National Qualifications

X857/76/12

Physics
Paper 1 — Multiple choice

Duration — 45 minutes

Total marks — 25

Attempt ALL questions.

You may use a calculator.

Instructions for the completion of Paper 1 are given on *page 02* of your answer booklet X857/76/02.

Record your answers on the answer grid on *page 03* of your answer booklet.

Reference may be made to the data sheet on *page 02* of this question paper and to the relationships sheet X857/76/22.

Space for rough work is provided at the end of this booklet.

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

SQA ©

X8577612

DATA SHEET

COMMON PHYSICAL QUANTITIES

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

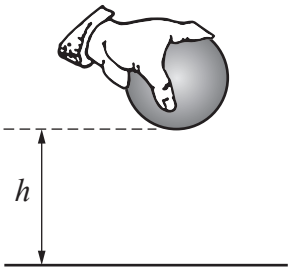
Substance	Density (kg m^{-3})	Melting point (K)	Boiling point (K)
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	. . . .
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	. . . .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

Total marks — 25

Attempt ALL questions

1. A specially adapted ball has an electronic timer, which starts to time when the ball is released and stops timing when the ball strikes a surface.



not to scale

The ball is dropped from rest through a height h onto a hard surface.

The time recorded on the ball is 0·40 s.

The effects of air resistance can be ignored.

The height h is

A 0·20 m

B 0·78 m

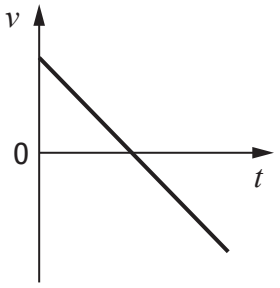
C 1·56 m

D 1·96 m

E 3·92 m.

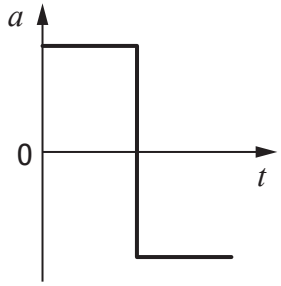
[Turn over

2. The velocity-time (v-t) graph for an object travelling in a straight line is shown below.

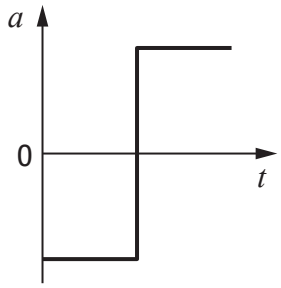


Which of the following is the corresponding acceleration-time (a-t) graph?

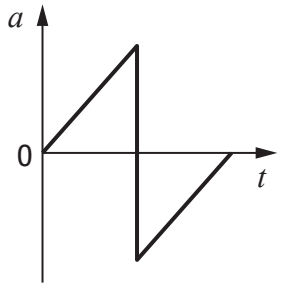
A



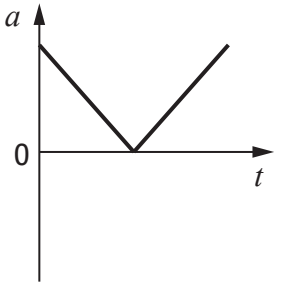
B



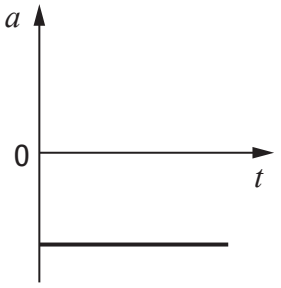
C



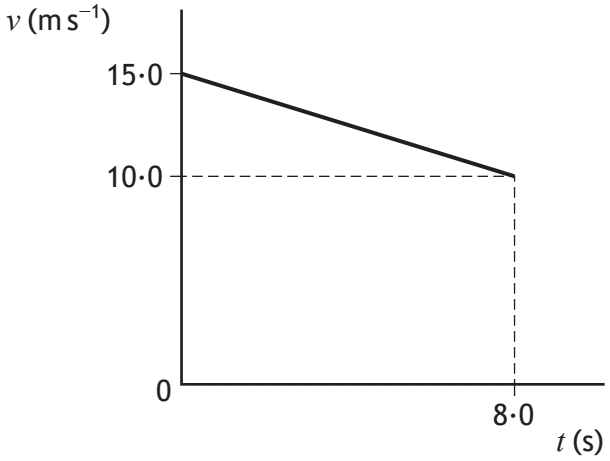
D



E



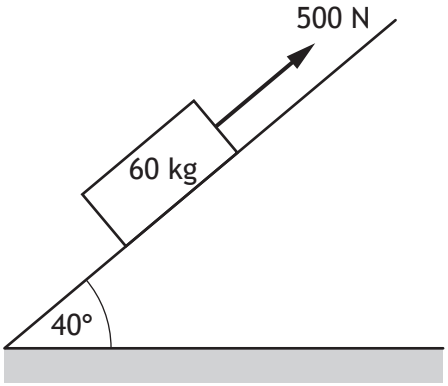
3. The velocity-time (v-t) graph for an object travelling along a straight line is shown.



Which row in the table shows the acceleration of the object during the 8·0 s and the displacement of the object at 8·0 s?

	Acceleration ($m\,s^{-2}$)	Displacement (m)
A	–0·63	100
B	–0·63	140
C	–1·9	100
D	–1·9	120
E	–3·1	140

4. A pulling force of 500 N is applied to a 60 kg block on a slope as shown.



The maximum acceleration of the block is

A $2{\cdot}0\ m\,s^{-2}$

B $5{\cdot}4\ m\,s^{-2}$

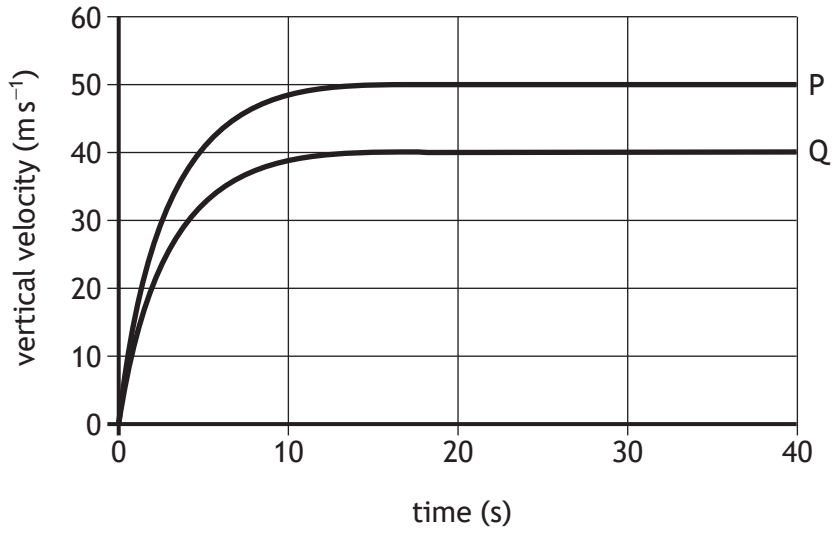
C $6{\cdot}3\ m\,s^{-2}$

D $7{\cdot}5\ m\,s^{-2}$

E $8{\cdot}3\ m\,s^{-2}$.

5. Two objects, P and Q, of the same mass are dropped from the same height.

The graph shows how the vertical velocities of the two objects vary with time for the first 40 s of their fall.



A group of students make the following statements based on information from the graph.

I The terminal velocity of object P is 50 m s^{-1}.

II Object Q reaches its terminal velocity at 10 s.

III At 40 s, both objects have fallen through the same distance.

Which of these statements is/are correct?

A I only

B I and II only

C I and III only

D II and III only

E I, II and III

6. The total mass of a motorcycle and rider is 250 kg.

During braking they are brought to rest from a speed of 16 m s^{-1} in a time of 10·0 s.

The maximum energy that could be converted to heat in the brakes is

A 2000 J

B 4000 J

C 32 000 J

D 40 000 J

E 64 000 J.

7. A carpenter is building a doorframe using a nail gun. The nail gun of mass 5·0 kg fires a nail of mass 4·0 g.

The nail gun and nail are initially at rest.

The speed of the nail immediately after firing is 150 m s^{-1}.

The recoil speed of the nail gun immediately after firing is

A 0·005 m s^{-1}

B 0·05 m s^{-1}

C 0·12 m s^{-1}

D 1·2 m s^{-1}

E 120 m s^{-1}.

8. The escape velocity v of an object is the minimum velocity required to allow the object to escape the gravitational field of a planet.

The following relationship is used to determine the escape velocity

$$v = \sqrt{\frac{2GM}{r}}$$

where G is the Universal Constant of Gravitation

M is the mass of the planet

r is the radius of the planet.

A planet has a mass of 4·87 $\times$ 10^{24} kg and a radius of 6·05 $\times$ 10^{6} m.

Based on this information, the escape velocity from this planet is

A 1·66 $\times$ 10^{-28} m s^{-1}

B 1·29 $\times$ 10^{-14} m s^{-1}

C 7·33 $\times$ 10^{3} m s^{-1}

D 1·04 $\times$ 10^{4} m s^{-1}

E 3·97 $\times$ 10^{9} m s^{-1}.

9. A spacecraft is travelling at 6·0 $\times$ 10^{7} m s^{-1} relative to a star.

An observer on the spacecraft measures the speed of light emitted by the star to be

A 2·4 $\times$ 10^{8} m s^{-1}

B 2·9 $\times$ 10^{8} m s^{-1}

C 3·0 $\times$ 10^{8} m s^{-1}

D 3·1 $\times$ 10^{8} m s^{-1}

E 3·6 $\times$ 10^{8} m s^{-1}.

[Turn over

10. A spacecraft is travelling at a speed of 0·45c relative to Earth.

An observer on Earth measures the time taken for the spacecraft to travel between two points to be 72 hours.

An observer on the spacecraft measures the time taken to travel between these two points to be

A 53 hours

B 64 hours

C 72 hours

D 81 hours

E 90 hours.

11. The redshift of light from a distant galaxy is 0·125.

The approximate distance to this distant galaxy is

A $3{\cdot}75 \times 10^{7}$ m

B $1{\cdot}81 \times 10^{8}$ m

C $5{\cdot}43 \times 10^{16}$ m

D $1{\cdot}63 \times 10^{25}$ m

E $1{\cdot}30 \times 10^{26}$ m.

12. A student makes the following statements about the Universe.

I Measurements of the velocities of galaxies and their distances from us lead to the theory of the origin of the expanding Universe.

II The mass of a galaxy can be estimated by the orbital speed of stars within it.

III Evidence supporting the existence of dark matter comes from the accelerating rate of expansion of the Universe.

Which of these statements is/are correct?

A I only

B I and II only

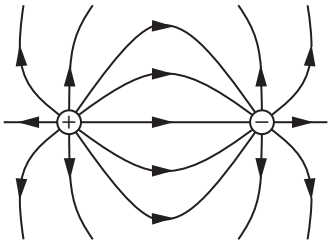
C I and III only

D II and III only

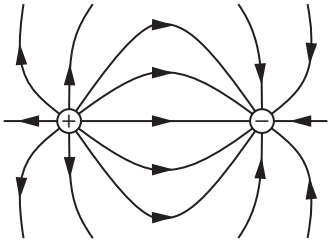
E I, II and III

13. Which of the following diagrams represents the electric field between a positive point charge and a negative point charge?

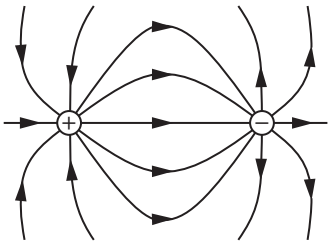
A



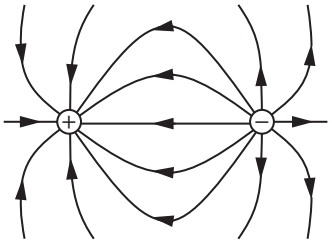
B



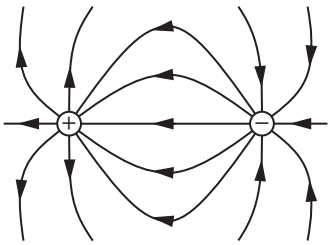
C



D



E



[Turn over

14. The group of matter particles known as fermions consists of

A baryons only

B quarks only

C leptons only

D quarks and leptons only

E baryons and mesons only.

15. A certain type of composite particle is made of two up quarks and a strange quark.

The charge on an up quark is $+\frac{2}{3}e$.

The charge on a strange quark is $-\frac{1}{3}e$.

Which of the following statements describes the nature and charge of this composite particle?

A The particle is a meson with a charge of $+1e$.

B The particle is a meson with a charge of $-1e$.

C The particle is a meson with no charge.

D The particle is a baryon with a charge of $-1e$.

E The particle is a baryon with a charge of $+1e$.

16. Two changes in a radioactive decay series are shown below.

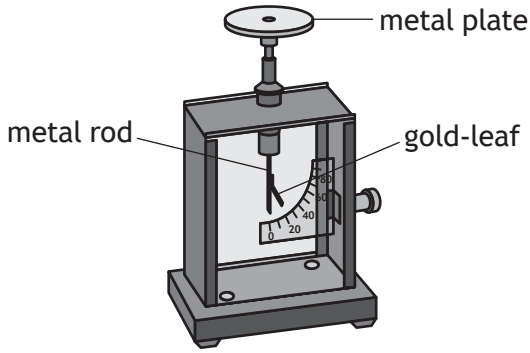
$$^{231}_{90}\text{Th} \xrightarrow{\beta} {}^{\text{P}}_{\text{Q}}\text{Pa} \xrightarrow{\alpha} {}^{\text{R}}_{\text{S}}\text{Ac}$$

A Thorium nucleus emits a beta particle and the product, a Protactinium nucleus, emits an alpha particle.

Which row in the table shows the numbers represented by P, Q, R, and S?

	P	Q	R	S
A	231	89	227	87
B	231	91	227	89
C	227	88	227	87
D	231	91	231	89
E	227	88	223	86

17. An experiment to demonstrate the photoelectric effect is set up as shown.



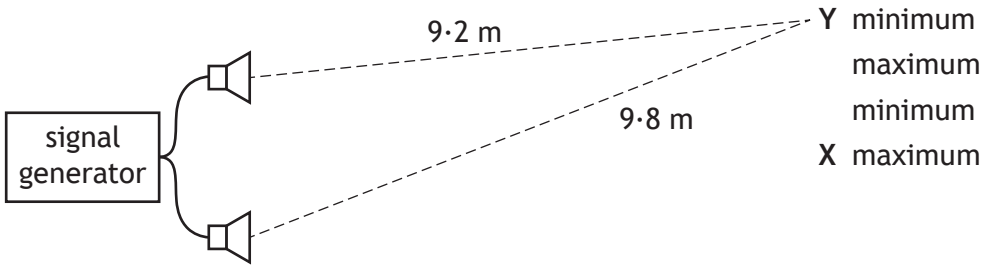
gold-leaf electroscope

Which row in the table shows the charge on the metal plate and the type of incident radiation most likely to cause photoelectric emission?

	Charge on metal plate	**Type of incident radiation**
A	negative	green light
B	positive	ultraviolet
C	negative	infrared
D	positive	red light
E	negative	ultraviolet

[Turn over

18. Two identical loudspeakers are connected to a signal generator as shown.



A microphone detects a maximum of sound at position X.

The microphone is now moved from X to Y.

As the microphone is moved from X to Y, a series of maxima and minima of sound are detected.

The microphone detects the second **minimum** of sound at position Y.

The wavelength of sound emitted by the loudspeakers is

A 0·17 m

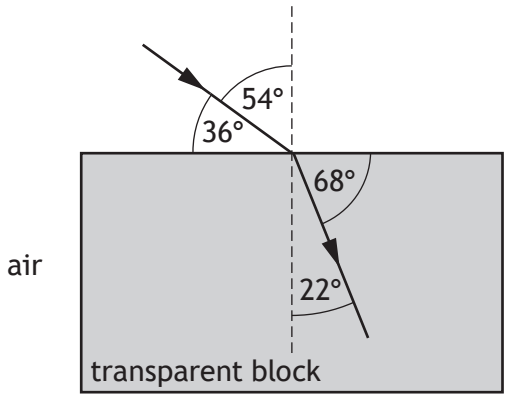
B 0·24 m

C 0·30 m

D 0·40 m

E 0·60 m.

19. A ray of red light passes from air into a transparent block as shown.



The speed of this light in the block is

A $1{\cdot}39 \times 10^8$ m s^{-1}

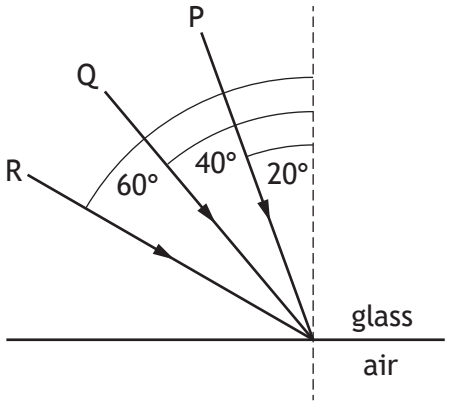
B $1{\cdot}91 \times 10^8$ m s^{-1}

C $2{\cdot}62 \times 10^8$ m s^{-1}

D $3{\cdot}00 \times 10^8$ m s^{-1}

E $4{\cdot}73 \times 10^8$ m s^{-1}.

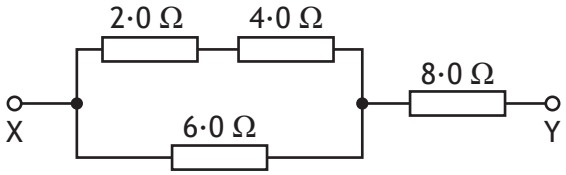
20. The diagram shows the path of three rays of red light P, Q and R in glass.
The rays are incident at the glass-air boundary as shown.



The refractive index of the glass for this light is 1·50.
Which of these rays pass from the glass into the air at this boundary?

A P only
B R only
C Q and R only
D P and Q only
E P, Q and R

21. Four resistors are connected as shown.



The total resistance between X and Y is

A 1·0 Ω
B 8·9 Ω
C 9·1 Ω
D 11 Ω
E 20 Ω.

[Turn over

22. A resistor of resistance 100 Ω is rated at 4 W.

The maximum voltage which can be applied across the resistor without exceeding its power rating is

A 0·04 V

B 5 V

C 20 V

D 25 V

E 400 V.

23. Capacitance is measured in farads.

One farad is equivalent to

A one coulomb per volt

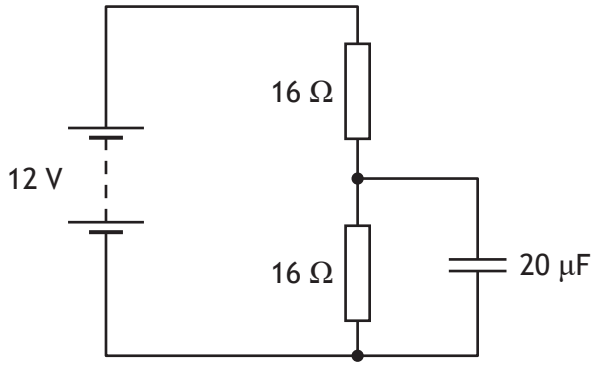
B one joule per volt

C one joule per coulomb

D one volt per second

E one joule per second.

24. A circuit containing a capacitor is set up as shown.



The battery has negligible internal resistance.

The maximum charge stored by the capacitor is

A $3{\cdot}6 \times 10^{-4}$ C

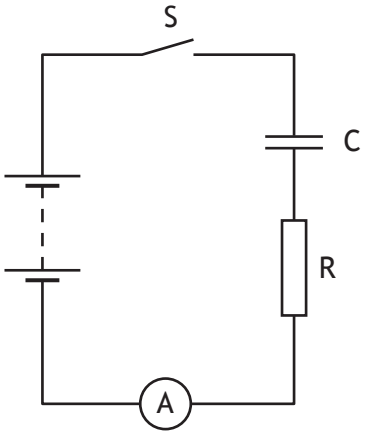
B $2{\cdot}4 \times 10^{-4}$ C

C $1{\cdot}2 \times 10^{-4}$ C

D $3{\cdot}3 \times 10^{-6}$ C

E $1{\cdot}7 \times 10^{-6}$ C.

25. A circuit is set up as shown.



Capacitor C is initially uncharged.

Switch S is closed and the time taken for the capacitor to fully charge is recorded.

The switch is now opened and the capacitor is discharged.

Resistor R is replaced by a resistor of greater resistance.

The switch is again closed and the capacitor charges.

Which row in the table shows the effect of this change, if any, on the time taken to fully charge the capacitor and the maximum energy stored in the capacitor?

	Time taken to fully charge the capacitor	**Maximum energy stored in the capacitor**
A	increases	increases
B	decreases	decreases
C	decreases	stays the same
D	increases	stays the same
E	stays the same	decreases

[END OF QUESTION PAPER]

SPACE FOR ROUGH WORK

SPACE FOR ROUGH WORK

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FOR OFFICIAL USE

National Qualifications

Mark

X857/76/02

Physics
Paper 1 — Multiple choice
Answer booklet

Duration — 45 minutes

X8577602

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

Instructions for the completion of Paper 1 are given on *page 02*.

Record your answers on the answer grid on *page 03*.

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

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

SQA ©

The questions for Paper 1 are contained in the question paper X857/76/12.

Read these and record your answers on the answer grid on *page 03*.

Use **blue** or **black** ink. Do NOT use gel pens or pencil.

1. The answer to each question is **either** A, B, C, D or E. Decide what your answer is, then fill in the appropriate bubble (see sample question below).

2. There is **only one correct** answer to each question.

3. Any rough working should be done on the space for rough work at the end of the question paper X857/76/12.

Sample question

The energy unit measured by the electricity meter in your home is the

A ampere

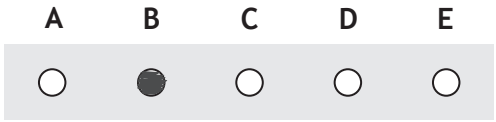
B kilowatt-hour

C watt

D coulomb

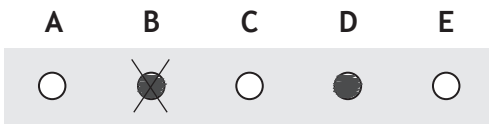
E volt.

The correct answer is **B** — kilowatt-hour. The answer **B** bubble has been clearly filled in (see below).

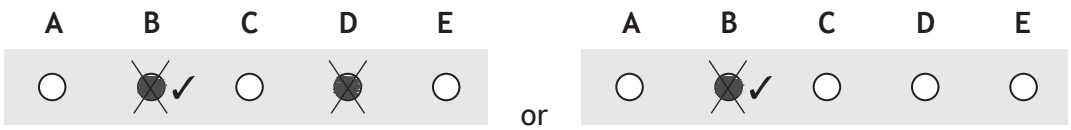


Changing an answer

If you decide to change your answer, cancel your first answer by putting a cross through it (see below) and fill in the answer you want. The answer below has been changed to **D**.



If you then decide to change back to an answer you have already scored out, put a tick (✓) to the **right** of the answer you want, as shown below:



Paper 1 — Answer grid

0BJ25AE1

	A	B	C	D	E
1	○	○	○	○	○
2	○	○	○	○	○
3	○	○	○	○	○
4	○	○	○	○	○
5	○	○	○	○	○
6	○	○	○	○	○
7	○	○	○	○	○
8	○	○	○	○	○
9	○	○	○	○	○
10	○	○	○	○	○
11	○	○	○	○	○
12	○	○	○	○	○
13	○	○	○	○	○
14	○	○	○	○	○
15	○	○	○	○	○
16	○	○	○	○	○
17	○	○	○	○	○
18	○	○	○	○	○
19	○	○	○	○	○
20	○	○	○	○	○
21	○	○	○	○	○
22	○	○	○	○	○
23	○	○	○	○	○
24	○	○	○	○	○
25	○	○	○	○	○

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National
Qualifications

X857/76/22

Physics
Paper 1 — Relationships sheet

Duration — 45 minutes

©

X8577622

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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National Qualifications

Mark

X857/76/01

Physics Paper 2

Duration — 2 hours 15 minutes

X8577601

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 X857/76/11.

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.

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DATA SHEET

COMMON PHYSICAL QUANTITIES

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

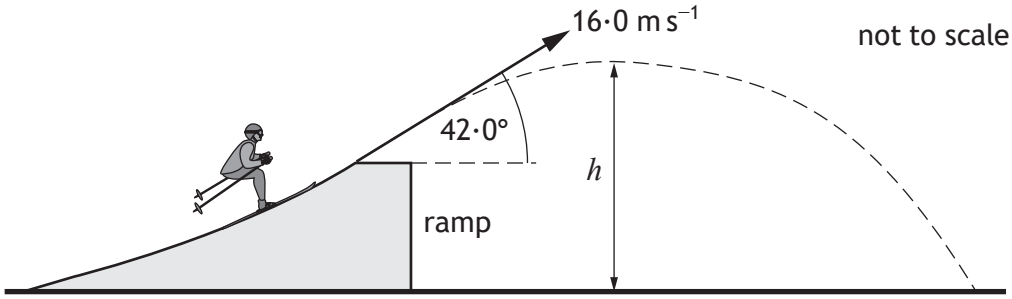
[Turn over for next question

DO NOT WRITE ON THIS PAGE

Total marks — 130

Attempt ALL questions

1. A skier launches from a ramp. The skier leaves the ramp with a launch velocity of 16·0 m s^{-1} at 42·0° to the horizontal.



The effects of air resistance can be ignored.

(a) Calculate

(i) the horizontal component of the launch velocity of the skier **1**

Space for working and answer

(ii) the vertical component of the launch velocity of the skier. **1**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

(b) Calculate the time taken for the skier to reach the maximum height h after launch. **3**

Space for working and answer

(c) The skier takes a further 1·40 s to travel from the maximum height h to the ground.

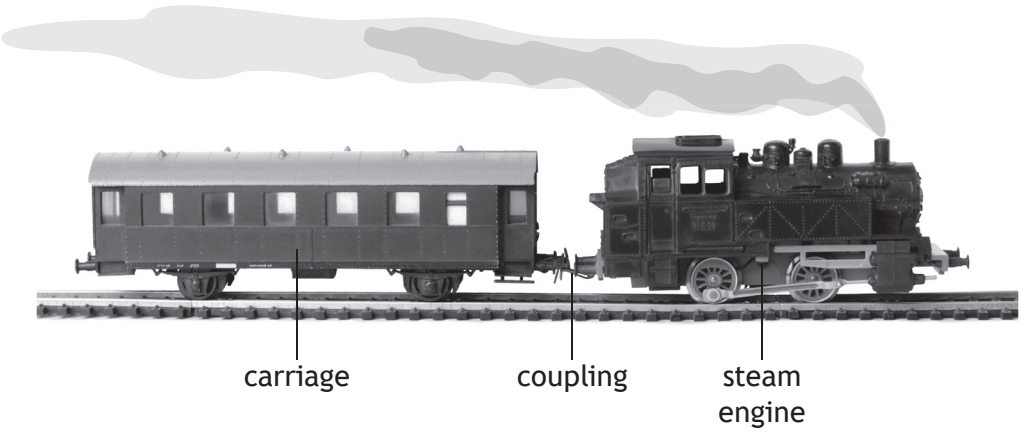
Determine the horizontal distance the skier travels from leaving the ramp until landing. **3**

Space for working and answer

(d) State how the value of the kinetic energy of the skier just before landing on the ground compares to their kinetic energy as they leave the ramp.

Justify your answer. **2**

2. A train consists of a steam engine coupled to a carriage. The train is accelerating along a straight level track.



The steam engine provides a driving force of $1{\cdot}15 \times 10^5$ N.

The mass of the steam engine is $9{\cdot}75 \times 10^4$ kg.

The mass of the carriage and passengers is $3{\cdot}56 \times 10^4$ kg.

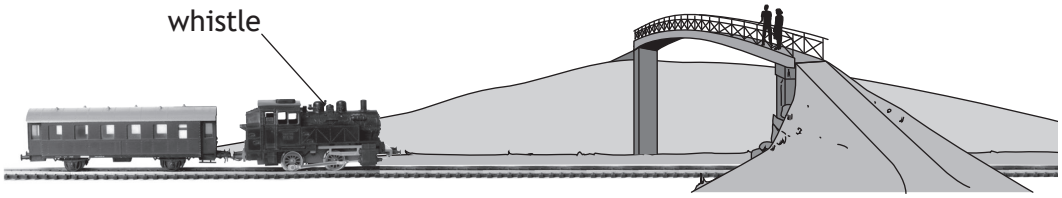
The effects of friction can be ignored.

(a) Determine the tension in the coupling between the steam engine and the carriage. **4**

Space for working and answer

2. (continued)

(b) Later in the journey, the train is travelling at a constant speed as it approaches a bridge. Two students are standing on the bridge.



(i) The engine driver sounds a whistle. The whistle emits sound with a frequency of 511 Hz.

The frequency of the sound heard by the students standing on the bridge is 531 Hz.

The speed of sound in air is 340 m s^{-1}.

Calculate the speed of the train. **3**

Space for working and answer

(ii) One student suggests that a passenger sitting in the carriage behind the engine will hear a lower frequency of sound than the frequency emitted by the whistle.

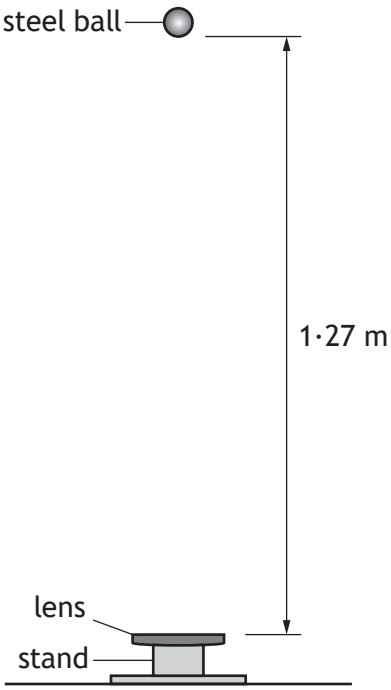
State whether the student is correct.

You must justify your answer. **2**

3. A manufacturer tests whether a Perspex lens will break during an impact.

The lens is placed on a stand and a steel ball is dropped from rest onto the lens.

The ball has a mass of $1{\cdot}59 \times 10^{-2}$ kg and is dropped from a height of 1·27 m above the lens.



(a) Calculate the speed of the ball as it reaches the lens. **3**

Space for working and answer

3. (continued)

(b) The ball collides with the lens and rebounds upwards.

The magnitude of the change in momentum of the ball is $0{\cdot}14\ \text{kg m s}^{-1}$.

Calculate the speed of the ball immediately after it rebounds from the lens. **3**

Space for working and answer

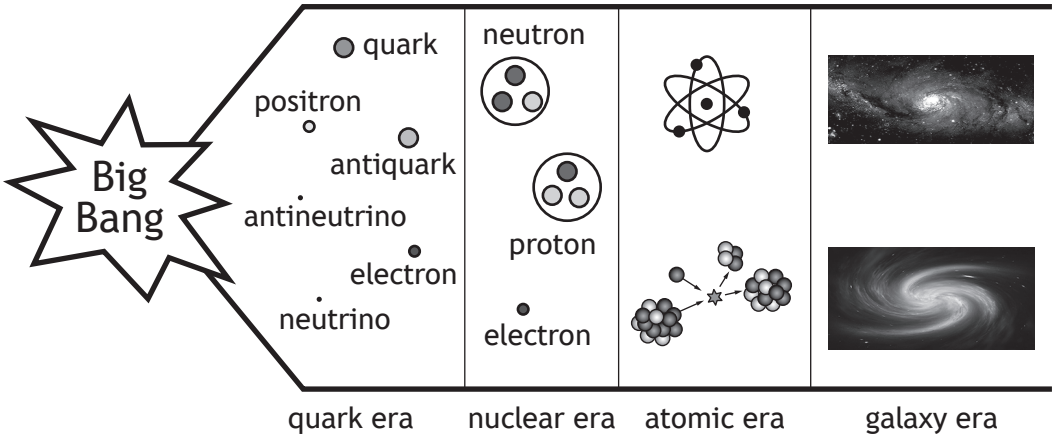
(c) The collision between the ball and the lens is inelastic.

Explain what is meant by an *inelastic collision*. **1**

(d) The test is repeated with a second lens made of a softer material.

Explain why this would make the lens less likely to break. **2**

4. A student finds the following diagram on a website. The website states that the diagram illustrates the evolution of the Universe from the Big Bang to the present day.



Using your knowledge of physics, comment on the diagram. **3**

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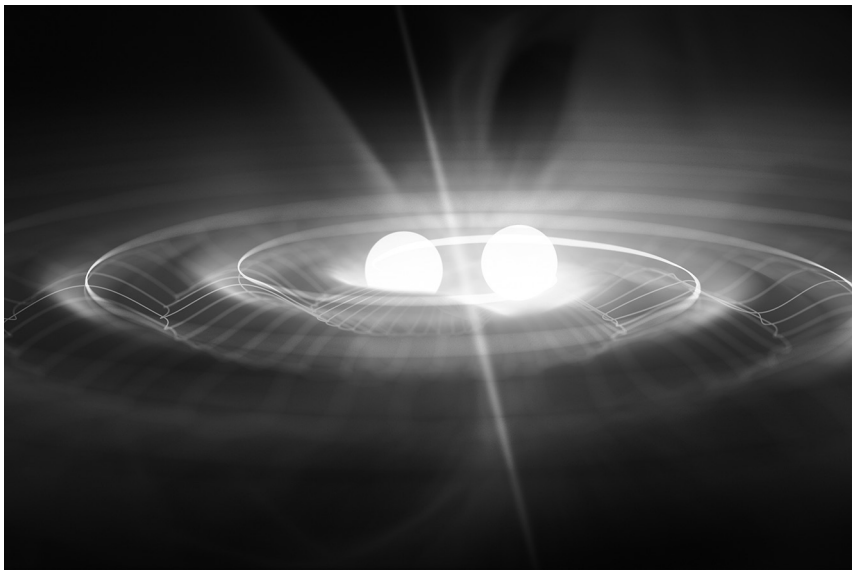
4. (continued)

5. Astronomers have recently detected gravitational waves produced by the merging of two neutron stars.

An artist's illustration of two neutron stars merging is shown.



One of the neutron stars had a mass of $3{\cdot}18 \times 10^{30}$ kg.

The second neutron star had a mass of $2{\cdot}27 \times 10^{30}$ kg.

(a) Calculate the separation of the neutron stars when the gravitational force of attraction between them was $1{\cdot}59 \times 10^{39}$ N. **3**

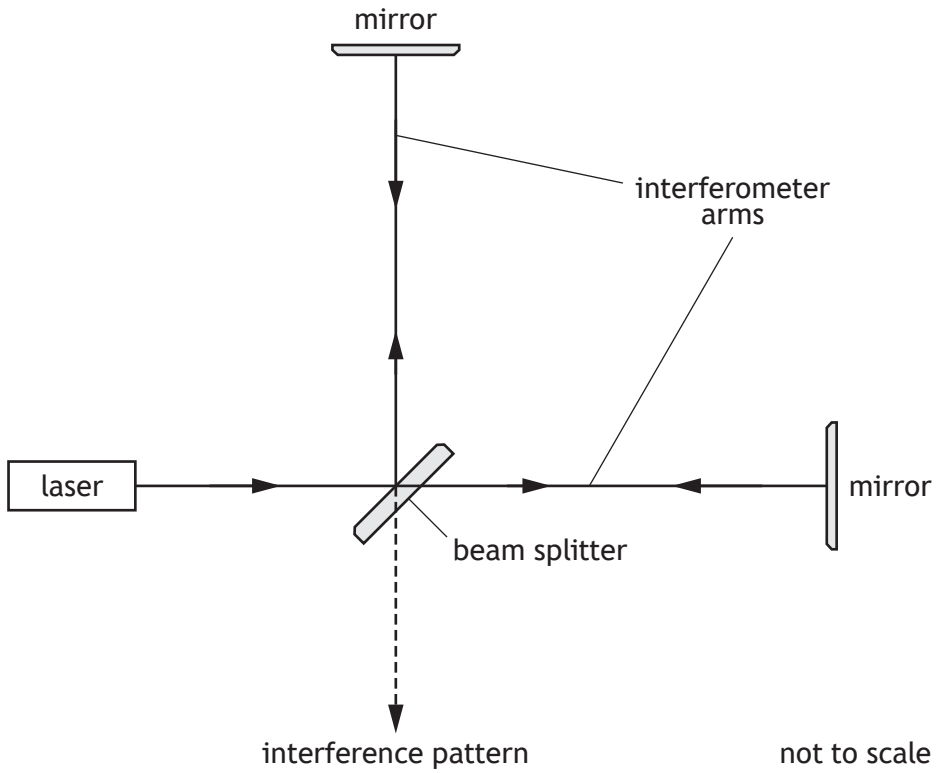
Space for working and answer

5. (continued)

(b) An interferometer is a device that can be used to detect gravitational waves.

In the interferometer, a beam of coherent light from a laser is split into two by a beam splitter.

The two beams then travel down the interferometer arms, reflect from mirrors, and finally meet to produce an interference pattern.



(i) Explain, in terms of waves, how a minimum is formed in the interference pattern. **1**

[Turn over

5. (b) (continued)

(ii) Each interferometer arm is 4·0 km long.

A gravitational wave changes the length of the arms, affecting the interference pattern produced.

The change in length of one of the arms is approximately $4{\cdot}0 \times 10^{-18}$ m.

In terms of orders of magnitude, compare the change in length of the interferometer arm with its original length. **2**

Space for working and answer

[Turn over for next question

DO NOT WRITE ON THIS PAGE

6. White light from the Sun is analysed to produce the following absorption spectrum.

The spectral lines are known as Fraunhofer lines.

(a) Some Fraunhofer lines are produced by the transition of electrons between energy levels in hydrogen atoms.

Some of the energy levels of the hydrogen atom are shown.

E_4 —————— $-0{\cdot}871 \times 10^{-19}$ J

E_3 —————— $-1{\cdot}36 \times 10^{-19}$ J

E_2 —————— $-2{\cdot}42 \times 10^{-19}$ J

E_1 —————— $-5{\cdot}45 \times 10^{-19}$ J

E_0 —————— $-21{\cdot}8 \times 10^{-19}$ J

(i) One of the Fraunhofer lines is due to the electron transition from E_1 to E_4.

Determine the frequency of the photon absorbed when an electron makes this transition. **3**

Space for working and answer

6. (a) (continued)

(ii) Calculate the wavelength of the photon absorbed. **3**

Space for working and answer

(iii) Determine the colour of the light absorbed during this electron transition. **1**

[Turn over

6. (continued)

(b) The spectral lines observed in the spectrum from a distant galaxy are redshifted. A galaxy known as NGC 6745 has a recessional velocity of $4{\cdot}51 \times 10^6$ m s^{-1}.

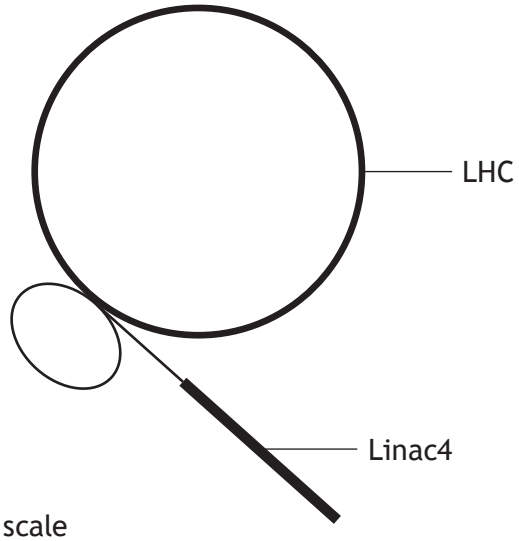
Calculate the redshift of the light from this galaxy. **3**

Space for working and answer

(c) The light from the majority of galaxies in the Universe is redshifted.

Explain how this evidence supports the Big Bang theory. **2**

7. The Large Hadron Collider (LHC) at CERN has been upgraded recently. One of the upgrades is the addition of a linear particle accelerator known as Linac4.

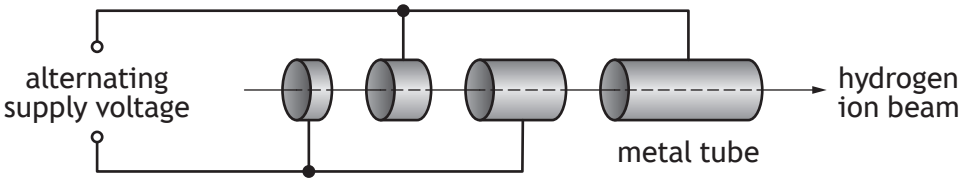


not to scale

Linac4 accelerates hydrogen ions before they enter the main LHC.

Linac4 consists of hollow metal tubes placed in a vacuum. The hydrogen ions are accelerated across the gaps between the tubes.

Part of Linac4 is shown below.



(a) (i) Explain why an alternating supply voltage is used in Linac4. **1**

(ii) Suggest one reason why the lengths of the tubes increase along Linac4. **1**

[Turn over

MARKS

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(b) Linac4 accelerates the hydrogen ions to a speed of $0{\cdot}50c$. The hydrogen ions then travel through a connecting tube before entering the LHC.

The connecting tube has a length of 13 m in the frame of reference of a stationary observer.

Calculate the length of the connecting tube in the frame of reference of the hydrogen ions. **3**

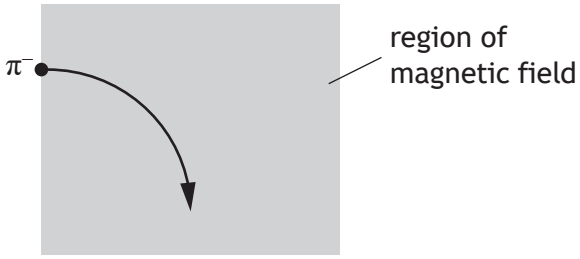
Space for working and answer

(c) Hydrogen ions can be collided within the LHC to produce other particles.

One of the particles produced is known as a π^- meson. The π^- meson is negatively charged.

(i) State what is meant by the term *meson*. **1**

(ii) The π^- meson enters a region of magnetic field and follows the path shown.



Determine the direction of the magnetic field acting upon the π^- meson. **1**

7. (continued)

(d) In July 2018, scientists at CERN announced that the Higgs boson had been observed to decay into two bottom quarks.

(i) One of the fundamental forces involved in the decay of the Higgs boson is the weak nuclear force.

Name a force mediating particle for the weak nuclear force. **1**

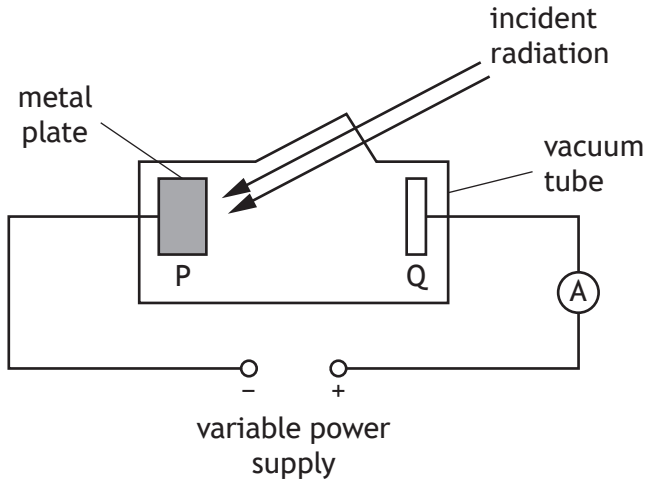
(ii) A bottom quark has a mass-energy equivalence of 4·20 GeV.

(1 eV = $1{\cdot}60 \times 10^{-19}$ J)

Determine the mass of the bottom quark. **4**

Space for working and answer

8. A student investigates the photoelectric effect using the apparatus shown.



The student notices that when white light is incident on metal plate P, the reading on the ammeter is 0 A. However, when ultraviolet radiation is incident on plate P, the reading on the ammeter is greater than 0 A.

(a) Explain why ultraviolet radiation produces a reading greater than 0 A on the ammeter, but white light does not. **1**

(b) The energy of a photon of ultraviolet radiation incident on plate P is $8{\cdot}0 \times 10^{-19}$ J.

The work function of the metal is $6{\cdot}9 \times 10^{-19}$ J.

The power supply is set to 12·0 V.

(i) Determine the maximum kinetic energy of an electron ejected from the surface of metal plate P. **1**

Space for working and answer

8. (b) (continued)

(ii) Show that the kinetic energy gained by the electron as it accelerates from plate P to plate Q is $1{\cdot}92 \times 10^{-18}$ J. **2**

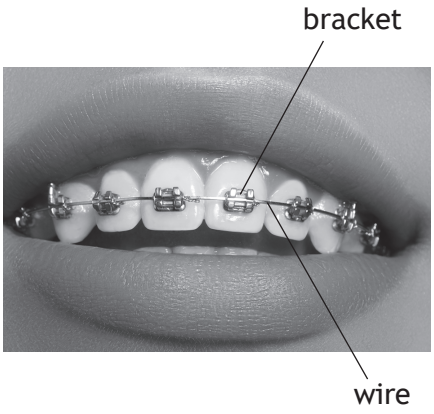
Space for working and answer

(iii) Determine the maximum speed of this electron as it reaches plate Q. **4**

Space for working and answer

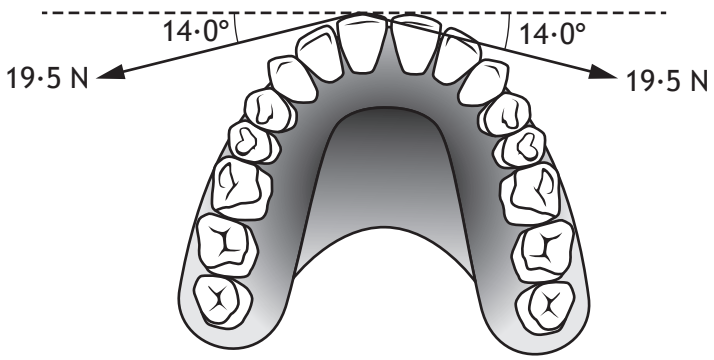
9. Dental braces are used to adjust the position of a patient's teeth.

Bonding cement is used to attach brackets to each tooth and then a stainless steel wire is attached to the brackets.



(a) The tension in the wire exerts two forces to move one of the patient's front teeth backward.

Both forces are 19·5 N as shown.



(i) Determine the magnitude of the resultant force applied to the tooth. **2**

Space for working and answer

(ii) Explain why the wire does not cause the tooth to move sideways. **1**

MARKS

DO NOT WRITE IN THIS MARGIN

(b) Light from an LED is used to harden the bonding cement applied to the patient's teeth.

(i) The irradiance of the light from the LED on the cement on one tooth is 11 800 W m^{-2}.

The bonding cement on this tooth has an area of $1{\cdot}24 \times 10^{-5}$ m^2.

The cement requires 2·10 J of energy to harden.

Determine the minimum time for which the light from the LED must be applied. **5**

Space for working and answer

9. (b) (continued)

(ii) Concern has been raised about the effect the light from the LED may have upon dental assistants' eyes.

A medical researcher investigates how the irradiance I varies with distance d from the LED.

The following results are obtained.

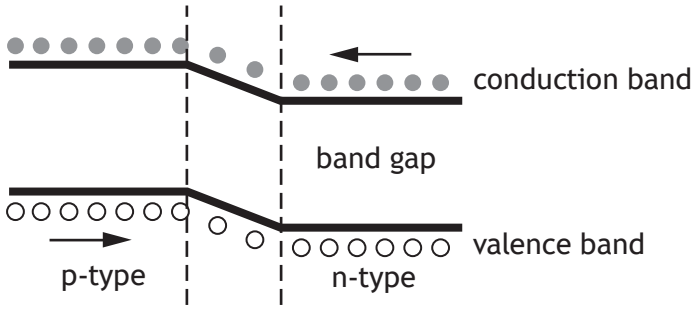
d (m)	0·30	0·40	0·50	0·60
I (W m^{-2})	6·3	3·5	2·3	1·6

Use **all the data** to show that the LED acts as a point source over this range. **3**

9. (b) (continued)

(iii) The LED is made from doped semiconductor material to create a p-n junction.

The diagram represents the band structure of the LED.

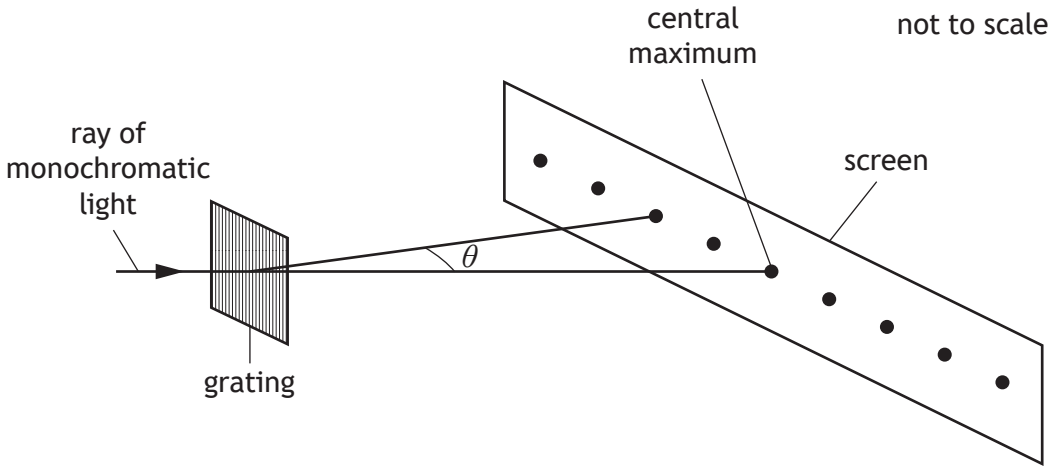


(A) State what is meant by a *doped semiconductor*. **1**

(B) A voltage is applied across the LED so that it is forward biased and emits light.

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

10. A technician carries out an experiment to determine the wavelength of monochromatic light from a laser.



(a) A pattern of bright spots is observed on the screen.

The technician measures the angle θ between the central maximum and the second order maximum five times.

The results are shown.

14·0° 13·5° 14·5° 14·5° 13·0°

(i) Calculate

(A) the mean value for the angle θ **1**

Space for working and answer

(B) the approximate random uncertainty in this value. **2**

Space for working and answer

10. (a) (continued)

(ii) The spacing between the lines on the grating is $4{\cdot}00 \times 10^{-6}$ m.

Calculate the wavelength of the light from the laser. **3**

Space for working and answer

(iii) The technician repeats the experiment and this time measures the angle between the central maximum and the third order maximum.

Explain why this gives a more precise value for the wavelength of the light. **1**

(b) The laser is now replaced by a source of white light. The pattern observed on the screen consists of a white central maximum and a series of continuous spectra on each side of the white central maximum.

Explain, in terms of path difference, why the central maximum is white. **1**

[Turn over

11. The use of analogies from everyday life can help people to better understand physics concepts.

The arrangement of books on the shelves of a bookcase can be used as an analogy for the Bohr model of the atom.

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

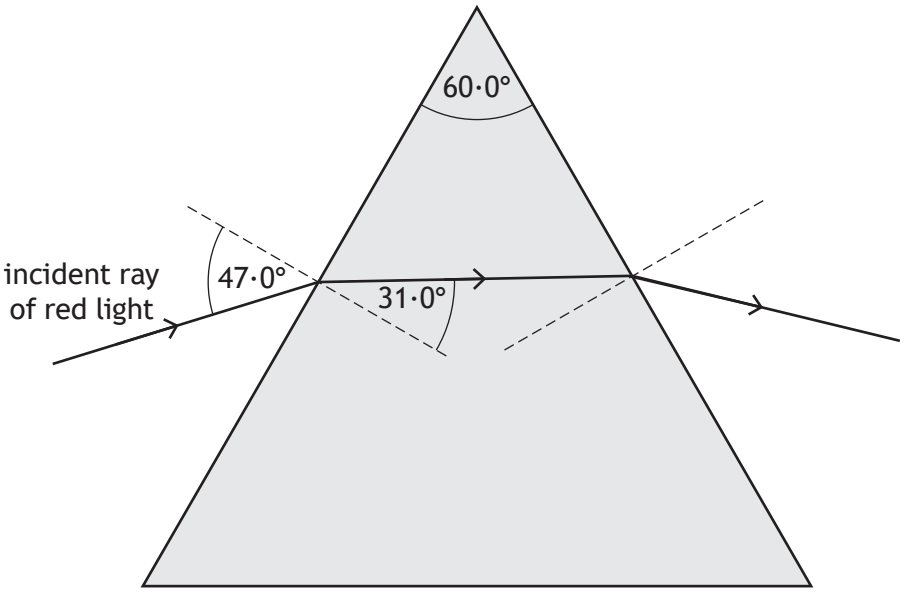
DO NOT WRITE IN THIS MARGIN

11. (continued)

12. A technician fills a hollow prism with a sugar solution.

The technician shines red light from a laser into the prism.

The angle through which the light refracts depends upon the concentration of the sugar solution.



hollow prism
filled with solution

(a) (i) Calculate the refractive index of this solution. **3**

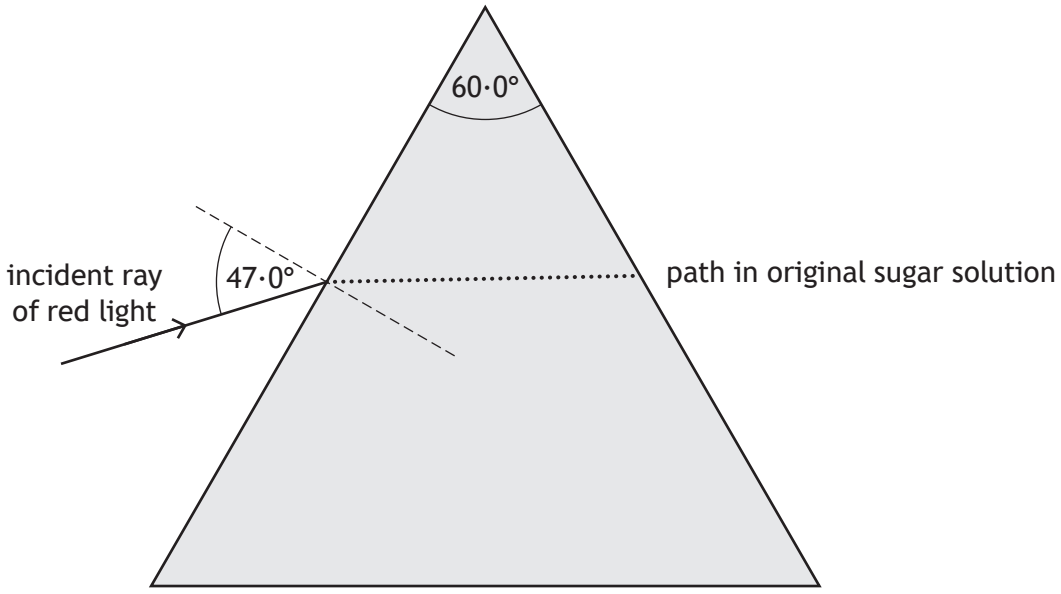
Space for working and answer

(ii) State how the frequency of the light in the solution compares to the frequency of the light in air. **1**

12. (continued)

(b) The prism is now filled with a more concentrated sugar solution, which has a greater refractive index.

On the diagram below, draw the path the ray will now follow **inside** the prism. **1**



hollow prism filled with more concentrated solution

(An additional diagram, if required can be found on *page 45*.)

(c) The experiment is repeated using green light from a laser and the more concentrated sugar solution. The light enters the prism at the same angle as before.

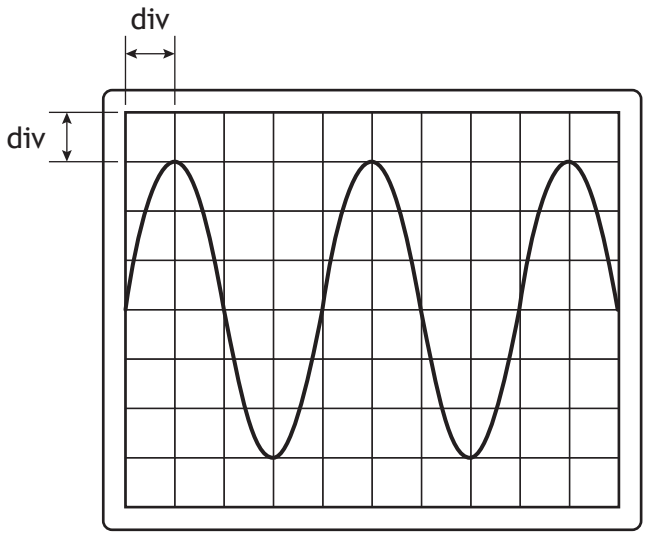
Explain the difference in the path taken by the green light compared to the path taken by the red light. **2**

[Turn over

13. A student connects a signal generator, which provides an alternating current, to an oscilloscope.

(a) State what is meant by an *alternating current*. **1**

(b) The oscilloscope screen shows the output of the signal generator.



The Y-gain setting on the oscilloscope is 5·0 V/div.

The timebase setting on the oscilloscope is 1·0 ms/div.

(i) Determine the peak voltage of the output of the signal generator. **1**

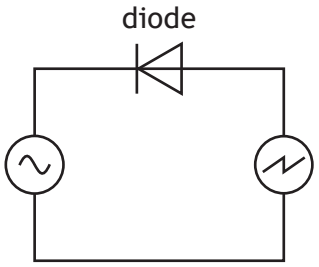
Space for working and answer

13. (b) (continued)

(ii) Determine the frequency of the output of the signal generator. **3**

Space for working and answer

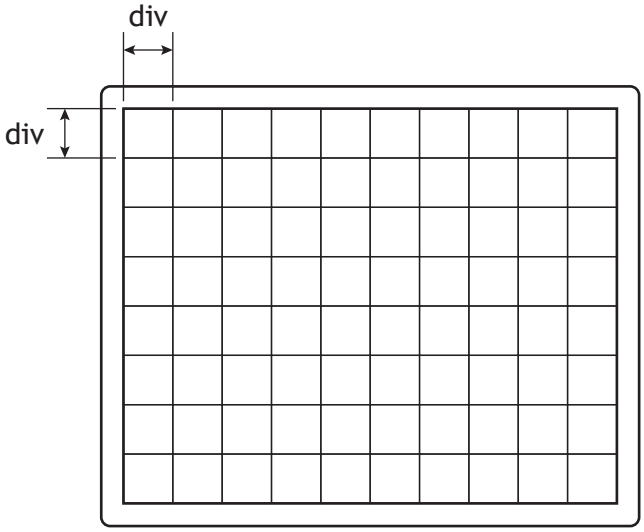
(c) The student connects a diode to the circuit as shown. The settings on the signal generator and the oscilloscope are unchanged.



Current can only flow in one direction through a diode.

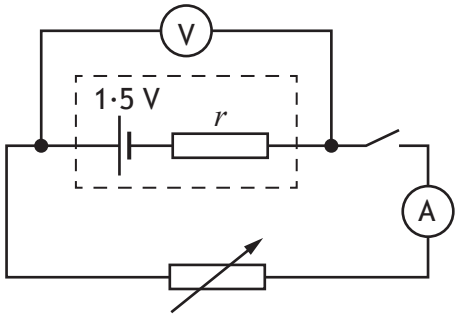
This changes the trace on the oscilloscope screen.

On the diagram below, draw the new trace seen on the oscilloscope screen. **2**



(An additional diagram, if required can be found on *page 45*.)

14. A student carries out an experiment, using the apparatus shown, to determine a value for the internal resistance r of a cell.



(a) Describe how the student would use this apparatus, and analyse the data obtained, to determine the value for the internal resistance of the cell. **3**

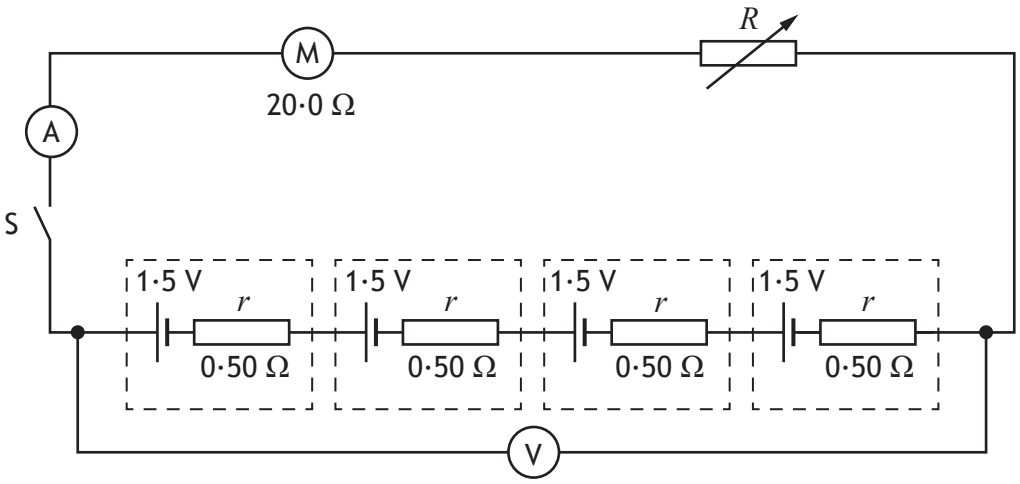
MARKS

DO NOT WRITE IN THIS MARGIN

(b) The internal resistance of the cell is determined to be 0·50 Ω.

Four identical cells are now connected to a motor and a variable resistor as shown.

The EMF of each cell is 1·5 V.



(i) State what is meant by an *EMF of 1·5 V*. **1**

(ii) Switch S is now closed. The reading on the ammeter is 0·20 A.

Determine the resistance R of the variable resistor. **4**

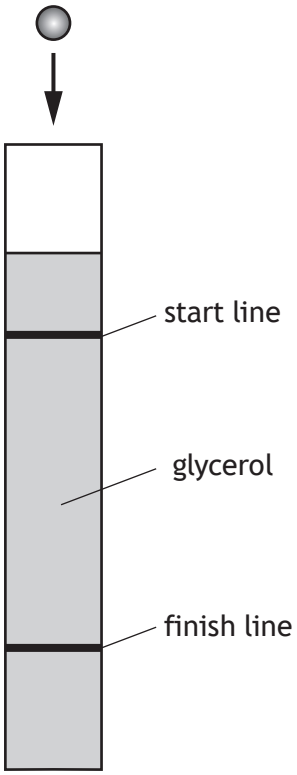
Space for working and answer

14. (continued)

(c) The resistance of the variable resistor is now increased.
State what happens to the reading on the voltmeter.
Justify your answer. **3**

15. A student carries out an experiment to measure the terminal velocity of ball bearings with different diameters falling through glycerol.

Each ball bearing is dropped into a long tube filled with glycerol.



(a) Explain in terms of the forces acting on the ball bearing, why it reaches its terminal velocity. **2**

[Turn over

MARKS

DO NOT WRITE IN THIS MARGIN

(b) The student measures the diameter d of each ball bearing and records the corresponding terminal velocity v_t.

The results are shown in the table.

d (m)	d^2 (m^2)	v_t (m s^{-1})
$3{\cdot}15 \times 10^{-3}$	$0{\cdot}99 \times 10^{-5}$	0·05
$4{\cdot}77 \times 10^{-3}$	$2{\cdot}28 \times 10^{-5}$	0·10
$6{\cdot}34 \times 10^{-3}$	$4{\cdot}02 \times 10^{-5}$	0·18
$9{\cdot}52 \times 10^{-3}$	$9{\cdot}06 \times 10^{-5}$	0·32
$12{\cdot}65 \times 10^{-3}$	$16{\cdot}00 \times 10^{-5}$	0·52

(i) Using the square-ruled paper on *page 42*, draw a graph of v_t against d^2. **3**

(The table of results is also shown on *page 43*, opposite the square-ruled paper.)

(ii) The student suspects that the results show that there is a systematic uncertainty in the measurements.

Suggest a reason why the student has come to this conclusion. **1**

(iii) Calculate the gradient of your graph. **2**

Space for working and answer

15. (b) (continued)

(iv) The terminal velocity v_t of each ball bearing is given by

$$v_t = \frac{375g}{\eta} \times d^2$$

where η is the viscosity of the glycerol in pascal seconds (Pa s)

d is the diameter of the ball bearing in m

g is gravitational field strength on Earth in N kg^{-1}.

Use the gradient of your graph to determine the viscosity of the glycerol. **2**

Space for working and answer

[END OF QUESTION PAPER]

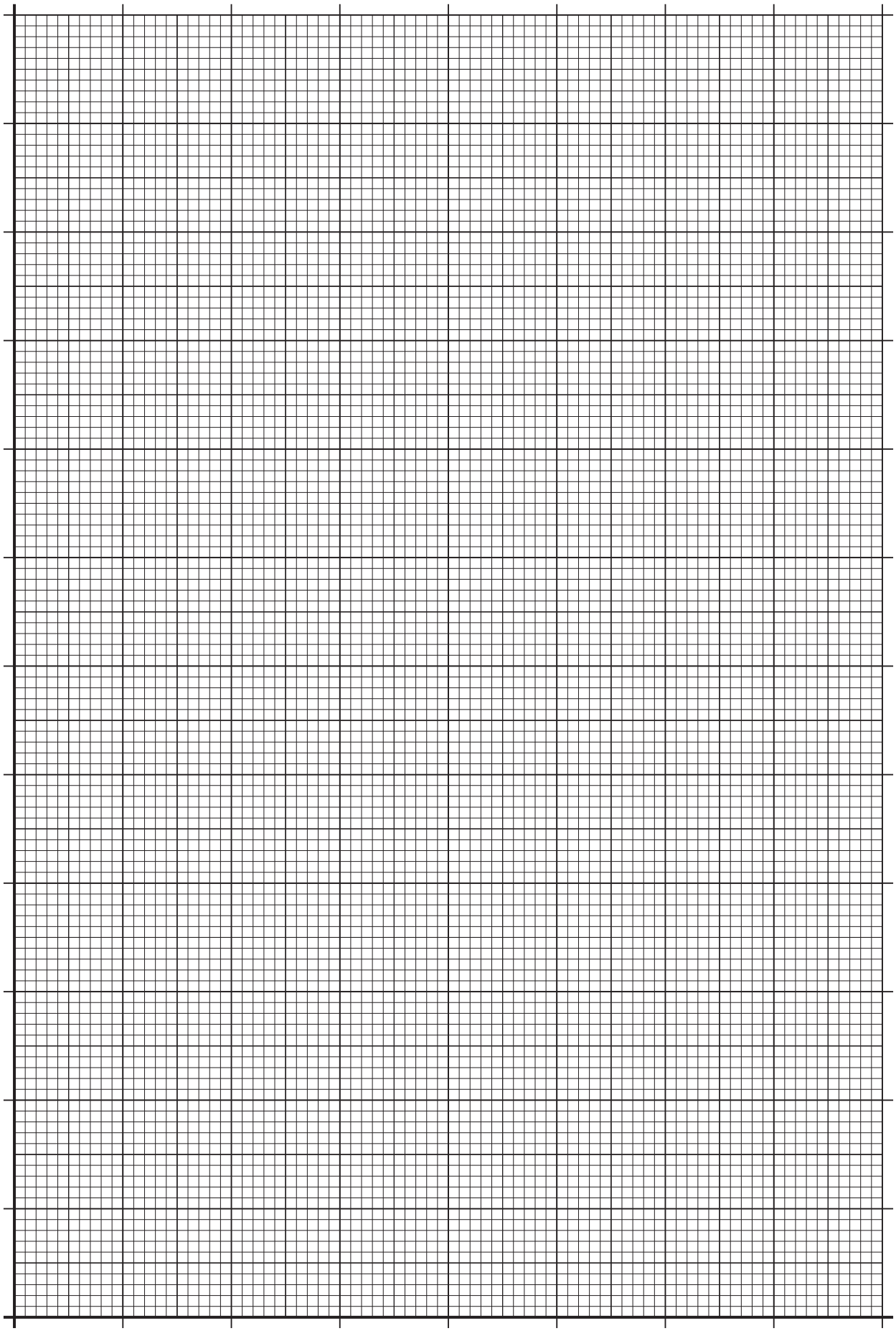


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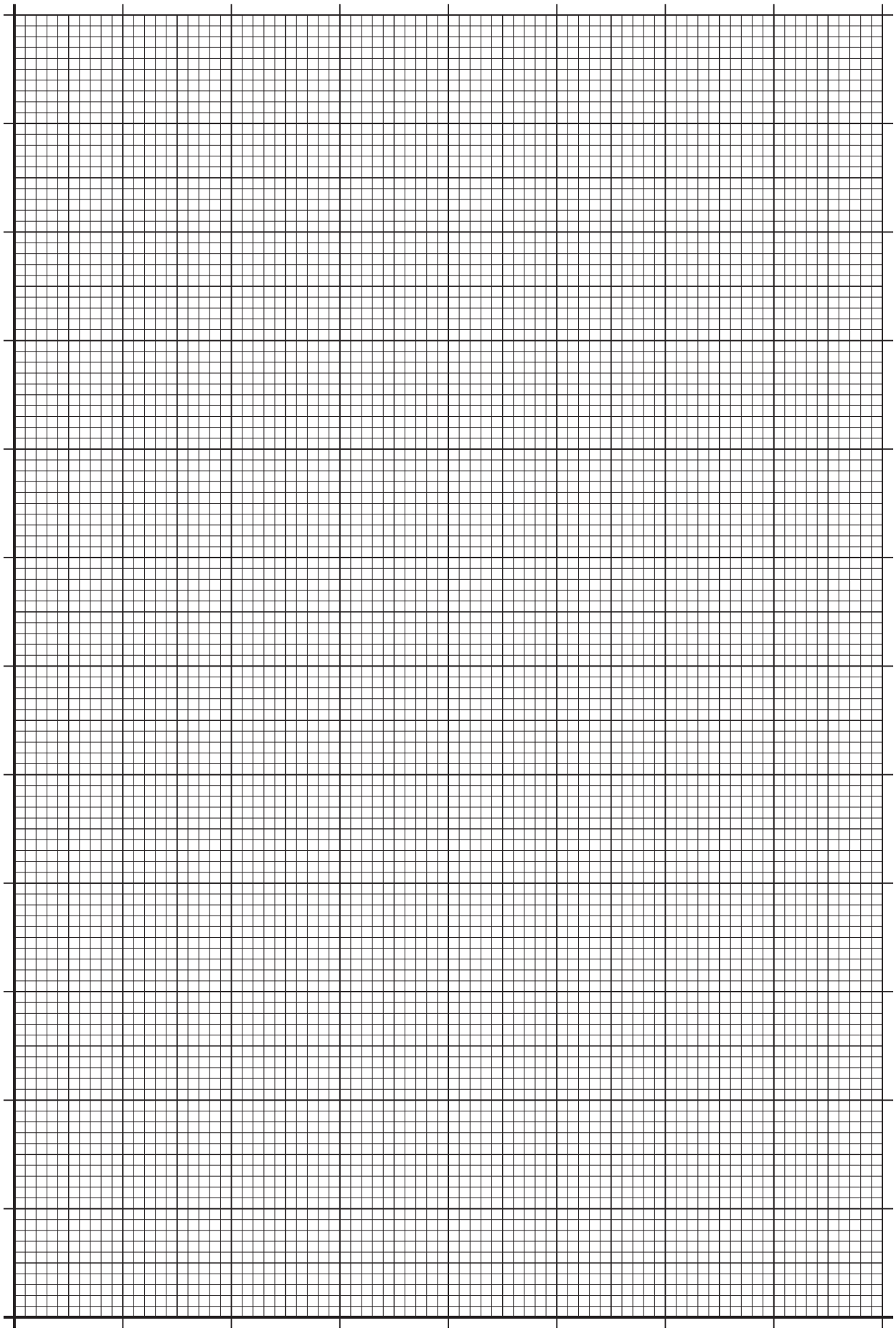
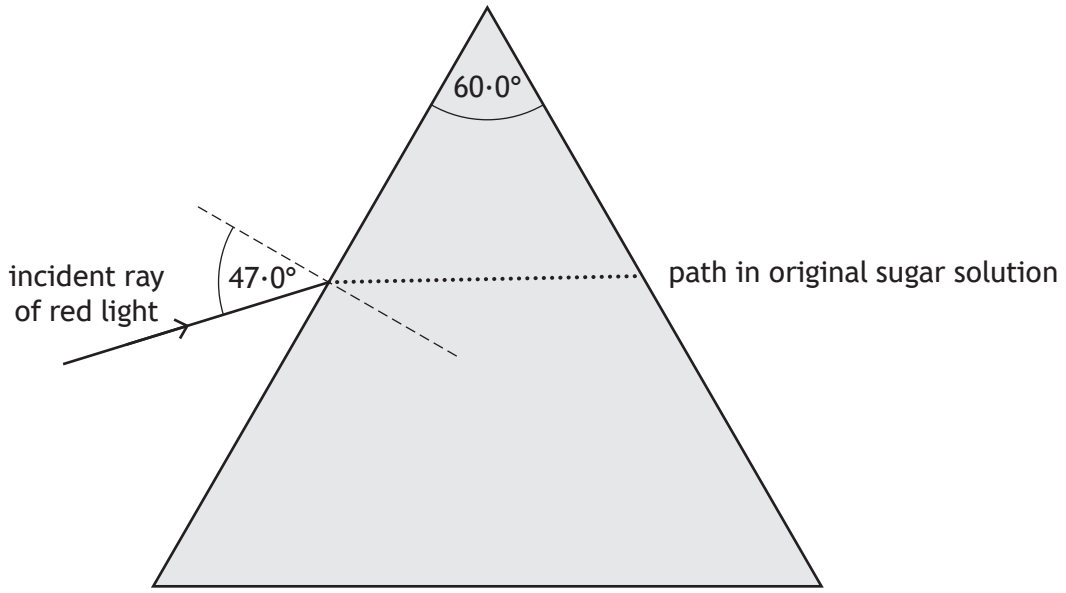
Table of results for use with question 15 (b) (i)

d (m)	d^2 (m^2)	v_t (m s^{-1})
$3{\cdot}15 \times 10^{-3}$	$0{\cdot}99 \times 10^{-5}$	0·05
$4{\cdot}77 \times 10^{-3}$	$2{\cdot}28 \times 10^{-5}$	0·10
$6{\cdot}34 \times 10^{-3}$	$4{\cdot}02 \times 10^{-5}$	0·18
$9{\cdot}52 \times 10^{-3}$	$9{\cdot}06 \times 10^{-5}$	0·32
$12{\cdot}65 \times 10^{-3}$	$16{\cdot}00 \times 10^{-5}$	0·52

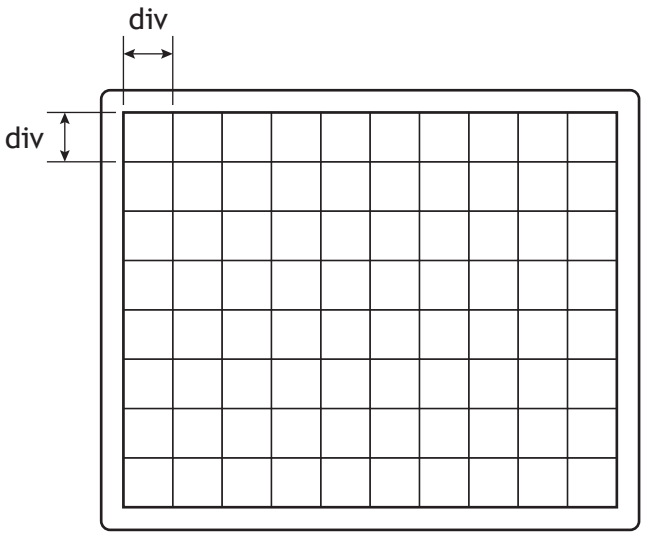


ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional diagram for use with question 12 (b)



Additional diagram for use with question 13 (c)



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ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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National
Qualifications

X857/76/11

Physics
Paper 2 — Relationships sheet

Duration — 2 hours 15 minutes

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X8577611

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