H

National Qualifications 2019

X857/76/12

Physics
Paper 1 — Multiple choice

WEDNESDAY, 15 MAY

9:00 AM – 9:45 AM

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.

X85776 12

A/PB

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 } 10 590 }	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

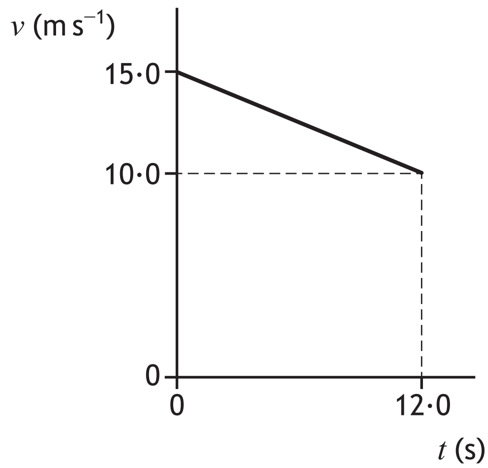
Substance	*Density*/kg m^{-3}	*Melting point*/K	*Boiling point*/K
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	....
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	....	....
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 mark — 25

Attempt ALL questions

1. The graph shows how the speed v of a car varies with time t.



The average speed of the car during the 12·0 s is

A $1{\cdot}25\,\text{m}\,\text{s}^{-1}$

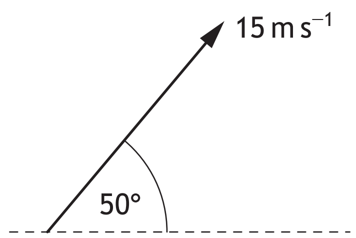
B $2{\cdot}08\,\text{m}\,\text{s}^{-1}$

C $2{\cdot}50\,\text{m}\,\text{s}^{-1}$

D $7{\cdot}50\,\text{m}\,\text{s}^{-1}$

E $12{\cdot}5\,\text{m}\,\text{s}^{-1}$.

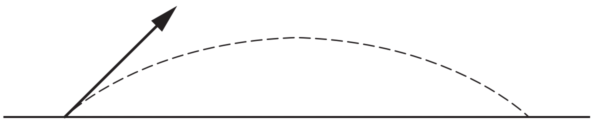
2. A stone is thrown at 50° to the horizontal with a speed of $15\,\text{m}\,\text{s}^{-1}$.



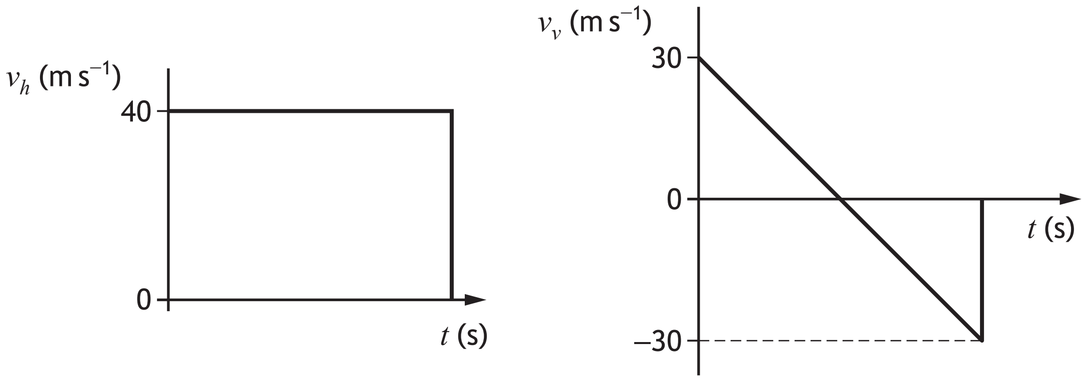
Which row in the table gives the horizontal component and the vertical component of the initial velocity of the stone?

	Horizontal component ($\text{m}\,\text{s}^{-1}$)	**Vertical component ($\text{m}\,\text{s}^{-1}$)**
A	15 sin 50	15 cos 50
B	15 cos 50	15 sin 50
C	15 cos 50	15 sin 40
D	15 cos 40	15 sin 50
E	15 sin 50	15 cos 40

3. A golfer strikes a golf ball, which then moves off at an angle to the ground. The ball follows the path shown.



The graphs show how the horizontal component of the velocity v_h and the vertical component of the velocity v_v of the ball vary with time t.



The speed of the ball just before it hits the ground is

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

B $30\,m\,s^{-1}$

C $40\,m\,s^{-1}$

D $50\,m\,s^{-1}$

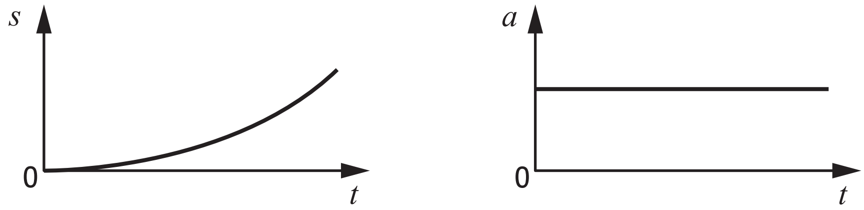
E $70\,m\,s^{-1}$.

4. A car accelerates from rest along a straight level road.

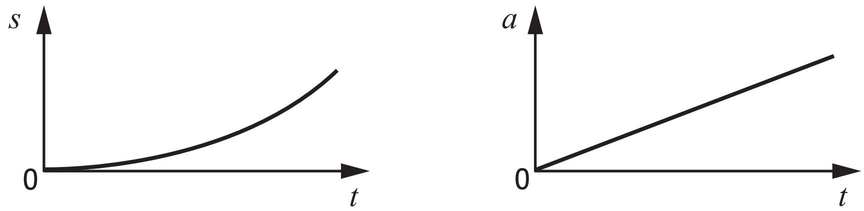
The acceleration of the car is constant.

Which pair of displacement-time (s-t) and acceleration-time (a-t) graphs represent the motion of the car?

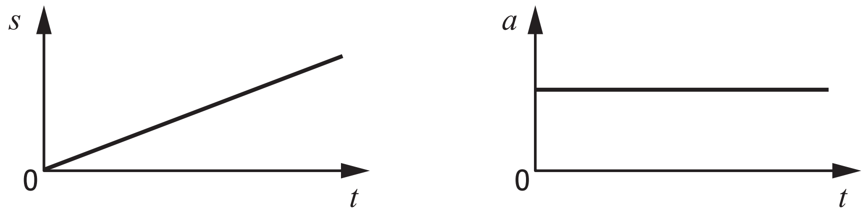
A



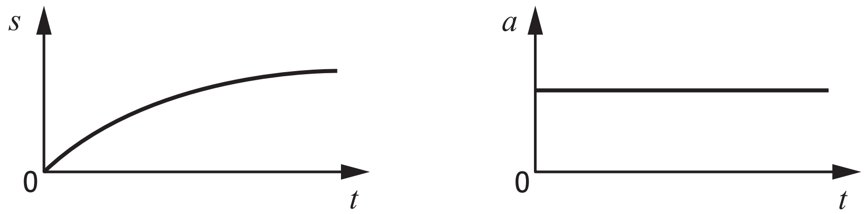
B



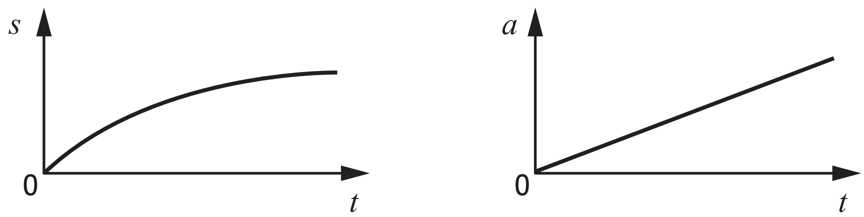
C



D

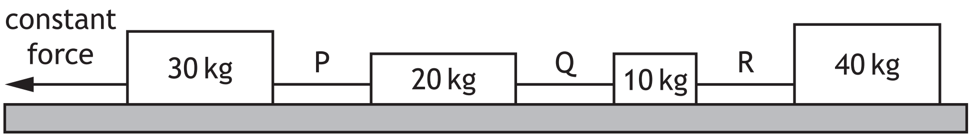


E



[Turn over

5. Four masses on a horizontal, frictionless surface are linked together by strings P, Q and R. A constant force is applied as shown.



The tension in the strings is

A greatest in P and least in Q

B greatest in P and least in R

C greatest in R and least in Q

D greatest in R and least in P

E the same in P, Q and R.

6. A student makes the following statements about an elastic collision.

I Total momentum is conserved.

II Total kinetic energy is conserved.

III Total energy is conserved.

Which of these statements is/are correct?

A I only

B II only

C I and II only

D I and III only

E I, II and III

7. The terminal velocity v_t of a skydiver is given by the relationship

$$v_t = \sqrt{\frac{2mg}{\rho A C_d}}$$

where

m is the mass of the skydiver in kg

g is the gravitational field strength in N kg^{-1}

C_d is the drag coefficient

ρ is the density of air in kg m^{-3}

A is the area of the skydiver in m^2.

When in freefall, a skydiver of mass 95 kg has a drag coefficient of 1·0 and a terminal velocity of $44\,\text{m s}^{-1}$.

The gravitational field strength is $9·8\,\text{N kg}^{-1}$ and the density of air is $1·21\,\text{kg m}^{-3}$.

The area of the skydiver is

A 0·59 m^2

B 0·79 m^2

C 0·89 m^2

D 4·2 m^2

E 35 m^2.

8. A spacecraft is travelling at a constant speed relative to a nearby planet.

A technician on the spacecraft measures the length of the spacecraft as 275 m.

An observer on the planet measures the length of the spacecraft as 125 m.

The speed of the spacecraft relative to the observer on the nearby planet is

A $1·54 \times 10^4\,\text{m s}^{-1}$

B $2·22 \times 10^8\,\text{m s}^{-1}$

C $2·67 \times 10^8\,\text{m s}^{-1}$

D $3·00 \times 10^8\,\text{m s}^{-1}$

E $7·14 \times 10^{16}\,\text{m s}^{-1}$.

[Turn over

9. The redshift of a distant galaxy is 0·014.

According to Hubble's law, the distance of the galaxy from Earth is

A $9{\cdot}66 \times 10^{-12}$ m

B $1{\cdot}83 \times 10^{24}$ m

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

D $9{\cdot}32 \times 10^{27}$ m

E $6{\cdot}33 \times 10^{39}$ m.

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

I The force due to gravity acts against the expansion of the Universe.

II Measurements show the rate of expansion of the Universe is increasing.

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

Which of these statements is/are correct?

A I only

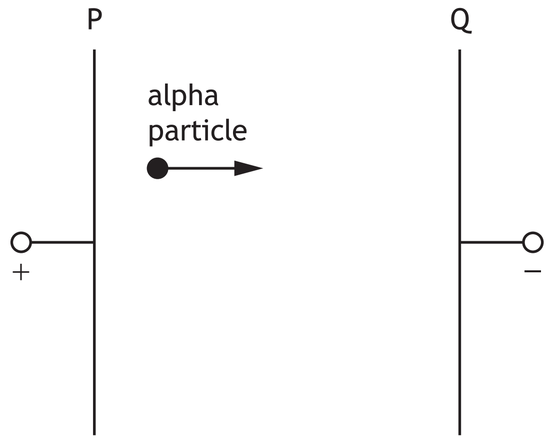
B II only

C III only

D I and II only

E I, II and III

11. An alpha particle is accelerated in an electric field between metal plates P and Q.



The charge on the alpha particle is $3{\cdot}2 \times 10^{-19}$ C.

The kinetic energy gained by the alpha particle while travelling from plate P to plate Q is $8{\cdot}0 \times 10^{-16}$ J.

The potential difference across plates P and Q is

A $2{\cdot}6 \times 10^{-34}$ V

B $2{\cdot}0 \times 10^{-4}$ V

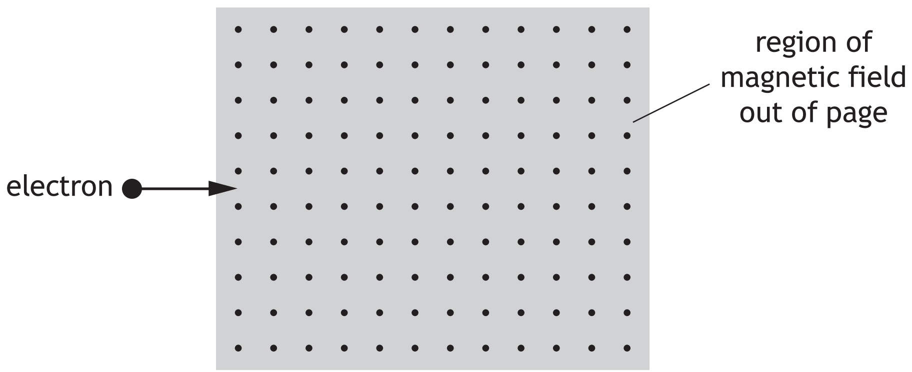
C $4{\cdot}0 \times 10^{-4}$ V

D $2{\cdot}5 \times 10^{3}$ V

E $5{\cdot}0 \times 10^{3}$ V.

[Turn over

12. An electron enters a region of uniform magnetic field as shown.



The direction of the magnetic force on the electron immediately after entering the field is

A towards the top of the page

B towards the bottom of the page

C towards the right of the page

D into the page

E out of the page.

13. A student makes the following statements about the Standard Model.

I Every particle has an antiparticle.

II Alpha decay is evidence for the existence of the neutrino.

III The W-boson is associated with the strong nuclear force.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E I and III only

14. A nucleus represented by $^{223}_{87}Fr$ decays by beta emission.

The symbol representing the nucleus formed as a result of this decay is

A $^{224}_{87}Fr$

B $^{222}_{87}Fr$

C $^{223}_{88}Ra$

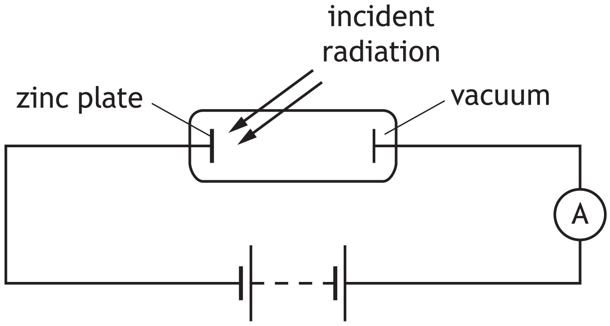
D $^{223}_{86}Rn$

E $^{224}_{88}Ra$.

[Turn over

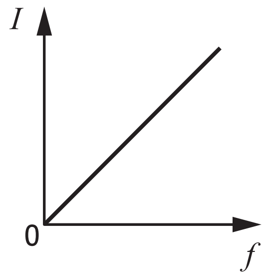
15. The diagram shows an experiment set up to investigate the photoelectric effect.

The frequency of the incident radiation is varied and the current in the circuit is measured.

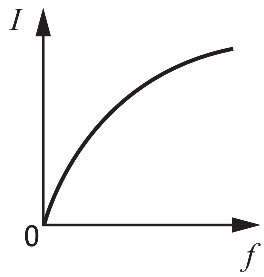


Which graph shows the relationship between the current I in the circuit and the frequency f of the incident radiation?

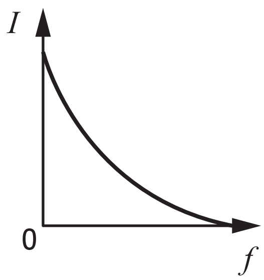
A



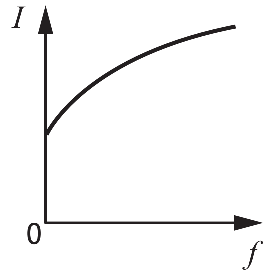
B



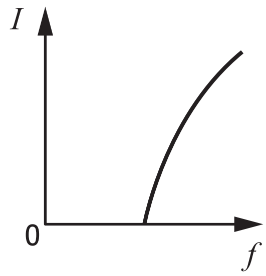
C



D



E



16. A photon of energy $6{\cdot}40 \times 10^{-19}$ J is incident on a metal plate.

This causes photoemission to take place.

The work function of the metal is $4{\cdot}20 \times 10^{-19}$ J.

The maximum speed of the photoelectron is

A $1{\cdot}19 \times 10^{6}\,\text{m s}^{-1}$

B $9{\cdot}60 \times 10^{5}\,\text{m s}^{-1}$

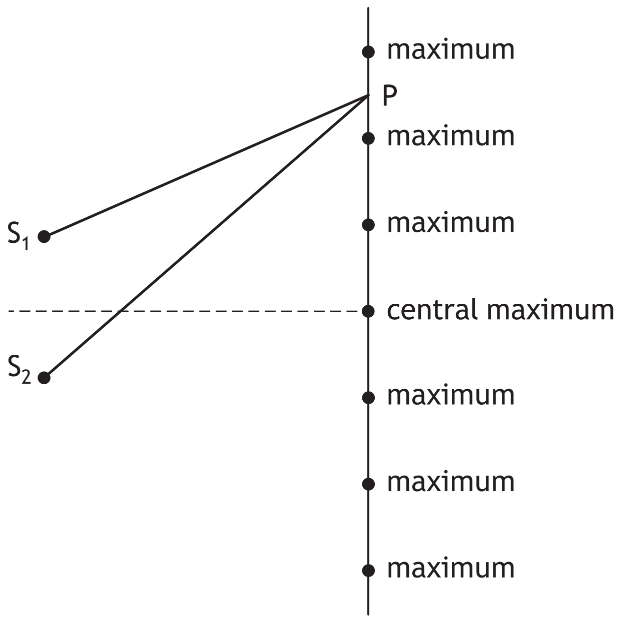
C $6{\cdot}95 \times 10^{5}\,\text{m s}^{-1}$

D $6{\cdot}79 \times 10^{5}\,\text{m s}^{-1}$

E $4{\cdot}91 \times 10^{5}\,\text{m s}^{-1}$.

17. Waves from two coherent sources, S_1 and S_2, produce an interference pattern.

Maxima are detected at the positions shown.



The wavelength of the waves is 28 mm.

For the third **minimum** at P the path difference ($S_2P - S_1P$) is

A 42 mm

B 56 mm

C 70 mm

D 84 mm

E 98 mm.

[Turn over

18. A ray of monochromatic light passes from air into water.

The wavelength of this light in air is 589 nm.

The speed of this light in water is

A $2{\cdot}56 \times 10^2\,\mathrm{m\,s^{-1}}$

B $4{\cdot}52 \times 10^2\,\mathrm{m\,s^{-1}}$

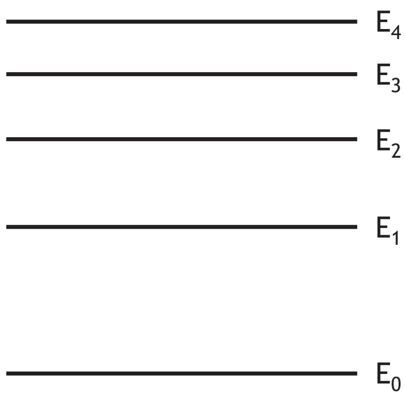
C $2{\cdot}26 \times 10^8\,\mathrm{m\,s^{-1}}$

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

E $3{\cdot}99 \times 10^8\,\mathrm{m\,s^{-1}}$.

19. When light passes through the outer layers of the Sun certain frequencies of light are absorbed by hydrogen atoms, producing dark lines in the spectrum.

The diagram represents some of the energy levels for a hydrogen atom.



The number of absorption lines in the spectrum caused by the transition of electrons between these energy levels is

A 4

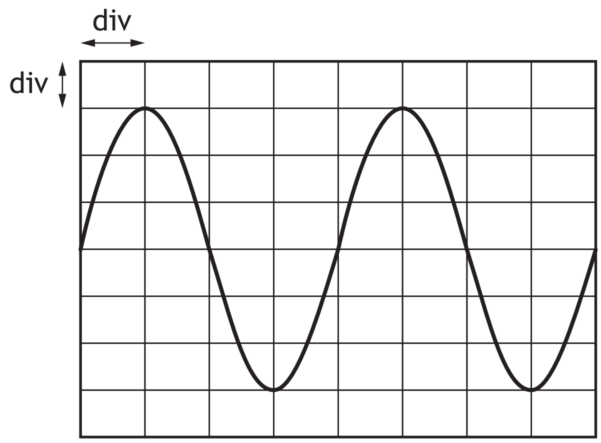
B 6

C 9

D 10

E 20.

20. The output from an AC power supply is connected to an oscilloscope. The trace seen on the oscilloscope screen is shown.



The Y-gain setting on the oscilloscope is 1·0 V/div.

The rms voltage of the power supply is

A 2·1 V

B 3·0 V

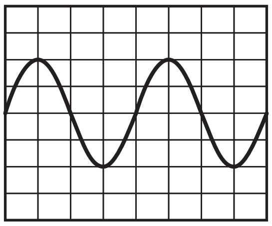
C 4·0 V

D 4·2 V

E 6·0 V.

[Turn over

21. The output from a signal generator is connected to an oscilloscope. The trace observed on the oscilloscope screen is as shown in the diagram.



The frequency of the signal from the signal generator is now doubled.

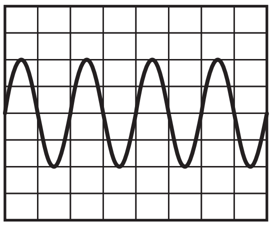
The amplitude of the signal is unchanged.

The Y-gain setting on the oscilloscope is unchanged.

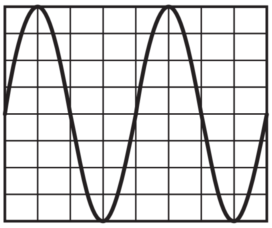
The timebase setting on the oscilloscope is changed from 1·0 ms/division to 0·5 ms/division.

Which of the following diagrams shows the trace that is now observed on the oscilloscope screen?

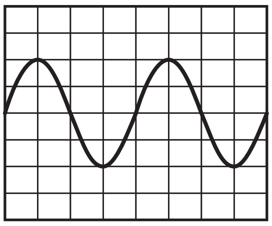
A



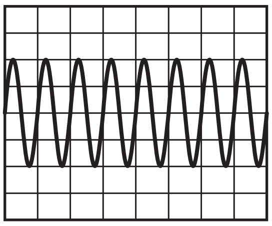
D



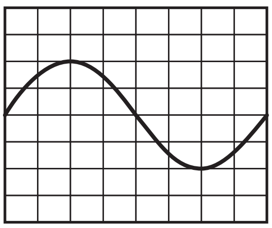
B



E



C



22. A student sets up a circuit and measures the voltage across and the current in a resistor.

The measurements and their uncertainties are

$$\text{voltage} = (10{\cdot}0 \pm 0{\cdot}1)\,\text{V}$$
$$\text{current} = (0{\cdot}50 \pm 0{\cdot}01)\,\text{A}$$

The approximate absolute uncertainty in the calculated value of the resistance of the resistor is

A $\pm 0{\cdot}11\,\Omega$

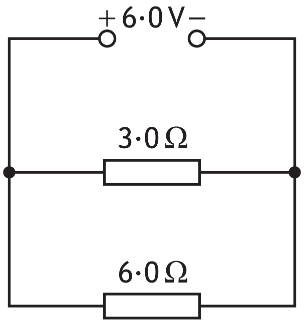
B $\pm 0{\cdot}2\,\Omega$

C $\pm 0{\cdot}4\,\Omega$

D $\pm 1\,\Omega$

E $\pm 2\,\Omega$.

23. A circuit is set up as shown.



The power supply has negligible internal resistance.

The power dissipated in the $3{\cdot}0\,\Omega$ resistor is

A $3{\cdot}0\,\text{W}$

B $6{\cdot}0\,\text{W}$

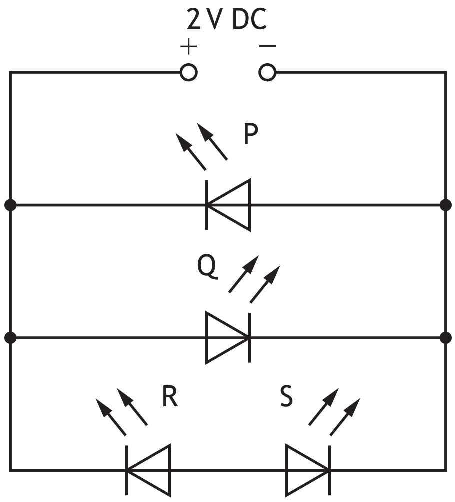
C $9{\cdot}0\,\text{W}$

D $12\,\text{W}$

E $18\,\text{W}$.

[Turn over

24. A student connects four identical light emitting diodes (LEDs) to a 2 V DC supply as shown.



Which of the LEDs P, Q, R, and S will light?

A P only

B Q only

C P and Q only

D P and R only

E Q and S only.

25. A student makes the following statements about uncertainties.

I All measurements of physical quantities are liable to uncertainties.

II Random uncertainties occur when a measurement is repeated and slight variations occur.

III Systematic uncertainties in a quantity occur when measurements are either all smaller or all larger than the true value of the quantity.

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

[END OF QUESTION PAPER]

SPACE FOR ROUGH WORK

SPACE FOR ROUGH WORK

FOR OFFICIAL USE

H

National Qualifications 2019

Mark

X857/76/02

Physics
Paper 1 — Multiple choice
Answer booklet

WEDNESDAY, 15 MAY

9:00 AM – 9:45 AM

X857760 2

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.

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

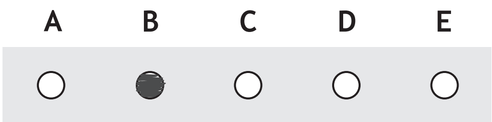
B kilowatt-hour

C watt

D coulomb

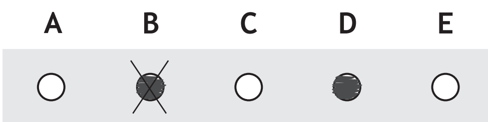
E volt.

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

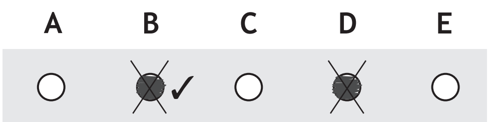


Changing an answer

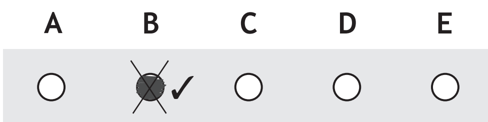
If you decide to change your answer, cancel your first answer by putting a cross through it (see below) and fill in the answer you want. The answer below has been changed to **D**.



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:



or



Paper 1 — Answer grid

Physics

	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
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2019

X857/76/22

Physics
Paper 1 — Relationships sheet

WEDNESDAY, 15 MAY

9:00 AM – 9:45 AM

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 $W = Fd$

$E_p = mgh$

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

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

$p = mv$

$Ft = mv - mu$

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

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

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

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

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

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

$v = H_0 d$

$W = QV$

$E = mc^2$

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

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

$I_1 d_1^2 = I_2 d_2^2$

$E = hf$

$E_k = hf - hf_0$

$v = f\lambda$

$E_2 - E_1 = hf$

$d \sin\theta = m\lambda$

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

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

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

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

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

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

$V = IR$

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

$R_T = R_1 + R_2 + \ldots$

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

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

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

$E = V + Ir$

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

$Q = It$

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

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

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

or

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

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

Key

Atomic number Symbol Electron arrangement Name

Transition elements (groups 3–12)

Group 1 (1)	Group 2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	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	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	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	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	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	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	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	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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2019

Mark

X857/76/01

Physics Paper 2

WEDNESDAY, 15 MAY

10:15 AM – 12:30 PM

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.

X857760101

DATA SHEET

COMMON PHYSICAL QUANTITIES

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

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 } 10 590 }	Infrared
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.

* X 8 5 7 7 6 0 1 0 2 *

[Turn over for next question

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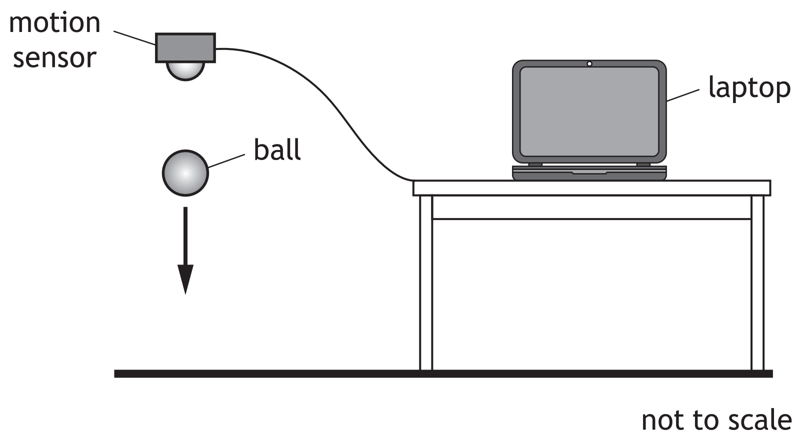
Total marks — 130

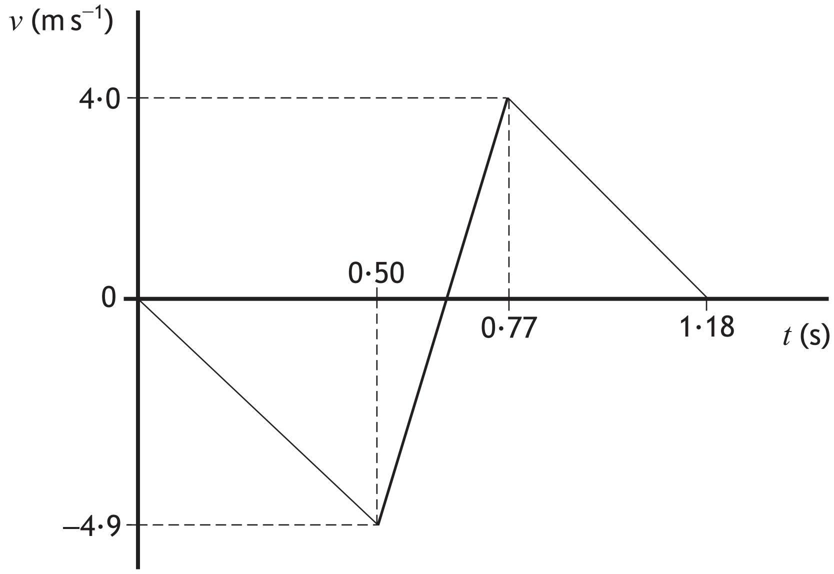
Attempt ALL questions

1. A student carries out an experiment with a tennis ball and a motion sensor connected to a laptop.



The ball is released from rest below the sensor.

The graph shows how the vertical velocity v of the ball varies with time t, from the moment the ball is released until it rebounds to its new maximum height.



MARKS DO NOT WRITE IN THIS MARGIN

1. **(continued)**

(a) Using information from the graph

(i) show that the initial acceleration of the ball is $-9{\cdot}8\,\text{m}\,\text{s}^{-2}$ **2**

Space for working and answer

(ii) determine the height from which the ball is released. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

1. (continued)

(b) The mass of the ball is 57·0 g.

(i) Determine the magnitude of the change in momentum of the ball during the bounce. **3**

Space for working and answer

(ii) Determine the magnitude of the average force exerted by the ball on the ground during the bounce. **3**

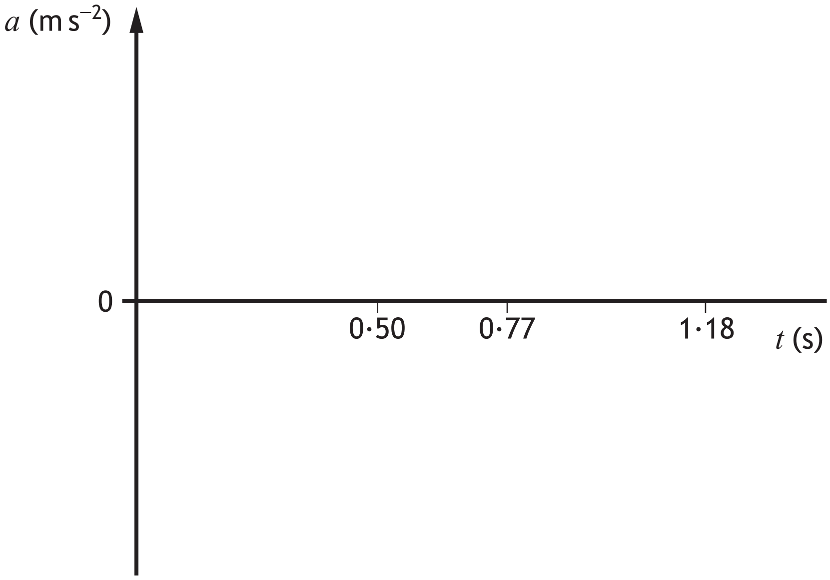
Space for working and answer

1. **(continued)**

(c) Complete the sketch graph of acceleration a against time t for the ball, between 0 s and 1·18 s after it is released.

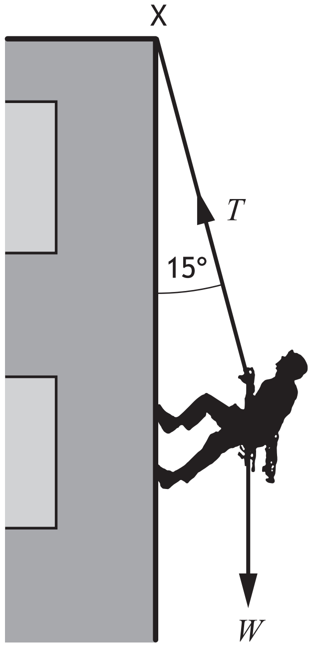
Numerical values are **not** required on the acceleration axis. **2**

(An additional graph, if required, can be found on *page 44*)



[Turn over

2. A student abseils down the outside of a building using a rope.



not to scale

The mass of the student is 55 kg.

The rope, of negligible mass, is attached to a fixed point X at the top of the building.

The rope makes an angle of 15° to the building.

(a) Calculate the weight W of the student. **3**

Space for working and answer

2. (continued)

(b) Determine the tension T in the rope. 3

Space for working and answer

(c) As the student abseils down the building the angle the rope makes with the building decreases.

State whether the tension in the rope increases, decreases or stays the same.

Justify your answer. 2

[Turn over

3. A footballer tells teammates that a football can be kicked a much greater distance when the ball is initially travelling towards them, compared to kicking a stationary ball.

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

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3. (continued)

[Turn over

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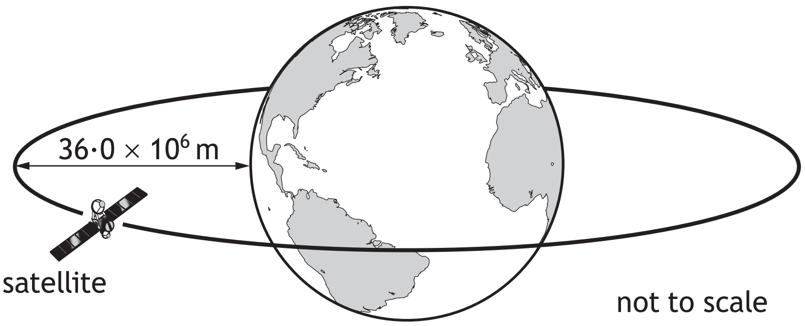
4. A communications satellite orbits the Earth at a height of $36 \cdot 0 \times 10^6$ m above the surface of the Earth.



The mass of the Earth is $6 \cdot 0 \times 10^{24}$ kg and the radius of the Earth is $6 \cdot 4 \times 10^6$ m.

(a) Determine the distance between the centre of the Earth and the satellite. **1**

Space for working and answer

(b) The gravitational force of attraction between the Earth and the satellite is 57 N.

Calculate the mass of the satellite. **3**

Space for working and answer

4. (continued)

(c) Determine the value of the Earth's gravitational field strength g at the satellite. **3**

Space for working and answer

(d) A second satellite has a **quarter** of the mass of the first satellite.

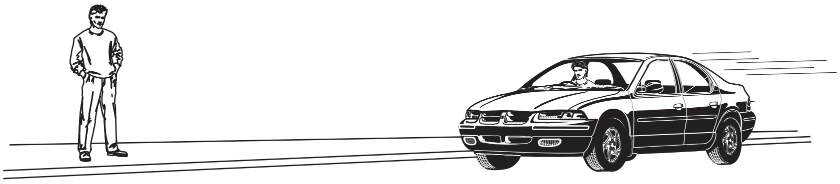
The distance from the centre of the Earth to the second satellite is **half** the distance from the centre of the Earth to the first satellite.

State how the gravitational force of attraction between the second satellite and the Earth compares to the gravitational force of attraction between the first satellite and the Earth.

Justify your answer. **3**

MARKS | DO NOT WRITE IN THIS MARGIN

5. (a) A person is standing at the side of a road. A car travels along the road towards the person, at a constant speed of $12\,m\,s^{-1}$. The car emits a sound of frequency 510 Hz.



The person observes that the frequency of the sound heard changes as the car passes.

(i) State the name given to this effect. **1**

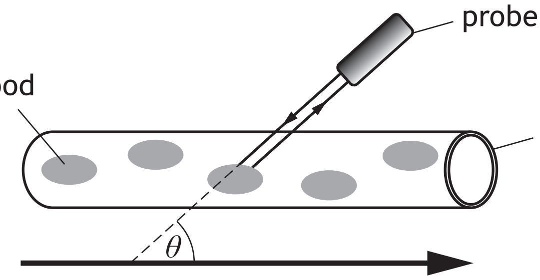
(ii) Calculate the frequency of the sound heard by the person as the car approaches.

The speed of sound in air is $340\,m\,s^{-1}$. **3**

Space for working and answer

 MARKS DO NOT WRITE IN THIS MARGIN

(b) This same effect is used to determine the speed of red blood cells through blood vessels.



Ultrasound waves are transmitted by a probe. The frequency of the ultrasound waves changes as they reflect from the blood cells. The probe detects the reflected waves.

The velocity of the red blood cells can be determined using the following relationship

$$\Delta f = \frac{2f\ v_{rbc}\ \cos\theta}{v}$$

where Δf is the change in frequency

f is the transmitted frequency

v_{rbc} is the velocity of the red blood cells

v is the velocity of the ultrasound

θ is the angle between the direction of the waves and the direction of the blood flow.

The frequency of the ultrasound transmitted by the probe is 3·70 MHz.

The velocity of the ultrasound is 1540 m s^{-1}.

During one test, the angle between the direction of the waves and blood flow is 60·0°. The change in frequency of the ultrasound is 286 Hz.

Calculate the velocity of the red blood cells during this test. **2**

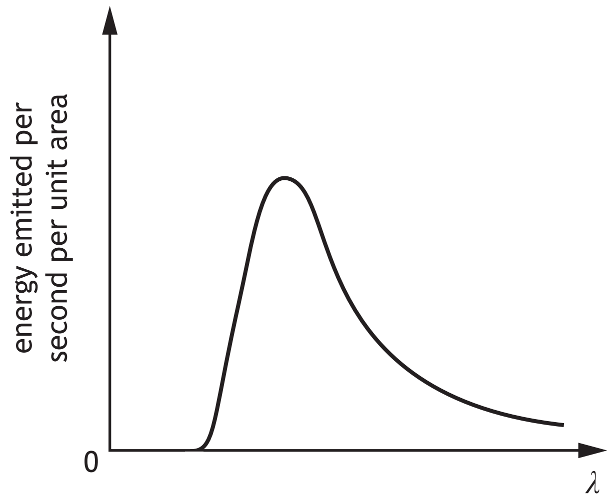
Space for working and answer

* X 8 5 7 7 6 0 1 1 5 *

[Turn over

6. Stars emit radiation with a range of wavelengths. The peak wavelength of the radiation depends on the surface temperature of the star.

(a) The graph shows how the energy emitted per second per unit area varies with the wavelength λ of the radiation for a star with a surface temperature of 5000 K.



A second star has a surface temperature of 6000 K.

On the graph above, add a line to show how the energy emitted per second per unit area varies with the wavelength λ of the radiation for the second star. **2**

(An additional graph, if required, can be found on *page 44*)

MARKS DO NOT WRITE IN THIS MARGIN

6. **(continued)**

(b) The table gives the surface temperature T, in kelvin, of four different stars and the peak wavelength λ_{peak} of radiation emitted from each star.

T (K)	λ_{peak} (m)
7700	$3{\cdot}76 \times 10^{-7}$
8500	$3{\cdot}42 \times 10^{-7}$
9600	$3{\cdot}01 \times 10^{-7}$
12 000	$2{\cdot}42 \times 10^{-7}$

Use **all** the data in the table to show that the relationship between the surface temperature T of a star and the peak wavelength λ_{peak} radiated from the star is **3**

$$T = \frac{2 \cdot 9 \times 10^{-3}}{\lambda_{peak}}$$

Space for working and answer

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

7. Scientists have recently discovered a type of particle called a pentaquark. Pentaquarks are very short lived and contain five quarks.

A lambda b (Λ_b) pentaquark contains the following quarks: 2 up, 1 down, 1 charm, and 1 anticharm quark.

(a) Quarks and leptons are fundamental particles.

(i) Explain what is meant by the term *fundamental particle*. **1**

(ii) State the name given to the group of matter particles that contains quarks and leptons. **1**

(b) The table contains information about the charge on the quarks that make up the Λ_b pentaquark.

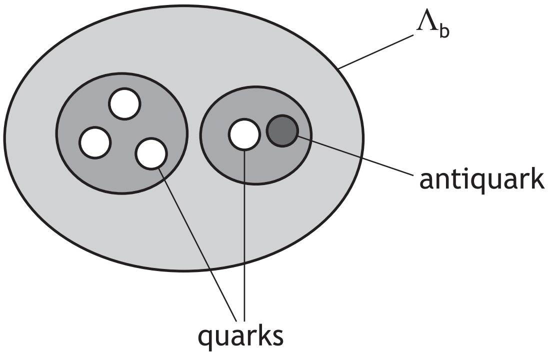
Type of quark	Charge
up	$+\frac{2}{3}e$
down	$-\frac{1}{3}e$
charm	$+\frac{2}{3}e$
anticharm	$-\frac{2}{3}e$

Determine the total charge on the Λ_b pentaquark. **2**

Space for working and answer

7. (continued)

(c) One theory to explain the structure of the Λ_b pentaquark suggests that three of the quarks group together and one quark and the antiquark group together within the pentaquark.



(i) State the type of particle that is made of a quark-antiquark pair. **1**

(ii) The mean lifetime of another quark-antiquark pair is $8{\cdot}0 \times 10^{-21}$ s in its own frame of reference.

During an experiment the quark-antiquark pair is travelling with a velocity of $0{\cdot}91c$ relative to a stationary observer.

Calculate the mean lifetime of this quark-antiquark pair relative to the stationary observer. **3**

Space for working and answer

7. (continued)

(d) The Λ_b pentaquark has a mass-energy equivalence of 4450 MeV.

One eV is equal to $1{\cdot}60 \times 10^{-19}$ J.

(i) Determine the energy, in joules, of the Λ_b pentaquark. **1**

Space for working and answer

(ii) Calculate the mass of the Λ_b pentaquark. **3**

Space for working and answer

[Turn over for next question

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MARKS | DO NOT WRITE IN THIS MARGIN

8. The Sun emits energy at an average rate of $4{\cdot}1 \times 10^{26}\,J\,s^{-1}$. This energy is produced by nuclear reactions taking place inside the Sun.

The following statement shows one reaction that takes place inside the Sun.

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He + ^{1}_{0}n$$

(a) State the name given to this type of nuclear reaction. **1**

(b) The mass of the particles involved in this reaction are shown in the table.

Particle	**Mass (kg)**
$^{2}_{1}H$	$3{\cdot}3436 \times 10^{-27}$
$^{3}_{2}He$	$5{\cdot}0082 \times 10^{-27}$
$^{1}_{0}n$	$1{\cdot}6749 \times 10^{-27}$

Determine the energy released in this reaction. **4**

Space for working and answer

* X 8 5 7 7 6 0 1 2 2 *

8. (continued)

(c) Determine the number of these reactions that would be required per second to produce the Sun's average energy output. **2**

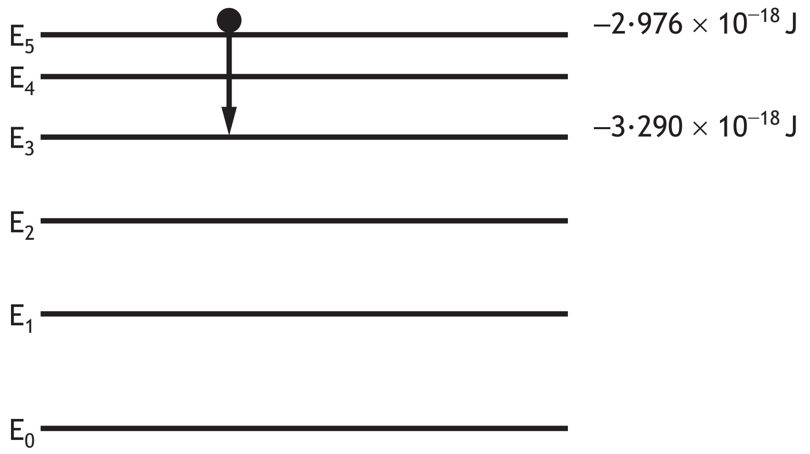
Space for working and answer

[Turn over

9. A laser emits light when electrons are stimulated to fall from a high energy level to a lower energy level.

The diagram shows some of the energy levels involved.

In one particular laser, a photon is produced by the electron transition from E_5 to E_3 as shown.

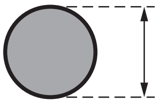


(a) (i) Determine the wavelength of the photon emitted. **4**

Space for working and answer

9. (a) (continued)

(ii) The laser beam is shone onto a screen. The beam produces a spot of diameter $8{\cdot}00 \times 10^{-4}$ m.

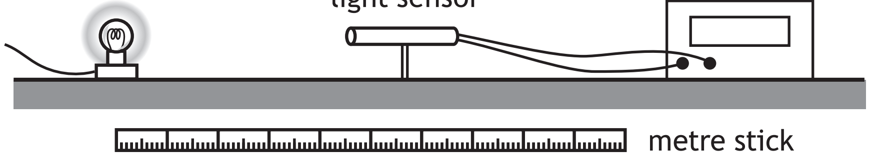


The irradiance of the spot of light on the screen is $9950\,\mathrm{W\,m^{-2}}$.

Determine the power of the laser beam. **4**

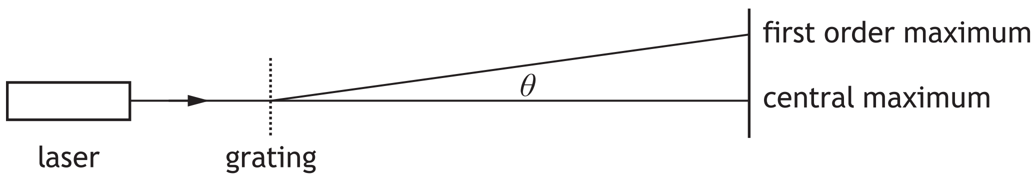
Space for working and answer

(b) A student investigates how irradiance I varies with distance d from a point source of light, using the apparatus shown.



Describe how this apparatus could be used to verify the inverse square law for a point source of light. **3**

10. A student carries out an experiment to investigate the effect of a grating on beams of light from three different lasers.



The three different lasers produce red, green and blue light respectively.

Each laser beam is directed in turn towards the grating.

The grating has a slit separation of $3{\cdot}3 \times 10^{-6}$ m.

(a) State which of these three colours of laser light would produce the smallest angle θ between the central maximum and the first order maximum.

Justify your answer. **3**

10. (continued)

(b) The angle θ between the central maximum and the first order maximum for light from one of the lasers is 8·9°.

(i) Calculate the wavelength of this light. **3**

Space for working and answer

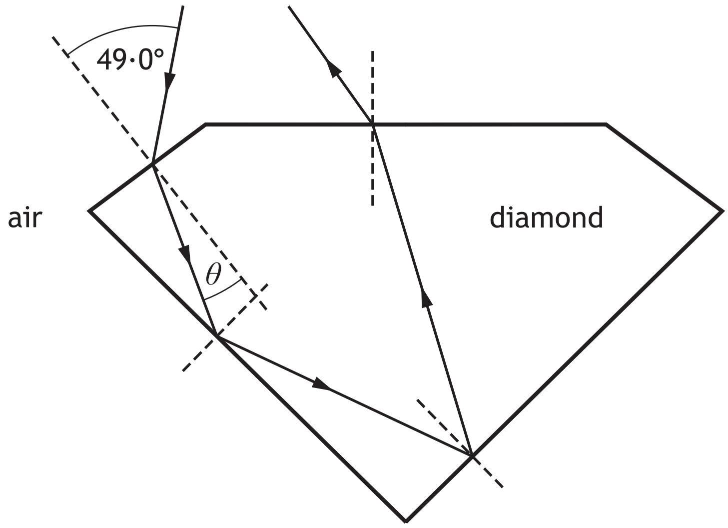
(ii) Determine the colour of the light from this laser. **1**

(iii) Another student suggests that a more accurate value for the wavelength of this laser light can be found if a grating with a slit separation of $5 \cdot 0 \times 10^{-6}$ m is used.

Explain why this suggestion is incorrect. **2**

[Turn over

11. Diamonds sparkle because light that enters the diamond is reflected back to an observer.



(a) A ray of monochromatic light is incident on a diamond at an angle of 49·0°.

The refractive index of diamond for this light is 2·42.

Calculate the angle of refraction θ. **3**

Space for working and answer

(b) Calculate the critical angle of the diamond for this light. **3**

Space for working and answer

11. (continued)

(c) Moissanite is a transparent material with a greater refractive index than diamond. A sample of moissanite is made into the same shape as the diamond.

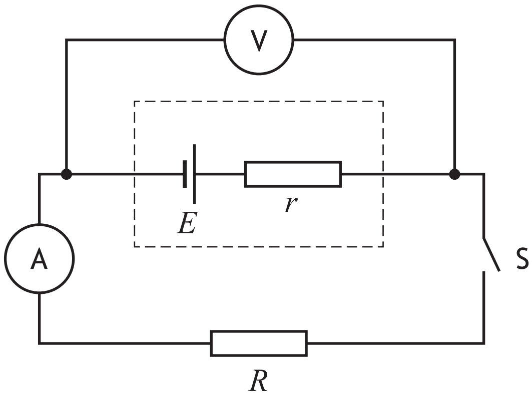
State whether the sample of moissanite sparkles more or less than the diamond.

You must justify your answer. **3**

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

12. (a) A student sets up the circuit shown.



When switch S is open the reading on the voltmeter is 1·5 V.

Switch S is now closed.

The reading on the voltmeter is now 1·3 V and the reading on the ammeter is 0·88 A.

(i) State the EMF E of the cell. **1**

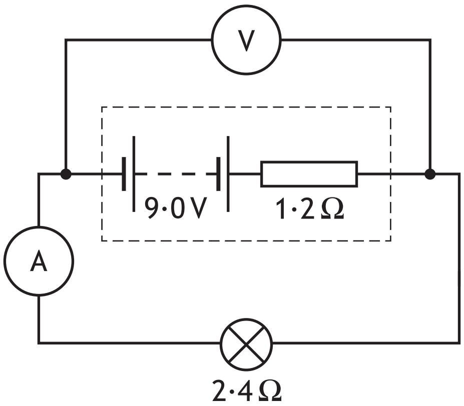
(ii) Calculate the internal resistance r of the cell. **3**

Space for working and answer

(iii) Explain why the reading on the voltmeter decreases when the switch is closed. **2**

12. (continued)

(b) A battery of EMF 9·0 V and internal resistance 1·2 Ω is connected in series with a lamp. The lamp has a resistance of 2·4 Ω.



(i) Determine the current in the lamp. **3**

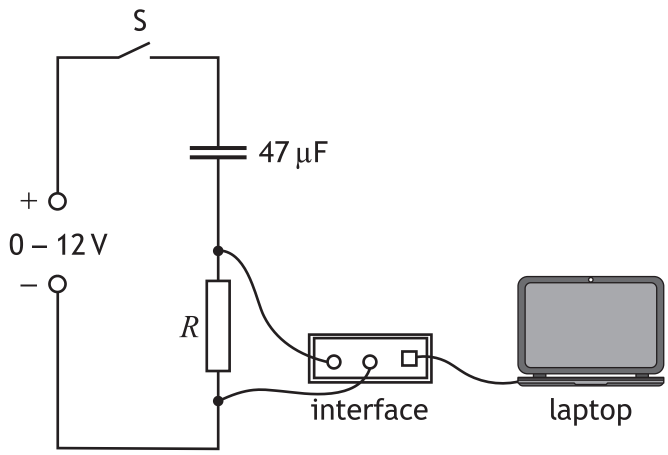
Space for working and answer

(ii) Calculate the power dissipated in the lamp. **3**

Space for working and answer

13. A student investigates the charging of a capacitor.

The student sets up the circuit as shown using a 47 μF capacitor.



The capacitor is initially uncharged. The switch S is now closed. A laptop connected to an interface displays a graph of current against time as the capacitor charges.

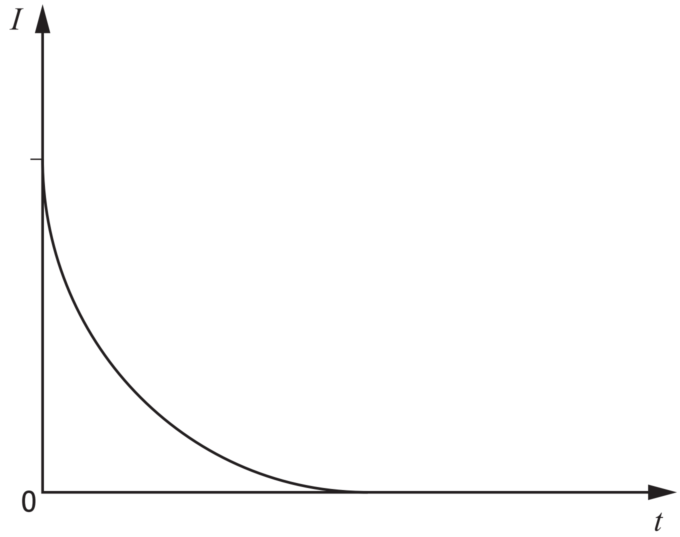
(a) The variable voltage supply is set at 6·0 V.

Calculate the maximum charge stored by the capacitor. **3**

Space for working and answer

13. (continued)

(b) The graph shows how the current I varies with time t as the capacitor charges.



Switch S is opened, and the capacitor is discharged.

The resistor is now replaced with one that has a greater resistance.

Switch S is again closed and the capacitor charges.

Add a line to the graph above to show how the current now varies with time as the capacitor charges. **2**

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

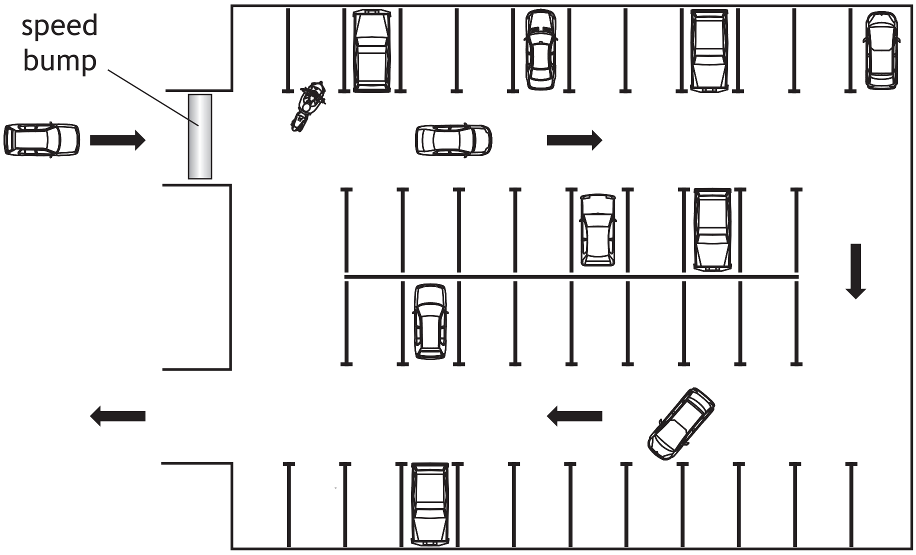
(c) Suggest an alteration the student could make to this circuit to increase the maximum energy stored by the 47 μF capacitor. **1**

[Turn over

13. (continued)

(d) The use of analogies from everyday life can help improve the understanding of physics concepts.

Vehicles using a car park may be taken as an analogy for the charging of a capacitor.



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

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13. (d) (continued)

[Turn over

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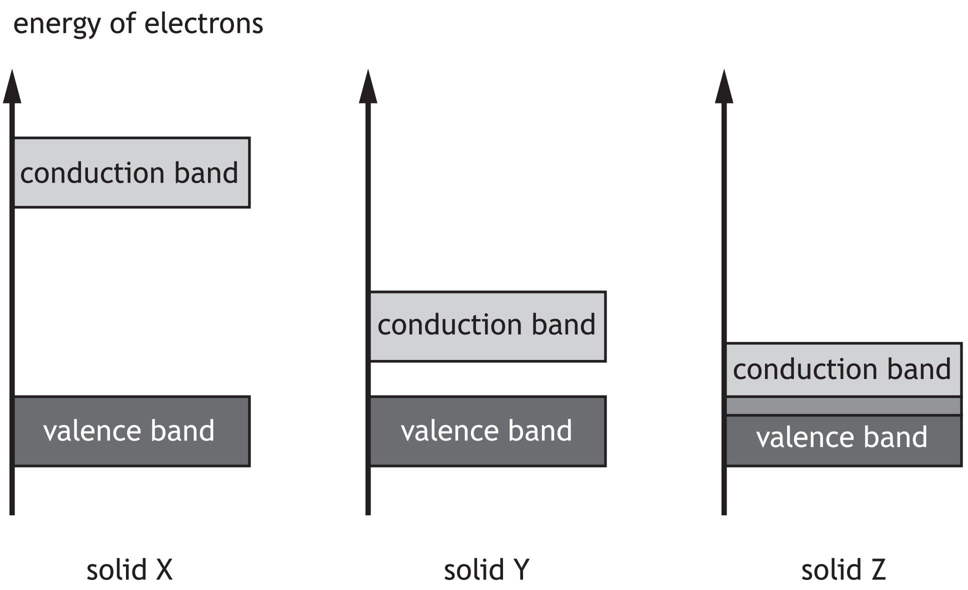
14. Solids can be categorised as conductors, insulators or semiconductors depending on their ability to conduct electricity. Their electrical conductivity can be explained using band theory.

The diagrams show the valence and conduction bands of three solids X, Y and Z.

One represents a conductor, one represents an insulator and one represents a semiconductor.



(a) Complete the table to show which solid represents a conductor, an insulator and a semiconductor. **1**

Solid	Category
X	
Y	
Z	

14. (continued)

(b) Using **band theory**, explain why conduction can take place in a semiconductor at room temperature. **2**

(c) Silicon can be doped with arsenic to produce an n-type semiconductor.

State the effect that doping has on the conductivity of silicon. **1**

(d) Resistivity is a measure of a material's property to oppose the flow of charge.

The resistivity of silicon is $2 \cdot 3 \times 10^{3}\ \Omega\,\mathrm{m}$.

The resistivity of copper is $1 \cdot 7 \times 10^{-8}\ \Omega\,\mathrm{m}$.

Compare the resistivity of silicon to the resistivity of copper in terms of orders of magnitude. **2**

Space for working and answer

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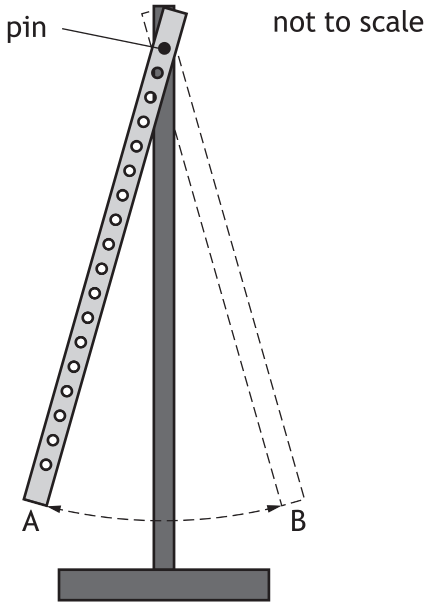
15. A 1·00 m long wooden rod has a series of small holes drilled at 10 mm intervals along its length. The rod is hung on a horizontal pin passing through a hole 50 mm from one end.



The rod is then raised through a small angle and released.

The period T is the time for the rod to travel from A to B and back to A.

(a) Describe a method to obtain an accurate value for the period T using only a stopwatch. **2**

15. (continued)

(b) The rod is hung from different holes in turn, and the distance h from the pin to the midpoint of the rod is recorded.

T is determined for each value of h. The results are shown in the table.

h (m)	T (s)
0·45	1·60
0·40	1·56
0·35	1·54
0·30	1·53
0·25	1·53
0·22	1·55
0·20	1·58

(i) Using the square-ruled paper on *page 41*, draw a graph of T against h. **3**

(ii) Using your graph, state the **two** values of h that produce a period of 1·57 s. **1**

(iii) (A) Using your graph, estimate the minimum period T. **1**

(B) Suggest an improvement to the experimental procedure that would allow a more precise value for the minimum period T to be determined. **1**

[Turn over for next question

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15. (continued)

(c) The quantities T and h are related by the relationship

$$T^2 h = \frac{4\pi^2 h^2}{g} + C$$

where g is the gravitational field strength and C is a constant.

Use data **from the table on *page 40*** to calculate a value for C when h is 0·30 m.

A unit is not required. **2**

Space for working and answer

[END OF QUESTION PAPER]

* X 8 5 7 7 6 0 1 4 2 *

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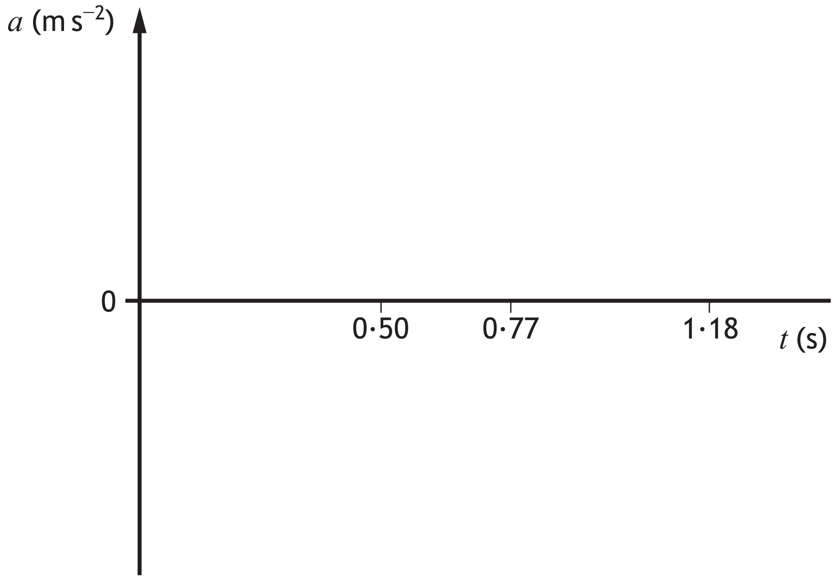
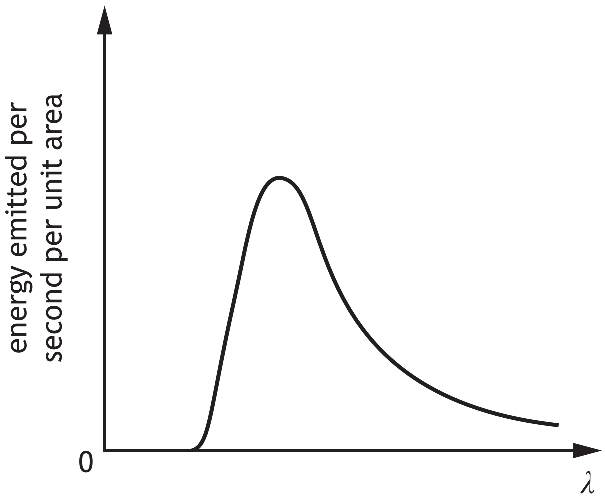
ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional graph for use with Question 1 (c)

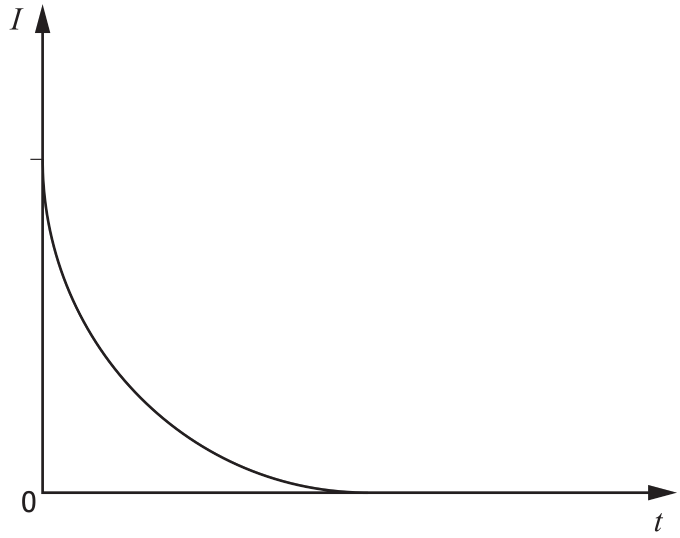


Additional graph for use with Question 6 (a)



ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional graph for use with Question 13 (b)



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ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

* X 8 5 7 7 6 0 1 4 6 *

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National
Qualifications
2019

X857/76/11

Physics
Paper 2 — Relationships sheet

WEDNESDAY, 15 MAY

10:15 AM – 12:30 PM

X8577611

A/PB

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 $W = Fd$

$E_p = mgh$

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

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

$p = mv$

$Ft = mv - mu$

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

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

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

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

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

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

$v = H_0 d$

$W = QV$

$E = mc^2$

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

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

$I_1 d_1^2 = I_2 d_2^2$

$E = hf$

$E_k = hf - hf_0$

$v = f\lambda$

$E_2 - E_1 = hf$

$d\sin\theta = m\lambda$

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

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

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

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

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

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

$V = IR$

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

$R_T = R_1 + R_2 + \ldots$

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

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

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

$E = V + Ir$

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

$Q = It$

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

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

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

or

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

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

Key

Atomic number
Symbol
Electron arrangement
Name

Transition elements

Group 1 (1)	Group 2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	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	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	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	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	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	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	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	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