National
Qualifications
SPECIMEN ONLY

SQ37/H/02

Physics
Section 1—Questions

Date — Not applicable

Duration — 2 hours and 30 minutes

Instructions for the completion of Section 1 are given on *Page two* of your question and answer booklet SQ37/H/01.

Record your answers on the answer grid on *Page three* of your question and answer booklet.

Reference may be made to the Data Sheet on *Page two* of this booklet and to the Relationships Sheet SQ37/H/11.

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

DATA SHEET

COMMON PHYSICAL QUANTITIES

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

REFRACTIVE INDICES

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

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

SPECTRAL LINES

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

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

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550 }	Infrared
	10590 }	
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.

SECTION 1 — 20 marks

Attempt ALL questions

1. A trolley has a constant acceleration of $3\,m\,s^{-2}$. This means that

A the distance travelled by the trolley increases by 3 metres per second every second

B the displacement of the trolley increases by 3 metres per second every second

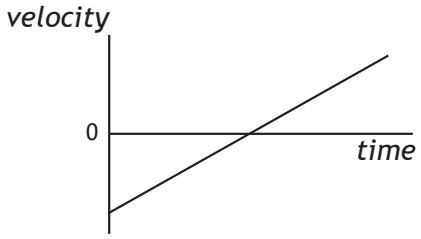
C the speed of the trolley is $3\,m\,s^{-1}$ every second

D the velocity of the trolley is $3\,m\,s^{-1}$ every second

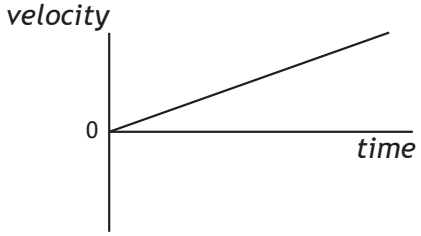
E the velocity of the trolley increases by $3\,m\,s^{-1}$ every second.

2. Which of the following velocity-time graphs represents the motion of an object that changes direction?

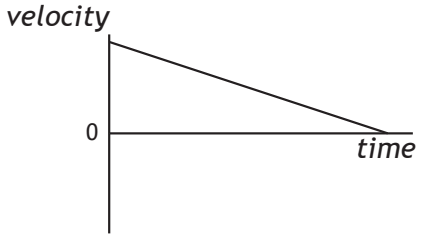
A



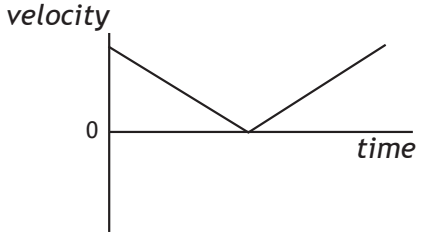
B



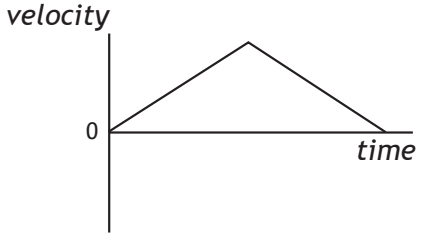
C



D



E



3. A football of mass 0·75 kg is initially at rest. A girl kicks the football and it moves off with an initial speed of 12 m s^{-1}. The time of contact between the girl's foot and the football is 0·15 s.

The average force applied to the football as it is kicked is

A 1·4 N

B 1·8 N

C 2·4 N

D 60 N

E 80 N.

4. Two small asteroids are 12 m apart.

The masses of the asteroids are $2{\cdot}0 \times 10^3$ kg and $0{\cdot}050 \times 10^3$ kg.

The gravitational force acting between the asteroids is

A $1{\cdot}2 \times 10^{-9}$ N

B $4{\cdot}6 \times 10^{-8}$ N

C $5{\cdot}6 \times 10^{-7}$ N

D $1{\cdot}9 \times 10^{-6}$ N

E $6{\cdot}8 \times 10^3$ N.

5. A spaceship on a launch pad is measured to have a length L. This spaceship has a speed of $2{\cdot}5 \times 10^8$ m s^{-1} as it passes a planet.

Which row in the table describes the length of the spaceship as measured by the pilot in the spaceship and an observer on the planet?

	Length measured by pilot in the spaceship	*Length measured by observer on the planet*
A	L	less than L
B	L	greater than L
C	L	L
D	less than L	L
E	greater than L	L

6. The siren on an ambulance is emitting sound with a constant frequency of 900 Hz. The ambulance is travelling at a constant speed of 25 m s^{-1} as it approaches and passes a stationary observer. The speed of sound in air is 340 m s^{-1}.

Which row in the table shows the frequency of the sound heard by the observer as the ambulance approaches and as it moves away from the observer?

	Frequency as ambulance approaches (Hz)	*Frequency as ambulance moves away* (Hz)
A	900	900
B	971	838
C	838	900
D	971	900
E	838	971

7. The photoelectric effect

A is evidence for the wave nature of light

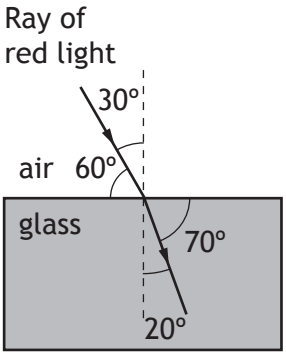
B can be observed using a diffraction grating

C can only be observed with ultra-violet light

D can only be observed with infra-red light

E is evidence for the particulate nature of light.

8. A ray of red light is incident on a glass block as shown.



The refractive index of the glass for this light is

A 0·53

B 0·68

C 1·46

D 1·50

E 2·53.

9. A ray of red light travels from air into water.

Which row in the table describes the change, if any, in speed and frequency of a ray of red light as it travels from air into water?

	Speed	*Frequency*
A	increases	increases
B	increases	stays constant
C	decreases	stays constant
D	decreases	decreases
E	stays constant	decreases

10. Light from a point source is incident on a screen. The screen is 3·0 m from the source.

The irradiance at the screen is 8·0 W m^{-2}.

The light source is now moved to a distance of 12 m from the screen.

The irradiance at the screen is now

A 0·50 W m^{-2}

B 1·0 W m^{-2}

C 2·0 W m^{-2}

D 4·0 W m^{-2}

E 8·0 W m^{-2}.

11. A student makes the following statements about an electron.

I An electron is a boson.

II An electron is a lepton.

III An electron is a fermion.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E II and III only

12. Radiation of frequency $9{\cdot}40 \times 10^{14}$ Hz is incident on a clean metal surface.

The work function of the metal is $3{\cdot}78 \times 10^{-19}$ J.

The maximum kinetic energy of an emitted photoelectron is

A $2{\cdot}45 \times 10^{-19}$ J

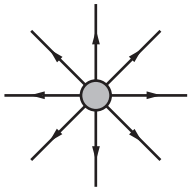
B $3{\cdot}78 \times 10^{-19}$ J

C $6{\cdot}23 \times 10^{-19}$ J

D $1{\cdot}00 \times 10^{-18}$ J

E $2{\cdot}49 \times 10^{33}$ J.

13. The diagram represents the electric field around a single point charge.



A student makes the following statements about this diagram.

I The separation of the field lines indicates the strength of the field.

II The arrows on the field lines indicate the direction in which an electron would move if placed in the field.

III The point charge is positive.

Which of these statements is/are correct?

A I only

B II only

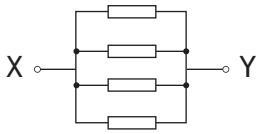
C I and III only

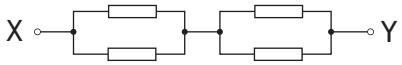
D II and III only

E I, II and III

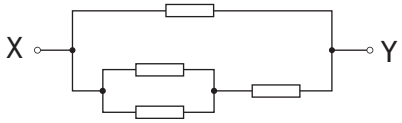
14. In the diagrams below, each resistor has the same resistance.

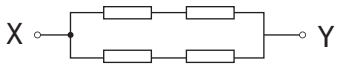
Which combination has the least value of the effective resistance between the terminals X and Y?

A 

B 

C 

D 

E 

15. A student makes the following statements about charges in electric fields.

I An electric field applied to a conductor causes the free electric charges in the conductor to move.

II When a charge is moved in an electric field work is done.

III An electric charge experiences a force in an electric field.

Which of these statements is/are correct?

A II only

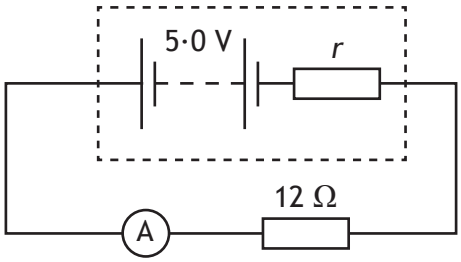
B III only

C I and II only

D II and III only

E I, II and III

16. A circuit is set up as shown.



The e.m.f. of the battery is 5·0 V.

The reading on the ammeter is 0·35 A.

The internal resistance *r* of the battery is

A 0·28 Ω

B 0·80 Ω

C 1·15 Ω

D 2·3 Ω

E 3·2 Ω.

17. The e.m.f. of a battery is

A the total energy supplied by the battery

B the voltage lost due to the internal resistance of the battery

C the total charge that passes through the battery

D the number of coulombs of charge passing through the battery per second

E the energy supplied to each coulomb of charge passing through the battery.

18. The r.m.s. voltage of the mains supply is 230 V.

The approximate value of the peak voltage is

A 115 V

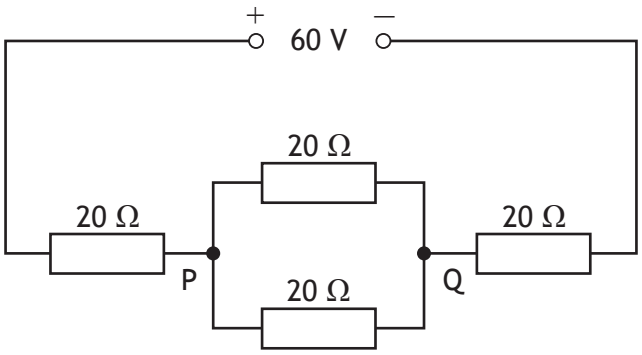
B 163 V

C 325 V

D 460 V

E 651 V.

19. Four resistors each of resistance 20 Ω are connected to a 60 V supply of negligible internal resistance as shown.



The potential difference across PQ is

A 12 V

B 15 V

C 20 V

D 24 V

E 30 V.

20. Photons with a frequency of $4{\cdot}57 \times 10^{14}$ Hz are incident on a p-n junction in a solar cell.

The maximum potential difference these photons produce across this junction is

A 1·34 V

B 1·89 V

C 2·67 V

D 3·79 V

E 5·34 V.

[END OF SECTION 1. NOW ATTEMPT THE QUESTIONS IN SECTION 2 OF YOUR QUESTION AND ANSWER BOOKLET]

National
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SQ37/H/11

Physics
Relationships Sheet

Date — Not applicable

SQ37H11

Relationships required for Physics Higher

$d = \overline{v}t$

$s = \overline{v}t$

$v = u + at$

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

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

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

$W = mg$

$F = ma$

$E_W = Fd$

$E_p = mgh$

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

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

$p = mv$

$Ft = mv - mu$

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

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

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

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

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

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

$v = H_0 d$

$W = QV$

$E = mc^2$

$E = hf$

$E_k = hf - hf_0$

$E_2 - E_1 = hf$

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

$v = f\lambda$

$d\sin\theta = m\lambda$

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

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

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

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

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

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

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

$Q = It$

$V = IR$

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

$R_T = R_1 + R_2 + \ldots.$

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

$E = V + Ir$

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

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

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

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

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

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

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

Group 1 (1)	Group 2 (2)	Transition Elements (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** 2,8,18,32,8,2 Nobelium	103 **Lr** 2,8,18,32,32,9,2 Lawrencium

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Qualifications
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Mark

SQ37/H/01

Physics Section 1— Answer Grid and Section 2

Date — Not applicable

Duration — 2 hours 30 minutes

* S Q 3 7 H 0 1 *

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

D D M M Y Y

Scottish candidate number

Total marks — 130

SECTION 1 — 20 marks
Attempt ALL questions.
Instructions for the completion of Section 1 are given on *Page two*.

SECTION 2 — 110 marks
Attempt ALL questions.
Reference may be made to the Data Sheet on *Page two* of the question paper SQ37/H/02 and to the Relationship Sheet SQ37/H/11.
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. You should score through your rough work when you have written your final copy.
Use **blue** or **black** ink.
Care should be taken to give an appropriate number of significant figures in the final answers to calculations.
Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

SQA ©

SECTION 1 — 20 marks

The questions for Section 1 are contained in the question paper SQ37/H/02.
Read these and record your answers on the answer grid on *Page three* opposite.
Do **NOT** use gel pens.

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.

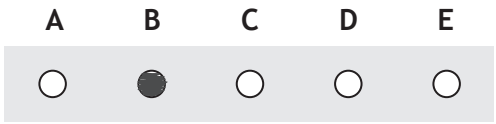
3. Any rough working should be done on the additional space for answers and rough work at the end of this booklet.

Sample Question

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

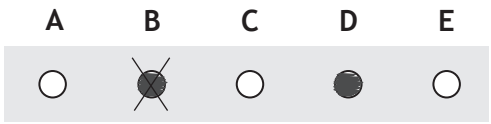
A ampere
B kilowatt-hour
C watt
D coulomb
E volt.

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

SECTION 1 — Answer Grid

0BJ20AE1

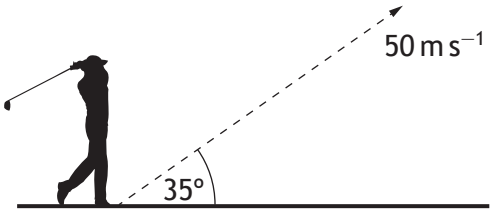
	A	B	C	D	E
1	○	○	○	○	○
2	○	○	○	○	○
3	○	○	○	○	○
4	○	○	○	○	○
5	○	○	○	○	○
6	○	○	○	○	○
7	○	○	○	○	○
8	○	○	○	○	○
9	○	○	○	○	○
10	○	○	○	○	○
11	○	○	○	○	○
12	○	○	○	○	○
13	○	○	○	○	○
14	○	○	○	○	○
15	○	○	○	○	○
16	○	○	○	○	○
17	○	○	○	○	○
18	○	○	○	○	○
19	○	○	○	○	○
20	○	○	○	○	○

SECTION 2 — 110 marks

Attempt ALL questions

MARKS | DO NOT WRITE IN THIS MARGIN

1. A golf ball is hit with a velocity of $50{\cdot}0\,m\,s^{-1}$ at an angle of 35° to the horizontal as shown.



(a) (i) Calculate the horizontal component of the initial velocity of the ball. **1**

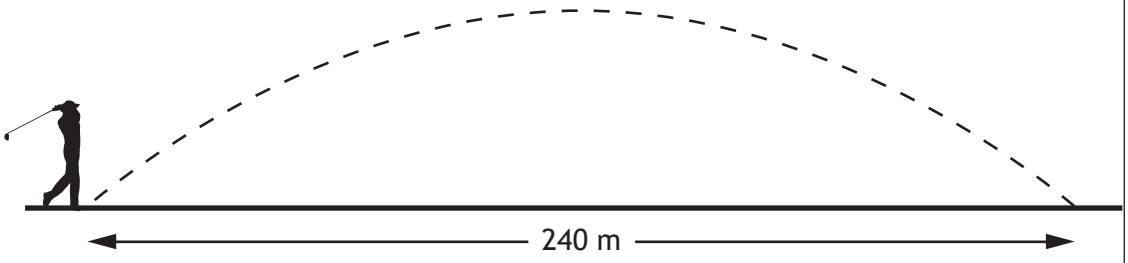
Space for working and answer

(ii) Calculate the vertical component of the initial velocity of the ball. **1**

Space for working and answer

1. (continued)

(b) The diagram below shows the trajectory of the ball when air resistance is negligible.



Show that the horizontal distance travelled by the ball is 240 m. **4**

Space for working and answer

2. An electric cart and driver accelerate up a slope. The slope is at an angle of 3·2° to the horizontal. The combined mass of the cart and driver is 220 kg.

(a) (i) Show that the component of the weight of the cart and driver acting down the slope is 120 N. **2**

Space for working and answer

(ii) At one point on the slope the driving force produced by the cart's motor is 230 N and at this point the total frictional force acting on the cart and driver is 48 N.

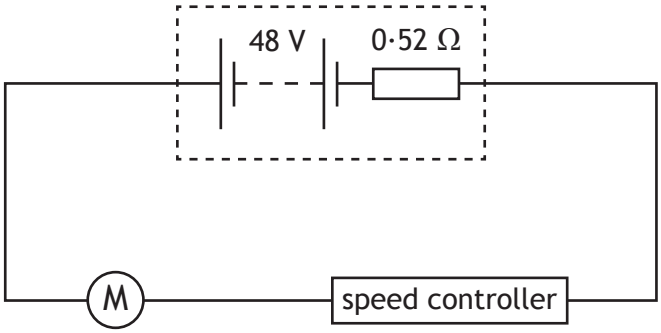
Calculate the acceleration of the cart and the driver at this point. **4**

Space for working and answer

2. (a) (continued)

(iii) Explain, in terms of the forces, why there is a maximum angle of slope that the cart can ascend. **2**

(b) The electric motor in the cart is connected to a battery of e.m.f. 48 V and internal resistance 0·52 Ω.



The current in the circuit is 22 A.

(i) Show that the lost volts in the battery is 11 V. **2**

Space for working and answer

2. (b) (continued)

(ii) Calculate the output power supplied to the circuit when the current is 22 A. **4**

Space for working and answer

(c) The driving force produced by the cart's motor is now increased.

State what happens to the potential difference across the battery.

You must justify your answer. **3**

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

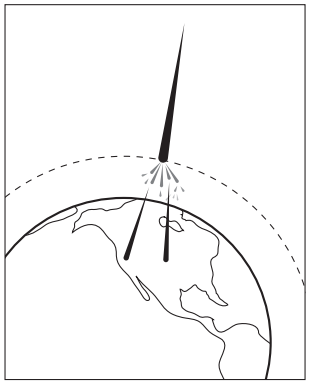
In order to make cars more efficient some manufacturers are developing kinetic energy recovery systems (KERS). These systems store some of the energy that would otherwise be lost as heat and sound.

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

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

Space for working and answer

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



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

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

Space for working and answer

(b) Calculate the mean lifetime of the muons as measured by the observer on Earth. **3**

Space for working and answer

4. (continued)

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

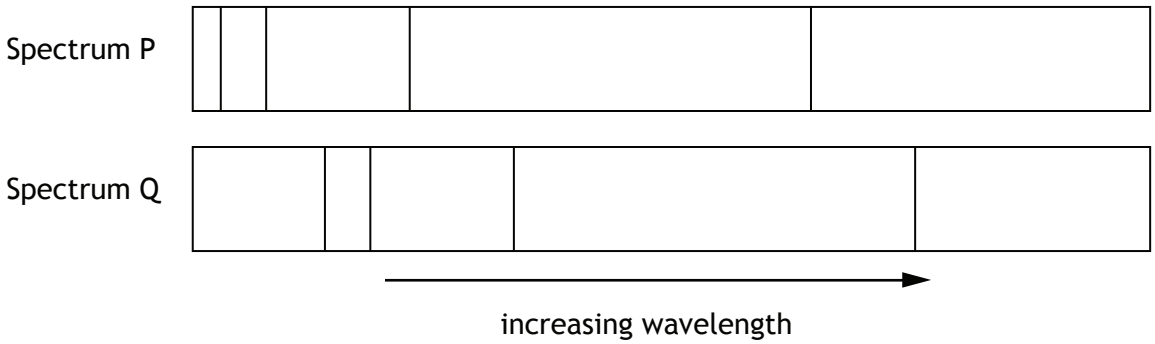
MARKS | DO NOT WRITE IN THIS MARGIN

5. A picture of a helmet designed to be worn when riding a bicycle is shown.

The bicycle helmet has a hard outer shell and a soft expanded polystyrene foam liner.

Using your knowledge of physics, comment on the suitability of this design for a bicycle helmet. **3**

6. (a) The diagram below represents part of the emission spectra for the element hydrogen.



Spectrum P is from a laboratory source.

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

(i) Explain why spectrum Q is redshifted. **2**

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

Calculate the recessional velocity of the star. **5**

Space for working and answer

6. (continued)

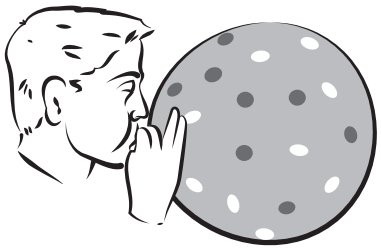
(b) The recessional velocity of a distant galaxy is $1{\cdot}2 \times 10^7\,m\,s^{-1}$.

Show that the approximate distance to this galaxy is $5{\cdot}2 \times 10^{24}\,m$. **2**

Space for working and answer

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

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



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

MARKS | DO NOT WRITE IN THIS MARGIN

7. Protons and neutrons are composed of combinations of up and down quarks. Up quarks have a charge of $+\frac{2}{3}e$ while down quarks have a charge of $-\frac{1}{3}e$.

(a) (i) Determine the combination of up and down quarks that makes up:

(A) a proton; **1**

(B) a neutron. **1**

(ii) Name the boson that is the mediating particle for the strong force. **1**

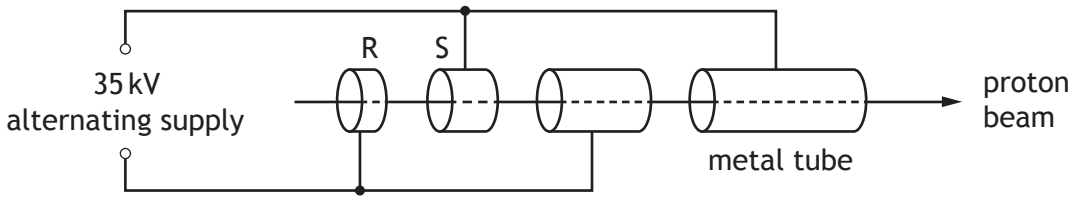
(b) A neutron decays into a proton, an electron and an antineutrino.

$$^{1}_{0}\text{n} \rightarrow {}^{1}_{1}\text{p} + {}^{0}_{-1}e + \overline{\nu}$$

Name of this type of decay. **1**

8. A linear accelerator is used to accelerate protons.

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



The diagram shows the path of protons through the accelerator.

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

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

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

Space for working and answer

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

Space for working and answer

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

MARKS | DO NOT WRITE IN THIS MARGIN

9. (a) The following statement represents a fusion reaction.

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

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

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

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

Space for working and answer

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

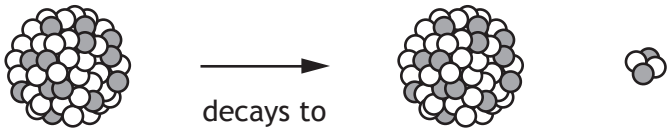
Space for working and answer

9. (a) (continued)

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

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

(b) A nucleus of radium-224 decays to radon by emitting an alpha particle.



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

Particle	*Mass* (kg)
radium-224	$3{\cdot}720 \times 10^{-25}$
radon-220	$3{\cdot}653 \times 10^{-25}$
alpha	$6{\cdot}645 \times 10^{-27}$

Before the decay the radium-224 nucleus is at rest.

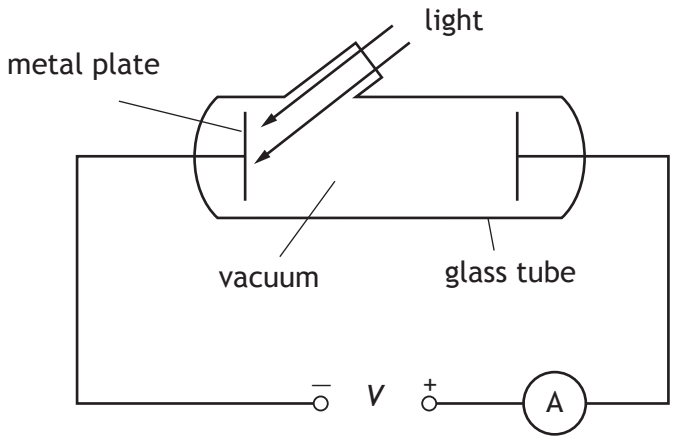
After the decay the alpha particle moves off with a velocity of $1{\cdot}460 \times 10^{7}\,\text{m}\,\text{s}^{-1}$.

Calculate the velocity of the radon-220 nucleus after the decay. **3**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

10. The diagram shows equipment used to investigate the photoelectric effect.



(a) When blue light is shone on the metal plate there is a current in the circuit. When blue light is replaced by red light there is no current.

Explain why this happens. **2**

(b) The blue light has a frequency of $7{\cdot}0 \times 10^{14}$ Hz.

The work function for the metal plate is $2{\cdot}0 \times 10^{-19}$ J.

Calculate the maximum kinetic energy of the electrons emitted from the plate by this light. **3**

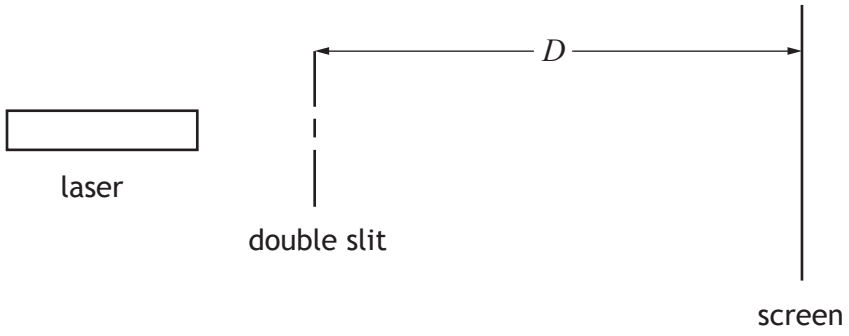
Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

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

(a) State what is meant by *coherent light*. **1**

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



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

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

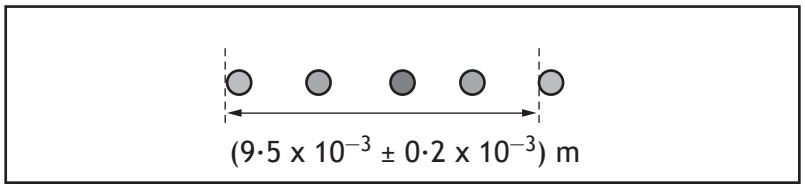
11. (b) (continued)

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

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

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

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



The student measures the distance, *D*, between the double slit and the screen as (0·750 ± 0·001) m.

Calculate the best estimate of the distance between the two slits.

An uncertainty in the calculated value is not required. **4**

Space for working and answer

11. (b) (continued)

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

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

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

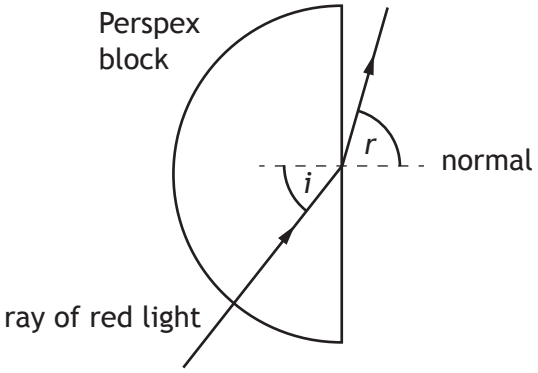
Space for working and answer

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

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

12. A student is investigating the refractive index of a Perspex block for red light.

The student directs a ray of red light towards a semicircular Perspex block as shown.



The angle of incidence *i* is then varied and the angle of refraction *r* is measured using a protractor.

The following results are obtained.

i (°)	*r* (°)	*sin i*	*sin r*
10	16	0·17	0·28
15	25	0·26	0·42
20	32	0·34	0·53
25	37	0·42	0·60
30	53	0·50	0·80

(a) (i) Using square ruled paper, draw a graph to show how sin *r* varies with sin *i*. **3**

(ii) Use the graph to determine the refractive index of the Perspex for this light. **2**

Space for working and answer

12. (a) (continued)

(iii) Suggest **two** ways in which the experimental procedure could be improved to obtain a more accurate value for the refractive index. **2**

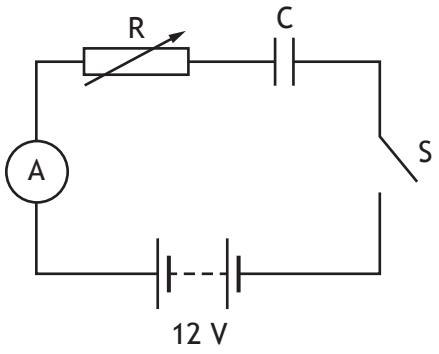
(b) The Perspex block is replaced by an identical glass block with a refractive index of 1·54 and the experiment is repeated.

Determine the maximum angle of incidence that would produce a refracted ray. **3**

Space for working and answer

13. A 200 μF capacitor is charged using the circuit shown.

The 12 V battery has negligible internal resistance.



The capacitor is initially uncharged.

The switch S is closed. The charging current is kept constant at 30 μA by adjusting the resistance of the variable resistor, R.

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

Space for working and answer

(b) (i) Calculate the charge on the capacitor 30 s after the switch S is closed. **3**

Space for working and answer

13. (b) (continued)

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

Space for working and answer

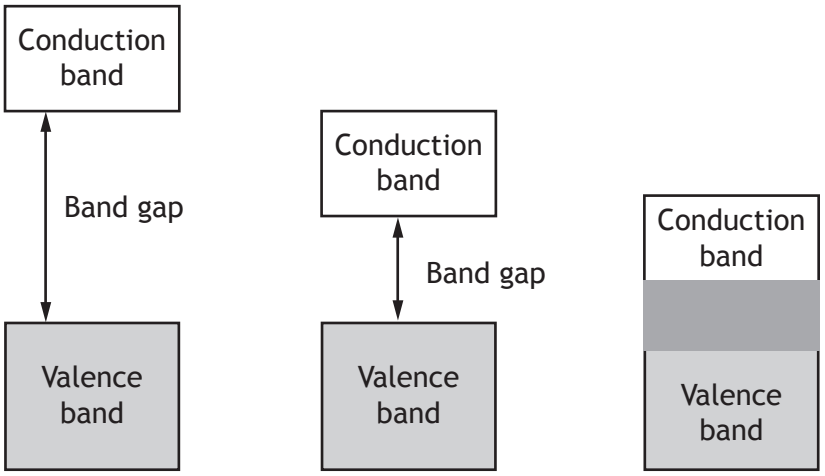
MARKS | DO NOT WRITE IN THIS MARGIN

14. The electrical conductivity of solids can be explained by band theory.

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

Shaded areas represent bands occupied by electrons.

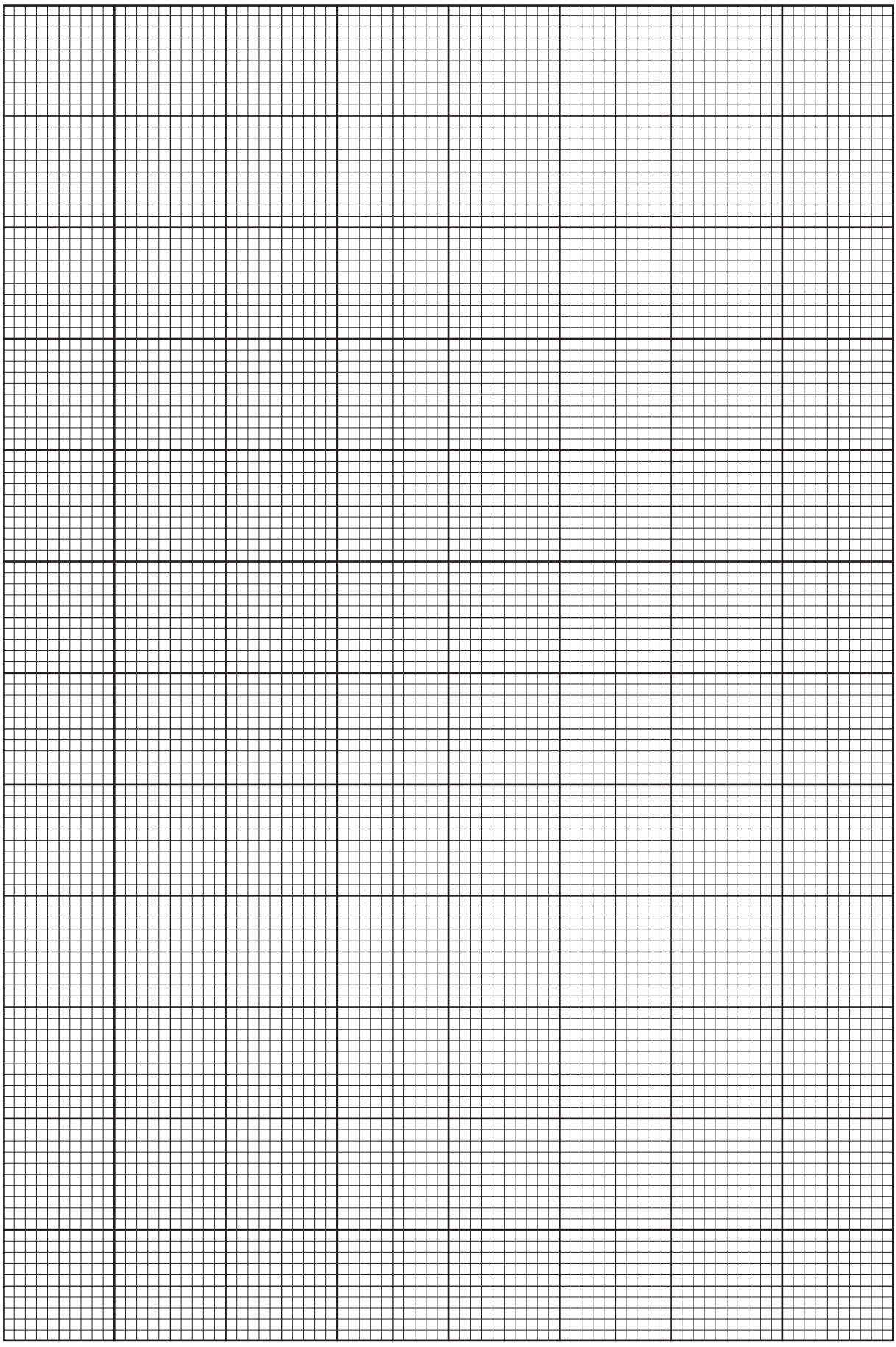
The band gap is also indicated.

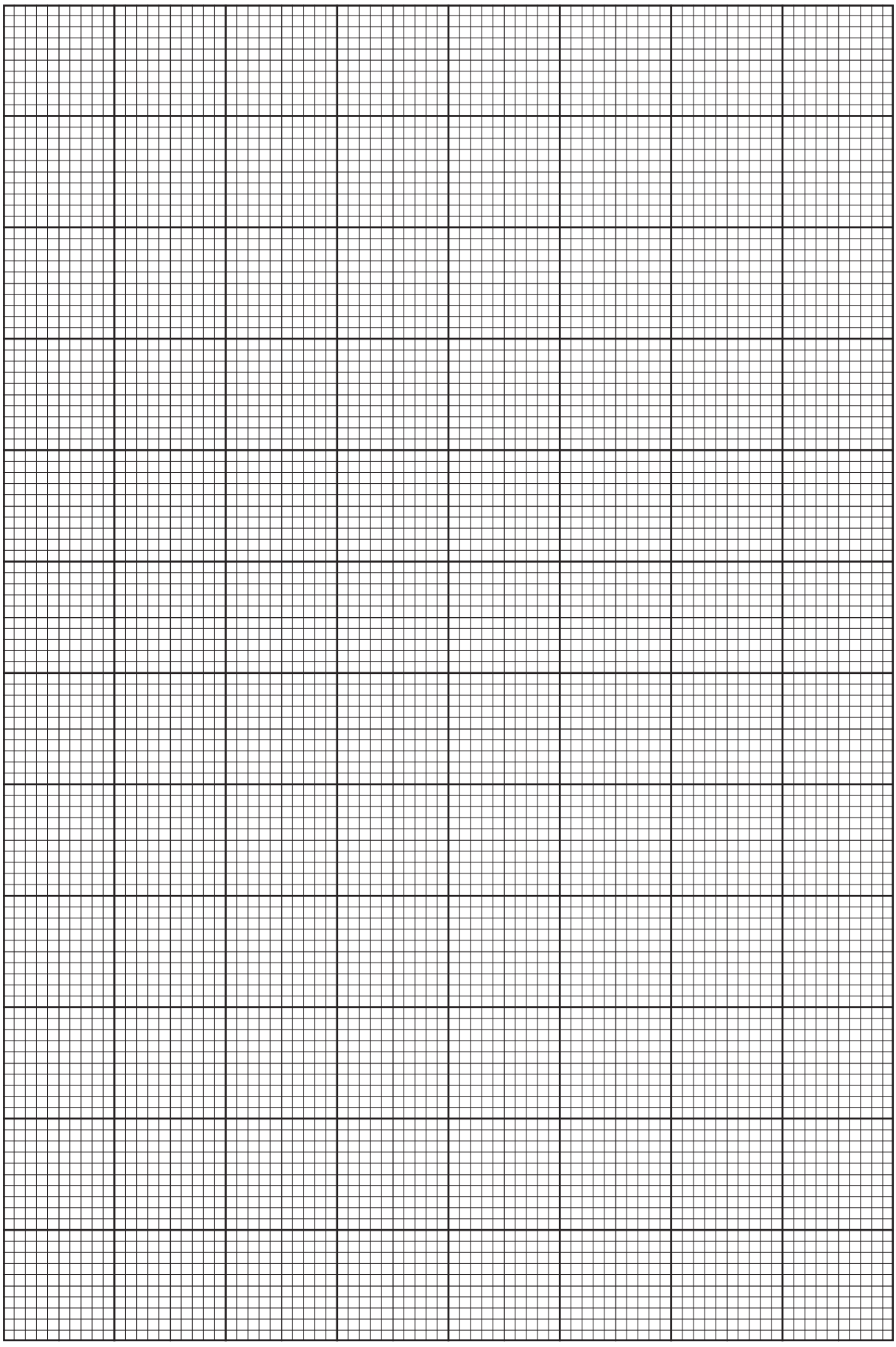


(a) State which material is a semiconductor. **1**

(b) A sample of pure semiconductor is heated. Use band theory to explain what happens to the resistance of the sample as it is heated. **2**

[END OF SPECIMEN QUESTION PAPER]





MARKS DO NOT WRITE IN THIS MARGIN

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

MARKS | DO NOT WRITE IN THIS MARGIN

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

National
Qualifications
SPECIMEN ONLY

SQ37/H/02 Physics

Marking Instructions

These Marking Instructions have been provided to show how SQA would mark this Specimen Question Paper.

General Marking Principles for Physics Higher

This information is provided to help you understand the general principles you must apply when marking candidate responses to questions in this Paper. These principles must be read in conjunction with the detailed marking instructions, which identify the key features required in candidate responses.

(a) Marks for each candidate response must always be assigned in line with these General Marking Principles and the Detailed Marking Instructions for this assessment.

(b) Marking should always be positive. This means that, for each candidate response, marks are accumulated for the demonstration of relevant skills, knowledge and understanding: they are not deducted from a maximum on the basis of errors or omissions.

(c) There are **no half marks** awarded.

(d) Where a wrong answer to part of a question is carried forward and the wrong answer is then used correctly in the following part, the candidate should be given credit for the subsequent part or 'follow on'.

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

(f) Credit should be given where a diagram or sketch conveys correctly the response required by the question. It will usually require clear and correct labels (or the use of standard symbols).

(g) Marks are provided for knowledge of relevant formulae alone. When a candidate writes down several formulae and does not select the correct one to continue with, for example by substituting values, no mark can be awarded.

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

(i) No marks should be awarded if a 'magic triangle' (eg 

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

(j) In rounding to an expected number of significant figures, the mark can be awarded for answers which have up to two figures more or one figure less than the number in the data with the fewest significant figures.

(k) The incorrect spelling of technical terms should usually be ignored and candidates should be awarded the relevant mark, provided that answers can be interpreted and understood without any doubt as to the meaning. Where there is ambiguity, the mark should not be awarded. Two specific examples of this would be when the candidate uses a term that might be interpreted as 'reflection, 'refraction' or 'diffraction' (eg 'defraction') or one that might be interpreted as either 'fission' or 'fusion' (eg 'fussion').

(l) Marks are awarded only for a valid response to the question asked. For example, in response to questions that ask candidates to:

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

(m) **Marking in calculations**

Question:

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

	Candidate answer	**Mark + Comment**
1.	$V = IR$	1 mark: formula
	$7{\cdot}5 = 1{\cdot}5R$	1 mark: substitution
	$R = 5{\cdot}0\ \Omega$	1 mark: correct answer
2.	$5{\cdot}0\ \Omega$	3 marks: correct answer
3.	5·0	2 marks: unit missing
4.	$4{\cdot}0\ \Omega$	0 marks: no evidence, wrong answer
5.	__ Ω	0 marks: no working or final answer
6.	$R = \frac{V}{I} = \frac{7{\cdot}5}{1{\cdot}5} = 4{\cdot}0\,\Omega$	2 marks: arithmetic error

7. $R = \frac{V}{I} = 4{\cdot}0\ \Omega$ — 1 mark: formula only

8. $R = \frac{V}{I} = \_\_\_\_\Omega$ — 1 mark: formula only

9. $R = \frac{V}{I} = \frac{7{\cdot}5}{1{\cdot}5} = \_\_\_\_\Omega$ — 2 marks: formula & subs, no final answer

10. $R = \frac{V}{I} = \frac{7{\cdot}5}{1{\cdot}5} = 4{\cdot}0$ — 2 marks: formula & subs, wrong answer

11. $R = \frac{V}{I} = \frac{1{\cdot}5}{7{\cdot}5} = 5{\cdot}0\,\Omega$ — 1 mark: formula but wrong substitution

12. $R = \frac{V}{I} = \frac{75}{1{\cdot}5} = 5{\cdot}0\,\Omega$ — 1 mark: formula but wrong substitution

13. $R = \frac{I}{V} = \frac{1{\cdot}5}{7{\cdot}5} = 5{\cdot}0\,\Omega$ — 0 marks: wrong formula

14. $V = IR$ — 2 marks: formula & subs, arithmetic error

    $7{\cdot}5 = 1{\cdot}5 \times R$

    $R = 0{\cdot}2\ \Omega$

15. $V = IR$

    $R = \frac{I}{V} = \frac{1{\cdot}5}{7{\cdot}5} = 0{\cdot}2\,\Omega$ — 1 mark: formula correct but wrong rearrangement of symbols

Marking Instructions for each question

SECTION 1

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

SECTION 2

Question			Expected response	Max mark	Additional guidance
1	a	i	(Initial horizontal component = $v\cos\theta$ = 50 cos35) = 41 m s^{-1} (1)	1	
		ii	(Initial vertical component = $v\sin\theta$ = 50 sin 35) = 29 m s^{-1} (1)	1	
	b		$v = u + at$ (1) $v = 29 - 9{\cdot}8t$ (1) $t = (0 - 29)/-9{\cdot}8$ $= 2{\cdot}96$ (s) $t_{TOTAL} = 5{\cdot}92$ (s) (1) $d_h = v_h t$ $= 41 \times 5{\cdot}92$ (1) (= 240 m)	4	$s = ut + \frac{1}{2}at^2$ (1) $0 = 29t + \frac{1}{2}9{\cdot}8t^2$ (1) $t = 5{\cdot}92$ (s) (1) $d_h = v_h t$ $= 41 \times 5{\cdot}92$ (1) (= 240 m) 240 m must be shown to access the final mark.
2	a	i	Component of weight down slope $= mg\sin\theta$ (1) $= 220 \times 9{\cdot}8 \times sin\ 3{\cdot}2^o$ (1) (=120 N)	2	must show all steps
		ii	Unbalanced Force = 230 – (120+48) = 62 N (1) $F = ma$ (1) $62 = 220 \times a$ (1) $a = 0{\cdot}28$ m s^{-2} (1)	4	
		iii	As angle (of slope) increases $mg\sin\theta$ increases (1) When $mgsin\theta \geqq$ engine force – friction, the vehicle cannot move up the slope (1)	2	Accept component of weight (down the slope) Accept force up the slope
	b	i	lost volts = Ir (1) $= 22 \times 0{\cdot}52$ (1) (= 11 V)	2	11 V must be shown to access the second mark.

Question			Expected response	Max mark	Additional guidance
		ii	$p.d. = 48 - 11$ $= 37$ V (1) $P = I\,V$ (1) $= 22 \times 37$ (1) $= 810$ W (1)	4	or 36·56 V (using lost volts = 11·44) 1 for formula anywhere Accept 800 or 814 W (804, 804.3 using 11.44)
	c		terminal potential difference decreases (1) current increases (1) lost volts increases (1)	3	Must attempt an explanation to get first mark. Correct conclusion 1 mark, so long as not followed by wrong physics.
3			estimate of masses (500 kg < car mass < 3000 kg) (1) estimate of speed (10 m s^{-1} < speed < 70 m s^{-1}) (1) $E_k = 1/2\ mv^2$ (1) Final answer and unit (1)	4	both estimates must be within the given tolerances in order to access the final 1 mark.
4	a		$d = vt$ (1) $d = (3 \times 10^8 \times 0{\cdot}995) \times 2{\cdot}2 \times 10^6$ (1) $d = 660$ m	2	660 m must be shown in order to access the second mark.
	b		$t' = \dfrac{t}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$ (1) $t' = \dfrac{2{\cdot}2\times10^{-6}}{\sqrt{1-\left(\frac{0{\cdot}995}{1}\right)^2}}$ (1) $= 2{\cdot}2\times10^{-5}$ s (1)	3	
	c		For an observer on Earth's frame of reference the mean life of the muon is much greater OR The distance in the muon frame of reference is shorter	1	

5	**a**	**The whole candidate response should first be read to establish its overall quality in terms of accuracy and relevance to the problem/situation presented.** There may be strengths and weaknesses in the candidate response: *assessors should focus as far as possible on the strengths, taking account of weaknesses (errors or omissions) only where they detract from the overall answer in a significant way, which should then be taken into account when determining whether the response demonstrates **reasonable**, **limited** or **no** understanding.* **Assessors should use their professional judgement to apply the guidance below to the wide range of possible candidate responses.**	This open-ended question requires comment on the **suitability of the design of the bicycle helmet**. Candidate responses are expected to make judgements on its suitability, on the basis of relevant physics ideas/concepts which might include one or more of: 'crumple zone'; impulse; energy being absorbed; air circulation and aerodynamics; or other relevant ideas/concepts.
		3 marks: The candidate has demonstrated a **good** conceptual understanding of the physics involved, providing a logically correct response to the problem/situation presented. This type of response might include a statement of principle(s) involved, a relationship or equation, and the application of these to respond to the problem/situation. This does not mean the answer has to be what might be termed an 'excellent' answer or a 'complete' one.	In response to this question, a **good** understanding might be demonstrated by a candidate response that: • makes a judgement on suitability based on one relevant physics idea/concept, in a **detailed/developed** response that is **correct or largely correct** (any weaknesses are minor and do not detract from the overall response), **OR** • makes judgement(s) on suitability based on a range of relevant physics ideas/concepts, in a response that is **correct or largely correct** (any weaknesses are minor and do not detract from the overall response), **OR** • otherwise demonstrates a good understanding of the physics involved.
		2 marks: The candidate has demonstrated a **reasonable** understanding of the physics involved, showing that the problem/situation is understood. This type of response might make some statement(s) that is/are relevant to the problem/situation, for example, a statement of relevant principle(s) or identification of a relevant relationship or equation.	In response to this question, a **reasonable** understanding might be demonstrated by a candidate response that: • makes a judgement on suitability based on one or more relevant physics idea(s)/concept(s), in a response that is **largely correct** but has **weaknesses** which detract to a small extent from the overall response, **OR** • otherwise demonstrates a reasonable understanding of the physics involved.
		1 mark: The candidate has demonstrated a **limited** understanding of the physics involved, showing that a	In response to this question, a **limited** understanding might be demonstrated by a

		little of the physics that is relevant to the problem/situation is understood. The candidate has made some statement(s) that is/are relevant to the problem/situation.	candidate response that: • makes a judgement on suitability based on one or more relevant physics idea(s)/concept(s), in a response that has **weaknesses** which detract to a large extent from the overall response, **OR** • otherwise demonstrates a limited understanding of the physics involved.
		0 marks: The candidate has demonstrated **no** understanding of the physics that is relevant to the problem/situation. The candidate has made no statement(s) that is/are relevant to the problem/situation.	Where the candidate has *only* demonstrated knowledge and understanding of physics **that is not relevant to the problem/situation presented,** 0 marks should be awarded.

Question			Expected response	Max mark	Additional guidance
6	a	i	The star is moving away from the Earth (1) Plus any one point from the following for 1 mark: • The apparent wavelength of the hydrogen spectra from the star has increased • The apparent frequency of the hydrogen spectra from the star is less than the actual frequency on Earth • The frequency of the light from the star has shifted towards the red end of the spectrum • Light from the star is experiencing a Doppler shift.	2	
		ii	$z = \frac{(\lambda_{obs} - \lambda_{rest})}{\lambda_{rest}}$ (1) $z = \frac{(676\times10^{-9} - 656\times10^{-9})}{656\times10^{-9}}$ (1) $z = 0{\cdot}03$ (1) $z = \frac{v}{c}$ (1) $v = 0{\cdot}03c$ $v = 9\times10^{6}\ \text{m s}^{-1}$ (1)	5	
	b		$v = H_0 d$ (1) $d = \frac{v}{H_0}$ $d = \frac{1{\cdot}2\times10^{7}}{2{\cdot}3\times10^{-18}}$ (1) $d = 5{\cdot}2\times10^{24}\ \text{m}$	2	

6	**c**	**The whole candidate response should first be read to establish its overall quality in terms of accuracy and relevance to the problem/situation presented.** There may be strengths and weaknesses in the candidate response: *assessors should focus as far as possible on the strengths, taking account of weaknesses (errors or omissions) only where they detract from the overall answer in a significant way, which should then be taken into account when determining whether the response demonstrates **reasonable**, **limited** or **no** understanding.* **Assessors should use their professional judgement to apply the guidance below to the wide range of possible candidate responses.**	This open-ended question requires comment on the **suitability of the expanding balloon model to explain the expansion of the universe**. Candidate responses are expected to make judgements on its suitability, on the basis of relevant physics ideas/concepts which might include one or more of: that distances between the dots increase similarly as the distances between the galaxies; it is the 2-dimensional surface that is being compared to 3-dimensional space – so centre of balloon has no physical analogue; galaxies themselves do not expand – they are bound by gravitation; or other relevant ideas/concepts.
		3 marks: The candidate has demonstrated a **good** conceptual understanding of the physics involved, providing a logically correct response to the problem/situation presented. This type of response might include a statement of principle(s) involved, a relationship or equation, and the application of these to respond to the problem/situation. This does not mean the answer has to be what might be termed an 'excellent' answer or a 'complete' one.	In response to this question, a **good** understanding might be demonstrated by a candidate response that: • makes a judgement on suitability based on one relevant physics idea/concept, in a **detailed/developed** response that is **correct or largely correct** (any weaknesses are minor and do not detract from the overall response), **OR** • makes judgement(s) on suitability based on a range of relevant physics ideas/concepts, in a response that is **correct or largely correct** (any weaknesses are minor and do not detract from the overall response), **OR** • otherwise demonstrates a good understanding of the physics involved.
		2 marks: The candidate has demonstrated a **reasonable** understanding of the physics involved, showing that the problem/situation is understood. This type of response might make some statement(s) that is/are relevant to the problem/situation, for example, a statement of relevant principle(s) or identification of a relevant relationship or equation.	In response to this question, a **reasonable** understanding might be demonstrated by a candidate response that: • makes a judgement on suitability based on one or more relevant physics idea(s)/concept(s), in a response that is **largely correct** but has **weaknesses** which detract to a small extent from the overall response, **OR** • otherwise demonstrates a reasonable understanding of the physics involved.
		1 mark: The candidate has demonstrated a **limited** understanding of the physics involved, showing that a	In response to this question, a **limited** understanding might be demonstrated by a candidate response that:

		little of the physics that is relevant to the problem/situation is understood. The candidate has made some statement(s) that is/are relevant to the problem/situation.	• makes a judgement on suitability based on one or more relevant physics idea(s)/concept(s), in a response that has **weaknesses** which detract to a large extent from the overall response, **OR** • otherwise demonstrates a limited understanding of the physics involved.

Question			Expected response	Max mark	Additional guidance
7	a	i	A = 2u + 1d	1	
			B = 1u + 2d	1	
		ii	gluon	1	
	b	i	beta decay	1	
8	a	i	$W = QV$ or $E_w = QV$ (1) $E_w = 1{\cdot}6 \times 10^{-19} \times 35000$ (1) $E_w = 5{\cdot}6 \times 10^{-15}$ J	2	
		ii	Original $E_k = ½\ mv^2$ (1) $E_k = ½\ (1{\cdot}673 \times 10^{-27})(1{\cdot}2 \times 10^6)^2$ (1) $E_k = 1{\cdot}20 \times 10^{-15}$(J) New $E_k = 1{\cdot}20 \times 10^{-15} + 5{\cdot}6 \times 10^{-15}$(J) New $E_k = 6{\cdot}8 \times 10^{-15}$(J) (1) $E_k = ½\ mv^2$ $6{\cdot}8 \times 10^{-15} = ½\ (1{\cdot}673 \times 10^{-27})v^2$ (1) $v = 2{\cdot}9 \times 10^6$ m s^{-1} (1)	5	$(1{\cdot}20456 \times 10^{-15})$ $(6{\cdot}80456 \times 10^{-15})$ Accept 3, 2·85, 2·852 but not 3·0
	b		Alternating voltage has constant frequency (1) OR As speed of protons increases, they travel further in the same time. (1)	1	
9	a	i	$\Delta m = 4 \times 1{\cdot}673 \times 10^{-27} - 6{\cdot}646 \times 10^{-27}$ $\Delta m = 4{\cdot}6 \times 10^{-29}(kg)$ (1) $E = mc^2$ (1) $E = 4{\cdot}6 \times 10^{-29} \times (3{\cdot}00 \times 10^8)^2$ (1) $E = 4{\cdot}14 \times 10^{-12}$ J (1)	4	Accept $4{\cdot}1 \times 10^{-12}$ J
		ii	1 kg hydrogen has $\frac{0{\cdot}20}{1{\cdot}673 \times 10^{-27}} = 1{\cdot}195 \times 10^{26}$ atoms (1) Provides	3	the division by 4 can be done in the last line

Question			Expected response	Max mark	Additional guidance
			$\frac{1\cdot195\times10^{26}}{4}=0\cdot2989\times10^{26}$ reactions (1) Releases $0\cdot2989\times10^{26}\times4\cdot14\times10^{-12}$ $=1\cdot2\times10^{14}$ J (1) (1)		Allow $1,\ 1\cdot24,\ 1\cdot247$ ($\times10^{14}$ J)
		iii	Large amount of energy released results in **very** high temperatures OR Strong magnetic fields are required for containment	1	
	b		$m_{Rn}v_{Rn} = -m_\alpha v_\alpha$ (1) $3\cdot653\times10^{-25}\times v_{Rn}=-6\cdot645\times10^{-27}\times1\cdot46\times10^{7}$ (1) $v_{Rn}=2\cdot656\times10^{5}\,\mathrm{m\,s^{-1}}$ (1)	3	OR $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ $0 = 3\cdot653\times10^{-25}\times v_{Rn} + 6\cdot645\times10^{-27}\times1\cdot46\times10^{7}$ $v_{Rn}=-2.656\times10^{5}\,\mathrm{m\,s^{-1}}$ 1 for equation 1 for sub 1 for answer 2 velocities must have opposite directions else max 1 mark
10	a		Blue light has higher frequency/energy per photon than red light. (1) Photons of red light do not have enough energy to eject electrons (1)	2	Or similar statement comparing blue and red light Or similar statement in terms of threshold frequency or work function
	b		$E_k = hf - hf_0$ (1) $=(6\cdot63\times10^{-34}\times7\cdot0\times10^{14})$ - $2\cdot0\times10^{-19}$ (1) $=2\cdot6\times10^{-19}\,\mathrm{J}$ (1)	3	Accept $3,\ 2\cdot64,\ 2\cdot641$ but not $3\cdot0$
11	a		Light with fixed/no phase difference.	1	
	b	i	Bright fringes are produced by waves meeting in phase/crest to crest/trough to trough	1	"Waves produced by constructive interference" does not answer question (0)

Question			Expected response	Max mark	Additional guidance
		ii	$\Delta x = \frac{\lambda D}{d}$ (1) $\frac{9{\cdot}5 \times 10^{-3}}{4} = \frac{633 \times 10^{-9} \times 0{\cdot}750}{d}$ (2) d = $2{\cdot}0 \times 10^{-4}$ m (1)	4	**(1)** data value of λ **(1)** substitution of values including division by 4 If not divided by 4 then max **(1)** data value of λ Accept 2, 1.999 $(\times 10^{-4}\,\text{m})$
		iii	$\%uncert\Delta x = \frac{0{\cdot}2 \times 100}{9{\cdot}5 \times 10^{-3}} = 2{\cdot}1\%$ (1) $\%uncert D = \frac{0{\cdot}002 \times 100}{0{\cdot}750} = 0{\cdot}27\%$ **(1)** Improve precision in measurement of Δx (1)	3	In order to gain final mark must have shown two calcuations of the correct form, percentage or fractional Award final mark even if D identified due to wrong arithmetic
		iv	(Green laser ➔)shorter λ (1) Fringes closer together (1)	2	Second mark only available if based on physics that is not wrong
12	a	i	Labels (quantities and units)and scale (1) Points correctly plotted (1) Correct best fit line (1)	3	Non-linear scale = 0 marks Allow 1/2 division tolerance in plotting points
		ii	Gradient of graph (1) Refractive index = 1·50 (1)	2	1 mark for knowing to calculate the gradient of best fit line. 1 mark for correct value.
		iii	Repeated measurements Increased range of measurements Narrower beam of light Increase the number of values within the range Protractor with more precise scale eg $\frac{1}{2}^{\circ}$ divisions	2	1 mark each up to a maximum of 2 marks. Note – do not accept 'bigger protractor'
	b		$\sin\theta_c = \frac{1}{n}$ (1) $\theta_c = \sin^{-1}\frac{1}{1{\cdot}54}$ (1) $\theta_c = 40{\cdot}5^{\circ}$ (1)	3	Accept 40, $40{\cdot}49$, $40{\cdot}493$
13	a		$R = V/I$ (1) $= 12 / (30 \times 10^{-6})$ (1)	3	Or equivalent in kΩ, MΩ

Question			Expected response	Max mark	Additional guidance
			$= 400\ 000\ \Omega$ (1)		
	b	**i**	$Q = It$ (1) $= 30 \times 10^{-6} \times 30$ (1) $= 900 \times 10^{-6}$ C (1)	**3**	Or equivalent milli/micro
		ii	$C = Q/V$ (1) $200 \times 10^{-6} = 900 \times 10^{-6} / V$ (1) $V = 4{\cdot}5$ V (1) Therefore voltage across resistor is $12 - 4{\cdot}5 = 7{\cdot}5$ V (1)	**4**	
14	**a**		Material 2	**1**	
	b		resistance decreases (1) electron jumps (from valence band) to conduction band (1)	**2**	

[END OF SPECIMEN MARKING INSTRUCTIONS]