (6 marks)

Diamond has a refractive index of 2.42. The surrounding air has a refractive index of 1.00.

a. Calculate the speed of light in diamond. Give your answer in $\mathrm{m\ s^{-1}}$. 1 mark

b. Calculate the critical angle for a diamond–air boundary. Give your answer in degrees. 2 marks

c. A ray travelling inside the diamond strikes a diamond–air boundary at an angle of incidence of 30°. Determine whether the ray emerges into the air. Justify your answer. 1 mark

d. A ray in air strikes the flat top face of the diamond at an angle of incidence of 45°. Calculate the angle of refraction inside the diamond. Give your answer in degrees. 2 marks

Question 3 (5 marks)

A $0.50\ \mathrm{kg}$ block of ice at $0^\circ\mathrm{C}$ is heated until all the ice has melted and the water formed reaches $40^\circ\mathrm{C}$.

Use the following values: latent heat of fusion of ice $= 3.34 \times 10^5\ \mathrm{J\ kg^{-1}}$; specific heat capacity of water $= 4180\ \mathrm{J\ kg^{-1}K^{-1}}$.

a. Calculate the energy required to melt the ice at $0^\circ\mathrm{C}$. Give your answer in J. 2 marks

b. Calculate the energy required to warm the water from $0^\circ\mathrm{C}$ to $40^\circ\mathrm{C}$. Give your answer in J. 2 marks

c. State the total energy supplied to the ice. Give your answer in J. 1 mark

Question 4 (6 marks)

The tungsten filament of a globe operates at a temperature of about $3200\ \mathrm{K}$. Wien's constant is $2.9 \times 10^{-3}\ \mathrm{m\ K}$.

a. Calculate the wavelength at which the filament's radiation is most intense. Give your answer in m. 2 marks

b. Identify the region of the electromagnetic spectrum in which the filament's radiation peaks. 1 mark

c. A new globe runs its filament at $6400\ \mathrm{K}$, twice the temperature. Without calculating, state the wavelength at which this filament's radiation is most intense, and explain your reasoning. 1 mark

d. Explain why a globe with a $3200\ \mathrm{K}$ filament is inefficient as a source of visible light, referring to where most of the radiated energy lies. 2 marks

Question 5 (6 marks)

Complete the following decay equations, finding the values of A and Z and identifying the daughter nucleus X in each case.

a. Uranium-238 decays by alpha emission. Uranium has atomic number 92.

$^{238}_{92}\mathrm{U} \rightarrow {}^{A}_{Z}X + {}^{4}_{2}\mathrm{He}$ 2 marks

b. Cobalt-60 decays by beta-minus (β^-) emission. Nickel has atomic number 28.

$^{60}_{27}\mathrm{Co} \rightarrow {}^{A}_{Z}X + {}^{0}_{-1}\mathrm{e}$ 2 marks

c. Of the three types of radiation — alpha, beta and gamma — identify the most penetrating and the most ionising. 2 marks

Question 6 (5 marks)

A sample of molybdenum-99, a radioisotope used in medical imaging, has a half-life of $66\,\mathrm{h}$. When first prepared, its corrected count rate is 1200 counts per minute.

a. State what is meant by the half-life of a radioisotope. 1 mark

b. Calculate the corrected count rate of the sample $198\,\mathrm{h}$ after preparation. 2 marks

c. A student claims that $264\,\mathrm{h}$ after preparation, the count rate will have fallen to exactly zero because all the nuclei will have decayed. Explain why this claim is incorrect. 2 marks

Question 7 (5 marks)

In a nuclear reactor, uranium-235 nuclei undergo fission.

a. Explain how a chain reaction is established in uranium-235. 2 marks

b. State the purpose of the moderator in a nuclear reactor. 1 mark

c. Use the binding energy per nucleon curve to explain why the fission of uranium-235 releases energy. 2 marks

Question 8 (6 marks)

An electric kettle is rated at $1800\,\mathrm{W}$ when connected to a $230\,\mathrm{V}$ household supply.

a. Calculate the current in the kettle when it is operating at its rated power. Give your answer in A. 2 marks

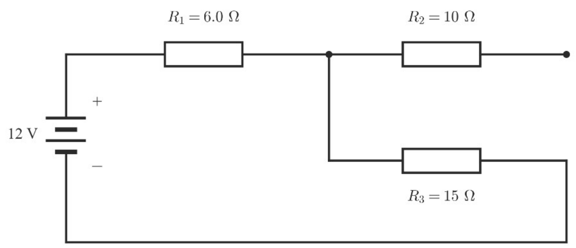
b. The kettle takes 4.0 minutes to boil. Calculate the charge that passes through the kettle in this time. Give your answer in C. 2 marks

c. Calculate the energy transferred by the kettle in the 4.0 minutes. Give your answer in J. 1 mark

d. In one week the kettle is used for a total of $5.0\,\mathrm{h}$. Electricity costs 30 cents per $\mathrm{kW\,h}$. Calculate the cost of using the kettle in that week. Give your answer in dollars. 1 mark

Question 9 (6 marks)

A $12\,\mathrm{V}$ battery of negligible internal resistance is connected to the circuit shown below. Resistor $R_1 = 6.0\,\Omega$ is in series with the parallel combination of $R_2 = 10\,\Omega$ and $R_3 = 15\,\Omega$.



a. Calculate the equivalent resistance of the parallel combination of R_2 and R_3. Give your answer in Ω. 1 mark

b. Calculate the total resistance of the circuit. Give your answer in Ω. 1 mark

c. Calculate the current delivered by the battery. Give your answer in A. 1 mark

d. Calculate the potential difference across the parallel combination. Give your answer in V. 1 mark

e. Calculate the current in resistor R_2. Give your answer in A. 2 marks

Question 10 (5 marks)

A thermistor is connected in series with a fixed $4.0\,\mathrm{k}\,\Omega$ resistor across a $12\,\mathrm{V}$ supply. The output potential difference, V_{out}, is measured across the thermistor. The resistance of the thermistor is $8.0\,\mathrm{k}\,\Omega$ at $20^{\circ}\mathrm{C}$ and $2.0\,\mathrm{k}\,\Omega$ at $60^{\circ}\mathrm{C}$.

a. Calculate V_{out} at $20^{\circ}\mathrm{C}$. Give your answer in V. 2 marks

b. Calculate V_{out} at $60^{\circ}\mathrm{C}$. Give your answer in V. 1 mark

c. State and explain what happens to V_{out} as the temperature of the thermistor rises from $20^{\circ}\mathrm{C}$ to $60^{\circ}\mathrm{C}$. 1 mark

d. The thermistor acts as a transducer in this circuit. Identify the conversion it performs. 1 mark

Question 11 (5 marks)

Australian household circuits are supplied at $230\,\mathrm{V}$ and are wired in parallel. Safety devices include fuses, circuit breakers and residual current devices (RCDs). An RCD installed in a household circuit is rated to trip when the residual current reaches $30\,\mathrm{mA}$.

Source: Energy Safe Victoria, Household wiring, retrieved 2026-08-18.

a. State two reasons why household circuits are wired in parallel rather than in series. 2 marks

b. Explain how an RCD protects a person, and why a fuse alone does not provide the same protection. 2 marks

c. State the first thing a person should do if they see someone receiving an electric shock from an active appliance. 1 mark

Question 12 (5 marks)

A car starts from rest on a straight, level road and accelerates uniformly at $2.0\,\mathrm{m\,s^{-2}}$ for $6.0\,\mathrm{s}$.

a. Calculate the speed of the car at the end of the $6.0\,\mathrm{s}$. Give your answer in $\mathrm{m\,s^{-1}}$. 1 mark

b. Calculate the distance travelled by the car during the $6.0\,\mathrm{s}$. Give your answer in m. 2 marks

c. The driver then brakes, and the car comes to rest over a distance of $48\,\mathrm{m}$. Calculate the acceleration of the car while it is braking. Give your answer in $\mathrm{m\,s^{-2}}$. 2 marks

Question 13 (5 marks)

A suitcase of mass 25 kg is pulled along a horizontal airport floor by a strap. The pull from the strap is horizontal and has magnitude 80 N, and the friction force opposing the motion is 30 N.

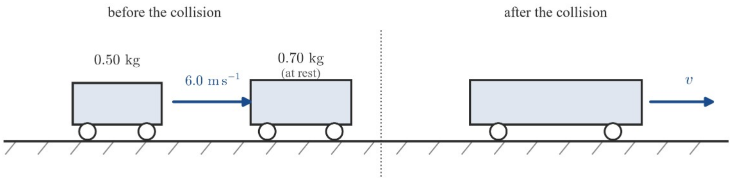
a. Calculate the magnitude of the force due to gravity on the suitcase, $F_{\text{on suitcase by Earth}}$. Give your answer in N. 1 mark

b. The suitcase has no vertical acceleration. State the magnitude of the normal force on the suitcase by the floor, and justify your answer. 2 marks

c. Calculate the acceleration of the suitcase. Give your answer in m s^{-2}. 2 marks

Question 14 (5 marks)

Trolley A, of mass 0.50 kg, moves at $6.0\ \text{m s}^{-1}$ along a straight horizontal track towards trolley B, of mass 0.70 kg, which is at rest. The two trolleys collide and lock together.



a. Calculate the total momentum of the two trolleys before the collision. Give your answer in kg m s^{-1}. 1 mark

b. Calculate the speed of the two trolleys immediately after the collision. Give your answer in m s^{-1}. 2 marks

c. Calculate the magnitude of the impulse delivered to trolley B during the collision. Give your answer in N s. 1 mark

d. Explain, with reference to kinetic energy, why this collision is described as inelastic. 1 mark

Question 15 (5 marks)

An electric motor is used to raise an object of mass 2.0 kg vertically through a height of 1.5 m. The object rises at constant speed and takes 3.0 s to reach the top.

a. Calculate the work done on the object by the force exerted by the motor. Give your answer in J. 2 marks

b. Calculate the useful power output of the motor. Give your answer in W. 1 mark

c. During the lift, the motor draws electrical power at a rate of 20 W. Calculate the efficiency of the motor. 2 marks

Question 16 (20 marks)

A group of students investigate the turning effect of a force. A uniform metre rule is pivoted at its centre, the 50 cm mark. An object hangs from a loop on the left-hand side of the rule, at a distance d from the pivot; the force due to gravity on the object has magnitude W. A force meter pulls the rule downwards at the 90 cm mark, holding the rule horizontal. For each value of d, the students adjust the force meter until the rule is horizontal and read the force F. Their results are shown in the table. The uncertainty in each reading of force is ± 0.05 N.

Distance d (m)	0.05	0.10	0.20	0.30	0.40	0.50
Force F (N)	0.13	0.25	0.51	0.74	1.02	1.24

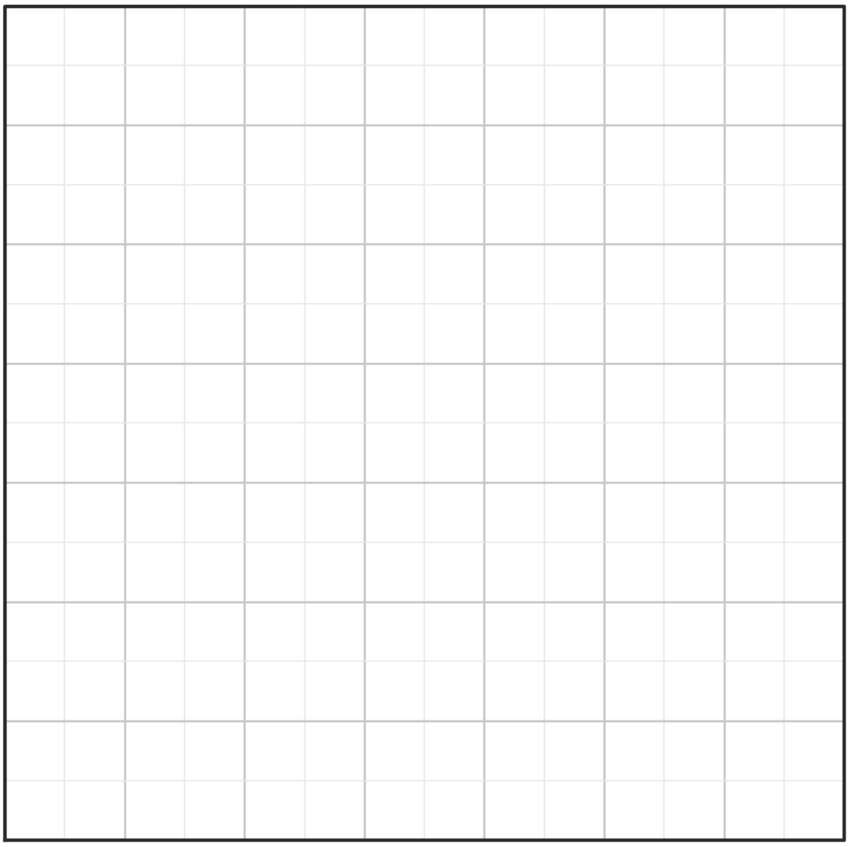
a. Identify the independent variable, the dependent variable and one controlled variable in this investigation. 3 marks

b. The students wait until the rule is horizontal and still before reading the force meter. Explain how reading the force meter while the rule is still moving would affect the data. 2 marks

c. The force meter has a scale marked in steps of $0.1\,\mathrm{N}$ rather than $1\,\mathrm{N}$. Explain why this choice improves the investigation. 2 marks

d. Each force is measured three times and the mean value is used. State the purpose of repeating the measurements and taking the mean. 1 mark

e. On the grid provided, plot a graph of force F (vertical axis) against distance d (horizontal axis). Include uncertainty bars of $\pm 0.05\,\mathrm{N}$ on each point, and draw a line of best fit. 5 marks



f. Determine the gradient of your line of best fit. Use two points on the line that are far apart. 2 marks

g. The rule is balanced, so the clockwise and anticlockwise moments about the pivot are equal: $F \times 0.40 = W \times d$. i. Show that the gradient of your graph equals $\frac{W}{0.40}$. ii. Use your gradient from part **f** to determine the value of W in N. iii. Predict the force meter reading when $d = 0.60\,\mathrm{m}$. 3 marks

h. The investigation is repeated with the force meter pulling at the $70\,\mathrm{cm}$ mark instead of the $90\,\mathrm{cm}$ mark. Predict and justify how the gradient of the force–distance graph would change. 2 marks

End of Section B

Practice Exam 4 — Formula Sheet

This formula sheet is provided for use with all practice examinations in this booklet. Part 1 reproduces, unaltered and with attribution, the items of the official VCE Physics Formula Sheet (© VCAA 2026) that lie within the Units 1 & 2 study design; items that belong to Units 3 & 4 only are omitted. Part 2 is a house supplement drawn from the key knowledge of the Units 1 & 2 study design (2023–2027): it carries the relationships that Units 1 & 2 students apply which the official sheet does not give.

Part 1 — VCE Physics Formula Sheet: Units 1 & 2 items

Motion and related energy transformations

velocity	$v=\frac{\Delta s}{\Delta t}$
acceleration	$a=\frac{\Delta v}{\Delta t}$
constant acceleration	$v=u+at$
	$s=ut+\frac{1}{2}at^2$
	$s=vt-\frac{1}{2}at^2$
	$v^2=u^2+2as$
	$s=\frac{1}{2}(u+v)t$
Newton’s second law	$\Sigma F=ma$
Hooke’s law	$F=-kx$
elastic potential energy	$E_s=\frac{1}{2}kx^2$
gravitational potential energy	$E_g=mg\Delta h$
kinetic energy	$E_k=\frac{1}{2}mv^2$
impulse	$F\Delta t=m\Delta v$
momentum	$p=mv$

Generation and transmission of electricity

current	$I=\frac{V}{R}$
power	$P=VI$
resistors in series	$R_T=R_1+R_2+\ldots$
resistors in parallel	$\frac{1}{R_T}=\frac{1}{R_1}+\frac{1}{R_2}+\ldots$

Waves

wave equation	$v=f\lambda$

Part 2 — Units 1 & 2 supplement

Waves and light

wavelength, frequency, period and speed	$\lambda=\frac{v}{f}=vT$

refraction (Snell's Law)	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
	$n_1 v_1 = n_2 v_2$
critical angle	$n_1 \sin\theta_c = n_2 \sin 90^\circ$

Thermal energy

Celsius–kelvin conversion	$T(\mathrm{K}) = T(°\mathrm{C}) + 273.15$
raising temperature	$Q = m\,c\,\Delta T$
change of state	$Q = m\,L$
Wien's Law	$\lambda_{\max} T = \text{constant}$

Radiation from the nucleus

Provenance note (TOC §2.7): D = E/m, H = w_R × D and E = mc² do not appear on the official Units 1 & 2 formula sheet; they are included in this supplement because the Units 1 & 2 key knowledge requires dose calculations and treats mass–energy conversion qualitatively.

radioactive decay (whole half-lives)	$N = N_0 \left(\frac{1}{2}\right)^n$
	$n = \frac{t}{t_{1/2}}$
absorbed dose	$D = \frac{E}{m}$ (unit: Gy)
equivalent dose	$H = w_R \times D$ (unit: Sv)
effective dose	$\Sigma\, w_T H_T$ over tissues T (unit: Sv)

Nuclear energy

mass–energy conversion	$E = m c^2$

Electricity

current and charge	$I = \frac{Q}{t}$
potential difference	$V = \frac{E}{Q}$
power and energy	$P = \frac{E}{t}$
voltage divider	$V_{\text{out}} = V_{\text{in}} \times \frac{R_2}{R_1 + R_2}$

Forces, work and energy

work done by a constant force	$W = F\,s \cos\theta$
work done	area under a force–distance graph
torque	$\tau = r_{\perp} F$
force due to gravity	$F_{\text{on body by Earth}} = m\,g$
Newton's third law	$F_{\text{on A by B}} = -F_{\text{on B by A}}$
change in momentum	$\Delta p = F_{\text{net}} \Delta t$
efficiency	$\eta = \frac{\text{useful energy out}}{\text{total energy in}}$

Data

acceleration due to gravity at Earth's surface	$g = 9.8$ m s^{-2} (9.8 N kg^{-1})
speed of light in a vacuum	$c = 3.00 \times 10^{8}$ m s^{-1}
Wien's Law constant	2.9×10^{-3} m K

The Units 1 & 2 study design gives the gravitational field strength near Earth's surface as g = 9.8 N kg^{-1} (9.8 m s^{-2}), and this is the value used throughout this booklet. The official VCE Physics Formula Sheet gives g = 9.81 m s^{-2} for Units 3 & 4.

Metric (SI) multipliers

pico (p)	10^{-12}	kilo (k)	10^{3}
nano (n)	10^{-9}	mega (M)	10^{6}
micro (μ)	10^{-6}	giga (G)	10^{9}
milli (m)	10^{-3}	tera (T)	10^{12}

Unit conversions

1 tonne (t)	$= 10^{3}$ kg
1 kilowatt hour (kW h)	$= 3.6 \times 10^{6}$ J

Nomenclature

force due to gravity	F_{g}
force on A by B	$F_{\text{on A by B}}$
normal force	F_{N}

End of Formula Sheet

Practice Exam 4 — solutions

Section A — answer key

Question	Answer	Question	Answer
1	C	11	C
2	B	12	A
3	A	13	A
4	C	14	B
5	B	15	D
6	D	16	B
7	C	17	A
8	D	18	C
9	B	19	A
10	D	20	C

Question 1 — C. The speed of a wave is $v=\frac{\lambda}{T}=\frac{0.80}{0.50}=1.6\,\mathrm{m\ s^{-1}}$. **A** multiplies wavelength by period instead of dividing; **B** inverts the ratio (T/λ); **D** doubles the correct value.

Question 2 — B. All electromagnetic waves travel at the same speed in a vacuum, so a higher frequency must come with a shorter wavelength: ultraviolet radiation has a shorter wavelength and a higher frequency than infrared radiation. **A** reverses the wavelength comparison; **C** reverses the frequency comparison; **D** wrongly claims the two radiations travel at different speeds in a vacuum.

Question 3 — A. By Snell's Law, $n_1 \sin\theta_1 = n_2 \sin\theta_2$, so $\sin\theta_2=\frac{1.00\times\sin 30^{\circ}}{1.50}=0.333$ and $\theta_2=19^{\circ}$. **B** has no corresponding correct operation; **C** assumes the ray is not bent at all; **D** multiplies instead of dividing ($\sin\theta_2=1.50\times\sin 30^{\circ}=0.75$, giving 48°).

Question 4 — C. $Q=mc\Delta T=2.0\times4180\times50=4.18\times10^{5}\,\mathrm{J}$, where $\Delta T=70-20=50\,\mathrm{K}$. **A** omits the mass; **B** uses the final temperature ($70\,\mathrm{K}$) instead of the temperature change; **D** doubles the correct value.

Question 5 — B. Stability comes from the strong nuclear force, which attracts all nucleons to one another over short distances and overcomes the electrostatic repulsion between the protons. **A** is wrong because neutrons carry no charge and protons repel one another electrostatically; **C** misstates the role of the strong force; **D** describes shielding, which is not the mechanism that binds the nucleus.

Question 6 — D. In beta-minus emission a neutron changes into a proton: the nucleon number is unchanged ($A=14$) and the proton number rises by one ($Z=6+1=7$), which is nitrogen. **A** removes a nucleon; **B** corresponds to a fall in proton number (the beta-plus direction); **C** adds a nucleon.

Question 7 — C. The equivalent dose is $H=w_R\times D=20\times0.10=2.0\,\mathrm{Sv}$. **A** divides by the weighting factor instead of multiplying; **B** quotes the absorbed dose as if it were the equivalent dose (that is, uses $w_R=1$); **D** uses the weighting factor itself as the answer.

Question 8 — D. $Q=It=0.80\times300=240\,\mathrm{C}$, since 5.0 minutes $=300\,\mathrm{s}$. **A** uses $t=5.0\,\mathrm{s}$ without converting minutes; **B** uses only one minute (0.80×60); **C** carries an extra factor of ten.

Question 9 — B. $E=Pt=0.80\,\mathrm{kW}\times5.0\,\mathrm{h}=4.0\,\mathrm{kW\ h}$. **A** inverts the ratio ($0.80/5.0=0.16$); **C** gives the energy in joules ($4.0\times3.6\times10^{6}=1.4\times10^{7}\,\mathrm{J}$), not in $\mathrm{kW\ h}$; **D** gives the answer in $\mathrm{W\ h}$ rather than $\mathrm{kW\ h}$ ($800\times5.0=4.0\times10^{3}$).

Question 10 — D. For the parallel pair, $\frac{1}{R_p}=\frac{1}{9.0}+\frac{1}{4.5}=\frac{1}{3.0}$, so $R_p=3.0\,\Omega$; the total resistance is $5.0+3.0=8.0\,\Omega$. **A** quotes the parallel pair alone; **B** sums all three resistors as if they were in series $(5.0+9.0+4.5)$; **C** replaces the parallel pair by its series sum $(9.0+4.5=13.5)$ without adding the series resistor.

Question 11 — C. In parallel, each lamp receives the full $12\,\text{V}$: $P=\frac{V^2}{R}=\frac{12^2}{6.0}=24\,\text{W}$ per lamp, so $48\,\text{W}$ in total. **A** treats the lamps as if they were in series ($R=12\,\Omega$, $P=144/12=12\,\text{W}$); **B** counts only one lamp; **D** doubles the correct total.

Question 12 — A. As the thermistor warms, its resistance falls, so its share of the supply potential difference falls: $V_{\text{out}}=V_{\text{in}}\times\frac{R_{\text{thermistor}}}{R_{\text{thermistor}}+R_{\text{fixed}}}$ decreases. **B** wrongly claims the circuit current decreases (it increases, since the total resistance falls); **C** ignores the way the supply potential difference is shared between the two components; **D** wrongly has the output increasing.

Question 13 — A. Momentum has both magnitude and direction, so it is a vector; kinetic energy has magnitude only, so it is a scalar. **B** lists two vector quantities; **C** wrongly labels speed as a vector (speed is a scalar); **D** wrongly labels displacement as a scalar (displacement is a vector).

Question 14 — B. The distance travelled is the area under the velocity–time graph: $1/2\times8.0\times20+20\times4.0=80+80=160\,\text{m}$. **A** counts only the accelerating phase; **C** uses the average speed of $10\,\text{m s}^{-1}$ over the whole $12\,\text{s}$; **D** uses $20\,\text{m s}^{-1}$ for the whole $12\,\text{s}$.

Question 15 — D. By Newton's third law, $F_{\text{on truck by car}}=-F_{\text{on car by truck}}$: the two forces are always equal in magnitude and opposite in direction, regardless of the masses or speeds of the vehicles. **A** wrongly links the size of the force to the mass; **B** confuses the forces with the resulting changes in motion (the smaller car accelerates more because it has less mass, not because the force on it is larger); **C** wrongly links the forces to the speeds.

Question 16 — B. The torque is $\tau=r_{\perp}F=0.25\times20=5.0\,\text{N m}$. **A** halves the correct value; **C** quotes the force itself as if it were the torque; **D** divides the force by the distance instead of multiplying.

Question 17 — A. The uncertainty in a single reading due to the scale divisions is half the smallest division: $2\,\text{mL}\div2=1\,\text{mL}$, so the reading is uncertain by $\pm1\,\text{mL}$. **B** takes the whole division; **C** takes half the division again (a quarter); **D** doubles the division.

Question 18 — C. The $3.4\,\text{s}$ reading is an anomaly: it is well clear of the other four, which cluster at 2.1–$2.2\,\text{s}$. The best treatment is to repeat the measurement and investigate how it arose (for example, miscounting the swings) before deciding whether to include it. **A** deletes data without justification; **B** invents a weighting procedure rather than checking the reading; **D** falsifies the data.

Question 19 — A. Group X's interval is 9.1–$9.9\,\text{m s}^{-2}$ and group Y's is 9.8–$10.6\,\text{m s}^{-2}$; the intervals overlap, so the two results are consistent within uncertainty. **B** and **C** ignore the uncertainty intervals and compare only the mean values; **D** wrongly treats equal uncertainties as evidence of disagreement.

Question 20 — C. Writing $v^2=2as$ in the form $y=mx$ with $y=v^2$ and $x=s$ gives a straight line through the origin with gradient $2a$, from which a follows. **A** and **B** produce curved graphs, not straight lines; **D** has the correct axes but the wrong gradient.

Section B — worked solutions

Question 1 $\lambda=0.12\,\text{m}$, $T=0.40\,\text{s}$.

(a) The wavelength is $0.12\,\text{m}$ and the period is $0.40\,\text{s}$. **(1 mark: both values stated.)**

(b) $f=\frac{1}{T}=\frac{1}{0.40}=2.5\,\text{Hz}$. **(1 mark: correct frequency.)**

(c) $v=f\lambda=2.5\times0.12=0.30\,\text{m s}^{-1}$. **(1 mark** $v=f\lambda$; **1 mark** correct value $0.30\,\text{m s}^{-1}$.)

(d) The frequency is set by the source (the wave generator), so it does not change when the wave slows. Since $v=f\lambda$ and v is smaller while f stays the same, the wavelength decreases. **(1 mark** wavelength decreases, with the correct justification in terms of $v=f\lambda$ and an unchanged frequency.)

Question 2 $n_{\text{diamond}}=2.42$, $n_{\text{air}}=1.00$, $c=3.00\times10^{8}\,\text{m s}^{-1}$.

(a) $v=\dfrac{c}{n}=\dfrac{3.00\times10^{8}}{2.42}=1.24\times10^{8}\,\text{m s}^{-1}$. **(1 mark: correct value.)**

(b) At the critical angle the refracted ray runs along the boundary (90°), so

$$n_1\sin\theta_c=n_2\sin90^\circ\Rightarrow\sin\theta_c=\frac{n_2}{n_1}=\frac{1.00}{2.42}=0.413,$$

giving $\theta_c=24^\circ$ (24.4° unrounded). **(1 mark** $\sin\theta_c=n_2/n_1$; **1 mark** correct value 24°.)

(c) The angle of incidence (30°) is greater than the critical angle (24°), so the ray undergoes total internal reflection and does not emerge into the air. **(1 mark** correct determination with the comparison shown.)

(d) Snell's Law with the ray passing from air into diamond:

$$\sin\theta_2=\frac{n_1\sin\theta_1}{n_2}=\frac{1.00\times\sin45^\circ}{2.42}=\frac{0.707}{2.42}=0.292,$$

giving $\theta_2=17^\circ$. **(1 mark** correct substitution into Snell's Law; **1 mark** correct value 17°.)

Question 3 $m=0.50\,\text{kg}$, $L_f=3.34\times10^{5}\,\text{J kg}^{-1}$, $c=4180\,\text{J kg}^{-1}\text{K}^{-1}$, $\Delta T=40\,\text{K}$.

(a) $Q=mL_f=0.50\times3.34\times10^{5}=1.67\times10^{5}\,\text{J}$. **(1 mark** $Q=mL_f$; **1 mark** correct value $1.67\times10^{5}\,\text{J}$.)

(b) $Q=mc\Delta T=0.50\times4180\times40=8.36\times10^{4}\,\text{J}$. **(1 mark** $Q=mc\Delta T$; **1 mark** correct value $8.36\times10^{4}\,\text{J}$.)

(c) Total $=1.67\times10^{5}+8.36\times10^{4}=2.51\times10^{5}\,\text{J}\approx2.5\times10^{5}\,\text{J}$. **(1 mark: correct total.)**

Question 4 $T=3200\,\text{K}$, Wien's constant $=2.9\times10^{-3}\,\text{m K}$.

(a) By Wien's Law, $\lambda_{\max}=\dfrac{2.9\times10^{-3}}{T}$, so

$$\lambda_{\max}=\frac{2.9\times10^{-3}}{3200}=9.1\times10^{-7}\,\text{m}.$$

(1 mark Wien's Law; **1 mark** correct value $9.1\times10^{-7}\,\text{m}$.)

(b) Infrared. **(1 mark: correct region.)**

(c) Wien's Law gives $\lambda_{\max}\propto\dfrac{1}{T}$, so doubling the temperature halves the peak wavelength: $\lambda_{\max}\approx4.5\times10^{-7}\,\text{m}$. **(1 mark** halves to about 4.5×10^{-7} m, with the inverse proportionality stated.)

(d) At $3200\,\text{K}$ the filament's radiation peaks in the infrared, so most of the energy it radiates is infrared (thermal) radiation rather than visible light. Only a small fraction of the radiated energy is useful visible light, which is why the globe is inefficient as a light source. **(1 mark** most of the radiated energy is infrared; **1 mark** only a small fraction is visible light, hence inefficient.)

Question 5

(a) Top numbers: $238 = A + 4$, so $A = 234$. Bottom numbers: $92 = Z + 2$, so $Z = 90$, which is thorium: $^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\text{He}$. **(1 mark** $A = 234$, $Z = 90$; **1 mark** daughter identified as thorium, Th.)

(b) Top numbers: $60 = A + 0$, so $A = 60$. Bottom numbers: $27 = Z + (-1)$, so $Z = 28$, which is nickel (a neutron has changed into a proton): $^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{Ni} + {}^{0}_{-1}\text{e}$. **(1 mark** $A = 60$, $Z = 28$; **1 mark** daughter identified as nickel, Ni.)

(c) The most penetrating radiation is gamma; the most ionising radiation is alpha. **(1 mark** gamma most penetrating; **1 mark** alpha most ionising.)

Question 6 $t_{1/2} = 66\,\text{h}$, initial count rate $= 1200$ counts per minute.

(a) The half-life is the time taken for half the nuclei in a sample to decay (equivalently, the time for the activity or count rate to halve). **(1 mark: correct statement.)**

(b) $198\,\text{h}$ is three half-lives, so the count rate halves three times:

$$1200 \rightarrow 600 \rightarrow 300 \rightarrow 150 \text{ counts per minute}.$$

(1 mark recognition of three half-lives; **1 mark** correct value 150 counts per minute.)

(c) Radioactive decay is a random process: it is not possible to predict when any particular nucleus will decay. The number of undecayed nuclei halves during each half-life rather than falling by a fixed amount, so the count rate approaches zero but does not reach it on schedule. After $264\,\text{h}$ (four half-lives) the count rate would be $1200/2^4 = 75$ counts per minute, not zero. **(1 mark** decay is random / the count rate halves each half-life rather than reaching zero; **1 mark** correct supporting statement, e.g. 75 counts per minute remaining.)

Question 7

(a) A uranium-235 nucleus absorbs a neutron and splits (fissions), releasing energy and two or three more neutrons. Those neutrons can be absorbed by further uranium-235 nuclei, causing further fissions that release further neutrons, so the reaction sustains itself. **(1 mark** neutron absorbed by U-235, nucleus splits and releases energy and neutrons; **1 mark** the released neutrons cause further fissions.)

(b) The moderator slows the neutrons down, so they are more likely to be absorbed by uranium-235 nuclei and cause further fissions. **(1 mark: slows the neutrons, with the reason.)**

(c) The binding energy per nucleon curve shows that medium-mass nuclei have a higher binding energy per nucleon than heavy nuclei such as uranium-235. The fission products are therefore more tightly bound than the original nucleus, and the increase in binding energy is released as energy (from converted mass). **(1 mark** products have a higher binding energy per nucleon than U-235, read from the curve; **1 mark** the increase in binding energy is released.)

Question 8 $P = 1800\,\text{W}$, $V = 230\,\text{V}$, boiling time $= 4.0\,\text{min} = 240\,\text{s}$.

(a) $I = \dfrac{P}{V} = \dfrac{1800}{230} = 7.8\,\text{A}$. **(1 mark** $I = P/V$; **1 mark** correct value $7.8\,\text{A}$.)

(b) Carrying the unrounded current $I = 7.826\,\text{A}$,

$$Q = I\,t = 7.826 \times 240 = 1.9 \times 10^3\,\text{C}.$$

(1 mark $Q = I\,t$ with the time in seconds; **1 mark** correct value $1.9 \times 10^3\,\text{C}$.)

(c) $E = P\,t = 1800 \times 240 = 4.3 \times 10^5\,\text{J}$. **(1 mark: correct value.)**

(d) Energy used $= 1.8\,\text{kW} \times 5.0\,\text{h} = 9.0\,\text{kW h}$; cost $= 9.0 \times \$0.30 = \$2.70$. **(1 mark: correct cost $\$2.70$.)**

Question 9 $V = 12\,\text{V}$, $R_1 = 6.0\,\Omega$, $R_2 = 10\,\Omega$, $R_3 = 15\,\Omega$.

(a) $\dfrac{1}{R_\text{p}} = \dfrac{1}{10} + \dfrac{1}{15} = \dfrac{3+2}{30} = \dfrac{1}{6.0}$, so $R_\text{p} = 6.0\,\Omega$. **(1 mark: correct value $6.0\,\Omega$.)**

(b) $R_{\text{total}} = R_1 + R_\text{p} = 6.0 + 6.0 = 12\,\Omega$. **(1 mark: correct value** $12\,\Omega$**.)**

(c) $I = \dfrac{V}{R_{\text{total}}} = \dfrac{12}{12} = 1.0\text{ A}$. **(1 mark: correct value** 1.0 A**.)**

(d) $V_\text{p} = I\,R_\text{p} = 1.0 \times 6.0 = 6.0\text{ V}$. **(1 mark: correct value** 6.0 V**.)**

(e) The potential difference across each parallel branch is 6.0 V, so

$$I_2 = \frac{V_\text{p}}{R_2} = \frac{6.0}{10} = 0.60\text{ A}.$$

(1 mark correct approach ($I_2 = V_\text{p} / R_2$); **1 mark** correct value 0.60 A.)

Question 10 $V_{\text{in}} = 12\text{ V}$, fixed resistor $= 4.0\text{ k}\,\Omega$, output measured across the thermistor.

(a) By the voltage divider equation,

$$V_{\text{out}} = V_{\text{in}} \times \frac{R_{\text{thermistor}}}{R_{\text{fixed}} + R_{\text{thermistor}}} = 12 \times \frac{8.0}{4.0 + 8.0} = 8.0\text{ V}.$$

(1 mark divider equation; **1 mark** correct value 8.0 V.)

(b) $V_{\text{out}} = 12 \times \dfrac{2.0}{4.0 + 2.0} = 4.0\text{ V}$. **(1 mark: correct value** 4.0 V**.)**

(c) V_{out} decreases: as the temperature rises, the thermistor's resistance falls, so its share of the supply potential difference falls. **(1 mark** correct statement with the correct explanation.)

(d) The thermistor converts a change in temperature into a change in an electrical quantity (its resistance, and hence the output potential difference). **(1 mark: correct conversion identified.)**

Question 11

(a) Any two of: each appliance receives the full 230 V supply potential difference; each appliance can be switched on and off independently, so turning one off does not affect the others; adding another appliance does not reduce the potential difference across those already connected. **(2 marks: two correct reasons.)**

(b) An RCD compares the current in the active wire with the current in the neutral wire. If some current leaks to earth through a person, the two currents are no longer equal, and the RCD detects this imbalance and opens the circuit very quickly (it is rated to trip at 30 mA). A fuse responds only when the current in the circuit becomes much larger than normal, so it protects the wiring and appliances but does not respond to the small leakage current through a person. **(1 mark** the RCD detects the imbalance between the active and neutral currents and opens the circuit; **1 mark** a fuse responds only to large overcurrents, not to small leakage currents through a person.)

(c) Do not touch the person; first switch off the supply (or disconnect the appliance from the supply) before approaching. **(1 mark: correct first action.)**

Question 12 $u = 0$, $a = 2.0\text{ m s}^{-2}$ for the first 6.0 s.

(a) $v = u + a t = 0 + 2.0 \times 6.0 = 12\text{ m s}^{-1}$. **(1 mark: correct value.)**

(b) $s = u t + 1/2\, a t^2 = 0 + 1/2 \times 2.0 \times 6.0^2 = 36\text{ m}$. **(1 mark** correct equation; **1 mark** correct value 36 m.)

(c) During braking, $u = 12\text{ m s}^{-1}$, $v = 0$ and $s = 48\text{ m}$. From $v^2 = u^2 + 2 a s$,

$$0 = 12^2 + 2 \times a \times 48 \Rightarrow a = -\frac{144}{96} = -1.5\text{ m s}^{-2}.$$

The acceleration while braking is $-1.5\,\mathrm{m\ s^{-2}}$ (a deceleration of $1.5\,\mathrm{m\ s^{-2}}$). **(1 mark** correct equation; **1 mark** correct value $-1.5\,\mathrm{m\ s^{-2}}$.)

Question 13 $m = 25\,\mathrm{kg}$, pull $= 80\,\mathrm{N}$, friction $= 30\,\mathrm{N}$, $g = 9.8\,\mathrm{N\ kg^{-1}}$.

(a) $F_{\text{on suitcase by Earth}} = m\,g = 25 \times 9.8 = 245\,\mathrm{N}$. **(1 mark: correct value** $245\,\mathrm{N}$**.)**

(b) The normal force on the suitcase by the floor is $245\,\mathrm{N}$, directed upwards. The suitcase has no vertical acceleration, so the net vertical force on it is zero (Newton's first or second law): the normal force must balance the force due to gravity. **(1 mark** correct value $245\,\mathrm{N}$; **1 mark** justification in terms of zero vertical acceleration.)

(c) The net horizontal force is $80 - 30 = 50\,\mathrm{N}$, so by Newton's second law

$$a = \frac{F_{\text{net}}}{m} = \frac{50}{25} = 2.0\,\mathrm{m\ s^{-2}}.$$

(1 mark correct net force; **1 mark** correct value $2.0\,\mathrm{m\ s^{-2}}$.)

Question 14 $m_A = 0.50\,\mathrm{kg}$, $u_A = 6.0\,\mathrm{m\ s^{-1}}$, $m_B = 0.70\,\mathrm{kg}$, $u_B = 0$.

(a) Only trolley A is moving before the collision, so

$$p = m_A u_A = 0.50 \times 6.0 = 3.0\,\mathrm{kg\ m\ s^{-1}}.$$

(1 mark: correct value.)

(b) Momentum is conserved (no external horizontal force). After the collision the trolleys move together with combined mass $1.20\,\mathrm{kg}$:

$$v = \frac{p}{m_A + m_B} = \frac{3.0}{1.20} = 2.5\,\mathrm{m\ s^{-1}}.$$

(1 mark conservation of momentum; **1 mark** correct value $2.5\,\mathrm{m\ s^{-1}}$.)

(c) The impulse delivered to trolley B equals its change in momentum:

$$\Delta p_B = m_B \Delta v = 0.70 \times 2.5 = 1.75\,\mathrm{N\ s}\,(\approx 1.8\,\mathrm{N\ s}).$$

(1 mark: correct value $1.75\,\mathrm{N\ s}$**, accept** $1.8\,\mathrm{N\ s}$**.)**

(d) Kinetic energy before: $1/2 \times 0.50 \times 6.0^2 = 9.0\,\mathrm{J}$. Kinetic energy after: $1/2 \times 1.20 \times 2.5^2 = 3.75\,\mathrm{J}$. Kinetic energy is not conserved — $5.25\,\mathrm{J}$ is converted to other forms (thermal energy, sound, deformation) — so the collision is inelastic. **(1 mark** correct comparison of kinetic energies with the conclusion.)

Question 15 $m = 2.0\,\mathrm{kg}$, $h = 1.5\,\mathrm{m}$, $t = 3.0\,\mathrm{s}$, $g = 9.8\,\mathrm{N\ kg^{-1}}$.

(a) The object rises at constant speed, so the force exerted by the motor balances the force due to gravity: $F = m\,g = 2.0 \times 9.8 = 19.6\,\mathrm{N}$. The force and the displacement are in the same direction, so

$$W = F\,s\cos\theta = 19.6 \times 1.5 = 29\,\mathrm{J}.$$

(1 mark correct force ($= m\,g$, constant speed); **1 mark** correct value $29\,\mathrm{J}$.)

(b) $P = \frac{E}{t} = \frac{29.4}{3.0} = 9.8\,\mathrm{W}$. **(1 mark: correct value** $9.8\,\mathrm{W}$**.)**

(c) Energy input $= P_{\text{electrical}} \times t = 20 \times 3.0 = 60\,\mathrm{J}$. The useful energy output is the $29.4\,\mathrm{J}$ of work from part **a**, so

$$\eta = \frac{\text{useful energy output}}{\text{energy input}} = \frac{29.4}{60} = 0.49,$$

an efficiency of 49%. **(1 mark** correct input energy; **1 mark** correct efficiency 49%.)

Question 16

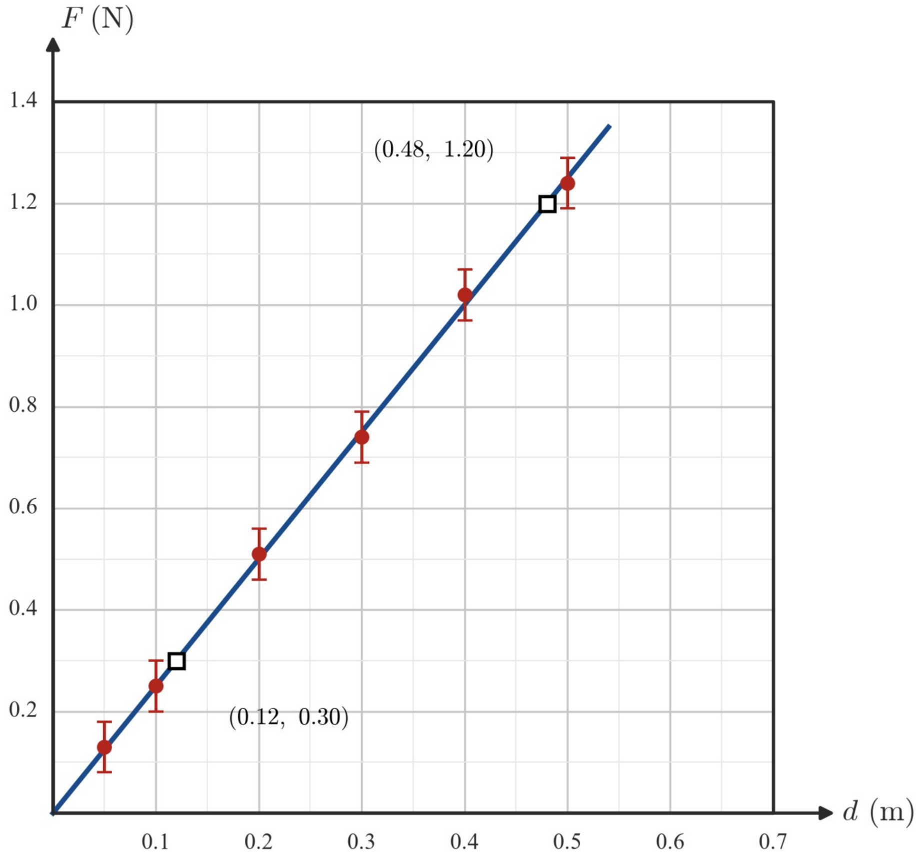
(a) Independent variable: the distance d of the object from the pivot. Dependent variable: the force F read on the force meter. Controlled variable: any one of — the same object (so W is unchanged) throughout; the force meter always pulling at the $90\,\text{cm}$ mark; the same metre rule and pivot position; the rule adjusted to be horizontal before each reading; the force meter always pulling vertically (downwards). **(1 mark for each correct identification, 3 marks total.)**

(b) While the rule is still moving, it is not in rotational equilibrium, so the force meter reading is not equal to the balancing force and is not a well-defined value: the readings would scatter more widely and the random error in the force readings would be larger. Waiting until the rule is horizontal and still ensures the moments are balanced when the force is read. **(1 mark** readings scatter / are not the balancing force while the rule moves; **1 mark** link to larger random error or to the need for rotational equilibrium.)

(c) A scale marked in $0.1\,\text{N}$ steps has a greater resolution than one marked in $1\,\text{N}$ steps, so each force reading can be made with a smaller uncertainty. This matters here because the forces are small (0.1–$1.3\,\text{N}$), so a $1\,\text{N}$ scale could barely distinguish between readings at all. **(1 mark** greater resolution / finer scale gives a smaller reading uncertainty; **1 mark** link to the small size of the forces.)

(d) Repeating each measurement and taking the mean reduces the effect of random errors in the force readings. **(1 mark: reduces the effect of random errors.)**

(e)



(1 mark correct axes (F vertical, d horizontal) with sensible scales filling the grid; **1 mark** all six points plotted correctly; **1 mark** uncertainty bars of $\pm 0.05\,\text{N}$ drawn on each point; **1 mark** a single straight line of best fit; **1 mark** the line balances the points and passes through or near the origin.)

(f) Two well-separated points on the line, for example $(0.12\,\text{m}, 0.30\,\text{N})$ and $(0.48\,\text{m}, 1.20\,\text{N})$:

$$\text{gradient} = \frac{1.20 - 0.30}{0.48 - 0.12} = \frac{0.90}{0.36} = 2.5\,\text{N m}^{-1}.$$

(Values from 2.4 to $2.6\,\text{N m}^{-1}$ are acceptable, depending on the student's line; the points must lie on the line, not be taken from the table.) **(1 mark** two well-separated points on the line of best fit; **1 mark** correct gradient.)

(g) i. From $F \times 0.40 = W \times d$, rearranging gives $F = \frac{W}{0.40} \times d$. This has the form $y = m\,x$ (a straight line through the origin with F on the vertical axis and d on the horizontal axis), so the gradient is $m = \frac{W}{0.40}$. **ii.** $W = \text{gradient} \times 0.40 = 2.5 \times 0.40 = 1.0\,\text{N}$. **iii.** $F = \frac{W}{0.40} \times d = \frac{1.0}{0.40} \times 0.60 = 1.5\,\text{N}$. **(1 mark** showing gradient $= W\,/\,0.40$ from the moment equation; **1 mark** correct value $W = 1.0\,\text{N}$; **1 mark** correct prediction $1.5\,\text{N}$.)

(h) The gradient would be larger (the line would be steeper). At the $70\,\text{cm}$ mark the force meter's distance from the pivot is $0.20\,\text{m}$, so balance requires $F \times 0.20 = W \times d$, giving gradient $= W\,/\,0.20$. Since W is unchanged and the moment arm has halved, the gradient doubles: from $2.5\,\text{N m}^{-1}$ to $5.0\,\text{N m}^{-1}$. The same moment must now be provided by a force acting at half the distance, so the required force at each d is twice as large. **(1 mark** predicts a larger / doubled gradient; **1 mark** justified via gradient $= W\,/\,0.20$ with the halved moment arm.)

End of solutions

Practice Exam 5 — Harder

- Reading time: **15 minutes**
- Writing time: **2 hours 30 minutes**
- Section A: 20 questions, 20 marks
- Section B: 20 questions, 100 marks
- Total 120 marks

There is no VCAA examination for VCE Physics Units 1 & 2. This practice examination is a house production whose format mirrors the VCE Physics Units 3 & 4 examination as a house convention. It is not a VCAA document, and results in it do not contribute to a study score.

Approved materials

- One scientific calculator
- Pre-written notes (one folded A3 sheet or two A4 sheets bound together by tape)

A formula sheet is provided at the end of this examination.

Students are **not** permitted to bring mobile phones and/or any unauthorised electronic devices into the examination room.

Section A — Multiple-choice questions (20 marks)

Answer **all** questions. Choose the response that is **correct** or that **best answers** the question. A correct answer scores 1; an incorrect answer scores 0. Marks will **not** be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question. Where a numerical answer is required, use the constants given on the formula sheet. Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1

Which one of the following statements about electromagnetic waves is correct?

A. They need a material medium such as air in order to travel.

B. They all have the same wavelength in a vacuum.

C. They are transverse waves and all travel at the same speed in a vacuum.

D. Higher-frequency electromagnetic waves travel faster than lower-frequency waves in a vacuum.

Question 2

Light of wavelength $600\,\text{nm}$ has a frequency closest to

A. $5.0 \times 10^{5}\,\text{Hz}$

B. $2.0 \times 10^{-15}\,\text{Hz}$

C. $1.8 \times 10^{11}\,\text{Hz}$

D. $5.0 \times 10^{14}\,\text{Hz}$

Question 3

A ray of light travelling in air is incident at 40° on a flat glass surface of refractive index 1.52. The angle of refraction is closest to

A. 40°

B. 25°

C. 78°

D. 0.42°

Question 4

A mass of $2.0\,\text{kg}$ of water (specific heat capacity $4.2 \times 10^3\,\text{J kg}^{-1}\text{K}^{-1}$) is heated so that its temperature rises by 5.0°C. The thermal energy absorbed by the water is closest to

A. $4.2 \times 10^4\,\text{J}$

B. $4.2 \times 10^3\,\text{J}$

C. $2.1 \times 10^4\,\text{J}$

D. $8.4 \times 10^4\,\text{J}$

Question 5

A heated metal block at temperature T, in kelvin, emits radiation with peak wavelength λ. When the block is heated to $2T$, the peak wavelength becomes closest to

A. $\lambda/4$

B. 2λ

C. $\lambda/2$

D. λ

Question 6

Greenhouse gases such as carbon dioxide, methane and water vapour contribute to the warming of Earth's surface mainly because they

A. reflect ultraviolet radiation from the Sun back towards the surface.

B. absorb visible light from the Sun before it can reach space.

C. prevent convection from carrying energy out of the atmosphere.

D. absorb infrared radiation emitted by Earth's surface and re-emit some of it back towards the surface.

Question 7

A nucleus of thorium-234, ${}^{234}_{90}\text{Th}$, decays by β^- emission. The daughter nucleus is

A. ${}^{230}_{88}\text{Ra}$

B. ${}^{234}_{92}\text{U}$

C. ${}^{234}_{91}\text{Pa}$

D. ${}^{233}_{90}\text{Th}$

Question 8

A radioactive sample has a half-life of 4.0 hours. The fraction of undecayed nuclei remaining after 16 hours is

A. $\frac{1}{16}$

B. $\frac{1}{8}$

C. $\frac{1}{4}$

D. $\frac{1}{24}$

Question 9

Which one of the following best explains why energy is released when a uranium-235 nucleus undergoes fission?

A. The total mass of the fission products is greater than the mass of the original uranium nucleus.

B. The neutron absorbed by the nucleus releases its kinetic energy when it comes to rest.

C. Electrical energy stored in the protons of the nucleus is converted into thermal energy.

D. The fission products have a higher binding energy per nucleon than the uranium nucleus.

Question 10

A charge of $450\,\mathrm{C}$ passes a point in a circuit in 3.0 minutes. The current at that point is

A. $150\,\mathrm{A}$

B. $0.0067\,\mathrm{A}$

C. $2.5\,\mathrm{A}$

D. $1350\,\mathrm{A}$

Question 11

A $2.2\,\mathrm{kW}$ appliance operates for 2.0 hours. The energy used is closest to

A. $3.6 \times 10^{6}\,\mathrm{J}$

B. $4.4 \times 10^{3}\,\mathrm{J}$

C. $1.6 \times 10^{4}\,\mathrm{J}$

D. $1.6 \times 10^{7}\,\mathrm{J}$

Question 12

A $3.0\,\Omega$ resistor and a $6.0\,\Omega$ resistor are connected in parallel, and this combination is connected in series with a $5.0\,\Omega$ resistor. The total resistance of the combination is closest to

A. $14\,\Omega$

B. $7.0\,\Omega$

C. $2.0\,\Omega$

D. $1.4\,\Omega$

Question 13

A voltage divider consists of a $3.0\,\mathrm{k}\,\Omega$ resistor R_1 and a $5.0\,\mathrm{k}\,\Omega$ resistor R_2 connected in series across an $8.0\,\mathrm{V}$ supply. The output voltage measured across R_2 is closest to

A. $5.0\,\mathrm{V}$

B. $3.0\,\mathrm{V}$

C. $8.0\,\mathrm{V}$

D. $4.8\,\mathrm{V}$

Question 14

Which one of the following best describes how a residual current device (RCD) protects a person from electric shock?

A. It melts and breaks the circuit when the current exceeds its rated value.

B. It limits the supply voltage to a value that is safe to touch.

C. It detects an imbalance between the currents in the active and neutral conductors and opens the circuit quickly.

D. It stores charge during normal operation and releases it safely to earth.

Question 15

Which row correctly classifies the quantities as vectors or scalars?

A. Vectors: velocity and distance. Scalars: force and mass.

B. Vectors: speed and force. Scalars: displacement and mass.

C. Vectors: distance and speed. Scalars: displacement and force.

D. Vectors: displacement and force. Scalars: distance and speed.

Question 16

A car accelerates from rest at $3.0\,\mathrm{m\,s^{-2}}$. The distance travelled in the first $4.0\,\mathrm{s}$ is closest to

A. $24\,\mathrm{m}$

B. $12\,\mathrm{m}$

C. $48\,\mathrm{m}$

D. $6.0\,\mathrm{m}$

Question 17

A box of mass $4.0\,\mathrm{kg}$ is pushed along a horizontal floor. The applied force is $25\,\mathrm{N}$ and the friction force is $5.0\,\mathrm{N}$. The acceleration of the box is closest to

A. $1.25\,\mathrm{m\,s^{-2}}$

B. $6.25\,\mathrm{m\,s^{-2}}$

C. $7.5\,\mathrm{m\,s^{-2}}$

D. $5.0\,\mathrm{m\,s^{-2}}$

Question 18

A ball is dropped from rest at a height of $7.2\,\mathrm{m}$. Ignoring air resistance, the speed of the ball just before it hits the ground is closest to

A. $8.4\,\mathrm{m\,s^{-1}}$

B. $11.9\,\mathrm{m\,s^{-1}}$

C. $141\,\mathrm{m\,s^{-1}}$

D. $71\,\mathrm{m\,s^{-1}}$

Question 19

A student measures the time taken for a ball to roll down a ramp five times and uses the mean of the five values. Using the mean mainly

A. eliminates any systematic error in the stopwatch.

B. reduces the effect of random errors on the value used.

C. improves the resolution of the stopwatch.

D. guarantees that the result equals the true value.

Question 20

A force acting on an object increases uniformly from 0 to $20\,\mathrm{N}$ as the object moves $4.0\,\mathrm{m}$ in the direction of the force. The work done by this force is

A. $40\,\mathrm{J}$

B. $80\,\mathrm{J}$

C. $5.0\,\mathrm{J}$

D. $4.0\,\mathrm{J}$

Practice Exam 5 — Section B

Answer **all** questions in the spaces provided. Write your responses in English. Where an answer box is provided, write your final answer in the box. If an answer box has a unit printed in it, give your answer in that unit. In questions where more than one mark is available, appropriate working **must** be shown. Take $g = 9.8\,\mathrm{m\ s^{-2}}$ ($9.8\,\mathrm{N\ kg^{-1}}$) and $c = 3.00 \times 10^{8}\,\mathrm{m\ s^{-1}}$ where required; other values are given in the question or on the formula sheet. Unless otherwise indicated, the diagrams in this examination are **not** drawn to scale.

Question 1 (4 marks)

A research vessel transmits two signals towards a receiver $12\,\mathrm{km}$ away: a radio pulse of frequency $450\,\mathrm{MHz}$ and a pulse of green light of wavelength $530\,\mathrm{nm}$. Both signals travel through air.

a. State, with a reason, which pulse reaches the receiver first. 1 mark

b. Calculate the wavelength of the radio pulse. Give your answer in m. 2 marks

c. Calculate the frequency of the green light. Give your answer in Hz. 1 mark

Question 2 (6 marks)

A solid glass rod of refractive index 1.60 is surrounded by air (refractive index 1.00) and is used to guide light from one end to the other.

a. Light enters the end of the rod from air. State what happens to the speed and to the frequency of the light as it enters the glass. 1 mark

b. Show that the speed of light in the glass rod is $1.88 \times 10^{8}\,\mathrm{m\ s^{-1}}$ (to three significant figures). 2 marks

c. Calculate the critical angle for the glass–air boundary at the side of the rod. Give your answer in degrees. 2 marks

d. Explain why light that enters the rod remains inside the glass even when the rod bends gently. 1 mark

Question 3 (5 marks)

A well-insulated container holds $0.25\,\mathrm{kg}$ of water at $20^{\circ}\mathrm{C}$. A student adds $0.050\,\mathrm{kg}$ of ice at $0^{\circ}\mathrm{C}$ and stirs gently. Assume that no energy is exchanged with the surroundings.

specific heat capacity of water $= 4.2 \times 10^{3}\,\mathrm{J\ kg^{-1}K^{-1}}$

specific latent heat of fusion of ice $= 3.3 \times 10^{5}\,\mathrm{J\ kg^{-1}}$

a. Convert the initial temperature of the water to kelvin. 1 mark

b. Determine the final temperature of the mixture once all of the ice has melted. Give your answer in °C. 3 marks

c. Explain, in terms of the kinetic model of particles, why water evaporating from the skin cools the skin. 1 mark

Question 4 (5 marks)

An industrial kiln is heated to $950^{\circ}\mathrm{C}$. Treat the kiln as an object whose emission follows Wien's law:

$$\lambda_{max} T = 2.9 \times 10^{-3}\,\mathrm{m\ K}$$

a. Determine the peak wavelength of the radiation emitted by the kiln. Give your answer in m. 2 marks

b. (Circle your answer.) The kiln is heated further, to $1200^{\circ}\mathrm{C}$. The peak wavelength will

become longer / remain the same / become shorter

Justify your choice without calculating a value. 1 mark

c. Name the region of the electromagnetic spectrum in which the wavelength found in part **a.** lies. 1 mark

d. State, with a reason, how the total energy radiated by the kiln across all wavelengths changes as its temperature increases. 1 mark

Question 5 (2 marks)

a. Explain, in terms of the absorption and re-emission of radiation, how greenhouse gases in the atmosphere (such as carbon dioxide, methane and water vapour) raise the temperature of Earth's surface. 2 marks

Question 6 (4 marks)

A nucleus of lead-214, $^{214}_{82}\text{Pb}$, decays by β^- emission to form nucleus Q. Nucleus Q then decays by β^- emission to form nucleus R. Nucleus R then decays by α emission to form nucleus S.

a. Describe, in terms of the nucleons, what happens inside a nucleus during β^- decay. 1 mark

b. Determine the mass number and the atomic number of nucleus R. 2 marks

c. Determine the mass number and the atomic number of nucleus S. 1 mark

Question 7 (3 marks)

A sample of iodine-131 contains 8.0×10^{12} undecayed nuclei. The half-life of iodine-131 is 8.0 days.

a. State what is meant by the half-life of a radioactive isotope. 1 mark

b. Calculate the number of undecayed nuclei remaining after 24 days. 2 marks

Question 8 (5 marks)

A technician's hand is exposed to α radiation. A mass of $0.40\,\text{kg}$ of tissue absorbs $0.060\,\text{J}$ of energy. The radiation weighting factor w_R for α radiation is 20.

a. Calculate the absorbed dose received by the tissue. Give your answer in Gy. 2 marks

b. Calculate the equivalent dose received by the tissue. Give your answer in Sv. 2 marks

c. The same absorbed dose from γ radiation would have a lower equivalent dose. Explain why. 1 mark

Question 9 (4 marks)

A uranium-235 nucleus absorbs a slow-moving neutron and splits into two smaller nuclei.

a. Name the process described and state what is released, in addition to energy, that allows the process to continue. 1 mark

b. Explain the condition required for a self-sustaining chain reaction. 1 mark

c. Explain, in terms of binding energy per nucleon, why this process releases energy. 2 marks

Question 10 (5 marks)

A battery-powered pump is connected to a $12\,\text{V}$ battery. The battery moves a charge of $450\,\text{C}$ through the circuit in 3.0 minutes.

a. Show that the current in the pump motor is $2.5\,\text{A}$. 1 mark

b. Calculate the energy delivered to the pump by the battery. Give your answer in J. 2 marks

c. Calculate the power of the pump motor. Give your answer in W. 2 marks

Question 11 (6 marks)

A $6.0\,\Omega$ resistor and a $12.0\,\Omega$ resistor are connected in parallel. This combination is connected in series with an $8.0\,\Omega$ resistor and a $9.0\,\mathrm{V}$ battery of negligible internal resistance.

a. Calculate the equivalent resistance of the parallel combination. Give your answer in Ω. 2 marks

b. State the total resistance of the circuit. Give your answer in Ω. 1 mark

c. Calculate the total current supplied by the battery, and hence determine the potential difference across the parallel combination. Give the current in A and the potential difference in V.

2 marks

d. Calculate the current in the $6.0\,\Omega$ resistor. Give your answer in A. 1 mark

Question 12 (4 marks)

A voltage divider is made from a $4.0\,\mathrm{k}\,\Omega$ resistor R_1 and a thermistor R_2 connected in series across a $9.0\,\mathrm{V}$ supply. The output voltage is measured across the thermistor. At $20^{\circ}\mathrm{C}$ the resistance of the thermistor is $6.0\,\mathrm{k}\,\Omega$.

a. Calculate the output voltage at $20^{\circ}\mathrm{C}$. Give your answer in V. 2 marks

b. The resistance of the thermistor decreases as its temperature rises. State the effect of an increase in temperature on the output voltage. 1 mark

c. Explain your answer to part **b.** 1 mark

Question 13 (4 marks)

A $2.0\,\mathrm{kW}$ portable heater is used for an average of 5.0 hours per day over a week (7 days). The electricity price is $\$0.35$ per $\mathrm{kW\,h}$.

a. Calculate the energy used by the heater over the week in $\mathrm{kW\,h}$, and hence find the cost of running the heater for the week.

2 marks

b. Convert the weekly energy use to joules. Give your answer in J. 1 mark

c. Explain why household circuits are wired in parallel rather than in series. 1 mark

Question 14 (3 marks)

Household circuits are protected by fuses and by residual current devices (RCDs).

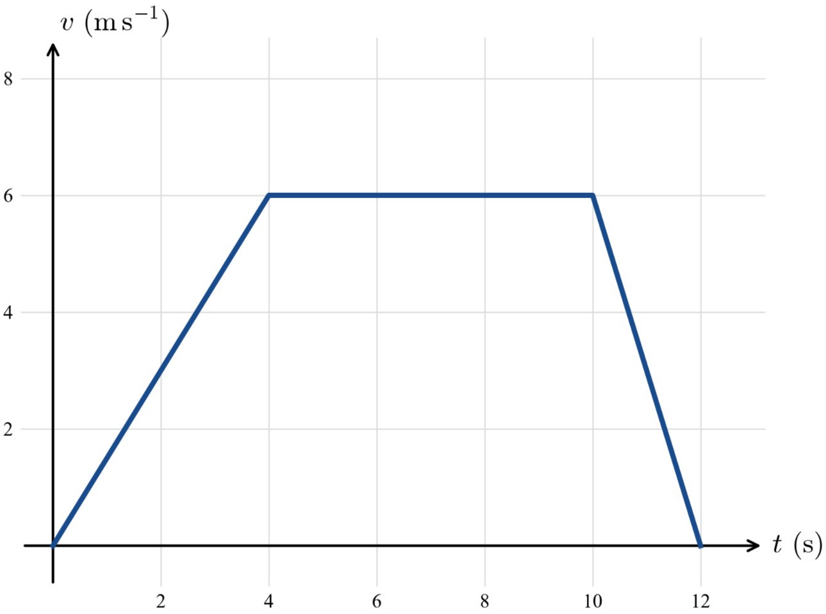
a. Describe how a fuse and how an RCD each operate to protect a circuit. 2 marks

b. Explain why a $10\,\mathrm{A}$ fuse in a lighting circuit does not protect a person who receives an electric shock from that circuit.

1 mark

Question 15 (4 marks)

A cart moves along a straight track. The velocity–time graph for the motion is shown below.



a. Calculate the acceleration of the cart during the first 4.0 s. Give your answer in m s^{-2}. 1 mark

b. Calculate the total distance travelled by the cart in the 12 s shown. Give your answer in m. 2 marks

c. State, with a reason, during which time interval the net force on the cart has the greatest magnitude. 1 mark

Question 16 (5 marks)

Trolley A, of mass 0.90 kg, moves along a horizontal track at 2.0 m s^{-1}. It collides with stationary trolley B, of mass 0.60 kg, and the trolleys stick together. The collision lasts 0.060 s.

a. Show that the speed of the joined trolleys immediately after the collision is 1.2 m s^{-1}. 2 marks

b. Calculate the average force on trolley B during the collision. Give your answer in N. 2 marks

c. Compare the force on trolley A by trolley B with the force on trolley B by trolley A during the collision. 1 mark

Question 17 (4 marks)

An electric motor takes in energy at a rate of 150 W. It lifts a crate of mass 25 kg vertically through 1.2 m in 4.0 s.

a. Calculate the gain in gravitational potential energy of the crate. Give your answer in J. 2 marks

b. Calculate the total energy supplied to the motor in the 4.0 s. Give your answer in J. 1 mark

c. Calculate the efficiency of the motor. 1 mark

Question 18 (4 marks)

A uniform beam of length 3.0 m and mass 18 kg rests horizontally on two vertical supports: support A at the left end of the beam and support B 2.0 m from the left end.

a. Calculate the force due to gravity on the beam. Give your answer in N. 1 mark

b. By taking moments about support A, calculate the upward force on the beam at support B. Give your answer in N. 2 marks

c. Hence state the upward force on the beam at support A. Give your answer in N. 1 mark

Question 19 (3 marks)

A toy launcher uses a spring of spring constant $250\,\mathrm{N\ m^{-1}}$. The spring is compressed by $0.080\,\mathrm{m}$ and then released, launching a ball of mass $0.060\,\mathrm{kg}$ horizontally along a smooth surface.

a. Calculate the force needed to compress the spring by $0.080\,\mathrm{m}$. Give your answer in N. 1 mark

b. Assuming all of the elastic potential energy stored in the spring is converted into kinetic energy of the ball, calculate the speed of the ball as it leaves the launcher. Give your answer in $\mathrm{m\ s^{-1}}$.

2 marks

Question 20 (20 marks)

A group of students investigates the acceleration due to gravity, g, by timing the fall of a steel ball.

The students release the ball from rest using an electromagnet at a range of heights h above the floor, and measure the time of fall t with a stopwatch. Their results are shown in the table. The uncertainty in each time reading is $\pm 0.02\,\mathrm{s}$.

h (m)	0.50	1.00	1.50	2.00	2.50	3.00
t (s)	0.32	0.45	0.55	0.64	0.71	0.78

a. Identify the independent variable, the dependent variable and one controlled variable in this investigation. 3 marks

b. For an object falling from rest with acceleration g, $h = 1/2\, g t^2$. Rearrange this equation to make t^2 the subject, and explain why a graph of t^2 (vertical axis) against h (horizontal axis) is expected to be a straight line through the origin.

2 marks

c. State why the ball is released from rest rather than thrown. 1 mark

d. The students repeat each time measurement three times and use the mean. State the purpose of repeating the measurements and taking the mean. 1 mark

e. Calculate the value of t^2 for each height. On the grid provided, plot a graph of t^2 (vertical axis) against h (horizontal axis), and draw a line of best fit.

5 marks

f. Determine the gradient of your line of best fit. Give your answer in $s^2\,m^{-1}$. 2 marks

g. The gradient of the t^2–h graph for this experiment is equal to $\frac{2}{g}$. Use your gradient from part **f.** to determine the acceleration due to gravity g, and compare your value with the accepted value of $9.8\,m\,s^{-2}$. Give your answer in $m\,s^{-2}$.

3 marks

h. Another group performs the experiment with a light hollow plastic ball of the same size, so that air resistance has a significant effect. Predict, with reasons, the effect on (i) the gradient of their graph and (ii) their calculated value of g.

2 marks

i. A third group uses a steel ball of twice the mass. State how the gradient of their graph compares with the gradient found in part **f.** 1 mark

Practice Exam 5 — Formula Sheet

This formula sheet is provided for use with all practice examinations in this booklet. Part 1 reproduces, unaltered and with attribution, the items of the official VCE Physics Formula Sheet (© VCAA 2026) that lie within the Units 1 & 2 study design; items that belong to Units 3 & 4 only are omitted. Part 2 is a house supplement drawn from the key knowledge of the Units 1 & 2 study design (2023–2027): it carries the relationships that Units 1 & 2 students apply which the official sheet does not give.

Part 1 — VCE Physics Formula Sheet: Units 1 & 2 items

Motion and related energy transformations

velocity	$v = \frac{\Delta s}{\Delta t}$
acceleration	$a = \frac{\Delta v}{\Delta t}$
constant acceleration	$v = u + at$
	$s = ut + \frac{1}{2}at^2$
	$s = vt - \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
	$s = \frac{1}{2}(u+v)t$
Newton's second law	$\Sigma F = ma$
Hooke's law	$F = -kx$
elastic potential energy	$E_s = \frac{1}{2}kx^2$
gravitational potential energy	$E_g = mg\Delta h$
kinetic energy	$E_k = \frac{1}{2}mv^2$
impulse	$F\Delta t = m\Delta v$
momentum	$p = mv$

Generation and transmission of electricity

current	$I = \frac{V}{R}$
power	$P = VI$
resistors in series	$R_T = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$

Waves

wave equation	$v = f\lambda$

Part 2 — Units 1 & 2 supplement

Waves and light

wavelength, frequency, period and speed	$\lambda = \frac{v}{f} = vT$

refraction (Snell's Law) $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$n_1 v_1 = n_2 v_2$

critical angle $n_1 \sin\theta_c = n_2 \sin 90^\circ$

Thermal energy

Celsius–kelvin conversion $T(\mathrm{K}) = T(°\mathrm{C}) + 273.15$

raising temperature $Q = m c \Delta T$

change of state $Q = m L$

Wien's Law $\lambda_{\max} T = \text{constant}$

Radiation from the nucleus

Provenance note (TOC §2.7): D = E/m, H = w_R × D and E = mc² do not appear on the official Units 1 & 2 formula sheet; they are included in this supplement because the Units 1 & 2 key knowledge requires dose calculations and treats mass–energy conversion qualitatively.

radioactive decay (whole half-lives) $N = N_0 \left(\frac{1}{2}\right)^n$

$n = \frac{t}{t_{1/2}}$

absorbed dose $D = \frac{E}{m}$ (unit: Gy)

equivalent dose $H = w_R \times D$ (unit: Sv)

effective dose $\Sigma\, w_T H_T$ over tissues T (unit: Sv)

Nuclear energy

mass–energy conversion $E = m c^2$

Electricity

current and charge $I = \frac{Q}{t}$

potential difference $V = \frac{E}{Q}$

power and energy $P = \frac{E}{t}$

voltage divider $V_{\text{out}} = V_{\text{in}} \times \frac{R_2}{R_1 + R_2}$

Forces, work and energy

work done by a constant force $W = F s \cos\theta$

work done area under a force–distance graph

torque $\tau = r_\perp F$

force due to gravity $F_{\text{on body by Earth}} = m g$

Newton's third law $F_{\text{on A by B}} = -F_{\text{on B by A}}$

change in momentum $\Delta p = F_{\text{net}} \Delta t$

efficiency $\eta = \frac{\text{useful energy out}}{\text{total energy in}}$

Data

acceleration due to gravity at Earth's surface	$g = 9.8$ m s^{-2} (9.8 N kg^{-1})
speed of light in a vacuum	$c = 3.00 \times 10^{8}$ m s^{-1}
Wien's Law constant	2.9×10^{-3} m K

The Units 1 & 2 study design gives the gravitational field strength near Earth's surface as g = 9.8 N kg^{-1} (9.8 m s^{-2}), and this is the value used throughout this booklet. The official VCE Physics Formula Sheet gives g = 9.81 m s^{-2} for Units 3 & 4.

Metric (SI) multipliers

pico (p)	10^{-12}	kilo (k)	10^{3}
nano (n)	10^{-9}	mega (M)	10^{6}
micro (μ)	10^{-6}	giga (G)	10^{9}
milli (m)	10^{-3}	tera (T)	10^{12}

Unit conversions

1 tonne (t)	= 10^{3} kg
1 kilowatt hour (kW h)	= 3.6×10^{6} J

Nomenclature

force due to gravity	F_{g}
force on A by B	$F_{\text{on A by B}}$
normal force	F_{N}

End of Formula Sheet

Practice Exam 5 — Solutions

Section A — answer key

Question	Answer	Question	Answer
1	C	11	D
2	D	12	B
3	B	13	A
4	A	14	C
5	C	15	D
6	D	16	A
7	C	17	D
8	A	18	B
9	D	19	B
10	C	20	A

Question 1 — C. Electromagnetic waves are transverse waves that need no medium and all travel at the same speed $c = 3.00 \times 10^{8}\,\mathrm{m\ s^{-1}}$ in a vacuum. A is false — electromagnetic waves, unlike mechanical waves, travel through a vacuum; B is false — different regions of the spectrum have different wavelengths; D is false — the speed in a vacuum is the same for all frequencies.

Question 2 — D. $f = \frac{c}{\lambda} = \frac{3.00 \times 10^{8}}{600 \times 10^{-9}} = 5.0 \times 10^{14}\,\mathrm{Hz}$. A omits the nano conversion ($3.00 \times 10^{8} / 600$), B inverts the formula (λ / c), and C multiplies c by the wavelength in nm instead of dividing.

Question 3 — B. Snell's law: $\sin\theta_2 = \frac{n_1 \sin\theta_1}{n_2} = \frac{1.00 \times \sin 40^{\circ}}{1.52} = 0.423$, so $\theta_2 = 25^{\circ}$. A assumes no bending; C inverts the ratio ($\sin\theta_2 = 1.52 \sin 40^{\circ}$, giving 78°); D gives the value of $\sin\theta_2$ in degrees without taking the inverse sine.

Question 4 — A. $Q = m c \Delta T = 2.0 \times 4.2 \times 10^{3} \times 5.0 = 4.2 \times 10^{4}\,\mathrm{J}$. B drops a factor of 10; C halves the answer; D doubles it.

Question 5 — C. Wien's law gives $\lambda_{max} T = \text{constant}$, so doubling T halves the peak wavelength: $\lambda'_{max} = \lambda / 2$. A applies an inverse-square relationship; B assumes the wavelength increases with temperature; D assumes no change.

Question 6 — D. Greenhouse gases absorb the infrared radiation emitted by Earth's surface and re-emit it in all directions, including back towards the surface, which raises the surface temperature. A confuses the mechanism with reflection of UV (the role of the ozone layer is absorption, not warming); B wrongly involves visible light; C wrongly involves convection.

Question 7 — C. In β^{-} decay a neutron changes into a proton, so the mass number is unchanged (234) and the atomic number increases by one: $90 \rightarrow 91$, giving $^{234}{}_{91}\mathrm{Pa}$. A is an α decay ($A - 4$, $Z - 2$); B increases Z by two; D reduces the mass number, which never happens in β decay.

Question 8 — A. $16\,\mathrm{h}$ is four half-lives, so the fraction remaining is $\left(\frac{1}{2}\right)^{4} = \frac{1}{16}$. B uses three half-lives; C uses two; D divides by the time instead of counting half-lives.

Question 9 — D. The fission products are medium-mass nuclei with a higher binding energy per nucleon than uranium-235, so the nucleons end up more tightly bound; the increase in binding energy corresponds to a decrease in total mass, which is released as energy. A has the mass change backwards; B and C invent mechanisms that do not occur.

Question 10 — C. $I = \frac{Q}{t} = \frac{450}{180} = 2.5\,\text{A}$ (3.0 minutes $= 180\,\text{s}$). A divides by minutes instead of seconds; B inverts the formula; D multiplies charge and time.

Question 11 — D. $E = 2.2\,\text{kW} \times 2.0\,\text{h} = 4.4\,\text{kW h} = 4.4 \times 3.6 \times 10^{6} = 1.584 \times 10^{7}\,\text{J} \approx 1.6 \times 10^{7}\,\text{J}$. A is only one kW h; B converts to watt hours ($4.4 \times 10^{3}\,\text{W h}$) and labels the result in joules; C multiplies by 3.6×10^{3} instead of 3.6×10^{6}.

Question 12 — B. Parallel combination: $\frac{1}{R_p} = \frac{1}{3.0} + \frac{1}{6.0} = \frac{1}{2.0}$, so $R_p = 2.0\,\Omega$. Total: $R_T = 2.0 + 5.0 = 7.0\,\Omega$. A treats all three as series ($14\,\Omega$); C stops at the parallel combination alone; D treats all three as parallel.

Question 13 — A. Voltage divider: $V_{out} = V_{in} \times \frac{R_2}{R_1 + R_2} = 8.0 \times \frac{5.0}{3.0 + 5.0} = 5.0\,\text{V}$. B gives the voltage across R_1 instead; C gives the full supply voltage; D uses the inverted ratio ($8.0 \times 3.0 / 5.0$).

Question 14 — C. An RCD compares the currents in the active and neutral conductors; an imbalance means current is leaking (for example through a person to earth), so the RCD opens the circuit within milliseconds. A describes a fuse; B and D describe devices that do not exist in this form.

Question 15 — D. Displacement and force have magnitude and direction, so they are vectors; distance and speed have magnitude only, so they are scalars. A and B misplace distance and speed; C reverses the classification.

Question 16 — A. $s = \frac{1}{2} a t^{2} = \frac{1}{2} \times 3.0 \times 4.0^{2} = 24\,\text{m}$. B uses $s = at$; C uses $s = at^{2}$; D uses $s = \frac{1}{2} at$.

Question 17 — D. $\Sigma F = 25 - 5.0 = 20\,\text{N}$, so $a = \frac{\Sigma F}{m} = \frac{20}{4.0} = 5.0\,\text{m s}^{-2}$. A uses friction alone ($5.0 / 4.0$); B uses the applied force alone ($25 / 4.0$); C adds the two forces ($(25 + 5.0) / 4.0$).

Question 18 — B. Energy conservation: $v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 7.2} = 11.9\,\text{m s}^{-1}$. A uses $\sqrt{gh}$; C gives $2gh$ without taking the square root; D gives gh.

Question 19 — B. Averaging repeated readings reduces the effect of random errors on the value used. A is false — repeating readings does not remove systematic errors; C is false — averaging does not change the resolution of the instrument; D is false — the mean is not guaranteed to equal the true value.

Question 20 — A. The work done equals the area under the force–displacement graph: a triangle of base $4.0\,\text{m}$ and height $20\,\text{N}$, so $W = 1/2 \times 20 \times 4.0 = 40\,\text{J}$. B uses the full rectangle (20×4.0) instead of the triangle; C divides the force by the displacement; D quotes the displacement rather than calculating an area.

Section B — worked solutions

Question 1 (4 marks)

a. (1 mark) Both pulses are electromagnetic waves, so both travel through air at (very close to) the speed of light c. They travel the same distance, so they reach the receiver at the same time [1].

b. (2 marks) $\lambda = \frac{c}{f}$ [1]:

$$\lambda = \frac{3.00 \times 10^{8}}{450 \times 10^{6}} = 0.67\,\text{m}\,[1].$$

c. (1 mark)

$$f = \frac{c}{\lambda} = \frac{3.00 \times 10^{8}}{530 \times 10^{-9}} = 5.7 \times 10^{14}\,\text{Hz}\,[1].$$

Question 2 (6 marks)

a. (1 mark) The speed decreases (light travels more slowly in the glass than in air); the frequency is unchanged — the frequency is set by the source [1].

b. (2 marks) Using $n_1 v_1 = n_2 v_2$ with medium 1 = vacuum and medium 2 = the glass:

$$v = \frac{c}{n} = \frac{3.00 \times 10^8}{1.60} = 1.875 \times 10^8\,\text{m s}^{-1} = 1.88 \times 10^8\,\text{m s}^{-1}\,(3\text{ s.f.}),\text{as required.}$$

(1 mark for the method, 1 mark for the value.)

c. (2 marks) At the critical angle the refracted ray emerges at 90°, with light travelling in the denser medium (the glass):

$$n_1 \sin\theta_c = n_2 \sin 90^\circ \Rightarrow \sin\theta_c = \frac{n_2}{n_1} = \frac{1.00}{1.60} = 0.625[1]$$

$$\theta_c = \sin^{-1}(0.625) = 38.7^\circ[1].$$

d. (1 mark) Light travelling along the rod strikes the glass–air boundary at angles greater than the critical angle. Since the glass has the higher refractive index, total internal reflection occurs at every reflection, so the light is guided around gentle bends without escaping [1].

Question 3 (5 marks)

a. (1 mark) $T = 20 + 273 = 293\,\text{K}$ [1].

b. (3 marks) Energy lost by the warm water = energy to melt the ice + energy to warm the melted ice:

$$m_w c(20 - T) = m_i L + m_i c(T - 0)[1]$$

$$0.25 \times 4.2 \times 10^3 \times (20 - T) = 0.050 \times 3.3 \times 10^5 + 0.050 \times 4.2 \times 10^3 \times T[1]$$

$$21\,000 - 1050T = 16\,500 + 210T \Rightarrow 4500 = 1260T \Rightarrow T = 3.6^\circ\text{C}[1].$$

(Check: the warm water can supply $0.25 \times 4.2 \times 10^3 \times 20 = 21\,000\,\text{J}$ by cooling to 0°C, more than the $16\,500\,\text{J}$ needed to melt the ice, so all the ice melts.)

c. (1 mark) The most energetic molecules escape from the surface during evaporation, so the average kinetic energy of the molecules left behind decreases; lower average kinetic energy means a lower temperature [1].

Question 4 (5 marks)

a. (2 marks) Convert to kelvin: $T = 950 + 273 = 1223\,\text{K}$ [1]:

$$\lambda_{max} = \frac{2.9 \times 10^{-3}}{1223} = 2.4 \times 10^{-6}\,\text{m}[1].$$

b. (1 mark) Circle: **become shorter**. Wien's law gives $\lambda_{max} T = \text{constant}$, so as the temperature increases the peak wavelength decreases [1].

c. (1 mark) Infrared [1].

d. (1 mark) The total energy radiated increases — a hotter object emits more energy per second across the whole spectrum [1].

Question 5 (2 marks)

a. (2 marks) Earth's surface emits infrared radiation [context]. Greenhouse gases absorb some of this infrared radiation [1] and re-emit it in all directions, including back towards the surface; this returned energy raises the temperature of Earth's surface above what it would be without the atmosphere [1].

Question 6 (4 marks)

a. (1 mark) A neutron in the nucleus changes into a proton, emitting an electron (the β^- particle) [1].

b. (2 marks) In each β^- decay the mass number is unchanged and the atomic number increases by 1. After two β^- decays [1]:

$$A = 214, Z = 82 + 2 = 84 [1].$$

(Nucleus R is $^{214}_{84}Po$.)

c. (1 mark) In α decay the mass number decreases by 4 and the atomic number decreases by 2: $A = 214 - 4 = 210$, $Z = 84 - 2 = 82$ [1]. (Nucleus S is $^{210}_{82}Pb$.)

Question 7 (3 marks)

a. (1 mark) The half-life is the time taken for half of the undecayed nuclei in a sample to decay (equivalently, the time for the activity to halve) [1].

b. (2 marks) Number of half-lives: $n = 24 / 8.0 = 3$ [1]:

$$N = N_0 \left(\frac{1}{2}\right)^n = 8.0 \times 10^{12} \times \left(\frac{1}{2}\right)^3 = 1.0 \times 10^{12} [1].$$

Question 8 (5 marks)

a. (2 marks) $D = \frac{E}{m}$ [1]:

$$D = \frac{0.060}{0.40} = 0.15\,\mathrm{Gy} [1].$$

b. (2 marks) $H = w_R \times D$ [1]:

$$H = 20 \times 0.15 = 3.0\,\mathrm{Sv} [1].$$

c. (1 mark) γ radiation has a radiation weighting factor of 1 (much lower than the 20 for α), because γ radiation ionises far less densely and so causes less biological damage per gray of absorbed dose [1].

Question 9 (4 marks)

a. (1 mark) The process is nuclear fission; two or three neutrons are also released, which allows the process to continue [1].

b. (1 mark) On average, at least one of the neutrons released by each fission must go on to cause a further fission. This requires enough uranium in a suitable shape (a critical mass) so that neutrons are not all lost by escape or absorbed without causing fission [1].

c. (2 marks) The fission products are medium-mass nuclei with a higher binding energy per nucleon than uranium-235, meaning the nucleons in the products are more tightly bound [1]. The total mass of the products is therefore less than the mass of the original nucleus and neutron, and this lost mass is released as energy [1].

Question 10 (5 marks)

a. (1 mark) 3.0 minutes $= 180\,\mathrm{s}$:

$$I = \frac{Q}{t} = \frac{450}{180} = 2.5\,\mathrm{A}, \text{as required.}$$

b. (2 marks) $V=\frac{E}{Q}$, so $E=V\,Q$ [1]:

$$E=12\times450=5400\,\mathrm{J}\,[1].$$

c. (2 marks) $P=\frac{E}{t}$ [1]:

$$P=\frac{5400}{180}=30\,\mathrm{W}\,[1].$$

(Equivalently, $P=V\,I=12\times2.5=30\,\mathrm{W}$.)

Question 11 (6 marks)

a. (2 marks)

$$\frac{1}{R_p}=\frac{1}{6.0}+\frac{1}{12.0}=\frac{3}{12}=\frac{1}{4.0}\,[1],\text{so }R_p=4.0\,\Omega\,[1].$$

b. (1 mark) $R_T=R_p+8.0=4.0+8.0=12.0\,\Omega$ [1].

c. (2 marks)

$$I=\frac{V}{R_T}=\frac{9.0}{12.0}=0.75\,\mathrm{A}\,[1].$$

The parallel combination is in series with the battery, so it carries this current:

$$V_p=I\,R_p=0.75\times4.0=3.0\,\mathrm{V}\,[1].$$

d. (1 mark) Each resistor in the parallel combination has $3.0\,\mathrm{V}$ across it:

$$I_6=\frac{3.0}{6.0}=0.50\,\mathrm{A}\,[1].$$

Question 12 (4 marks)

a. (2 marks) $V_{out}=V_{in}\times\frac{R_2}{R_1+R_2}$ [1]:

$$V_{out}=9.0\times\frac{6.0}{4.0+6.0}=9.0\times0.60=5.4\,\mathrm{V}\,[1].$$

b. (1 mark) The output voltage decreases [1].

c. (1 mark) As the thermistor's resistance decreases, its share $\frac{R_2}{R_1+R_2}$ of the total resistance decreases, so a smaller share of the supply voltage falls across it (and a larger share falls across R_1) [1].

Question 13 (4 marks)

a. (2 marks) Total time $=5.0\times7=35\,\mathrm{h}$:

$$E=P\,t=2.0\times35=70\,\mathrm{kW\,h}\,[1];$$

$$\text{cost}=70\times0.35=\$24.50\,[1].$$

b. (1 mark)

$$E=70\times3.6\times10^6=2.5\times10^8\,\mathrm{J}\,[1].$$

c. (1 mark) In parallel, each appliance receives the full mains voltage and can operate independently — switching one appliance off (or one failing) does not affect the others, which would not be true in series [1].

Question 14 (3 marks)

a. (2 marks) Fuse: when the current exceeds its rated value the fuse wire heats and melts, breaking the circuit and protecting the wiring and appliances from overheating [1]. RCD: it continuously compares the currents in the active and neutral conductors; if they are not equal (residual current leaking, for example through a person to earth), it opens the circuit within milliseconds at currents as low as about $30\,\mathrm{mA}$, protecting people [1].

b. (1 mark) A current that can injure or kill a person is of the order of tens of mA, far below the $10\,\mathrm{A}$ needed to melt the fuse — so the fuse would not blow during a shock, and would not act fast enough to prevent harm in any case [1].

Question 15 (4 marks)

a. (1 mark) The acceleration is the gradient of the velocity–time graph:

$$a=\frac{\Delta v}{\Delta t}=\frac{6.0-0}{4.0}=1.5\,\mathrm{m\ s^{-2}}[1].$$

b. (2 marks) Distance = area under the velocity–time graph [1]:

$$s=1/2(4.0)(6.0)+(6.0)(6.0)+1/2(2.0)(6.0)=12+36+6=54\,\mathrm{m}[1].$$

c. (1 mark) The net force has its greatest magnitude during the final $2.0\,\mathrm{s}$: the magnitude of the deceleration is $6.0/2.0=3.0\,\mathrm{m\ s^{-2}}$, twice the acceleration in the first interval, and $\Sigma F=ma$ with the mass constant [1].

Question 16 (5 marks)

a. (2 marks) Momentum is conserved (no external horizontal force):

$$m_A u_A+m_B u_B=(m_A+m_B)v[1]$$

$$0.90\times 2.0+0=1.50\,v\Rightarrow v=\frac{1.8}{1.50}=1.2\,\mathrm{m\ s^{-1}},\text{as required}[1].$$

b. (2 marks) Impulse on B = change in momentum of B: $F\Delta t=m_B v-m_B u_B$ [1]:

$$F=\frac{0.60\times 1.2-0}{0.060}=12\,\mathrm{N}\,(\text{in the direction of motion})[1].$$

c. (1 mark) By Newton's third law, $F_{\text{on A by B}}=-F_{\text{on B by A}}$: the two forces are equal in magnitude (each $12\,\mathrm{N}$) and opposite in direction [1].

Question 17 (4 marks)

a. (2 marks) $E_g=mg\Delta h$ [1]:

$$E_g=25\times 9.8\times 1.2=294\,\mathrm{J}\approx 290\,\mathrm{J}[1].$$

b. (1 mark) $P=\frac{E}{t}$, so $E=Pt$:

$$E=150\times 4.0=600\,\mathrm{J}[1].$$

c. (1 mark)

$$\eta=\frac{\text{useful energy out}}{\text{total energy in}}=\frac{294}{600}=0.49,\text{i.e.}\,49\,\%[1].$$

Question 18 (4 marks)

a. (1 mark) $F_g = m\,g = 18 \times 9.8 = 176\,\mathrm{N}$ [1].

b. (2 marks) The beam is uniform, so the force due to gravity acts at its centre, $1.5\,\mathrm{m}$ from support A. Taking moments about A (clockwise moment of F_g = anticlockwise moment of the force at B) [1]:

$$F_B \times 2.0 = 176.4 \times 1.5 \Rightarrow F_B = \frac{264.6}{2.0} = 132\,\mathrm{N}[1].$$

c. (1 mark) The beam is in equilibrium, so the upward forces balance the force due to gravity:

$$F_A = 176.4 - 132.3 = 44\,\mathrm{N}[1].$$

Question 19 (3 marks)

a. (1 mark) Hooke's law: $F = k\,x = 250 \times 0.080 = 20\,\mathrm{N}$ [1].

b. (2 marks) Elastic potential energy stored: $E_s = \frac{1}{2} k\,x^2 = \frac{1}{2} \times 250 \times 0.080^2 = 0.80\,\mathrm{J}$ [1]. This becomes kinetic energy:

$$1/2\,m\,v^2 = 0.80 \Rightarrow v = \sqrt{\frac{2 \times 0.80}{0.060}} = 5.2\,\mathrm{m\ s^{-1}}[1].$$

Question 20 (20 marks)

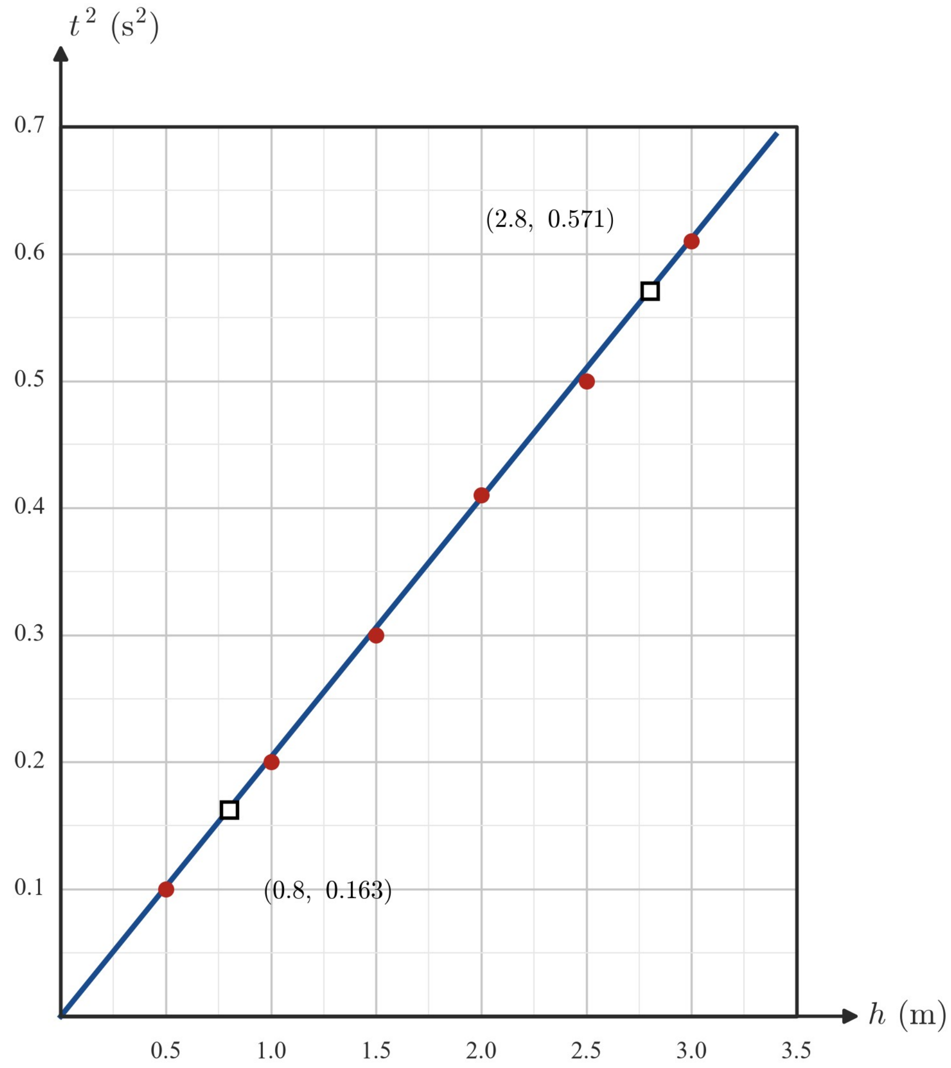
a. (3 marks) Independent variable: height h [1]. Dependent variable: time of fall t [1]. Controlled variable: any one of — the same ball; released from rest each time; the same release mechanism; the same timing method (for example the same person operating the stopwatch); the same falling distance measured in the same way [1].

b. (2 marks) Rearranging $h = 1/2\,g\,t^2$ gives $t^2 = \frac{2}{g} h$ [1]. This has the form $y = m\,x$: t^2 is proportional to h, so a graph of t^2 against h is a straight line through the origin with gradient $\frac{2}{g}$ [1].

c. (1 mark) Releasing from rest makes the initial speed $u = 0$, so the equation $h = 1/2\,g\,t^2$ applies; if the ball were thrown, u would be unknown and would differ from drop to drop [1].

d. (1 mark) Repeating and averaging reduces the effect of random errors in the time readings (and allows anomalous readings to be identified) [1].

e. (5 marks) Correct values of t^2 (0.10, 0.20, 0.30, 0.41, 0.50, $0.61\,\mathrm{s}^2$) [1]; axes labelled with quantities and units, suitable scale [1]; all six points plotted correctly [1]; single straight line of best fit [1]; the line follows the trend with points balanced on either side and passes through or near the origin [1].



The line shown has equation $t^2 = 0.204\,h$.

f. (2 marks) Two well-separated points on the line, for example $(0.8\,\text{m}, 0.163\,\text{s}^2)$ and $(2.8\,\text{m}, 0.571\,\text{s}^2)$ [1]:

$$\text{gradient} = \frac{0.571 - 0.163}{2.8 - 0.8} = \frac{0.408}{2.0} = 0.204\,\text{s}^2\,\text{m}^{-1}[1].$$

(Accept 0.19–$0.21\,\text{s}^2\,\text{m}^{-1}$ from the student's own line; the points must lie on the line, not be taken from the table.)

g. (3 marks) Gradient $= \frac{2}{g}$, so $g = \frac{2}{\text{gradient}}$ [1]:

$$g = \frac{2}{0.204} = 9.8\,\text{m s}^{-2}[1].$$

This agrees with the accepted value of $9.8\,\text{m s}^{-2}$ [1].

h. (2 marks) (i) With air resistance significant, the net downward force is less than the force due to gravity, so each fall takes longer and the values of t^2 are larger — the gradient is larger [1]. (ii) Since $g = \frac{2}{\text{gradient}}$, a larger gradient gives a smaller calculated value of g (an underestimate) [1].

i. (1 mark) The gradient is unchanged: in the absence of air resistance the acceleration due to gravity does not depend on the mass of the falling object [1].

Practice Exam 6 — Harder

- Reading time: **15 minutes**
- Writing time: **2 hours 30 minutes**
- Section A: 20 questions, 20 marks
- Section B: 19 questions, 100 marks
- Total 120 marks

Approved materials

- One scientific calculator
- Pre-written notes (one folded A3 sheet or two A4 sheets bound together by tape)

A formula sheet is provided at the end of this examination.

Students are **not** permitted to bring mobile phones and/or any unauthorised electronic devices into the examination room.

There is no VCAA external examination for Physics Units 1 and 2. The reading time, writing time, section structure, question counts and mark totals of this practice paper are house conventions of this workbook series, modelled on the Units 3 & 4 examination shape. They are not a VCAA requirement.

Section A — Multiple-choice questions (20 marks)

Answer **all** questions. Choose the response that is **correct** or that **best answers** the question. A correct answer scores 1; an incorrect answer scores 0. Marks will **not** be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question. Where a numerical answer is required, use the constants given on the formula sheet. Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1

A sound wave of frequency $512\,\text{Hz}$ has a wavelength of $0.664\,\text{m}$ in air. The speed of the sound wave is closest to:

A. $340\,\text{m s}^{-1}$

B. $170\,\text{m s}^{-1}$

C. $771\,\text{m s}^{-1}$

D. $1.3 \times 10^{-3}\,\text{m s}^{-1}$

Question 2

Which one of the following statements about electromagnetic waves is correct?

A. Radio waves travel faster than gamma rays in a vacuum.

B. Electromagnetic waves require a material medium in order to travel.

C. When light passes from air into glass, its frequency stays the same and its speed decreases.

D. Ultraviolet radiation has a longer wavelength than infrared radiation.

Question 3

A ray of light in air strikes the flat surface of a glass block of refractive index 1.50 at an angle of incidence of 35°. The angle of refraction of the ray inside the glass is closest to:

A. 59°

B. 68°

C. 35°

D. 22°

Question 4

A $60\,\mathrm{W}$ electric heater is used to warm a $0.40\,\mathrm{kg}$ metal block of specific heat capacity $900\,\mathrm{J\,kg^{-1}\,{}^\circ C^{-1}}$, starting at $20\,{}^\circ\mathrm{C}$. Assuming no energy is lost to the surroundings, the temperature of the block after 5.0 minutes of heating is closest to:

A. $21\,{}^\circ\mathrm{C}$

B. $50\,{}^\circ\mathrm{C}$

C. $70\,{}^\circ\mathrm{C}$

D. $120\,{}^\circ\mathrm{C}$

Question 5

A nucleus of radon-220 ($^{220}_{86}Rn$) decays by emitting an alpha particle. The daughter nucleus then decays by emitting a beta-minus particle. The resulting nucleus is:

A. $^{216}_{85}At$

B. $^{216}_{83}Bi$

C. $^{216}_{84}Po$

D. $^{220}_{85}At$

Question 6

A radioactive sample has a half-life of 12 days. The fraction of the original nuclei that have **decayed** after 36 days is:

A. $\frac{1}{8}$

B. $\frac{7}{8}$

C. $\frac{1}{4}$

D. $\frac{3}{4}$

Question 7

An organ of mass $4.0\,\mathrm{kg}$ absorbs $0.020\,\mathrm{J}$ of energy from alpha radiation. The radiation weighting factor for alpha radiation is 20. The equivalent dose received by the organ is:

A. $0.005\,\mathrm{Sv}$

B. $0.10\,\mathrm{Gy}$

C. $1.6\,\mathrm{Sv}$

D. $0.10\,\mathrm{Sv}$

Question 8

A $12\,\mathrm{V}$ battery supplies a device for 5.0 minutes, delivering a total charge of $900\,\mathrm{C}$. The total energy transferred by the battery to the device is:

A. $270\,\mathrm{kJ}$

B. $36\,\mathrm{J}$

C. $0.013\,\mathrm{J}$

D. $10.8\,\mathrm{kJ}$

Question 9

A $20\,\Omega$ resistor and a $30\,\Omega$ resistor are connected in parallel, and this combination is connected in series with an $8.0\,\Omega$ resistor. The circuit is connected to a $10\,\mathrm{V}$ supply of negligible internal resistance. The total current drawn from the supply is closest to:

A. $0.50\,\mathrm{A}$

B. $0.17\,\mathrm{A}$

C. $0.83\,\mathrm{A}$

D. $2.1\,\mathrm{A}$

Question 10

A $2.4\,\mathrm{kW}$ heater operates for 45 minutes. Electricity costs $\$0.30$ per $\mathrm{kW\,h}$. The cost of running the heater for this time is closest to:

A. $\$0.32$

B. $\$0.54$

C. $\$0.72$

D. $\$32$

Question 11

A voltage divider consists of a $4.0\,\mathrm{k}\,\Omega$ resistor and a $2.0\,\mathrm{k}\,\Omega$ resistor connected in series across a $12\,\mathrm{V}$ supply. The output voltage measured across the $2.0\,\mathrm{k}\,\Omega$ resistor is:

A. $2.0\,\mathrm{V}$

B. $4.0\,\mathrm{V}$

C. $6.0\,\mathrm{V}$

D. $8.0\,\mathrm{V}$

Question 12

A toaster and a kettle are both plugged into the same $230\,\mathrm{V}$ household circuit, and both are operating at their rated powers. Which one of the following statements is correct?

A. The two appliances are connected in series, so the same current flows through each.

B. The potential difference across each appliance is $230\,\mathrm{V}$.

C. The equivalent resistance of the circuit increases when the kettle is switched on.

D. The current in the kettle must be equal to the current in the toaster.

Question 13

A car accelerates from rest at $2.0\,\mathrm{m\,s^{-2}}$ for $6.0\,\mathrm{s}$, then brakes in a straight line with a constant deceleration of $3.0\,\mathrm{m\,s^{-2}}$ until it stops. The total distance travelled by the car from rest to rest is:

A. $24\,\mathrm{m}$

B. $36\,\mathrm{m}$

C. $60\,\mathrm{m}$

D. $84\,\mathrm{m}$

Question 14

A $4.0\,\mathrm{kg}$ box is pushed along a horizontal floor by a horizontal force of $26\,\mathrm{N}$. A friction force of $10\,\mathrm{N}$ opposes the motion. The acceleration of the box is:

A. $6.5\,\mathrm{m\,s^{-2}}$

B. $2.5\,\mathrm{m\,s^{-2}}$

C. $4.0\,\mathrm{m\,s^{-2}}$

D. $9.0\,\mathrm{m\,s^{-2}}$

Question 15

A $0.30\,\mathrm{kg}$ cart moving at $4.0\,\mathrm{m\,s^{-1}}$ along a straight track collides with a stationary $0.50\,\mathrm{kg}$ cart. The two carts couple together and move off as one. The kinetic energy lost in the collision is:

A. $0.9\,\mathrm{J}$

B. $1.5\,\mathrm{J}$

C. $2.4\,\mathrm{J}$

D. zero

Question 16

A sled is pulled $20\,\mathrm{m}$ along horizontal ground by a rope that makes an angle of 30° above the horizontal. The tension in the rope is $50\,\mathrm{N}$. The work done on the sled by the rope is closest to:

A. $433\,\mathrm{J}$

B. $1000\,\mathrm{J}$

C. $500\,\mathrm{J}$

D. $866\,\mathrm{J}$

Question 17

The time for a cart to roll down a ramp is measured as $(24.0 \pm 0.5)\,\mathrm{s}$. The percentage uncertainty in this measurement is closest to:

A. $0.5\,\%$

B. $2.1\,\%$

C. $21\,\%$

D. $48\,\%$

Question 18

A group of students measures the specific heat capacity of water and obtains a value of $4.6 \times 10^{3}\,\mathrm{J\,kg^{-1}\,K^{-1}}$. The accepted value is $4.2 \times 10^{3}\,\mathrm{J\,kg^{-1}\,K^{-1}}$. The percentage difference between the students' value and the accepted value is closest to:

A. $0.95\,\%$

B. $8.7\,\%$

C. $9.5\,\%$

D. $19\,\%$

Question 19

The spring constant k of a spring, defined by $F = k\,x$, can be expressed in SI base units as:

A. $\mathrm{kg\,s^{-2}}$

B. $\mathrm{kg\,m\,s^{-2}}$

C. $\mathrm{kg\,m^{2}\,s^{-2}}$

D. $\mathrm{kg\,s^{2}}$

Question 20

An investigation reports a measured value of the acceleration due to gravity as $(9.7 \pm 0.2)\,\mathrm{m\,s^{-2}}$. Which one of the following accepted values is consistent with this result?

A. $9.2\,\mathrm{m\,s^{-2}}$

B. $10.1\,\mathrm{m\,s^{-2}}$

C. $9.4\,\mathrm{m\,s^{-2}}$

D. $9.8\,\mathrm{m\,s^{-2}}$

Practice Exam 6 — Section B

Answer **all** questions in the spaces provided. Write your responses in English. Where an answer box is provided, write your final answer in the box. If an answer box has a unit printed in it, give your answer in that unit. In questions where more than one mark is available, appropriate working **must** be shown. Take $g = 9.8\,\text{m s}^{-2}$ and $c = 3.00 \times 10^{8}\,\text{m s}^{-1}$ where required; other constants are on the formula sheet. Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1 (5 marks)

A glass prism has a refractive index of 1.70. The cross-section of the prism is a 45°–45°–90° triangle. The surrounding air has a refractive index of 1.00.

a. A ray of light in air strikes a flat face of the prism at an angle of incidence of 30°. Calculate the angle of refraction of the ray inside the glass. Give your answer in degrees. 2 marks

b. Calculate the critical angle for a glass–air boundary for this glass. Give your answer in degrees. 2 marks

c. A ray travelling inside the prism strikes another face of the prism at an angle of incidence of 45°. State what happens to the ray, and justify your answer. 1 mark

Question 2 (6 marks)

A workshop melts down a small aluminium part of mass $0.20\,\text{kg}$, initially at $20\,°\text{C}$. Aluminium has a specific heat capacity of $900\,\text{J kg}^{-1}\,°\text{C}^{-1}$, a melting point of $660\,°\text{C}$ and a latent heat of fusion of $3.9 \times 10^{5}\,\text{J kg}^{-1}$. The part is heated by a $3.0\,\text{kW}$ electric heater.

a. Show that the energy required to raise the temperature of the part from $20\,°\text{C}$ to its melting point is $1.15 \times 10^{5}\,\text{J}$ (to three significant figures). 2 marks

b. Calculate the additional energy required to melt the part once it has reached $660\,°\text{C}$. Give your answer in J. 1 mark

c. State the total energy required to heat the part from $20\,°\text{C}$ and melt it completely. Give your answer in J. 1 mark

d. Calculate the minimum time for the heater to supply this total energy. Give your answer in s, and give one reason why the actual time in the workshop would be longer. 2 marks

Question 3 (5 marks)

Human skin has a temperature of about $37\,°\text{C}$. Treat the skin as an object whose emission follows Wien's law:

$$\lambda_{max} T = 2.9 \times 10^{-3}\,\text{m K}$$

a. Convert this temperature to kelvin, and calculate the peak wavelength of the electromagnetic radiation emitted by the skin. Give your answer in m. 2 marks

b. State the region of the electromagnetic spectrum in which this wavelength lies. 1 mark

c. Explain why a person whose skin is at $37\,°\text{C}$ does not appear to glow visibly, even though the skin emits electromagnetic radiation. 2 marks

Question 4 (6 marks)

An FM radio station broadcasts at a frequency of $100\,\text{MHz}$.

a. Calculate the wavelength of these radio waves in a vacuum. Give your answer in m. 2 marks

b. State one use in society of gamma radiation. 1 mark

c. Explain why white light separates into a range of colours when it passes through a glass prism. 2 marks

d. Name the optical processes that produce a rainbow when sunlight enters water droplets in the air. 1 mark

Question 5 (4 marks)

In a decay series, a nucleus of polonium-214 ($^{214}_{84}Po$) decays by alpha emission.

a. Write the decay equation for the alpha decay of polonium-214, identifying the daughter nucleus. 2 marks

b. Describe two properties of beta-minus radiation. 1 mark

c. Explain the role of the strong nuclear force in the stability of a nucleus. 1 mark

Question 6 (5 marks)

A sample of yttrium-90, a radioisotope used in the treatment of some cancers, has a half-life of $64\,\text{h}$. At noon on Monday the sample has an activity of $4.0 \times 10^{6}\,\text{Bq}$.

a. Calculate the activity of the sample at noon on the following Tuesday. Give your answer in Bq. 2 marks

b. Calculate the fraction of the original nuclei that have decayed after $128\,\text{h}$. 1 mark

c. Yttrium-90 emits beta-minus radiation. Evaluate why yttrium-90 is well suited to treating a tumour when a small sample is placed inside the body next to the tumour. 2 marks

Question 7 (4 marks)

During a medical procedure, a tumour of mass $0.080\,\text{kg}$ absorbs $0.024\,\text{J}$ of energy from gamma radiation. The radiation weighting factor is 1 for gamma radiation and 20 for alpha radiation.

a. Calculate the absorbed dose received by the tumour. Give your answer in Gy. 1 mark

b. Calculate the equivalent dose received by the tumour from the gamma radiation. Give your answer in Sv. 1 mark

c. Calculate the equivalent dose the tumour would receive if the same absorbed dose were delivered by alpha radiation instead, and explain why an alpha source inside the body is more dangerous than the same source outside the body. 2 marks

Question 8 (3 marks)

Each fission of a uranium-235 nucleus releases $3.2 \times 10^{-11}\,\text{J}$ of energy. A small nuclear reactor releases $2.0 \times 10^{7}\,\text{J}$ of energy from fission each second.

a. Calculate the number of fissions occurring in the reactor each second. 1 mark

b. State the role of the moderator in a nuclear reactor. 1 mark

c. Use the binding energy per nucleon curve to explain why fission of uranium-235 releases energy. 1 mark

Question 9 (5 marks)

An electric bicycle has a $36\,\text{V}$ battery and a motor rated at $250\,\text{W}$. When fully charged, the battery stores $0.30\,\text{kW h}$ of energy.

a. Calculate the current supplied to the motor when it operates at its rated power. Give your answer in A. 1 mark

b. Calculate the time for which the fully charged battery can run the motor at rated power. Give your answer in hours. 2 marks

c. Calculate the total charge that passes through the motor in this time. Give your answer in C. 1 mark

d. Give one reason why the bicycle's actual range is less than this calculation suggests. 1 mark

Question 10 (6 marks)

A $12\,\text{V}$ battery of negligible internal resistance is connected to a circuit consisting of a $6.0\,\Omega$ resistor in series with a parallel combination of a $12\,\Omega$ resistor and a $4.0\,\Omega$ resistor.

a. Show that the equivalent resistance of the whole circuit is $9.0\,\Omega$. 2 marks

b. Calculate the current drawn from the battery. Give your answer in A. 1 mark

c. Calculate the current in the $4.0\,\Omega$ resistor. Give your answer in A. 2 marks

d. Calculate the total power delivered by the battery. Give your answer in W. 1 mark

Question 11 (4 marks)

A temperature alarm uses a voltage divider consisting of a thermistor (a resistor whose resistance changes with temperature) in series with a fixed $4.0\,\mathrm{k}\,\Omega$ resistor, connected across a $6.0\,\mathrm{V}$ supply. The output voltage is measured across the fixed resistor. At room temperature the resistance of the thermistor is $8.0\,\mathrm{k}\,\Omega$, and its resistance decreases as the temperature rises.

a. Calculate the output voltage at room temperature. Give your answer in V. 2 marks

b. State and explain what happens to the output voltage as the temperature rises. 1 mark

c. Name one other electronic component from this list — diode, LED, LDR, potentiometer — and state the signal or energy conversion it performs. 1 mark

Question 12 (4 marks)

A kitchen circuit is protected by a $10\,\mathrm{A}$ fuse and supplies $230\,\mathrm{V}$. A $2000\,\mathrm{W}$ kettle and a $900\,\mathrm{W}$ toaster are both plugged into this circuit.

a. Calculate the total current drawn when both appliances are operating, and state what happens to the fuse. 2 marks

b. Explain how a residual current device (RCD) protects a person who accidentally touches an active conductor. 1 mark

c. State why appliances with metal cases are connected to the earth wire. 1 mark

Question 13 (3 marks)

A student measures the current in a filament lamp at several voltages and obtains the following results.

Voltage (V)	1.0	2.0	4.0	6.0	8.0
Current (A)	0.50	0.80	1.20	1.50	1.70

a. Calculate the resistance of the lamp when the voltage across it is $6.0\,\mathrm{V}$. Give your answer in Ω. 1 mark

b. State, with a reason from the data, whether the lamp is ohmic or non-ohmic. 1 mark

c. Explain physically why the resistance of the lamp changes as the voltage increases. 1 mark

Question 14 (5 marks)

A car accelerates from rest at $3.0\,\mathrm{m\ s^{-2}}$ for $8.0\,\mathrm{s}$, then continues at constant speed for a further $12\,\mathrm{s}$. The driver then brakes in a straight line, and the car comes to rest over a distance of $50\,\mathrm{m}$.

a. Show that the speed of the car at the end of the first $8.0\,\mathrm{s}$ is $24\,\mathrm{m\ s^{-1}}$. 1 mark

b. Calculate the total distance travelled by the car. Give your answer in m. 2 marks

c. Calculate the acceleration of the car during the braking stage. Give your answer in $\mathrm{m\ s^{-2}}$. 2 marks

Question 15 (4 marks)

A crate of mass $20\,\mathrm{kg}$ is pulled along a horizontal floor by a rope that makes an angle of 25° above the horizontal. The tension in the rope is $80\,\mathrm{N}$, and a friction force of $30\,\mathrm{N}$ opposes the motion.

a. Calculate the horizontal component of the tension in the rope. Give your answer in N. 1 mark

b. Calculate the acceleration of the crate. Give your answer in $\mathrm{m\ s^{-2}}$. 2 marks

c. State, with a reason, whether the magnitude of the normal force on the crate from the floor is greater than, equal to, or less than the magnitude of the force due to gravity on the crate. 1 mark

Question 16 (4 marks)

In a crash test, a $1200\,\mathrm{kg}$ car travelling at $15\,\mathrm{m\ s^{-1}}$ strikes a rigid barrier and comes to rest in $0.50\,\mathrm{s}$.

a. Calculate the change in momentum of the car, and hence calculate the average force exerted on the car by the barrier. 2 marks

b. In a second test, the car rebounds from the barrier at $3.0\,\mathrm{m\ s^{-1}}$. State, with a reason, whether the change in momentum of the car in this test is greater than, equal to, or less than in part **a.** 1 mark

c. Use the relationship between force, time and change in momentum to explain how airbags and crumple zones reduce the risk of injury to the car's occupants. 1 mark

Question 17 (4 marks)

A pile driver (a machine that drives posts into the ground) drops a $250\,\mathrm{kg}$ mass from a height of $4.0\,\mathrm{m}$ onto the top of a vertical post.

a. Calculate the loss of gravitational potential energy of the mass as it falls. Give your answer in J. 1 mark

b. Assuming all of this energy becomes kinetic energy of the mass, calculate the speed of the mass just before it strikes the post. Give your answer in $\mathrm{m\ s^{-1}}$. 1 mark

c. In the impact, $30\,\%$ of the falling energy is transferred as useful work, driving the post $0.15\,\mathrm{m}$ into the ground. Calculate the average force exerted on the post. Give your answer in N. 2 marks

Question 18 (3 marks)

A uniform beam of length $4.0\,\mathrm{m}$ and mass $20\,\mathrm{kg}$ rests on a pivot at its centre. A crate, for which the force due to gravity is $600\,\mathrm{N}$, hangs from the beam $1.5\,\mathrm{m}$ to the left of the pivot. A worker pushes vertically down on the right-hand end of the beam to hold it level.

a. Calculate the torque about the pivot due to the crate. Give your answer in $\mathrm{N\ m}$. 1 mark

b. Calculate the downward force the worker must apply at the end of the beam to hold it level. Give your answer in N. 1 mark

c. State the two conditions that must both be satisfied for the beam to be in equilibrium. 1 mark

Question 19 (20 marks)

A student investigates how the launch speed of a cart depends on the compression of a spring. The cart has mass $0.50\,\mathrm{kg}$ and rests against the spring on a level track. The spring is compressed by a distance x and the cart is released from rest. As the cart leaves the spring, its speed v is measured by a photogate. Each compression setting is repeated three times and a mean speed is recorded. The student hypothesises that all of the elastic potential energy stored in the spring is transferred to the kinetic energy of the cart. The results are shown below.

Compression x (m)	0.020	0.040	0.060	0.080	0.100
Mean speed v ($\mathrm{m\ s^{-1}}$)	0.19	0.41	0.54	0.82	1.01

The three speed readings recorded for the setting $x = 0.060\,\mathrm{m}$ were 0.58, 0.60 and $0.44\,\mathrm{m\ s^{-1}}$.

a. Identify the independent variable, the dependent variable and one controlled variable in this investigation. 3 marks

b. Show that, if the student's hypothesis is correct, then v^2 is proportional to x^2. 2 marks

c. State the purpose of repeating each setting three times. 1 mark

d. Using the mean speeds in the table, calculate the value of v^2 for each of the five settings. 2 marks

e. Identify the anomalous reading for the setting $x = 0.060\,\mathrm{m}$, suggest one possible cause, and state how the student should respond to it. 2 marks

f. State which quantity should be plotted on the vertical axis and which on the horizontal axis to test the hypothesis, explain what feature of the graph would support the hypothesis, and state the physical meaning of the gradient. 3 marks

g. Two well-separated points on the student's line of best fit are $\left(0.0010\,\mathrm{m}^2, 0.098\,\mathrm{m}^2\,\mathrm{s}^{-2}\right)$ and $\left(0.0100\,\mathrm{m}^2, 0.98\,\mathrm{m}^2\,\mathrm{s}^{-2}\right)$. Calculate the gradient of the line of best fit. 2 marks

h. Use your gradient to determine the spring constant k of the spring. Give your answer in $\mathrm{N\,m^{-1}}$. 2 marks

i. A separate direct measurement gives the spring constant as $55\,\mathrm{N\,m^{-1}}$. Evaluate whether the student's hypothesis is supported by the investigation. 2 marks

j. State one improvement to the method that would reduce the uncertainty in the results. 1 mark

Practice Exam 6 — Formula Sheet

This formula sheet is provided for use with all practice examinations in this booklet. Part 1 reproduces, unaltered and with attribution, the items of the official VCE Physics Formula Sheet (© VCAA 2026) that lie within the Units 1 & 2 study design; items that belong to Units 3 & 4 only are omitted. Part 2 is a house supplement drawn from the key knowledge of the Units 1 & 2 study design (2023–2027): it carries the relationships that Units 1 & 2 students apply which the official sheet does not give.

Part 1 — VCE Physics Formula Sheet: Units 1 & 2 items

Motion and related energy transformations

velocity	$v=\frac{\Delta s}{\Delta t}$
acceleration	$a=\frac{\Delta v}{\Delta t}$
constant acceleration	$v=u+at$
	$s=ut+\frac{1}{2}at^2$
	$s=vt-\frac{1}{2}at^2$
	$v^2=u^2+2as$
	$s=\frac{1}{2}(u+v)t$
Newton's second law	$\Sigma F=ma$
Hooke's law	$F=-kx$
elastic potential energy	$E_s=\frac{1}{2}kx^2$
gravitational potential energy	$E_g=mg\Delta h$
kinetic energy	$E_k=\frac{1}{2}mv^2$
impulse	$F\Delta t=m\Delta v$
momentum	$p=mv$

Generation and transmission of electricity

current	$I=\frac{V}{R}$
power	$P=VI$
resistors in series	$R_T=R_1+R_2+\ldots$
resistors in parallel	$\frac{1}{R_T}=\frac{1}{R_1}+\frac{1}{R_2}+\ldots$

Waves

wave equation	$v=f\lambda$

Part 2 — Units 1 & 2 supplement

Waves and light

wavelength, frequency, period and speed	$\lambda=\frac{v}{f}=vT$

refraction (Snell's Law) $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$n_1 v_1 = n_2 v_2$

critical angle $n_1 \sin\theta_c = n_2 \sin 90^\circ$

Thermal energy

Celsius–kelvin conversion $T(\mathrm{K}) = T(°\mathrm{C}) + 273.15$

raising temperature $Q = m c \Delta T$

change of state $Q = m L$

Wien's Law $\lambda_{\max} T = \text{constant}$

Radiation from the nucleus

Provenance note (TOC §2.7): D = E/m, H = w_R × D and E = mc² do not appear on the official Units 1 & 2 formula sheet; they are included in this supplement because the Units 1 & 2 key knowledge requires dose calculations and treats mass–energy conversion qualitatively.

radioactive decay (whole half-lives) $N = N_0 \left(\frac{1}{2}\right)^n$

$n = \frac{t}{t_{1/2}}$

absorbed dose $D = \frac{E}{m}$ (unit: Gy)

equivalent dose $H = w_R \times D$ (unit: Sv)

effective dose $\Sigma\, w_T H_T$ over tissues T (unit: Sv)

Nuclear energy

mass–energy conversion $E = m c^2$

Electricity

current and charge $I = \frac{Q}{t}$

potential difference $V = \frac{E}{Q}$

power and energy $P = \frac{E}{t}$

voltage divider $V_{\text{out}} = V_{\text{in}} \times \frac{R_2}{R_1 + R_2}$

Forces, work and energy

work done by a constant force $W = F s \cos\theta$

work done area under a force–distance graph

torque $\tau = r_{\perp} F$

force due to gravity $F_{\text{on body by Earth}} = m g$

Newton's third law $F_{\text{on A by B}} = -F_{\text{on B by A}}$

change in momentum $\Delta p = F_{\text{net}} \Delta t$

efficiency $\eta = \frac{\text{useful energy out}}{\text{total energy in}}$

Data

acceleration due to gravity at Earth's surface	$g = 9.8\ \mathrm{m\ s^{-2}}$ ($9.8\ \mathrm{N\ kg^{-1}}$)
speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \mathrm{m\ s^{-1}}$
Wien's Law constant	$2.9 \times 10^{-3}\ \mathrm{m\ K}$

The Units 1 & 2 study design gives the gravitational field strength near Earth's surface as g = 9.8 N kg^{-1} *(9.8 m s*$^{-2}$*), and this is the value used throughout this booklet. The official VCE Physics Formula Sheet gives g = 9.81 m s*$^{-2}$ *for Units 3 & 4.*

Metric (SI) multipliers

pico (p)	10^{-12}	kilo (k)	10^{3}
nano (n)	10^{-9}	mega (M)	10^{6}
micro (μ)	10^{-6}	giga (G)	10^{9}
milli (m)	10^{-3}	tera (T)	10^{12}

Unit conversions

1 tonne (t)	$= 10^{3}$ kg
1 kilowatt hour (kW h)	$= 3.6 \times 10^{6}$ J

Nomenclature

force due to gravity	F_{g}
force on A by B	$F_{\text{on A by B}}$
normal force	F_{N}

End of Formula Sheet

Practice Exam 6 — solutions

Section A — answer key

Question	Answer	Question	Answer
1	A	11	B
2	C	12	B
3	D	13	C
4	C	14	C
5	A	15	B
6	B	16	D
7	D	17	B
8	D	18	C
9	A	19	A
10	B	20	D

Question 1 — A. $v = f\lambda = 512 \times 0.664 = 340\,\mathrm{m\ s^{-1}}$. B halves the result; C divides f by λ instead of multiplying ($f/\lambda = 771$); D divides λ by f ($\lambda/f = 1.3 \times 10^{-3}$).

Question 2 — C. The frequency of a wave is set by the source and does not change when the wave enters a new medium, while its speed is determined by the medium, so light slows down in glass (and its wavelength decreases). A is wrong because all electromagnetic waves travel at the same speed c in a vacuum; B is wrong because electromagnetic waves are transverse waves that need no medium (unlike sound); D is wrong because ultraviolet radiation has a shorter wavelength than infrared.

Question 3 — D. Snell's law with $n_1 = 1.00$ (air): $\sin\theta_2 = \sin 35^\circ / 1.50 = 0.382$, so $\theta_2 = 22^\circ$. A multiplies by n instead of dividing ($\sin\theta_2 = 1.50\sin 35^\circ = 0.860 \Rightarrow 59^\circ$); B gives the complement of the correct answer ($90^\circ - 22^\circ$); C assumes no refraction.

Question 4 — C. Energy supplied: $E = Pt = 60 \times 300 = 18\,000\,\mathrm{J}$. Temperature rise: $\Delta T = E/(mc) = 18\,000/(0.40 \times 900) = 50\,°\mathrm{C}$, so the final temperature is $20 + 50 = 70\,°\mathrm{C}$. A uses $t = 5.0\,\mathrm{s}$ instead of $300\,\mathrm{s}$ (final temperature about $21\,°\mathrm{C}$); B gives the temperature rise rather than the final temperature; D halves the specific heat capacity ($\Delta T = 100\,°\mathrm{C}$).

Question 5 — A. Alpha emission reduces A by 4 and Z by 2: ${}^{220}_{86}\mathrm{Rn} \rightarrow {}^{216}_{84}\mathrm{Po} + {}^{4}_{2}\mathrm{He}$. Beta-minus emission then increases Z by 1 with A unchanged: ${}^{216}_{84}\mathrm{Po} \rightarrow {}^{216}_{85}\mathrm{At}$. B decreases Z in the second step (confusing β^- with β^+); C stops after the alpha decay; D omits the alpha decay altogether.

Question 6 — B. 36 days is three half-lives, so the fraction remaining is $(1/2)^3 = 1/8$ and the fraction that have decayed is $1 - 1/8 = 7/8$. A gives the fraction remaining rather than the fraction decayed; C and D come from miscounting the number of half-lives.

Question 7 — D. Absorbed dose $D = E/m = 0.020/4.0 = 0.005\,\mathrm{Gy}$; equivalent dose $H = w_R \times D = 20 \times 0.005 = 0.10\,\mathrm{Sv}$. A uses $w_R = 1$ (the gamma value); B gives the equivalent-dose value, but with the unit for absorbed dose (Gy instead of Sv); C calculates $D = E \times m = 0.08\,\mathrm{Gy}$ before multiplying by 20.

Question 8 — D. The energy transferred is $E = QV = 900 \times 12 = 10\,800\,\mathrm{J} = 10.8\,\mathrm{kJ}$. A multiplies charge by time ($Qt = 270\,000$); B calculates the power $P = VI = 36\,\mathrm{W}$ but treats it as an energy; C divides V by Q.

Question 9 — A. Parallel combination: $R_p = (20 \times 30)/(20 + 30) = 12\,\Omega$; total resistance $R_T = 12 + 8.0 = 20\,\Omega$; current $I = V/R_T = 10/20 = 0.50\,\mathrm{A}$. B treats all three resistors as being in series ($58\,\Omega$); C ignores the series $8.0\,\Omega$ resistor ($10/12 = 0.83\,\mathrm{A}$); D treats all three as being in parallel ($4.8\,\Omega$, giving $2.1\,\mathrm{A}$).

Question 10 — B. 45 minutes is $0.75\,\mathrm{h}$, so $E = P\,t = 2.4 \times 0.75 = 1.8\,\mathrm{kW\,h}$; cost $= 1.8 \times \$0.30 = \$0.54$. A writes 45 minutes as $0.45\,\mathrm{h}$ ($\$0.32$); C multiplies the power by the rate without the time (2.4×0.30); D treats 45 minutes as 45 hours ($2.4 \times 45 \times 0.30 \approx \$32$).

Question 11 — B. $V_{\mathrm{out}} = V_{\mathrm{in}} \times R_2 / (R_1 + R_2) = 12 \times 2.0 / (4.0 + 2.0) = 4.0\,\mathrm{V}$. A halves the correct value; C gives half the supply voltage (ignoring the unequal resistances); D calculates the voltage across the $4.0\,\mathrm{k\,\Omega}$ resistor instead ($8.0\,\mathrm{V}$).

Question 12 — B. Household circuits are wired in parallel, so each appliance has the full $230\,\mathrm{V}$ across it. A is wrong because the appliances are in parallel, not series; C is wrong because adding a parallel branch lowers the equivalent resistance; D is wrong because the currents depend on the appliances' power ratings, which differ.

Question 13 — C. First stage: $s_1 = 1/2\,a\,t^2 = 1/2 \times 2.0 \times 6.0^2 = 36\,\mathrm{m}$, reaching $v = a\,t = 12\,\mathrm{m\,s^{-1}}$. Braking stage: $s_2 = v^2 / (2 \times 3.0) = 144 / 6 = 24\,\mathrm{m}$. Total $= 36 + 24 = 60\,\mathrm{m}$. A gives the braking distance only; B the first stage only; D uses $s_2 = v\,t = 48\,\mathrm{m}$, omitting the factor of $1/2$.

Question 14 — C. Net force $\Sigma F = 26 - 10 = 16\,\mathrm{N}$, so $a = \Sigma F / m = 16 / 4.0 = 4.0\,\mathrm{m\,s^{-2}}$. A ignores friction entirely ($26 / 4.0 = 6.5$); B uses the friction force alone ($10 / 4.0 = 2.5$); D adds the two forces ($(26 + 10) / 4.0 = 9.0$).

Question 15 — B. Momentum is conserved: $0.30 \times 4.0 = (0.30 + 0.50)\,v$, so $v = 1.2 / 0.80 = 1.5\,\mathrm{m\,s^{-1}}$. Kinetic energy before: $1/2 \times 0.30 \times 4.0^2 = 2.4\,\mathrm{J}$; after: $1/2 \times 0.80 \times 1.5^2 = 0.9\,\mathrm{J}$; lost $= 1.5\,\mathrm{J}$. A gives the final kinetic energy; C the initial kinetic energy; D wrongly assumes kinetic energy is conserved (momentum is conserved, but in an inelastic collision the total kinetic energy decreases).

Question 16 — D. $W = F\,s \cos\theta = 50 \times 20 \times \cos 30^\circ = 866\,\mathrm{J}$. A uses $\cos 60^\circ$ ($433\,\mathrm{J}$); B ignores the angle ($1000\,\mathrm{J}$); C uses $\sin 30^\circ$, the vertical component, which does no work along the ground ($500\,\mathrm{J}$).

Question 17 — B. Percentage uncertainty $= \dfrac{0.5}{24.0} \times 100\,\% = 2.1\,\%$. A quotes the absolute uncertainty as if it were already a percentage; C moves the decimal point one place too far ($0.5 / 24.0$ evaluated as 0.21); D inverts the ratio ($24.0 / 0.5 = 48$).

Question 18 — C. Percentage difference $= \dfrac{|4.6 \times 10^3 - 4.2 \times 10^3|}{4.2 \times 10^3} \times 100\,\% = \dfrac{0.4 \times 10^3}{4.2 \times 10^3} \times 100\,\% = 9.5\,\%$. A moves the decimal point one place too far; B uses the students' value as the denominator ($0.4 / 4.6 = 8.7\,\%$); D doubles the numerator before dividing.

Question 19 — A. $k = \dfrac{F}{x}$, so its units are $\dfrac{\mathrm{N}}{\mathrm{m}}$. With $1\,\mathrm{N} = 1\,\mathrm{kg\,m\,s^{-2}}$, this gives $\dfrac{\mathrm{kg\,m\,s^{-2}}}{\mathrm{m}} = \mathrm{kg\,s^{-2}}$. B is the newton (a force); C is the joule (an energy); D inverts the power of the metre incorrectly.

Question 20 — D. The result $(9.7 \pm 0.2)\,\mathrm{m\,s^{-2}}$ represents the range 9.5–$9.9\,\mathrm{m\,s^{-2}}$. Only $9.8\,\mathrm{m\,s^{-2}}$ lies inside this range; 9.2, 9.4 and $10.1\,\mathrm{m\,s^{-2}}$ all fall outside it.

Section B — worked solutions

Question 1 (5 marks)

a. (2 marks) Snell's law, $n_1 \sin\theta_1 = n_2 \sin\theta_2$, with $n_1 = 1.00$ (air) and $n_2 = 1.70$ [1]:

$$\sin\theta_2 = \frac{\sin 30^\circ}{1.70} = \frac{0.500}{1.70} = 0.294\,,\theta_2 = 17^\circ\,[1].$$

b. (2 marks) At the critical angle the refracted ray runs along the boundary ($\theta_2 = 90^\circ$), so $n_1 \sin\theta_c = n_2 \sin 90^\circ$ with $n_1 = 1.70$ (glass) and $n_2 = 1.00$ (air) [1]:

$$\sin\theta_c = \frac{1.00}{1.70} = 0.588\,,\theta_c = 36^\circ[1].$$

c. (1 mark) The angle of incidence (45°) is greater than the critical angle (36°), and the ray is travelling in the denser medium (glass) towards the less dense medium (air), so the ray undergoes total internal reflection — it does not emerge, and is turned through 90°.

Question 2 (6 marks)

a. (2 marks) The temperature rise to the melting point is $\Delta T = 660 - 20 = 640\,°\mathrm{C}$ [1]:

$$Q = m\,c\,\Delta T = 0.20 \times 900 \times 640 = 115\,200\,\mathrm{J} = 1.15 \times 10^5\,\mathrm{J}\,(3\text{ s.f.})\,,\text{as required}[1].$$

b. (1 mark)

$$Q = m\,L = 0.20 \times 3.9 \times 10^5 = 7.8 \times 10^4\,\mathrm{J}\,.$$

c. (1 mark) Total energy $= 115\,200 + 78\,000 = 193\,200\,\mathrm{J} \approx 1.9 \times 10^5\,\mathrm{J}$.

d. (2 marks) Using $P = E/t$ [1]:

$$t = \frac{E}{P} = \frac{193\,200}{3000} = 64.4\,\mathrm{s} \approx 64\,\mathrm{s}[1].$$

The actual time would be longer because some of the heater's energy is transferred to the surroundings (the air, the container and the heater itself) rather than to the aluminium.

Question 3 (5 marks)

a. (2 marks) Temperature in kelvin: $T = 37 + 273 = 310\,\mathrm{K}$ [1]. Wien's law, $\lambda_{\mathrm{max}}T = 2.9 \times 10^{-3}\,\mathrm{m\ K}$:

$$\lambda_{\mathrm{max}} = \frac{2.9 \times 10^{-3}}{310} = 9.4 \times 10^{-6}\,\mathrm{m}[1].$$

b. (1 mark) Infrared.

c. (2 marks) At $310\,\mathrm{K}$ the radiation peaks in the infrared, well away from the visible region of the spectrum [1]. The intensity of visible wavelengths emitted at this temperature is extremely small — objects need temperatures of thousands of kelvin before they emit enough visible light to be seen glowing [1].

Question 4 (6 marks)

a. (2 marks) $f = 100\,\mathrm{MHz} = 1.0 \times 10^8\,\mathrm{Hz}$ [1]; using $v = f\,\lambda$ with $v = c$:

$$\lambda = \frac{c}{f} = \frac{3.00 \times 10^8}{1.0 \times 10^8} = 3.0\,\mathrm{m}[1].$$

b. (1 mark) Any one: treating cancer (destroying tumour cells); sterilising medical equipment; killing bacteria in food.

c. (2 marks) White light is a mixture of colours, and each colour has a different frequency and wavelength [1]. In glass, the different colours travel at slightly different speeds, so each colour refracts (bends) by a different amount — violet bends the most and red the least — and the colours separate (dispersion) [1].

d. (1 mark) Refraction and dispersion of the sunlight as it enters each droplet, followed by internal reflection inside the droplet (and refraction again as it leaves).

Question 5 (4 marks)

a. (2 marks) In alpha emission the mass number decreases by 4 and the atomic number by 2 [1]: ${}^{214}_{84}\mathrm{Po} \rightarrow {}^{210}_{82}\mathrm{Pb} + {}^{4}_{2}\mathrm{He}\,[1]$. The daughter nucleus is lead-210 (${}^{210}_{82}\mathrm{Pb}$).

b. (1 mark) Any two: it is a fast-moving electron emitted from the nucleus; it carries a charge of -1; it is moderately penetrating (stopped by a few millimetres of aluminium); it is moderately ionising.

c. (1 mark) The strong nuclear force attracts protons and neutrons to one another over very short distances inside the nucleus, holding the nucleus together against the electrostatic repulsion between the positively charged protons.

Question 6 (5 marks)

a. (2 marks) From noon on Monday to noon on the following Tuesday is $192\,\mathrm{h}$, which is three half-lives ($192/64=3$) [1]. The activity halves each half-life:

$$A=\frac{4.0\times10^{6}}{2\times2\times2}=5.0\times10^{5}\,\mathrm{Bq}\,[1].$$

b. (1 mark) $128\,\mathrm{h}$ is two half-lives, so the fraction remaining is $(1/2)^2=1/4$; the fraction that have decayed is $1-1/4=3/4$.

c. (2 marks) Any two points, 1 mark each: beta-minus radiation is moderately penetrating and ionising, so it deposits its energy over a short range (a few millimetres) in and around the tumour, damaging the tumour cells while largely sparing more distant healthy tissue; its half-life ($64\,\mathrm{h}$) is long enough for the sample to be prepared and placed, but short enough that the activity falls away quickly after the treatment.

Question 7 (4 marks)

a. (1 mark)

$$D=\frac{E}{m}=\frac{0.024}{0.080}=0.30\,\mathrm{Gy}.$$

b. (1 mark)

$$H=w_R\times D=1\times0.30=0.30\,\mathrm{Sv}.$$

c. (2 marks) For alpha radiation [1]:

$$H=w_R\times D=20\times0.30=6.0\,\mathrm{Sv}\,[1].$$

An alpha source inside the body is more dangerous because alpha radiation is strongly ionising but poorly penetrating: outside the body it is stopped by the outer dead layer of skin, but inside the body it deposits all of its energy in nearby living cells.

Question 8 (3 marks)

a. (1 mark)

$$N=\frac{2.0\times10^{7}}{3.2\times10^{-11}}=6.25\times10^{17}\approx6.3\times10^{17}\,\text{fissions per second}.$$

b. (1 mark) The moderator slows down the neutrons released in fission so that they are more likely to cause further fissions, sustaining the chain reaction.

c. (1 mark) Uranium-235 has a lower binding energy per nucleon than the medium-mass nuclei it splits into, so the fission fragments are more tightly bound; the increase in binding energy per nucleon means energy is released in the fission.

Question 9 (5 marks)

a. (1 mark)

$$I=\frac{P}{V}=\frac{250}{36}=6.9\,\mathrm{A}.$$

b. (2 marks) Convert the stored energy: $E = 0.30 \times 3.6 \times 10^6 = 1.08 \times 10^6$ J [1]. Using $P = E / t$:

$$t = \frac{E}{P} = \frac{1.08 \times 10^6}{250} = 4320\,\text{s} = 1.2\,\text{h}\,[1].$$

c. (1 mark) Using $I = Q / t$:

$$Q = I\,t = \frac{250}{36} \times 4320 = 30\,000\,\text{C} = 3.0 \times 10^4\,\text{C}.$$

d. (1 mark) Any one: some of the battery's energy is dissipated as heat in the motor and wiring (no motor is $100\,\%$ efficient); riding uphill or into wind or rough surfaces takes extra energy; the battery's internal resistance wastes energy.

Question 10 (6 marks)

a. (2 marks) Parallel combination [1]:

$$R_p = \frac{12 \times 4.0}{12 + 4.0} = \frac{48}{16} = 3.0\,\Omega,$$

so the equivalent resistance of the circuit is [1]

$$R_T = 6.0 + 3.0 = 9.0\,\Omega\text{, as required}.$$

b. (1 mark)

$$I = \frac{V}{R_T} = \frac{12}{9.0} = 1.33\,\text{A}.$$

c. (2 marks) The potential difference across the parallel combination is [1]

$$V_p = I\,R_p = 1.33 \times 3.0 = 4.0\,\text{V},$$

and this same potential difference is across the $4.0\,\Omega$ resistor, so [1]

$$I_{4.0} = \frac{4.0}{4.0} = 1.0\,\text{A}.$$

d. (1 mark)

$$P = V\,I = 12 \times 1.33 = 16\,\text{W}.$$

Question 11 (4 marks)

a. (2 marks) Using the voltage divider relationship with the output across the fixed resistor [1]:

$$V_{\text{out}} = V_{\text{in}} \times \frac{R_2}{R_1 + R_2} = 6.0 \times \frac{4.0}{8.0 + 4.0} = 2.0\,\text{V}\,[1].$$

b. (1 mark) The output voltage rises: as the temperature rises the thermistor's resistance falls, so its share of the supply voltage falls and the fixed resistor's share (the output voltage) rises.

c. (1 mark) Any one: an LED converts electrical energy into light; an LDR converts light intensity into a change of resistance; a diode converts an alternating signal into a one-way current (allows current in one direction only); a potentiometer converts a position into a change of resistance (variable voltage divider).

Question 12 (4 marks)

a. (2 marks) Total power $= 2000 + 900 = 2900\,\text{W}$; using $P = V\,I$ [1]:

$$I = \frac{2900}{230} = 12.6\,\text{A} > 10\,\text{A}\,,$$

so the fuse melts ("blows") and the circuit is disconnected [1].

b. (1 mark) An RCD continuously compares the current in the active wire with the current in the neutral wire; if a person touches an active conductor, some current flows through the person to earth, the two currents become unequal, and the RCD trips the circuit within milliseconds — far faster than a fuse.

c. (1 mark) The earth wire provides a low-resistance path from the metal case to the ground: if an active conductor touches the case, a large fault current flows through the earth wire and quickly blows the fuse (or trips the circuit breaker), instead of the case remaining active and shocking the next person who touches it.

Question 13 (3 marks)

a. (1 mark)

$$R = \frac{V}{I} = \frac{6.0}{1.50} = 4.0\,\Omega\,.$$

b. (1 mark) The lamp is non-ohmic: the ratio V / I is not constant (the resistance rises from $2.0\,\Omega$ at $1.0\,\text{V}$ to $4.7\,\Omega$ at $8.0\,\text{V}$), so the current is not proportional to the voltage.

c. (1 mark) As the current increases, the filament heats up, and the higher temperature of the filament increases its resistance.

Question 14 (5 marks)

a. (1 mark) Using $v = u + a\,t$ with $u = 0$:

$$v = 0 + 3.0 \times 8.0 = 24\,\text{m s}^{-1}\text{, as required}\,.$$

b. (2 marks) Accelerating stage: $s_1 = 1/2\,a\,t^2 = 1/2 \times 3.0 \times 8.0^2 = 96\,\text{m}$. Constant-speed stage: $s_2 = v\,t = 24 \times 12 = 288\,\text{m}$ [1]. Total distance:

$$s = 96 + 288 + 50 = 434\,\text{m}\,[\,1\,]\,.$$

c. (2 marks) Using $v^2 = u^2 + 2\,a\,s$ with $u = 24\,\text{m s}^{-1}$, $v = 0$ and $s = 50\,\text{m}$ [1]:

$$0 = 24^2 + 2\,a\,(50) \Rightarrow a = -\frac{576}{100} = -5.8\,\text{m s}^{-2}\,[\,1\,]\,.$$

(The negative sign shows the acceleration opposes the motion, as expected while braking.)

Question 15 (4 marks)

a. (1 mark)

$$F_{\text{horizontal}} = 80 \cos 25^{\circ} = 72.5\,\text{N}\,.$$

b. (2 marks) Net horizontal force [1]:

$$\Sigma\,F = 72.5 - 30 = 42.5\,\text{N}\,;$$

using $\Sigma\,F = m\,a$ [1]:

$$a = \frac{42.5}{20} = 2.1\,\text{m s}^{-2}\,.$$

c. (1 mark) The normal force is **less than** the force due to gravity: the rope pulls upward on the crate with a vertical component ($80\sin 25^\circ = 34\,\mathrm{N}$), so the floor does not need to support the crate's full load ($F_N = mg - 34 = 196 - 34 = 162\,\mathrm{N}$).

Question 16 (4 marks)

a. (2 marks) Taking the car's original direction as positive, the change in momentum is [1]

$$\Delta p = m\Delta v = 1200 \times (0 - 15) = -18\,000\,\mathrm{kg\ m\ s^{-1}},$$

of magnitude $1.8 \times 10^4\,\mathrm{kg\ m\ s^{-1}}$. Using $F\Delta t = m\Delta v = \Delta p$, the average force on the car is [1]

$$F = \frac{\Delta p}{\Delta t} = \frac{18\,000}{0.50} = 36\,000\,\mathrm{N} = 3.6 \times 10^4\,\mathrm{N},$$

directed opposite to the car's original motion.

b. (1 mark) Greater. If the car rebounds at $3.0\,\mathrm{m\ s^{-1}}$, its velocity changes from $+15$ to $-3.0\,\mathrm{m\ s^{-1}}$, a change of $18\,\mathrm{m\ s^{-1}}$, compared with $15\,\mathrm{m\ s^{-1}}$ when it simply stops — so the change in momentum is larger.

c. (1 mark) For the same change in momentum, $F = \Delta p / \Delta t$ shows that a longer stopping time gives a smaller average force; airbags and crumple zones increase the time over which an occupant (or the car) is brought to rest, which reduces the force on the occupant.

Question 17 (4 marks)

a. (1 mark)

$$\Delta E_g = mg\Delta h = 250 \times 9.8 \times 4.0 = 9800\,\mathrm{J}.$$

b. (1 mark) With $\Delta E_g = E_k = 1/2\,mv^2$:

$$v = \sqrt{\frac{2 \times 9800}{250}} = \sqrt{78.4} = 8.9\,\mathrm{m\ s^{-1}}.$$

c. (2 marks) Useful work $= 30\,\%$ of $9800\,\mathrm{J}$ [1]:

$$W = 0.30 \times 9800 = 2940\,\mathrm{J};$$

using $W = Fs$ with $s = 0.15\,\mathrm{m}$ [1]:

$$F = \frac{2940}{0.15} = 19\,600\,\mathrm{N} \approx 2.0 \times 10^4\,\mathrm{N}.$$

Question 18 (3 marks)

a. (1 mark)

$$\tau = r_\perp F = 1.5 \times 600 = 900\,\mathrm{N\ m},\ \text{anticlockwise}.$$

b. (1 mark) For rotational equilibrium the worker's clockwise torque must balance the crate's anticlockwise torque. The worker acts at the end of the beam, $2.0\,\mathrm{m}$ from the pivot:

$$F = \frac{900}{2.0} = 450\,\mathrm{N}.$$

(The beam's own force due to gravity acts at its centre, directly above the pivot, so it produces no torque about the pivot.)

c. (1 mark) The net force on the beam must be zero (translational equilibrium) and the net torque about any point must be zero (rotational equilibrium).

Question 19 (20 marks)

a. (3 marks) Independent variable: the compression x of the spring [1]. Dependent variable: the launch speed v of the cart [1]. Controlled variable — any one: the mass of the cart (the same cart is used); the same spring; the same photogate position; the level track; releasing the cart from rest each time [1].

b. (2 marks) The elastic potential energy stored in the spring is $E_s = 1/2\,k\,x^2$ and the kinetic energy of the cart is $E_k = 1/2\,m\,v^2$ [1]. If all of the stored energy is transferred to the cart,

$$1/2\,k\,x^2 = 1/2\,m\,v^2 \Rightarrow v^2 = \frac{k}{m}x^2,$$

and since k and m are constant, v^2 is proportional to x^2 [1].

c. (1 mark) Repeating each setting reduces the effect of random error on the mean and allows anomalous readings to be identified.

d. (2 marks) Squaring each mean speed [1]: $0.19^2 = 0.036$, $0.41^2 = 0.17$, $0.54^2 = 0.29$, $0.82^2 = 0.67$, $1.01^2 = 1.0$, all in $\mathrm{m^2\,s^{-2}}$ [1].

e. (2 marks) The anomalous reading is $0.44\ \mathrm{m\ s^{-1}}$, which sits well below the other two (0.58 and $0.60\ \mathrm{m\ s^{-1}}$) [1]. A possible cause is that the spring was not fully compressed before release (or the photogate was triggered too early / the cart ran with extra friction); the student should investigate and repeat that setting rather than silently discarding the reading [1].

f. (3 marks) Plot v^2 on the vertical axis and x^2 on the horizontal axis [1]. The hypothesis predicts $v^2 = (k/m)x^2$, so a straight line of best fit passing through (or very close to) the origin would support it [1]. The gradient of the line equals k/m — the spring constant divided by the mass of the cart [1].

g. (2 marks) Using the two stated points on the line of best fit (not data points) [1]:

$$\text{gradient} = \frac{0.98 - 0.098}{0.0100 - 0.0010} = \frac{0.882}{0.0090} = 98\ \mathrm{s^{-2}}\,[1].$$

h. (2 marks) Since gradient $= k/m$, [1]

$$k = \text{gradient} \times m = 98 \times 0.50 = 49\ \mathrm{N\ m^{-1}}\,[1].$$

i. (2 marks) The value obtained from the launch data ($49\ \mathrm{N\ m^{-1}}$) is lower than the directly measured spring constant ($55\ \mathrm{N\ m^{-1}}$), meaning the measured values of v^2 are systematically smaller than the hypothesis predicts [1]. Some of the energy stored in the spring is not transferred to the cart's kinetic energy — for example, energy remains as kinetic energy of the spring itself or is dissipated by friction and sound — so the hypothesis is not fully supported [1].

j. (1 mark) Any one: reduce friction (e.g. use a smoother track or an air track) so more of the spring's energy reaches the cart; increase the number of repeats at each setting; measure the compression with a more precise scale; check the photogate position so the speed is always measured at the same point.