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National
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SPECIMEN ONLY

Mark

S857/76/01

Physics
Paper 2

Date — Not applicable

Duration — 2 hours 15 minutes

S8577601

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day | Month | Year

Scottish candidate number

Total marks — 130

Attempt ALL questions.

You may use a calculator.

Reference may be made to the data sheet on *page 02* of this booklet and to the relationships sheet S857/76/11.

Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. Score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

SQA ©

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}\ \text{m s}^{-1}$	Planck's constant	h	$6{\cdot}63 \times 10^{-34}\ \text{J s}$
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}\ \text{C}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\ \text{kg}$
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}\ \text{m}^3\ \text{kg}^{-1}\ \text{s}^{-2}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\ \text{kg}$
Gravitational acceleration on Earth	g	$9{\cdot}8\ \text{m s}^{-2}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\ \text{kg}$
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}\ \text{s}^{-1}$			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550 }	Infrared
	10 590 }	
Helium-neon	633	Red

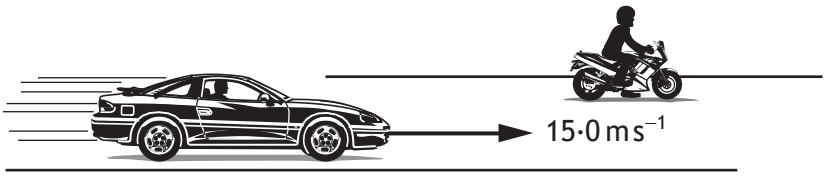
PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/kg m^{-3}	*Melting point*/K	*Boiling point*/K
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	. . . .
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	. . . .	. . . .
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

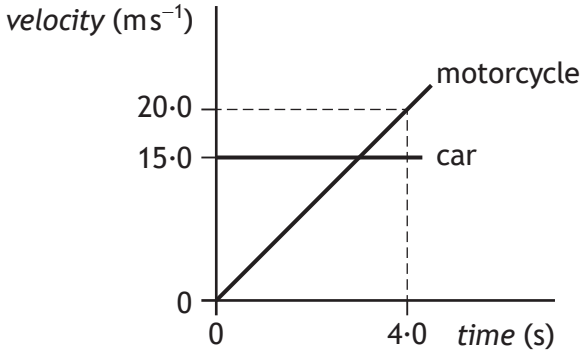
1. A car is travelling at a constant speed of $15{\cdot}0\,m\,s^{-1}$ along a straight, level road.

It passes a motorcycle, which is stationary at the roadside.



At the instant the car passes, the motorcycle starts to move in the same direction as the car.

The graph shows the motion of each vehicle from the instant the car passes the motorcycle.



(a) Calculate the initial acceleration of the motorcycle. **3**

Space for working and answer

(b) Determine the distance between the car and motorcycle at 4·0 s. **4**

Space for working and answer

MARKS

DO NOT WRITE IN THIS MARGIN

(c) The total mass of the motorcycle and rider is 290 kg. At a time of 2·0 s the driving force on the motorcycle is 1800 N.

(i) Determine the frictional force acting on the motorcycle at this time. **4**

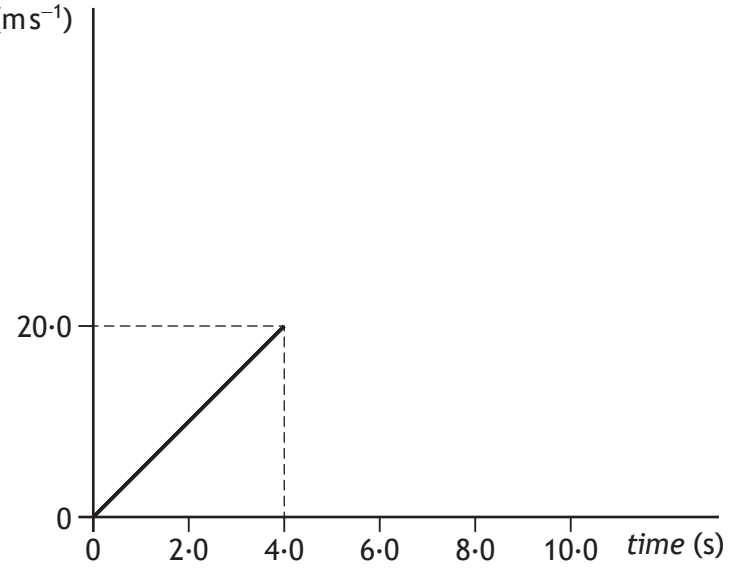
Space for working and answer

(ii) Explain why the driving force must be increased with time to maintain a constant acceleration. **2**

1. (continued)

(d) The driving force on the motorcycle reaches its maximum value at 5·0 s and then remains constant.

The velocity-time graph for the motorcycle during the first 4·0 s is shown below.



Extend the graph to show how the velocity of the motorcycle varies between 4·0 s and 10·0 s.

Additional numerical values on the velocity axis are **not** required. **1**

(An additional graph, if required, can be found on *page 42*.)

[Turn over

2. When a car brakes kinetic energy is turned into heat and sound.

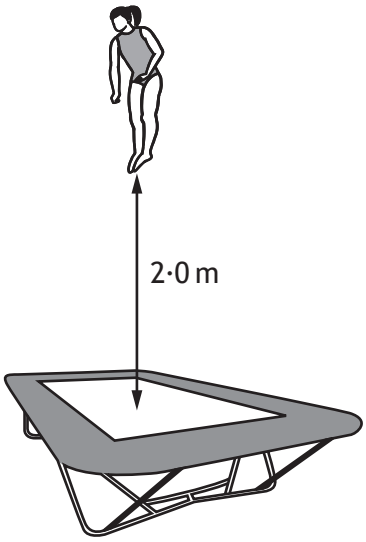
In order to make cars more efficient some manufacturers have developed kinetic energy recovery systems (KERS). These systems store some of the energy that would otherwise be lost as heat and sound.

Estimate the maximum energy that could be stored in such a system when a car brakes.

Cleary show your working for the calculation and any estimates you have made. **4**

Space for working and answer

3. (a) A gymnast of mass 42 kg is practising on a trampoline.



(i) At maximum height the gymnast's feet are 2·0 m above the trampoline.

Show that the speed of the gymnast, as they land on the trampoline, is 6·3 m s^{-1}. **2**

Space for working and answer

(ii) The gymnast rebounds with a speed of 5·3 m s^{-1}.

Calculate the magnitude of the change in momentum of the gymnast. **3**

Space for working and answer

3. (a) (continued)

(iii) The gymnast was in contact with the trampoline for 0·50 s.

Calculate the magnitude of the average force exerted by the trampoline on the gymnast. **3**

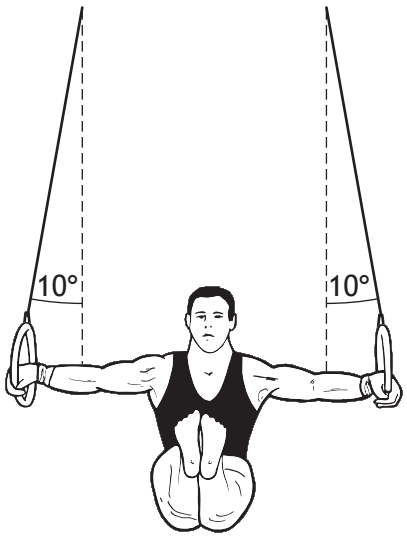
Space for working and answer

MARKS

DO NOT WRITE IN THIS MARGIN

(b) Another gymnast is practising on a piece of equipment called the rings. The gymnast grips two wooden rings suspended above the gym floor by strong vertical ropes as shown.

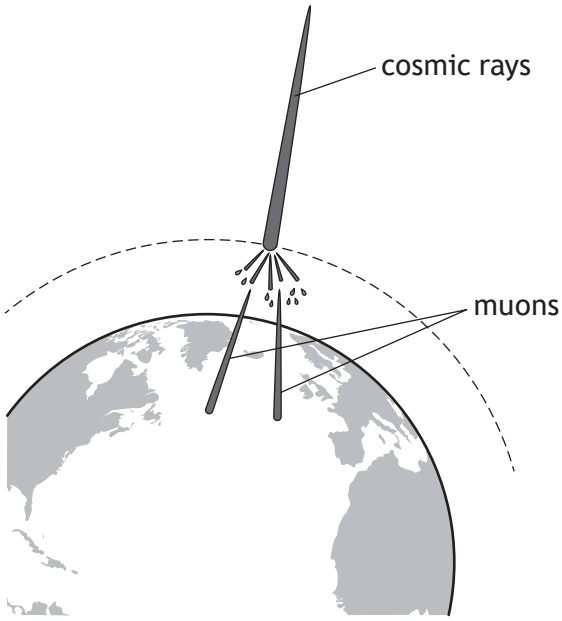
The gymnast now stretches out their arms until each rope makes an angle of 10° with the vertical as shown.



Explain why the tension in each rope increases as the gymnast stretches out their arms. **2**

[Turn over

4. Muons are sub-atomic particles produced when cosmic rays enter the atmosphere about 10 km above the surface of the Earth.



Muons have a mean lifetime of $2{\cdot}2 \times 10^{-6}$ s in their frame of reference. Muons are travelling at $0{\cdot}995c$ relative to an observer on Earth.

(a) Show that the mean distance travelled by the muons in their frame of reference is 660 m. **2**

Space for working and answer

(b) Calculate the mean lifetime of the muons measured by an observer on Earth.

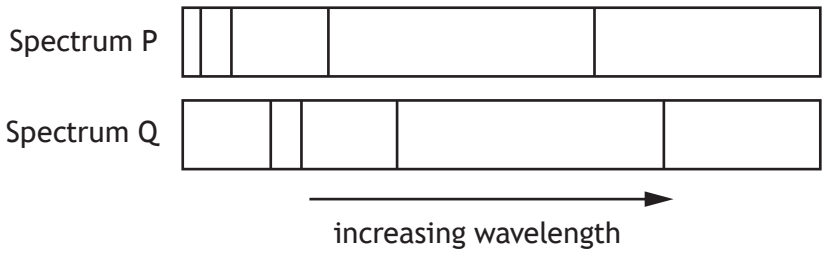
Space for working and answer **3**

4. (continued)

(c) Explain why a greater number of muons are detected on the surface of the Earth than would be expected if relativistic effects were not taken into account. **1**

[Turn over

5. (a) The diagram below represents part of the emission spectrum for the element hydrogen.



Spectrum P is from a laboratory source.

Spectrum Q shows the equivalent lines from a distant galaxy as observed on the Earth.

(i) Explain why the lines on spectrum Q are in a different position to those on spectrum P. **2**

(ii) One of the lines in spectrum P has a wavelength of 656 nm. The equivalent line in spectrum Q is measured to have a wavelength of 676 nm.

Determine the recessional velocity of the galaxy. **5**

Space for working and answer

5. (continued)

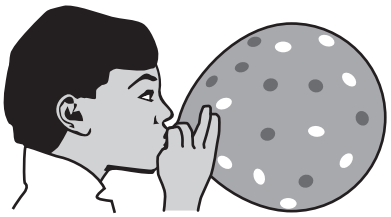
(b) The recessional velocity of another distant galaxy is $1{\cdot}2 \times 10^7\ m\,s^{-1}$.

Calculate the approximate distance to this galaxy. **3**

Space for working and answer

(c) A student explains the expansion of the Universe using an 'expanding balloon model'.

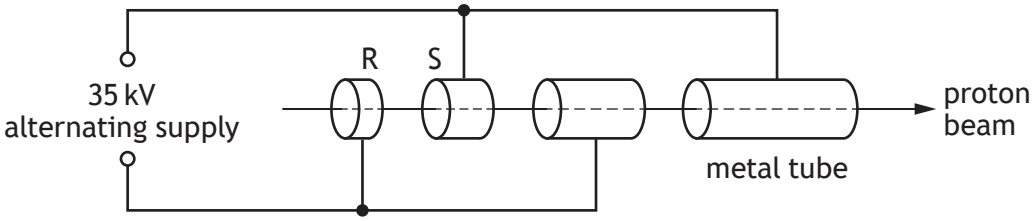
The student draws 'galaxies' on a balloon and then inflates it.



Using your knowledge of physics, comment on this model. **3**

6. A linear accelerator is used to accelerate protons.

The accelerator consists of hollow metal tubes placed in a vacuum.



The diagram shows the path of the protons through the accelerator.

Protons are accelerated across the gaps between the tubes by a potential difference of 35 kV.

(a) The protons are travelling at $1{\cdot}2 \times 10^{6}\ \text{m s}^{-1}$ at point R.

(i) Show that the work done on a proton as it accelerates from R to S is $5{\cdot}6 \times 10^{-15}$ J. **2**

Space for working and answer

(ii) Determine the speed of the proton as it reaches S. **5**

Space for working and answer

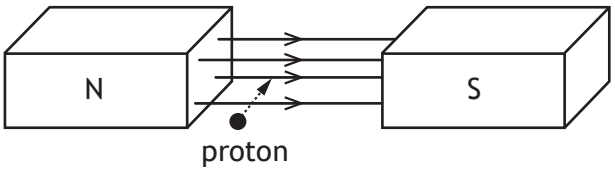
6. (continued)

(b) (i) Explain why an alternating supply is used in the linear accelerator. **1**

(ii) Suggest one reason why the lengths of the tubes increase along the accelerator. **1**

(c) In the Large Hadron Collider (LHC) beams of hadrons travel in opposite directions inside a circular accelerator and then collide. The accelerating particles are guided along the collider using strong magnetic fields.

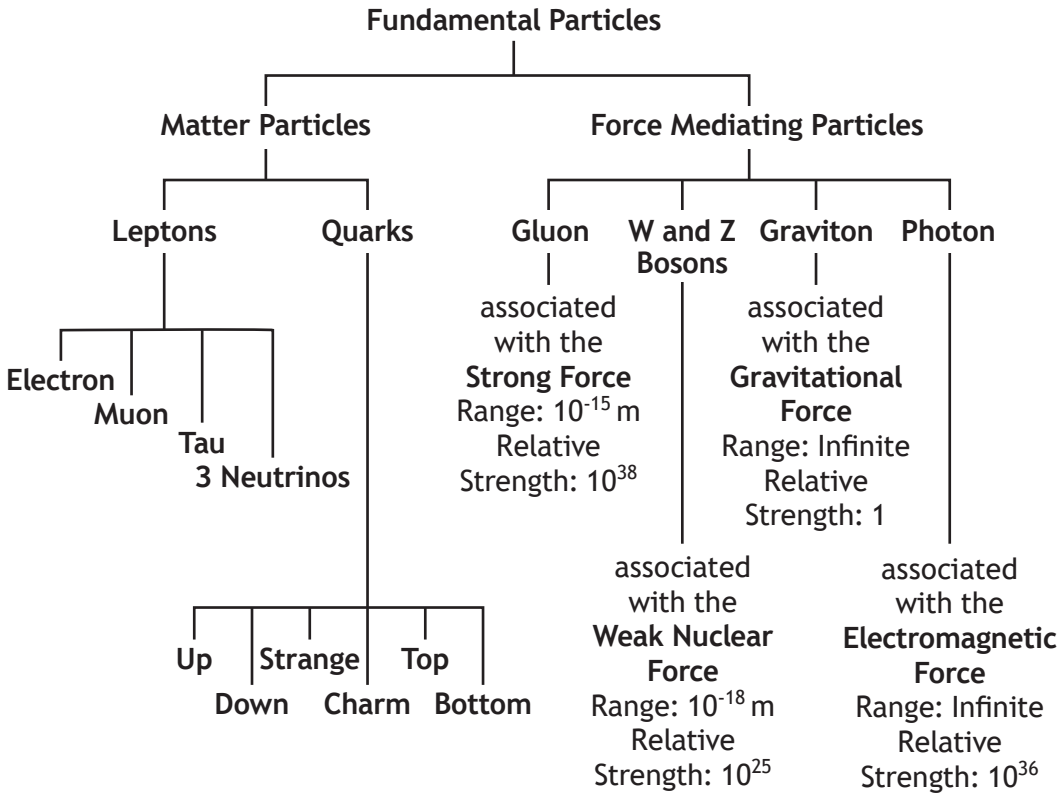
The diagram shows a proton entering a magnetic field.



In which direction is this proton initially deflected? **1**

[Turn over

7. The following diagram gives information about the Standard Model of fundamental particles and interactions.



Use information from the diagram and your knowledge of the Standard Model to answer the following questions.

(a) Explain why particles such as leptons and quarks are known as *fundamental particles*. **1**

(b) A particle called the sigma plus (Σ^+) has a charge of $+1e$. It contains two different types of quark. It has two up quarks each having a charge of $+\frac{2}{3}e$ and one strange quark.

Determine the charge on the strange quark. **1**

7. (continued)

(c) Explain why the gluon cannot be the force mediating particle for the gravitational force. **2**

(d) Compare the relative strength of the strong force with the weak nuclear force in terms of orders of magnitude. **1**

(e) A neutron decays into a proton, an electron and an antineutrino.

The equation for this decay is

$$ {}^{1}_{0}\mathrm{n} \rightarrow {}^{1}_{1}\mathrm{p} + {}^{0}_{-1}\mathrm{e} + \bar{\nu}_e $$

State the name of this type of decay. **1**

[Turn over

8. The following statement represents a fusion reaction.

$$4\,{}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + 2\,{}^{0}_{1}\mathrm{e}^{+}$$

The masses of the particles involved in the reaction are shown in the table.

Particle	*Mass* (kg)
${}^{1}_{1}\mathrm{H}$	$1{\cdot}673 \times 10^{-27}$
${}^{4}_{2}\mathrm{He}$	$6{\cdot}646 \times 10^{-27}$
${}^{0}_{1}\mathrm{e}^{+}$	negligible

(a) Calculate the energy released in this reaction. **4**

Space for working and answer

8. (continued)

(b) Calculate the energy released when 0·20 kg of hydrogen is converted to helium by this reaction. **3**

Space for working and answer

(c) Fusion reactors are being developed that use this type of reaction as an energy source.

Explain why this type of fusion reaction is hard to sustain in these reactors. **1**

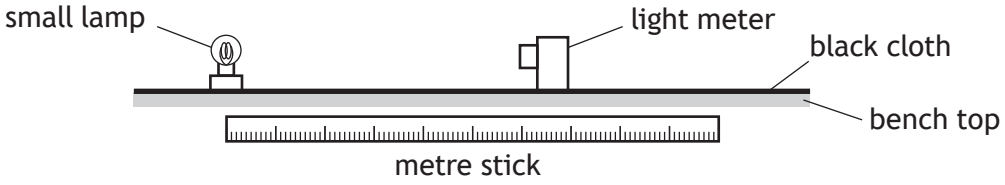
[Turn over

9. A student carries out an experiment to investigate how irradiance on a surface varies with distance from a small lamp.

Irradiance is measured using a light meter.

The distance between the small lamp and the light meter is measured with a metre stick.

The apparatus is set up in a darkened laboratory as shown.



The following results are obtained.

Distance from source (m)	0·200	0·300	0·400	0·500
Irradiance (units)	672	302	170	110

(a) State what is meant by the term *irradiance*. **1**

(b) Use **all** the data to find the relationship between irradiance I and distance d from the source.

You may wish to use the square-ruled paper on *page 37*. **3**

Space for working and answer

9. (continued)

(c) Suggest the purpose of the black cloth placed on top of the bench in the experimental setup. **1**

(d) The small lamp is replaced by a laser.

Light from the laser is shone onto the light meter.

A reading is taken from the light meter when the distance between the light meter and the laser is 0·200 m.

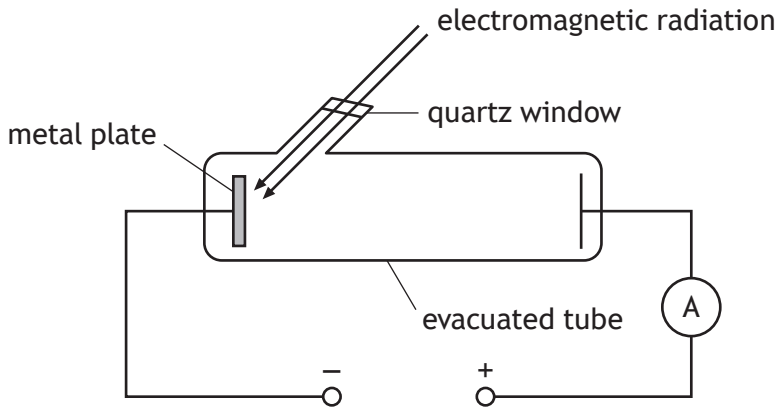
The distance is now increased to 0·500 m.

The reading on the light meter does not change.

Suggest why the reading on the light meter does not change. **1**

[Turn over

10. A metal plate emits electrons when certain wavelengths of electromagnetic radiation are incident on it.



The work function of the metal is $2{\cdot}24 \times 10^{-19}$ J.

(a) Electrons are released when electromagnetic radiation of wavelength 525 nm is incident on the surface of the metal plate.

(i) Show that the energy of each photon of the incident radiation is $3{\cdot}79 \times 10^{-19}$ J. **4**

Space for working and answer

(ii) Determine the maximum kinetic energy of an electron released from the surface of the metal plate. **1**

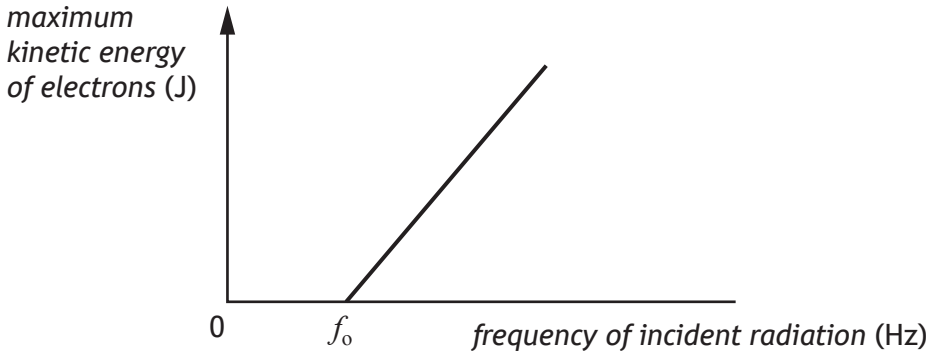
Space for working and answer

10. (continued)

(b) The frequency of the incident radiation in now varied through a range of values.

The maximum kinetic energy of electrons leaving the metal plate is determined for each frequency.

A graph of this maximum kinetic energy against frequency is shown.



(i) Explain why no electrons leave the metal plate when the frequency of the incident radiation is below f_0. **1**

(ii) Calculate the frequency f_0. **3**

Space for working and answer

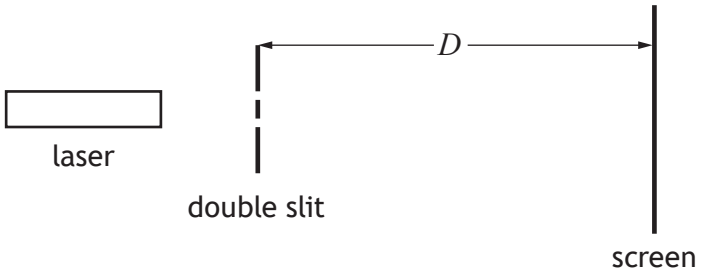
10. (continued)

(c) The use of analogies from everyday life can help better understanding of physics concepts. Throwing different balls at a coconut shy to dislodge a coconut is an analogy that can help understanding of the photoelectric effect .

Use your knowledge of physics to comment on this analogy. **3**

11. A helium-neon laser produces a beam of monochromatic light.

A student directs this laser beam onto a double slit arrangement as shown in the diagram.



A pattern of bright red fringes is observed on the screen.

(a) Explain, in terms of waves, why bright red fringes are produced. **1**

[Turn over

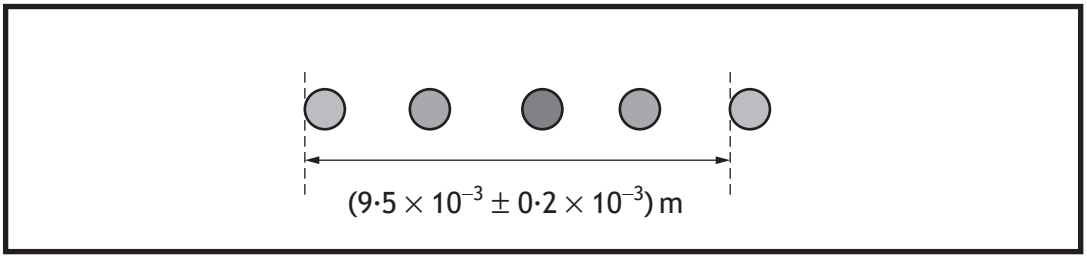
11. (continued)

(b) The average separation Δx between adjacent fringes is given by the relationship

$$\Delta x = \frac{\lambda D}{d}$$

where: λ is the wavelength of the light
D is the distance between the double slit and the screen
d is the distance between the two slits

The diagram shows the value measured by the student of the distance between a series of fringes and the uncertainty in this measurement.



The student measures the distance D between the double slit and the screen as $(0{\cdot}750 \pm 0{\cdot}001)$ m.

(i) Calculate the best estimate of the distance between the two slits.

An uncertainty in the calculated value is not required. **3**

Space for working and answer

11. (b) (continued)

(ii) The student wishes to determine more precisely the value of the distance between the two slits d.

Show, by calculation, which of the student's measurements should be taken more precisely in order to achieve this.

You must indicate clearly which measurement you have identified. **3**

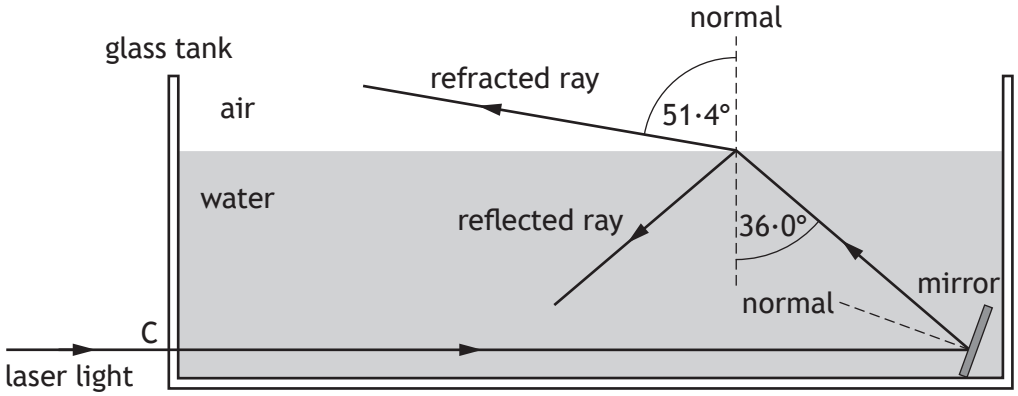
Space for working and answer

(c) The helium-neon laser is replaced by a laser emitting green light. No other changes are made to the experimental set-up.

Explain the effect this change has on the separation of the fringes observed on the screen. **2**

[Turn over

12. A technician investigates the path of laser light as it passes through a glass tank filled with water. The light enters the glass tank along the normal at **C** then reflects off a mirror submerged in the water.



not to scale

(a) Show that the refractive index of water for this laser light is 1·33. **2**

Space for working and answer

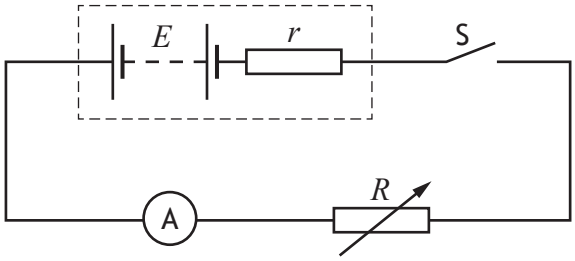
(b) The mirror is now adjusted until the light strikes the surface of the water at the critical angle.

(i) State what is meant by the *critical angle*. **1**

(ii) Calculate the critical angle for this light in the water. **3**

Space for working and answer

13. The following circuit is used to determine the internal resistance r of a battery of EMF E.

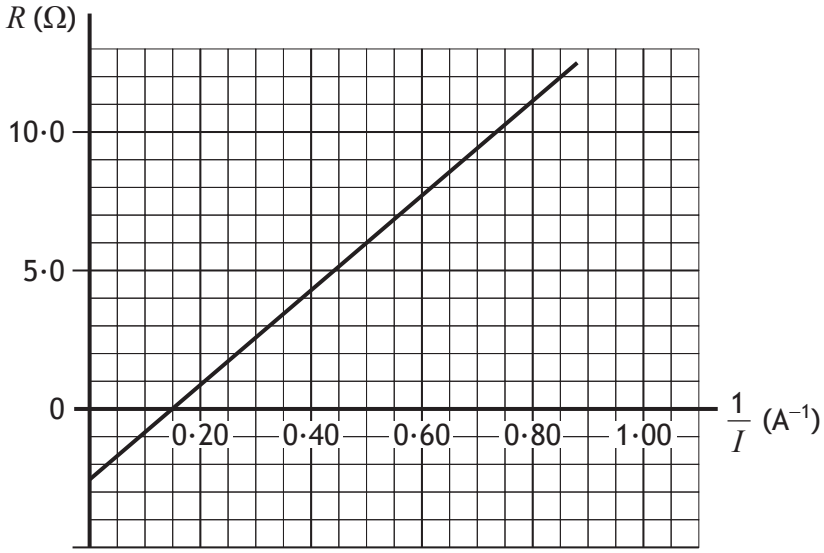


The variable resistor provides known values of resistance R.

For each value of resistance R the switch S is closed and the current I is noted.

For each current, the value of $\frac{1}{I}$ is calculated.

In one such experiment, the following graph of R against $\frac{1}{I}$ is obtained.



Conservation of energy applied to the complete circuit gives the following relationship.

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

This relationship is in the form of the equation of a straight line

$$y = mx + c$$

where m is the gradient and c is the y-intercept.

13. (continued)

(a) Use information from the graph to determine:

(i) the internal resistance of the battery **1**

(ii) the EMF of the battery. **2**

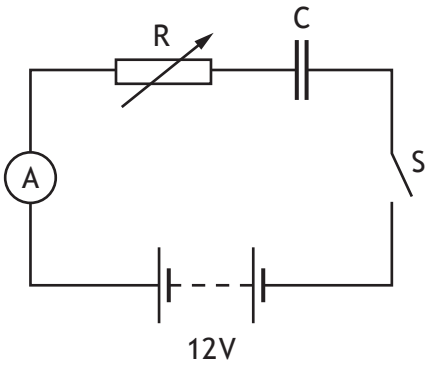
Space for working and answer

(b) The battery is accidentally short-circuited.
Calculate the current in the battery when this happens. **3**

Space for working and answer

14. A 220 μF capacitor is charged using the circuit shown.

The 12 V battery has negligible internal resistance.



The capacitor is initially uncharged.

The switch S is closed. The charging current is kept constant at $3{\cdot}0 \times 10^{-5}$ A by adjusting the resistance of variable resistor R.

(a) Calculate the resistance of the variable resistor R just after the switch is closed. **3**

Space for working and answer

(b) (i) Calculate the charge on the capacitor 25 s after switch S is closed. **3**

Space for working and answer

14. (b) (continued)

(ii) Calculate the potential difference across R at this time. **4**

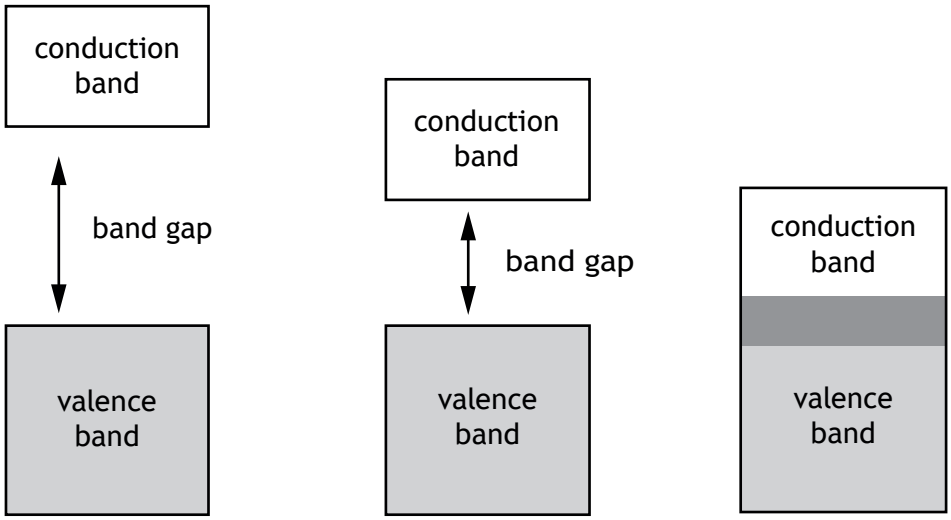
Space for working and answer

15. The electrical conductivity of solids can be explained using band theory.

The diagrams below show the distributions of the valence and conduction bands of materials classified as conductors, insulators and semiconductors.

Shaded areas represent bands occupied by electrons.

The band gap is also indicated.



Material 1 **Material 2** **Material 3**

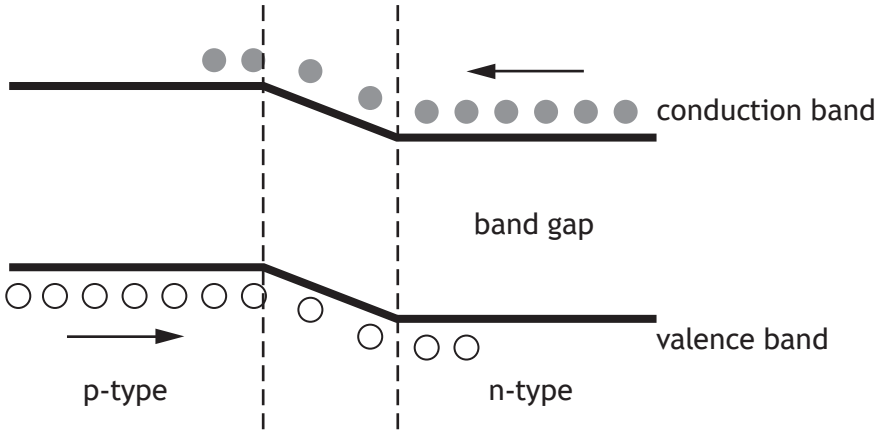
(a) State which material is a semiconductor. **1**

[Turn over

15. (continued)

(b) An LED is made from semiconductor material that has been doped with impurities to create a p-n junction.

The diagram represents the band structure of an LED.

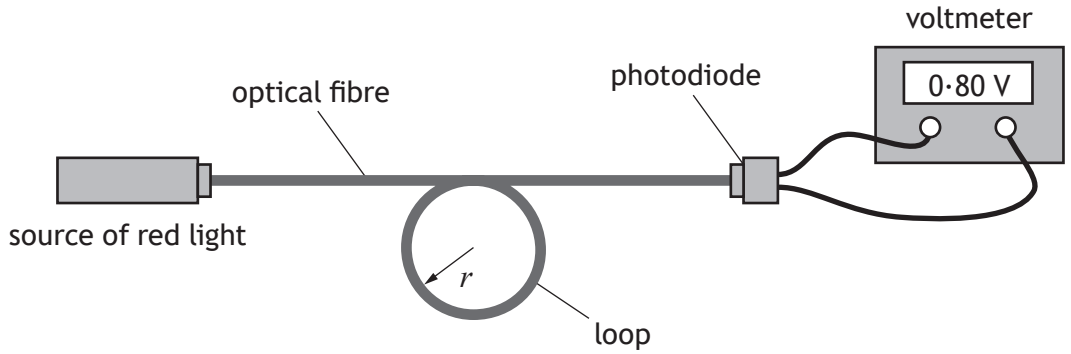


A voltage is applied across an LED so that it is forward biased and emits light.

Using **band theory**, explain how the LED emits light. **3**

16. A group of students carries out an experiment to investigate the transmission of light through an optical fibre.

Red light is transmitted through a loop of optical fibre and detected by a photodiode connected to a voltmeter as shown.



The photodiode produces a voltage proportional to the irradiance of light incident on it.

The students vary the radius, r, of the loop of the optical fibre and measure the voltage produced by the photodiode.

The results are shown in the table.

Radius of loop (mm)	*Voltage* (V)
5	0·48
10	0·68
15	0·76
20	0·79
30	0·80
40	0·80

(a) Using the square-ruled paper provided on *page 38*, draw a graph of these results. **3**

[Turn over

16. (continued)

(b) For use in communication systems, the amount of light transmitted through a loop of optical fibre must be at least 75% of the value of the fibre with no loop.

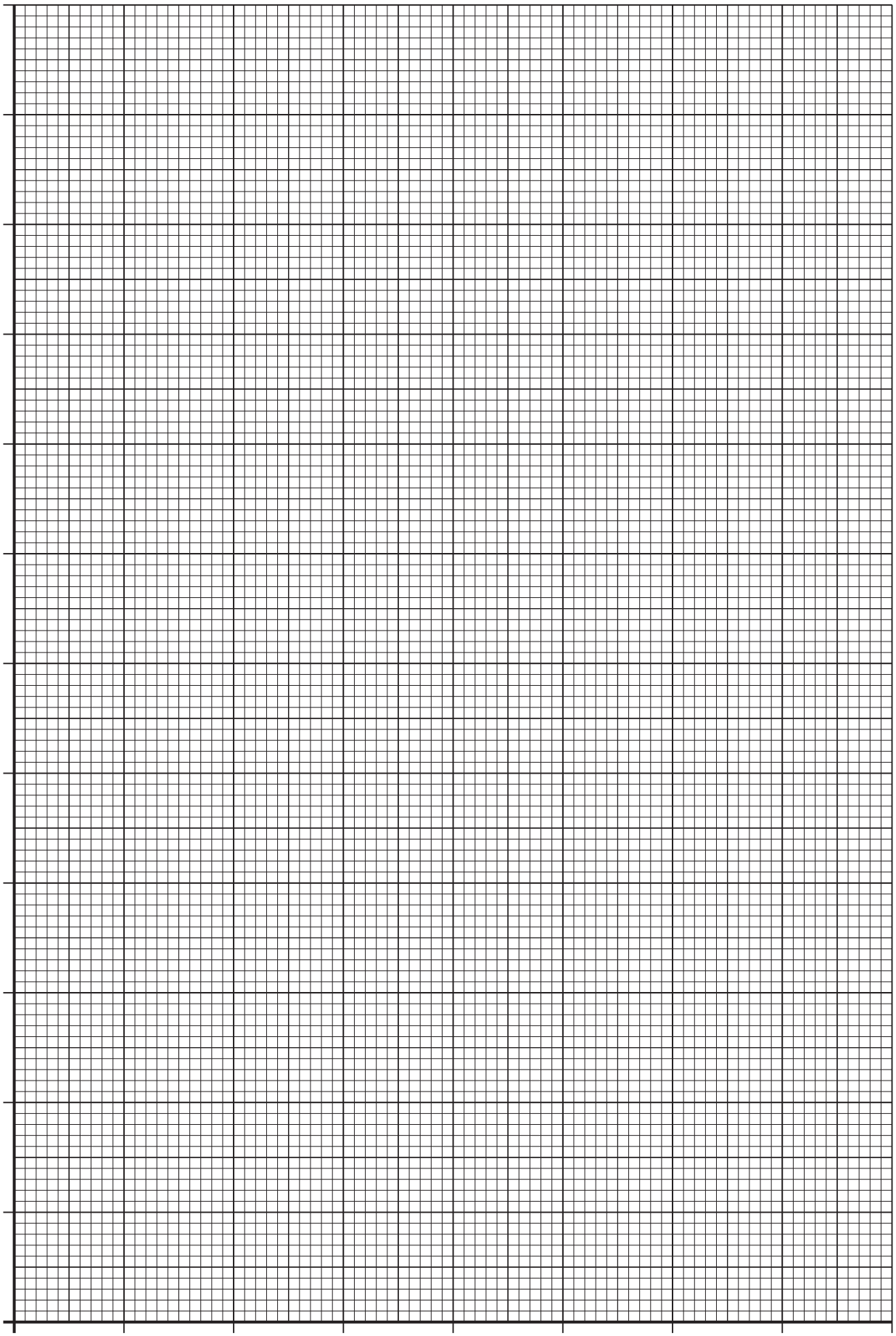
With no loop in this fibre the reading on the voltmeter is 0·80 V.

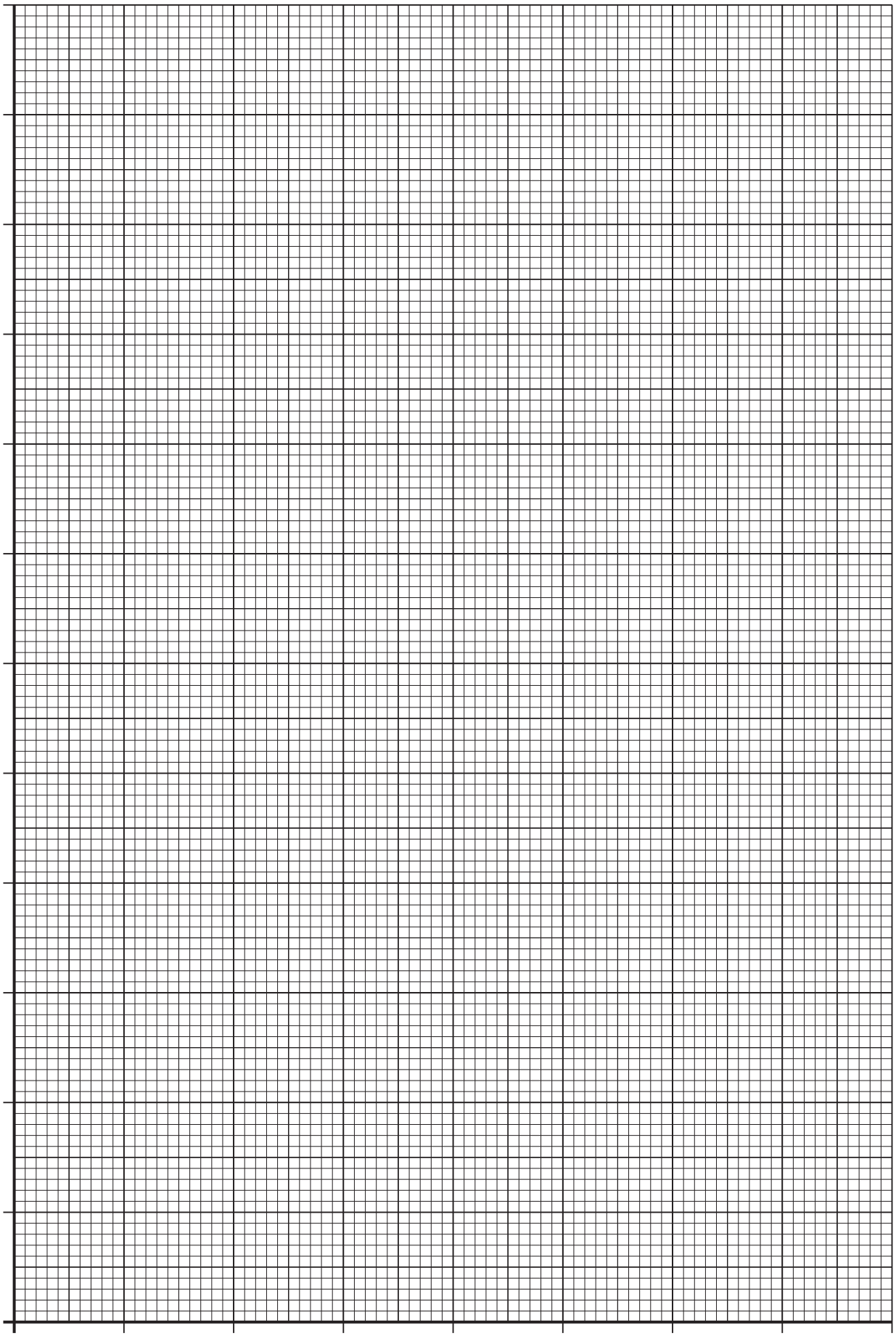
Use your graph to estimate the minimum radius of loop when using this fibre in communication systems. **1**

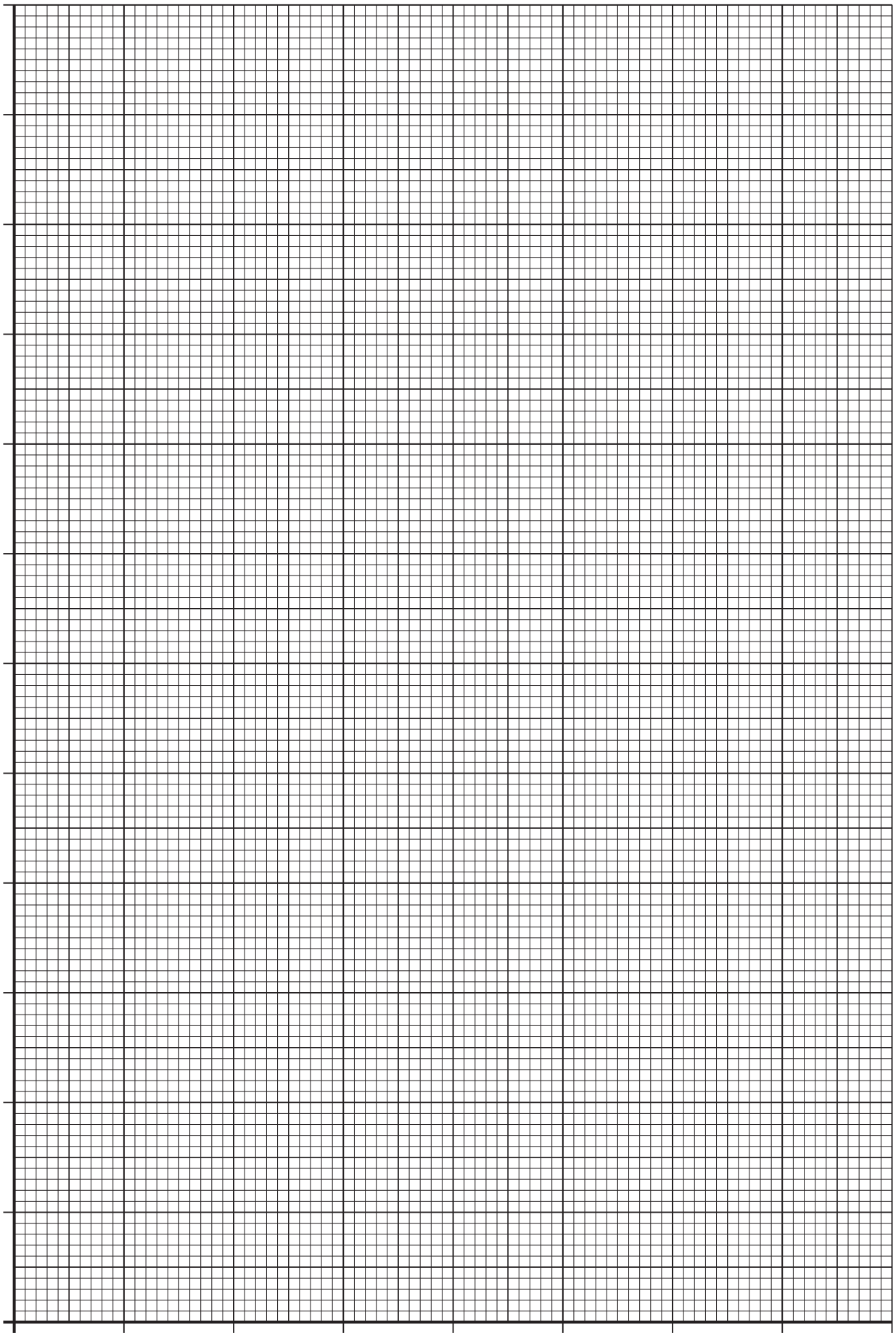
(c) Using the same apparatus, the students now wish to determine a better estimate of the true value of minimum radius of loop when using this fibre in communication systems.

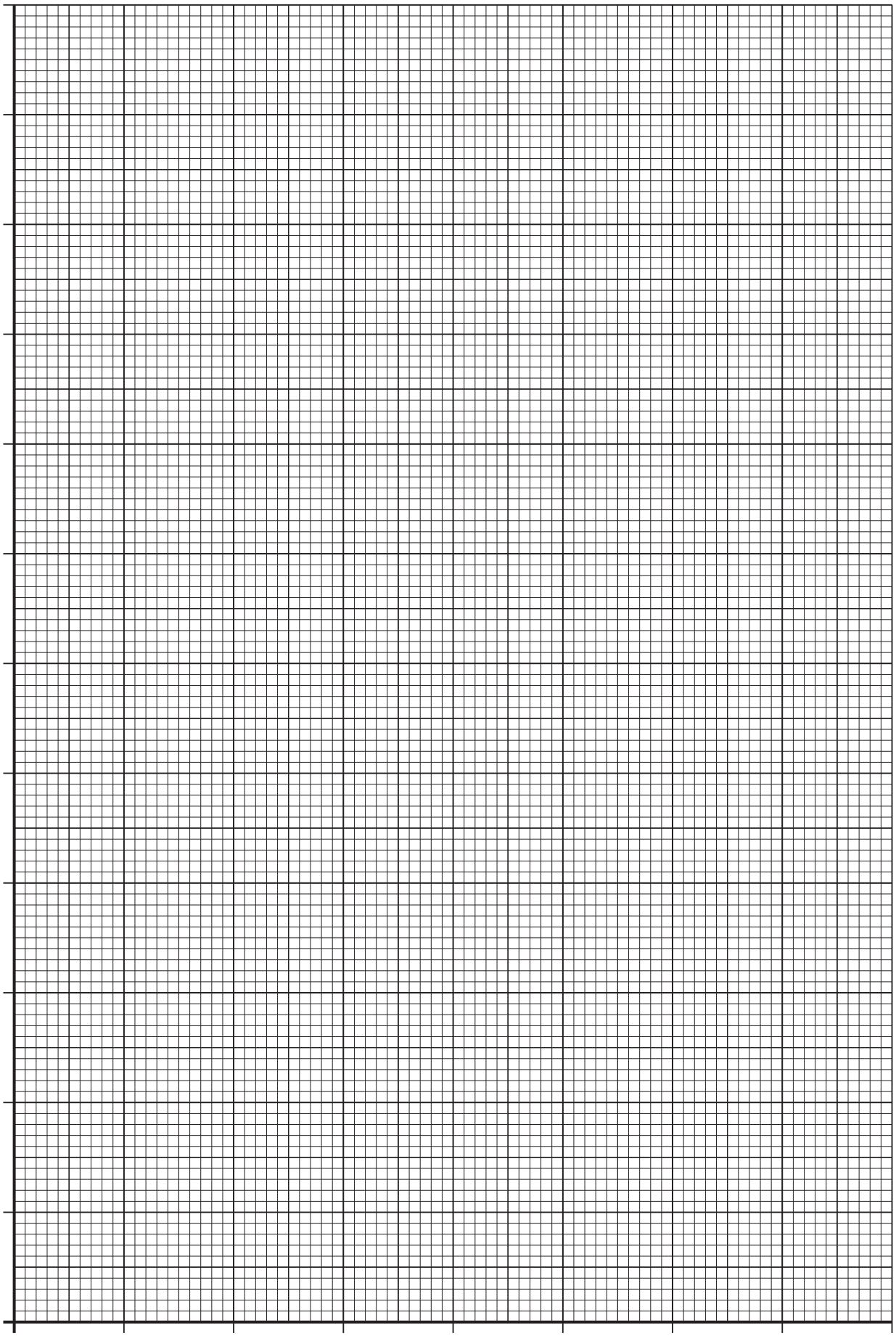
Suggest **two** improvements to the experimental procedure that would achieve this. **2**

[END OF SPECIMEN QUESTION PAPER]



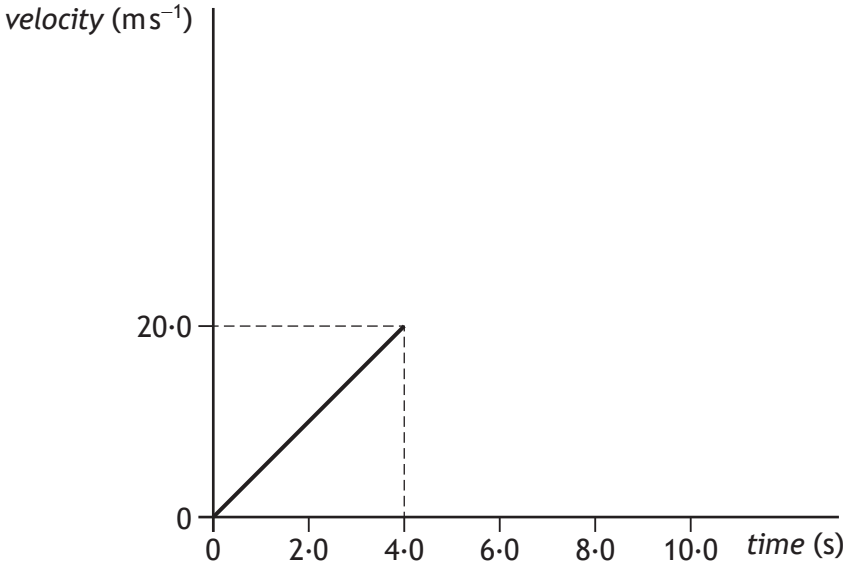






ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional graph for use with Question 1 (d)



ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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Physics
Paper 2 — Relationships sheet

Date — Not applicable

S8577611

Relationships required for Physics Higher

$d = \bar{v}t$

$s = \bar{v}t$

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

$s = \frac{1}{2}(u + v)t$

$F = ma$

$W = mg$

$E_w = Fd$, or $W = Fd$

$E_p = mgh$

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

$P = \dfrac{E}{t}$

$p = mv$

$Ft = mv - mu$

$F = G\dfrac{m_1 m_2}{r^2}$

$t' = \dfrac{t}{\sqrt{1 - \left(\dfrac{v}{c}\right)^2}}$

$l' = l\sqrt{1 - \left(\dfrac{v}{c}\right)^2}$

$f_o = f_s\left(\dfrac{v}{v \pm v_s}\right)$

$z = \dfrac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$

$z = \dfrac{v}{c}$

$v = H_0 d$

$W = QV$

$E = mc^2$

$I = \dfrac{P}{A}$

$I = \dfrac{k}{d^2}$

$I_1 d_1^2 = I_2 d_2^2$

$E = hf$

$E_k = hf - hf_0$

$v = f\lambda$

$E_2 - E_1 = hf$

$d \sin\theta = m\lambda$

$n = \dfrac{\sin\theta_1}{\sin\theta_2}$

$\dfrac{\sin\theta_1}{\sin\theta_2} = \dfrac{\lambda_1}{\lambda_2} = \dfrac{v_1}{v_2}$

$\sin\theta_c = \dfrac{1}{n}$

$V_{rms} = \dfrac{V_{peak}}{\sqrt{2}}$

$I_{rms} = \dfrac{I_{peak}}{\sqrt{2}}$

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

$V = IR$

$P = IV = I^2R = \dfrac{V^2}{R}$

$R_T = R_1 + R_2 + \ldots$

$\dfrac{1}{R_T} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

$V_1 = \left(\dfrac{R_1}{R_1 + R_2}\right)V_S$

$\dfrac{V_1}{V_2} = \dfrac{R_1}{R_2}$

$E = V + Ir$

$C = \dfrac{Q}{V}$

$Q = It$

$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\dfrac{Q^2}{C}$

path difference $= m\lambda$ or $\left(m + \frac{1}{2}\right)\lambda$ where $m = 0, 1, 2\ldots$

$$\textit{random uncertainty} = \frac{\textit{max. value} - \textit{min. value}}{\textit{number of values}}$$

or

$\Delta R = \dfrac{R_{\max} - R_{\min}}{n}$

Additional relationships

Circle

circumference $= 2\pi r$

area $= \pi r^2$

Sphere

area $= 4\pi r^2$

volume $= \frac{4}{3}\pi r^3$

Trigonometry

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$\sin^2\theta + \cos^2\theta = 1$$

Electron arrangements of elements

Group 1 (1)	Group 2 (2)	Group 3 (13)	Group 4 (14)	Group 5 (15)	Group 6 (16)	Group 7 (17)	Group 0 (18)
1 **H** 1 Hydrogen							2 **He** 2 Helium
3 **Li** 2,1 Lithium	4 **Be** 2,2 Beryllium	5 **B** 2,3 Boron	6 **C** 2,4 Carbon	7 **N** 2,5 Nitrogen	8 **O** 2,6 Oxygen	9 **F** 2,7 Fluorine	10 **Ne** 2,8 Neon
11 **Na** 2,8,1 Sodium	12 **Mg** 2,8,2 Magnesium	13 **Al** 2,8,3 Aluminium	14 **Si** 2,8,4 Silicon	15 **P** 2,8,5 Phosphorus	16 **S** 2,8,6 Sulfur	17 **Cl** 2,8,7 Chlorine	18 **Ar** 2,8,8 Argon
19 **K** 2,8,8,1 Potassium	20 **Ca** 2,8,8,2 Calcium	31 **Ga** 2,8,18,3 Gallium	32 **Ge** 2,8,18,4 Germanium	33 **As** 2,8,18,5 Arsenic	34 **Se** 2,8,18,6 Selenium	35 **Br** 2,8,18,7 Bromine	36 **Kr** 2,8,18,8 Krypton
37 **Rb** 2,8,18,8,1 Rubidium	38 **Sr** 2,8,18,8,2 Strontium	49 **In** 2,8,18, 18,3 Indium	50 **Sn** 2,8,18, 18,4 Tin	51 **Sb** 2,8,18, 18,5 Antimony	52 **Te** 2,8,18, 18,6 Tellurium	53 **I** 2,8,18, 18,7 Iodine	54 **Xe** 2,8,18, 18,8 Xenon
55 **Cs** 2,8,18,18, 8,1 Caesium	56 **Ba** 2,8,18,18, 8,2 Barium	81 **Tl** 2,8,18, 32,18,3 Thallium	82 **Pb** 2,8,18, 32,18,4 Lead	83 **Bi** 2,8,18, 32,18,5 Bismuth	84 **Po** 2,8,18, 32,18,6 Polonium	85 **At** 2,8,18, 32,18,7 Astatine	86 **Rn** 2,8,18, 32,18,8 Radon
87 **Fr** 2,8,18,32, 18,8,1 Francium	88 **Ra** 2,8,18,32, 18,8,2 Radium						

Key

Atomic number
Symbol
Electron arrangement
Name

Transition elements

(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
21 **Sc** 2,8,9,2 Scandium	22 **Ti** 2,8,10,2 Titanium	23 **V** 2,8,11,2 Vanadium	24 **Cr** 2,8,13,1 Chromium	25 **Mn** 2,8,13,2 Manganese	26 **Fe** 2,8,14,2 Iron	27 **Co** 2,8,15,2 Cobalt	28 **Ni** 2,8,16,2 Nickel	29 **Cu** 2,8,18,1 Copper	30 **Zn** 2,8,18,2 Zinc
39 **Y** 2,8,18,9,2 Yttrium	40 **Zr** 2,8,18, 10,2 Zirconium	41 **Nb** 2,8,18, 12,1 Niobium	42 **Mo** 2,8,18,13, 1 Molybdenum	43 **Tc** 2,8,18,13, 2 Technetium	44 **Ru** 2,8,18,15, 1 Ruthenium	45 **Rh** 2,8,18,16, 1 Rhodium	46 **Pd** 2,8,18, 18,0 Palladium	47 **Ag** 2,8,18, 18,1 Silver	48 **Cd** 2,8,18, 18,2 Cadmium
57 **La** 2,8,18,18, 9,2 Lanthanum	72 **Hf** 2,8,18,32, 10,2 Hafnium	73 **Ta** 2,8,18, 32,11,2 Tantalum	74 **W** 2,8,18,32, 12,2 Tungsten	75 **Re** 2,8,18,32, 13,2 Rhenium	76 **Os** 2,8,18,32, 14,2 Osmium	77 **Ir** 2,8,18,32, 15,2 Iridium	78 **Pt** 2,8,18,32, 17,1 Platinum	79 **Au** 2,8,18, 32,18,1 Gold	80 **Hg** 2,8,18, 32,18,2 Mercury
89 **Ac** 2,8,18,32, 18,9,2 Actinium	104 **Rf** 2,8,18,32, 32,10,2 Rutherfordium	105 **Db** 2,8,18,32, 32,11,2 Dubnium	106 **Sg** 2,8,18,32, 32,12,2 Seaborgium	107 **Bh** 2,8,18,32, 32,13,2 Bohrium	108 **Hs** 2,8,18,32, 32,14,2 Hassium	109 **Mt** 2,8,18,32, 32,15,2 Meitnerium	110 **Ds** 2,8,18,32, 32,17,1 Darmstadtium	111 **Rg** 2,8,18,32, 32,18,1 Roentgenium	112 **Cn** 2,8,18,32, 32,18,2 Copernicium

Lanthanides	57 **La** 2,8,18, 18,9,2 Lanthanum	58 **Ce** 2,8,18, 20,8,2 Cerium	59 **Pr** 2,8,18,21, 8,2 Praseodymium	60 **Nd** 2,8,18,22, 8,2 Neodymium	61 **Pm** 2,8,18,23, 8,2 Promethium	62 **Sm** 2,8,18,24, 8,2 Samarium	63 **Eu** 2,8,18,25, 8,2 Europium	64 **Gd** 2,8,18,25, 9,2 Gadolinium	65 **Tb** 2,8,18,27, 8,2 Terbium	66 **Dy** 2,8,18,28, 8,2 Dysprosium	67 **Ho** 2,8,18,29, 8,2 Holmium	68 **Er** 2,8,18,30, 8,2 Erbium	69 **Tm** 2,8,18,31, 8,2 Thulium	70 **Yb** 2,8,18,32, 8,2 Ytterbium	71 **Lu** 2,8,18,32, 9,2 Lutetium
Actinides	89 **Ac** 2,8,18,32, 18,9,2 Actinium	90 **Th** 2,8,18,32, 18,10,2 Thorium	91 **Pa** 2,8,18,32, 20,9,2 Protactinium	92 **U** 2,8,18,32, 21,9,2 Uranium	93 **Np** 2,8,18,32, 22,9,2 Neptunium	94 **Pu** 2,8,18,32, 24,8,2 Plutonium	95 **Am** 2,8,18,32, 25,8,2 Americium	96 **Cm** 2,8,18,32, 25,9,2 Curium	97 **Bk** 2,8,18,32, 27,8,2 Berkelium	98 **Cf** 2,8,18,32, 28,8,2 Californium	99 **Es** 2,8,18,32, 29,8,2 Einsteinium	100 **Fm** 2,8,18,32, 30,8,2 Fermium	101 **Md** 2,8,18,32, 31,8,2 Mendelevium	102 **No** 2,8,18,32, 32,8,2 Nobelium	103 **Lr** 2,8,18,32, 32,9,2 Lawrencium

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Physics
Paper 2

Marking Instructions

These marking instructions have been provided to show how SQA would mark this specimen question paper.

SQA
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General marking principles for Physics Higher

Always apply these general principles. Use them in conjunction with the detailed marking instructions, which identify the key features required in candidates' responses.

(a) Always use positive marking. This means candidates accumulate marks for the demonstration of relevant skills, knowledge and understanding; marks are not deducted for errors or omissions.

(b) If a candidate response does not seem to be covered by either the principles or detailed marking instructions, and you are uncertain how to assess it, you must seek guidance from your team leader.

(c) Do not award half marks.

(d) Where a candidate incorrectly answers part of a question and carries the incorrect answer forward in the following part, award marks if the incorrect answer has then been used correctly.

(e) Unless a numerical question specifically requires evidence of working to be shown, award full marks for a correct final answer (including units if required) on its own.

(f) Award marks for a diagram or sketch that correctly conveys the response required by the question. Clear and correct labels (or the use of standard symbols) are usually required for marks to be awarded.

(g) Award marks for knowledge of relevant relationships alone. When a candidate writes down several relationships and does not select the correct one to continue with, for example by substituting values, do not award a mark.

(h) Award marks for non-standard symbols where the symbols are defined and the relationship is correct, or where the substitution shows that the relationship used is correct. This must be clear and unambiguous.

(i) Do not award marks if a 'magic triangle' (eg) 

is the only statement in a candidate's response. To gain the mark, the correct relationship must be stated, for example $V = IR$ or $R = \frac{V}{I}$.

(j) In rounding to an expected number of significant figures, award the mark for responses that have up to two figures more or one figure less than the number in the data with the fewest significant figures.

(k) Award marks where candidates have incorrectly spelled technical terms, provided that responses can be interpreted and understood without any doubt as to the meaning. Where there is ambiguity, do not award the mark. Two specific examples of this would be when the candidate uses a term that might be interpreted as 'reflection', 'refraction' or 'diffraction' (for example 'defraction'), or one that might be interpreted as either 'fission' or 'fusion' (for example 'fussion').

(l) **Only award m**arks for a valid response to the question asked. Where candidates are asked to:

- **identify**, **name**, **give**, or **state**, they must only name or present in brief form.
- **describe**, they must provide a statement or structure of characteristics and/or features.
- **explain**, they must relate cause and effect and/or make relationships between things clear.
- **determine** or **calculate**, they must determine a number from given facts, figures or information.
- **estimate**, they must determine an approximate value for something.
- **justify**, they must give reasons to support their suggestions or conclusions. For example this might be by identifying an appropriate relationship and the effect of changing variables.
- **show that**, they must use physics [and mathematics] to prove something, for example a given value – *all steps, including the stated answer, must be shown*.
- **predict**, they must suggest what may happen based on available information.
- **suggest**, they must apply their knowledge and understanding of physics to a new situation. A number of responses are acceptable: award marks for any suggestions that are supported by knowledge and understanding of physics.
- **use their knowledge of physics or aspect of physics to comment on**, they must apply their skills, knowledge and understanding to respond appropriately to the problem/situation presented (for example by making a statement of principle(s) involved and/or a relationship or equation, and applying these to respond to the problem/situation). Candidates gain marks for the breadth and/or depth of their conceptual understanding.

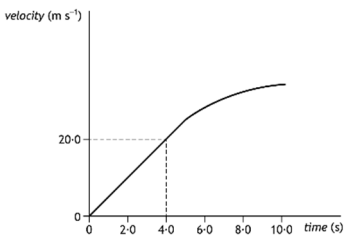
(m) Marking in calculations

Example question

The current in a resistor is 1·5 amperes when the potential difference across it is 7·5 volts. Calculate the resistance of the resistor. (3 marks)

	Example response	**Mark + Comment**
1.	$V = IR$ $7{\cdot}5 = 1{\cdot}5R$ $R = 5{\cdot}0\ \Omega$	1 mark: formula 1 mark: substitution 1 mark: correct answer
2.	$5{\cdot}0\ \Omega$	3 marks: correct answer
3.	5·0	2 marks: unit missing
4.	$4{\cdot}0\ \Omega$	0 marks: no evidence, wrong answer
5.	$\_\_\ \Omega$	0 marks: no working or final answer
6.	$R = \frac{V}{I} = \frac{7{\cdot}5}{1{\cdot}5} = 4{\cdot}0\ \Omega$	2 marks: arithmetic error
7.	$R = \frac{V}{I} = 4{\cdot}0\ \Omega$	1 mark: formula only
8.	$R = \frac{V}{I} = \_\_\ \Omega$	1 mark: formula only
9.	$R = \frac{V}{I} = \frac{7{\cdot}5}{1{\cdot}5} = \_\_\ \Omega$	2 marks: formula & substitution, no final answer
10.	$R = \frac{V}{I} = \frac{7{\cdot}5}{1{\cdot}5} = 4{\cdot}0$	2 marks: formula & substitution, wrong answer
11.	$R = \frac{V}{I} = \frac{1{\cdot}5}{7{\cdot}5} = 5{\cdot}0\ \Omega$	1 mark: formula but wrong substitution
12.	$R = \frac{V}{I} = \frac{75}{1{\cdot}5} = 5{\cdot}0\ \Omega$	1 mark: formula but wrong substitution
13.	$R = \frac{I}{V} = \frac{1{\cdot}5}{7{\cdot}5} = 5{\cdot}0\ \Omega$	0 marks: wrong formula
14.	$V = IR$ $7{\cdot}5 = 1{\cdot}5 \times R$ $R = 0{\cdot}2\ \Omega$	2 marks: formula & substitution, arithmetic error
15.	$V = IR$ $R = \frac{I}{V} = \frac{1{\cdot}5}{7{\cdot}5} = 0{\cdot}2\ \Omega$	1 mark: formula correct but wrong rearrangement of symbols

Marking instructions for each question

Question			Expected response	Max mark	Additional guidance
1.	(a)		$v = u + at$ **(1)** $20{\cdot}0 = 0 + a \times 4{\cdot}0$ **(1)** $a = 5{\cdot}0 \text{ m s}^{-2}$ **(1)**	**3**	Accept 5, 5·00, 5·000
	(b)		motorcycle $s = \text{area under graph}$ **(1)** $s = \frac{1}{2} \times 4{\cdot}0 \times 20{\cdot}0$ **(1)** car $s = \text{area under graph}$ $s = 4{\cdot}0 \times 15{\cdot}0$ **(1)** $s_{between} = (4{\cdot}0 \times 15{\cdot}0) - (\frac{1}{2} \times 4{\cdot}0 \times 20{\cdot}0)$ $s_{between} = 20 \text{ m}$ **(1)**	**4**	Accept 20·0, 20·00 Alternative method motorcycle $s = ut + \frac{1}{2}at^2$ $s = \frac{1}{2} \times 5{\cdot}0 \times 4{\cdot}0^2$ car $d = \bar{v}t$ $d = 15 \times 4{\cdot}0$ 1 mark for both relationships 1 mark for each substitution 1 mark for final answer
	(c)	(i)	$F = ma$ **(1)** $F = 290 \times 5{\cdot}0$ **(1)** $F = F_{Driving} - F_{Friction}$ $(290 \times 5{\cdot}0) = 1800 - F_{Friction}$ **(1)** $F_{Friction} = 350 \text{ N}$ **(1)**	**4**	Or consistent with (a) Accept 400, 350·0, 350·00
		(ii)	Frictional force /friction/drag/air resistance increases with speed **(1)** Driving force must be increased to ensure a constant unbalanced force **(1)**	**2**	
	(d)		 graph curves (gradually, away from velocity axis) after 5 s	**1**	Line can level out, but not curve downwards.

Question			Expected response	Max mark	Additional guidance
2.			Estimate of car mass (500 kg < mass < 3000 kg) **(1)** Estimate of car speed (20 m s^{-1} < speed < 70 m s^{-1}) **(1)** $E_k = \frac{1}{2}mv^2$ **(1)** Final answer **(1)**	**4**	Both estimates must be within the given tolerances in order to access the final 1 mark.

Question			Expected response	Max mark	Additional guidance
3.	(a)	(i)	$v^2 = u^2 + 2as$ **(1)** $v^2 = 0 + 2\times 9{\cdot}8\times 2{\cdot}0$ **(1)** $v = 6{\cdot}3$ m s^{-1} OR $(m)gh = \frac{1}{2}(m)v^2$ **(1)** $(42)\times 9{\cdot}8\times 2{\cdot}0 = \frac{1}{2}(42)v^2$ **(1)** $v = 6{\cdot}3$ m s^{-1}	**2**	SHOW question. A maximum of 1 mark is available if the final line is not shown.
		(ii)	$\Delta p = mv - mu$ **(1)** $\Delta p = (42\times(5{\cdot}3)) - (42\times(-6{\cdot}3))$ **(1)** $\Delta p = 490$ kg m s^{-1} **(1)**	**3**	Accept 500, 487, 487·2 Accept alternative direction convention.
		(iii)	$Ft = mv - mu$ **(1)** $F\times 0{\cdot}50 = 490$ **(1)** $F = 980$ N **(1)**	**3**	Or consistent with (a)(ii) Accept 1000, 980·0
	(b)		Tension (in rope) now has a horizontal component **(1)** Vertical component of tension (in rope) is unchanged **(1)**	**2**	Independent marks Statements must refer to forces on rope.

Question			Expected response	Max mark	Additional guidance
4.	(a)		$d = \bar{v}t$ **(1)** $d = (3{\cdot}00\times10^{8}\times0{\cdot}995)\times2{\cdot}2\times10^{-6}$ **(1)** $d = 660$ m	**2**	SHOW question. A maximum of 1 mark is available if the final line is not shown.
	(b)		$t' = \dfrac{t}{\sqrt{1-\left(\dfrac{v}{c}\right)^2}}$ **(1)** $t' = \dfrac{2{\cdot}2\times10^{-6}}{\sqrt{1-\left(\dfrac{0{\cdot}995}{1}\right)^2}}$ **(1)** $t' = 2{\cdot}2\times10^{-5}$ s **(1)**	**3**	Accept 2, 2·20, 2·203
	(c)		The mean lifetime of the muon is greater for an observer in Earth's frame of reference OR The mean distance travelled by a muon is shorter in the muon's frame of reference	**1**	

Question			Expected response	Max mark	Additional guidance
5.	(a)	(i)	The galaxy is moving away from Earth **(1)** The apparent wavelengths of the lines of the hydrogen spectrum from the galaxy have increased **(1)** OR The apparent frequencies of the lines of the hydrogen spectrum from the galaxy are less than the corresponding frequencies from the laboratory source OR The frequency of the light from the galaxy has shifted towards the red end of the spectrum OR Observed light from the galaxy shows redshift	**2**	
		(ii)	$z = \frac{(\lambda_{obs} - \lambda_{rest})}{\lambda_{rest}}$ **(1)** $z = \frac{(676\times10^{-9} - 656\times10^{-9})}{656\times10^{-9}}$ **(1)** $z = \frac{v}{c}$ **(1)** $\frac{(676\times10^{-9} - 656\times10^{-9})}{656\times10^{-9}} = \frac{v}{3{\cdot}00\times10^{8}}$ **(1)** $v = 9{\cdot}15\times10^{6}$ m s^{-1} **(1)**	**5**	Accept 9·1,9·146,9·1463
	(b)		$v = H_0 d$ **(1)** $1{\cdot}2\times10^{7} = 2{\cdot}3\times10^{-18}\times d$ **(1)** $d = 5{\cdot}2\times10^{24}$ m **(1)**	**3**	Accept 5, 5·22, 5·217

Question			Expected response	Max mark	Additional guidance
5.	(c)		**Award 1 mark** where the candidate has demonstrated a limited understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the physics within the problem. **Award 2 marks** where the candidate has demonstrated a reasonable understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 3 marks** where the candidate has demonstrated a good understanding of the physics involved. They show a good comprehension of the physics of the situation and provide a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 0 marks** where the candidate has not demonstrated an understanding of the physics involved. There is no evidence that they have recognised the area of physics involved, or they have not given any statement of a relevant physics principle. Award this mark also if the candidate merely restates the physics given in the question.	**3**	Candidates may use a variety of physics arguments to answer this question. Award marks based on candidates demonstrating, overall, good, reasonable, limited or no understanding.

Question			Expected response	Max mark	Additional guidance
6.	(a)	(i)	$W = QV$ **(1)** $W = 1{\cdot}60\times10^{-19}\times3{\cdot}5\times10^{4}$ **(1)** $W = 5{\cdot}6\times10^{-15}$ J	**2**	SHOW question. A maximum of 1 mark is available if the final line is not shown.
		(ii)	E_k at R $E_k = \frac{1}{2}mv^2$ **(1)** $E_k = 0{\cdot}5\times1{\cdot}673\times10^{-27}\times(1{\cdot}2\times10^{6})^2$ **(1)** E_k at S $E_k = \frac{1}{2}mv^2$ $\left[0{\cdot}5\times1{\cdot}673\times10^{-27}\times(1{\cdot}2\times10^{6})^2\right]$ $+5{\cdot}6\times10^{-15}$ $= 0{\cdot}5\times1{\cdot}673\times10^{-27}\times v^2$ addition **(1)** substitution **(1)** $v = 2{\cdot}9\times10^{6}$ m s^{-1} **(1)**	**5**	Accept 3,2·85,2·852
	(b)	(i)	To ensure the (accelerating) force is in the same direction OR To ensure the protons accelerate in the same direction OR To ensure that the direction of the electric field is correct when the proton passes through a tube	**1**	
	(b)	(ii)	Alternating voltage has a constant frequency (rather than a frequency that changes) OR As speed of proton increases, they travel further in the same time	**1**	
	(c)		Downwards	**1**	

Question			Expected response	Max mark	Additional guidance
7.	(a)		Fundamental particles cannot be subdivided	**1**	
	(b)		$-\frac{1}{3}e$	**1**	
	(c)		The strong force (associated with the gluon) has a short range. **(1)** The gravitational force (requires a force mediating particle that) has infinite range. **(1)**	**2**	
	(d)		(The strong force is) 13 (orders of magnitude) greater (than the weak force)	**1**	
	(e)		beta decay	**1**	

Question			Expected response	Max mark	Additional guidance
8.	(a)		mass loss $m = (4 \times 1{\cdot}673 \times 10^{-27}) - 6{\cdot}646 \times 10^{-27}$ **(1)** $E = mc^2$ **(1)** $E = ((4 \times 1{\cdot}673 \times 10^{-27}) - (6{\cdot}646 \times 10^{-27})) \times (3{\cdot}00 \times 10^{8})^2$ **(1)** $E = 4{\cdot}14 \times 10^{-12}$ J **(1)**	**4**	Accept 4·1, 4·140, 4·1400
	(b)		0·20 kg hydrogen has $\frac{0{\cdot}20}{1{\cdot}673 \times 10^{-27}}$ $(= 1{\cdot}195 \times 10^{26}$ atoms) **(1)** provides $\frac{1{\cdot}195 \times 10^{26}}{4} = 0{\cdot}2989 \times 10^{26}$ reactions **(1)** releases $0{\cdot}2989 \times 10^{26} \times 4{\cdot}14 \times 10^{-12}$ $= 1{\cdot}2 \times 10^{14}$ J **(1)**	**3**	Accept 1, 1·24,1·237 Multiplying the number of hydrogen nuclei by the energy for each reaction is wrong physics.
	(c)		The particles involved in fusion reactions must be at a high temperature	**1**	

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>9.</td><td>(a)</td><td></td><td>Irradiance is the power incident per unit area</td><td>1</td><td></td></tr>
<tr><td></td><td>(b)</td><td></td><td>Graphical method

Correct quantities on axes
(I and $1/d^2$) (1)

Accuracy of plotting and line of best fit (1)

Statement of relationship (1)

Do not award statement mark if less than three points plotted accurately.</td><td>3</td><td>ALTERNATIVE METHOD

<table><tr><td>d</td><td>0·200</td><td>0·300</td><td>0·400</td><td>0·500</td></tr><tr><td>I</td><td>672</td><td>302</td><td>170</td><td>110</td></tr><tr><td>Id^2</td><td>26·9</td><td>27·2</td><td>27·2</td><td>27·5</td></tr></table>
AND
Within the limits of experimental uncertainty, Id^2 is constant and so $I \alpha 1/d^2$.

Award 3 marks where all four calculated values in the table are correct and the final statement is correct.
Award 2 marks where all four calculated values in the table are correct and the final statement is incorrect or omitted.
Award 2 marks where three calculations in the table are correct and the final statement is correct.
Award 1 mark where three calculations in the table are correct and the final statement is incorrect or omitted.
Award 0 marks where fewer than three calculations are correct (a relationship cannot be stated from only two values or fewer).</td></tr>
<tr><td></td><td>(c)</td><td></td><td>(Black cloth) prevents reflections</td><td>1</td><td></td></tr>
<tr><td></td><td>(d)</td><td></td><td>The laser is not a point source
OR
Light from the laser does not conform to the inverse square law
OR
Laser beam does not spread out</td><td>1</td><td></td></tr>
</table>

Question			Expected response	Max mark	Additional guidance
10.	(a)	(i)	$v = f\lambda$ **(1)** $3{\cdot}00\times10^{8} = f\times525\times10^{-9}$ **(1)** $E = hf$ **(1)** $E = 6{\cdot}63\times10^{-34}\times\left(\frac{3{\cdot}00\times10^{8}}{525\times10^{-9}}\right)$ **(1)** $E = 3{\cdot}79\times10^{-19}$ J	**4**	SHOW question. A maximum of 3 marks is available if the final line is not shown.
		(ii)	$(E_k = 3{\cdot}79\times10^{-19} - 2{\cdot}24\times10^{-19})$ $E_k = 1{\cdot}55\times10^{-19}$ J	**1**	
	(b)	(i)	Photons with frequency below f_0 do not have enough energy to release electrons	**1**	
		(ii)	$E = hf_0$ **(1)** $2{\cdot}24\times10^{-19} = \left(6{\cdot}63\times10^{-34}\right)\times f_0$ **(1)** $f_0 = 3{\cdot}38\times10^{14}$ Hz **(1)**	**3**	Accept 3·4, 3·379, 3·3786

Question			Expected response	Max mark	Additional guidance
10.	(c)		**Award 1 mark** where the candidate has demonstrated a limited understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the physics within the problem. **Award 2 marks** where the candidate has demonstrated a reasonable understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 3 marks** where the candidate has demonstrated a good understanding of the physics involved. They show a good comprehension of the physics of the situation and provide a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 0 marks** where the candidate has not demonstrated an understanding of the physics involved. There is no evidence that they have recognised the area of physics involved, or they have not given any statement of a relevant physics principle. Award this mark also if the candidate merely restates the physics given in the question.	**3**	Candidates may use a variety of physics arguments to answer this question. Award marks based on candidates demonstrating, overall, good, reasonable, limited or no understanding.

Question			Expected response	Max mark	Additional guidance
11.	(a)		Bright fringes are produced by waves meeting in phase/crest to crest/trough to trough	**1**	
	(b)	(i)	$\Delta x = \frac{\lambda D}{d}$ $\frac{9{\cdot}5\times10^{-3}}{4} = \frac{633\times10^{-9}\times0{\cdot}750}{d}$ division by 4 **(1)** substitutions **(1)** $d = 2{\cdot}0\times10^{-4}$ m **(1)**	**3**	Accept 2,2·00,1·999 The mark for dividing by 4 is independent
		(ii)	$\%uncertainty\Delta x = \frac{0{\cdot}2\times10^{-3}\times100}{9{\cdot}5\times10^{-3}} = 2{\cdot}1\%$ **(1)** $\%uncertaintyD = \frac{0{\cdot}001\times100}{0{\cdot}750} = 0{\cdot}13\%$ **(1)** Improve precision in measurement of Δx **(1)**	**3**	
	(c)		Green light has a shorter wavelength **(1)** Fringes are closer together **(1)**	**2**	

Question			Expected response	Max mark	Additional guidance
12.	(a)		$n = \frac{\sin\theta_1}{\sin\theta_2}$ **(1)** $n = \frac{\sin(51{\cdot}4)}{\sin(36{\cdot}0)}$ **(1)** $n = 1{\cdot}33$	**2**	SHOW question. A maximum of 1 mark is available if the final line is not shown.
	(b)	(i)	(Critical angle is) the angle of incidence that produces an angle of refraction of 90°	**1**	
		(ii)	$\sin\theta_c = \frac{1}{n}$ **(1)** $\sin\theta_c = \frac{1}{1{\cdot}33}$ **(1)** $\theta_c = 48{\cdot}8^\circ$ **(1)**	**3**	Accept 49, 48·75, 48·753

Question			Expected response	Max mark	Additional guidance
13.	(a)	(i)	2·5 Ω	**1**	
		(ii)	$E = \frac{y_2 - y_1}{x_2 - x_1}$ $E = \frac{11 - 0}{0{\cdot}80 - 0{\cdot}15}$ substitution of two points on line **(1)** $E = 17$ V **(1)**	**2**	Or consistent with data points chosen
	(b)		$V = IR$ **(1)** $17 = I \times 2{\cdot}5$ **(1)** $I = 6{\cdot}8$ A **(1)**	**3**	Or consistent with (a)(i) and (a)(ii)

Question			Expected response	Max mark	Additional guidance
14.	(a)		$V = IR$ **(1)** $12 = 3{\cdot}0\times10^{-5}\times R$ **(1)** $R = 4{\cdot}0\times10^{5}\ \Omega$ **(1)**	**3**	Accept 4, 4·00, 4·000
	(b)	(i)	$Q = It$ **(1)** $Q = 3{\cdot}0\times10^{-5}\times25$ **(1)** $Q = 7{\cdot}5\times10^{-4}$ C **(1)**	**3**	Accept 8, 7·50, 7·500
		(ii)	$C = \frac{Q}{V}$ **(1)** $220\times10^{-6} = \frac{7{\cdot}5\times10^{-4}}{V}$ **(1)** $V = 3{\cdot}4$ (V) **(1)** Therefore voltage across resistor is $12 - 3{\cdot}4 = 8{\cdot}6$ V **(1)**	**4**	Or consistent with (b)(i) Accept 9, 8·59, 8·591

Question			Expected response	Max mark	Additional guidance
15.	(a)		Material 2	**1**	
	(b)		(Voltage applied causes) electrons to move towards conduction band of p-type **(1)** Electrons move/drop from conduction band to valence band **(1)** Photon emitted (when electron drops) **(1)**	**3**	If candidate does not refer to either conduction band or valence band, award 0 marks. Bands must be named correctly in first two marking points ie not valency or conductive. Award 0 marks for any answer using recombination of holes and electrons **on its own**, with no reference to band theory. The final mark is dependent upon having at least one of the first two statements correct.

Question			Expected response	Max mark	Additional guidance
16.	(a)		Suitable scales with labels on axes (quantity and unit) **(1)** Points plotted accurately **(1)** Acceptable line(curve) of best fit **(1)**	**3**	
	(b)		7·5 mm ±1mm	**1**	Or consistent with graph drawn
	(c)		Repeat measurements **(1)** Smaller steps/divisions/intervals in radius (around the 75% value or equivalent) **(1)**	**2**	

[END OF SPECIMEN MARKING INSTRUCTIONS]