National
Qualifications
EXEMPLAR PAPER ONLY

EP37/H/02

Physics
Section 1—Questions

Date — Not applicable

Duration — 2 hours 30 minutes

Instructions for the completion of Section 1 are given on *Page two* of your question and answer booklet EP37/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 EP37/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

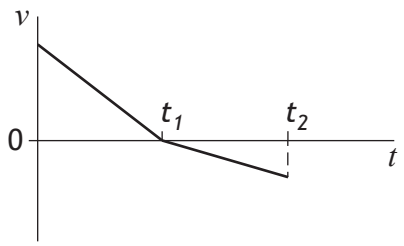
The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

SECTION 1 — 20 marks

Attempt ALL questions

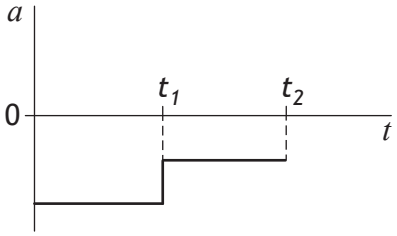
1. A trolley travels along a straight track.

The graph shows how the velocity v of the trolley varies with time t.

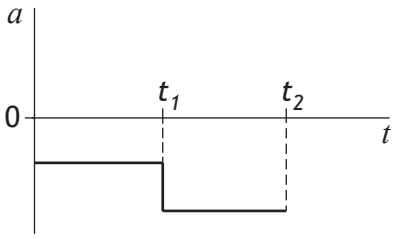


Which graph shows how the acceleration a of the trolley varies with time t?

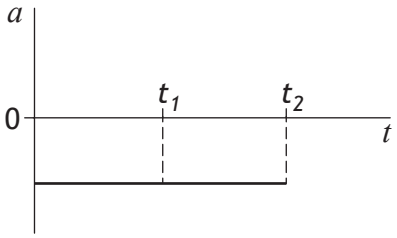
A



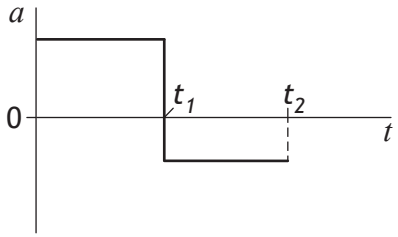
B



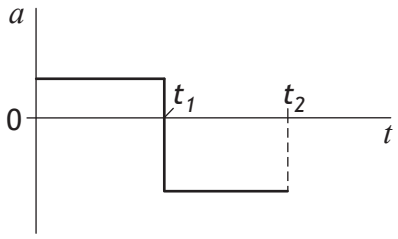
C



D



E



2. Two identical metal spheres X and Y are dropped onto a horizontal surface. The distance Y falls is double the distance X falls.

The effects of air resistance are negligible.

Which of the following statements is/are correct?

I The maximum kinetic energy of Y is double that of X.

II The maximum speed of Y is double the maximum speed of X.

III Y takes twice as long to fall as X.

A I only

B II only

C III only

D II and III only

E I, II and III

3. Two blocks are linked by a newton balance of negligible mass.

The blocks are placed on a level, frictionless surface. A force of 18·0 N is applied to the blocks as shown.

The reading on the newton balance is

A 7·2 N

B 9·0 N

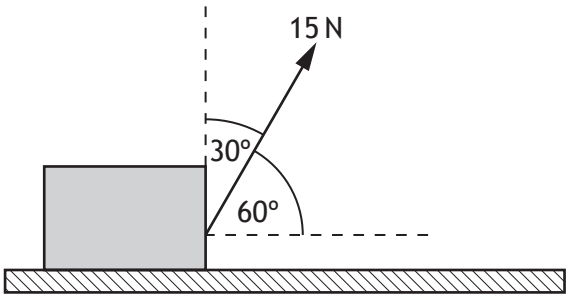
C 10·8 N

D 18·0 N

E 40·0 N.

4. A box is placed on a horizontal surface.

A force of 15 N acts on the box as shown.

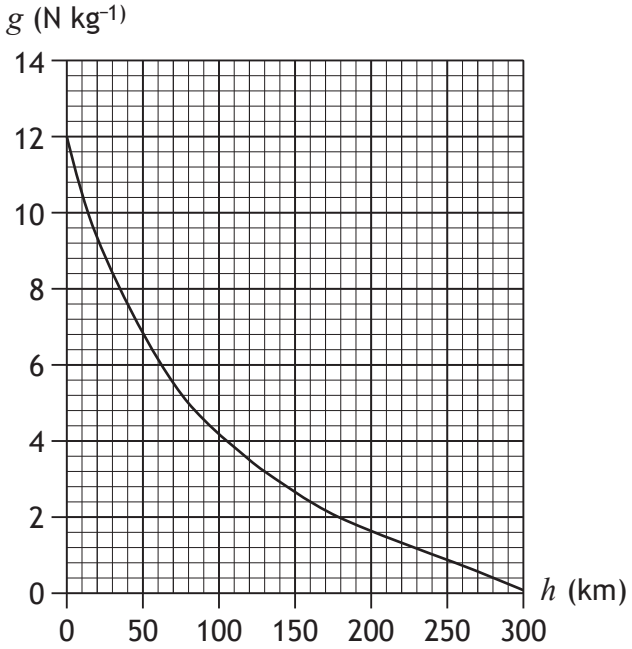


Which entry in the table shows the horizontal and vertical components of the force?

	Horizontal Component (N)	*Vertical Component* (N)
A	15 sin 60°	15 sin 30°
B	15 cos 60°	15 sin 30°
C	15 sin 60°	15 cos 60°
D	15 cos 30°	15 sin 30°
E	15 cos 60°	15 sin 60°

5. A rock of mass 0·80 kg falls towards the surface of a planet.

The graph shows how the gravitational field strength, g, of the planet varies with height, h, above the surface of the planet.



At one point during its fall the weight of the rock is 4·0 N. The height of this point above the surface of the planet is

A 15 km

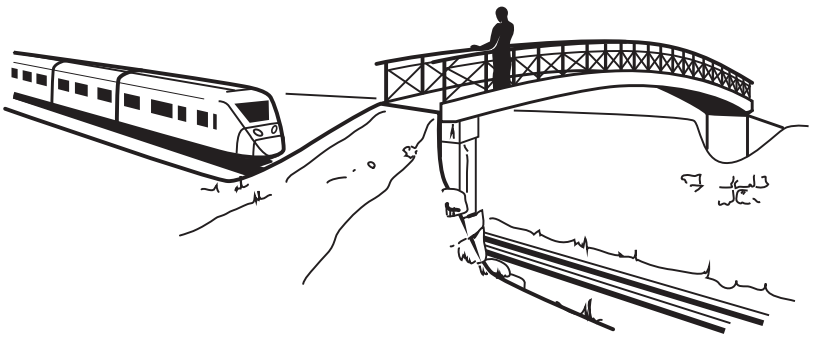
B 80 km

C 105 km

D 130 km

E 255 km.

6. A train is travelling at a constant speed of $16{\cdot}0\,m\,s^{-1}$ as it approaches a bridge.



A horn on the train emits sound of frequency 277 Hz.

The sound is heard by a person standing on the bridge.

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

The frequency of the sound heard by the person on the bridge is

A 265 Hz

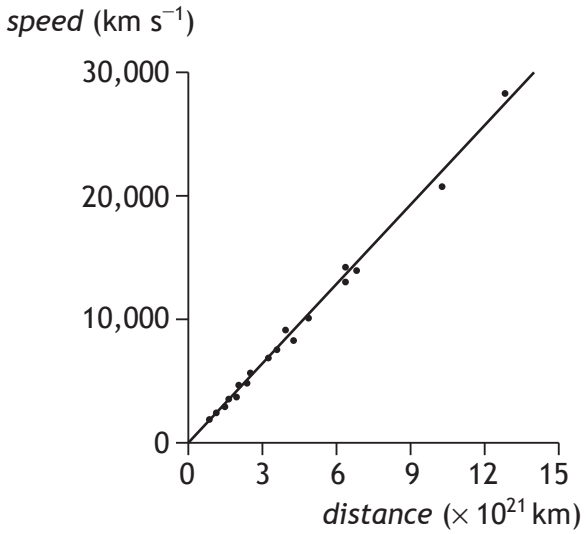
B 277 Hz

C 291 Hz

D 357 Hz

E 361 Hz.

7. Galaxies at different distances from the Earth have been found to have different speeds. The graph shows data for some distant galaxies.



A student studies this graph and makes the following statements.

I The speed of distant galaxies varies inversely with their distance from the Earth.

II The gradient of the line gives the value of Hubble's constant.

III The unit for Hubble's constant is s^{-1}.

Which of these statements is/are correct?

A I only

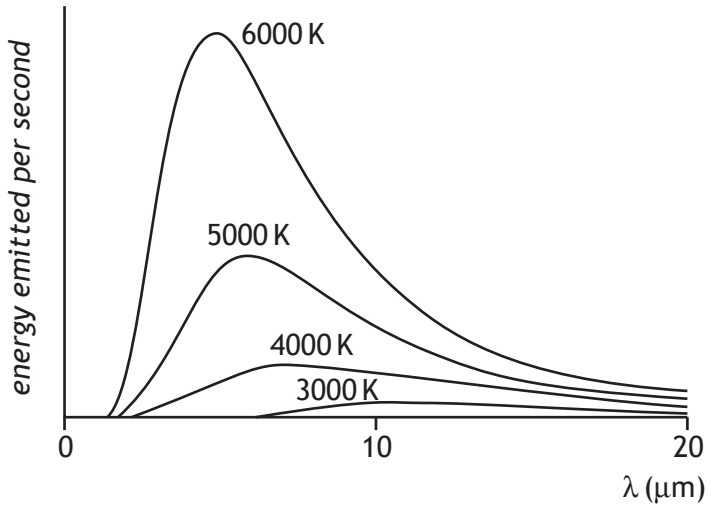
B II only

C III only

D I and II only

E II and III only

8. The graph shows how the energy emitted per second from the surface of a hot object varies with the wavelength, λ, of the emitted radiation at different temperatures.



A student makes the following statements based on the information shown in the graph.

I As the temperature of the object increases, the total energy emitted per second decreases.

II As the temperature of the object increases, the peak wavelength of the emitted radiation decreases.

III The frequency of the emitted radiation steadily increases as the emitted energy per second decreases.

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

9. The cooling of the Universe and cosmic microwave background radiation provide evidence for

A the photoelectric effect

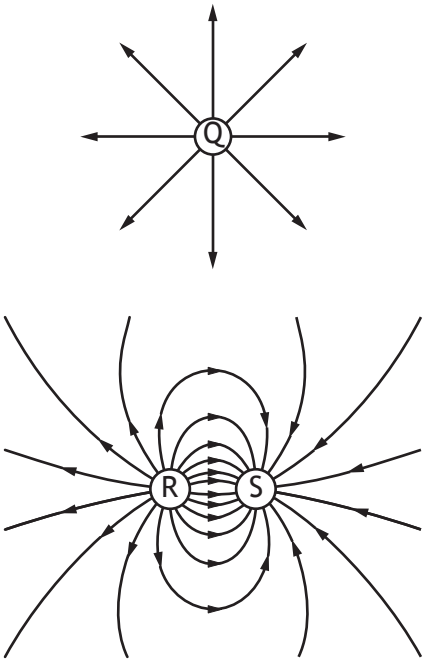
B the Bohr model of the atom

C the theory of special relativity

D the Big Bang theory

E Newton's Universal Law of Gravitation.

10. The electric field patterns around charged particles Q, R and S are shown.



Which row in the table shows the charges on particles Q, R and S?

	Charge on Q	*Charge on R*	*Charge on S*
A	positive	positive	negative
B	negative	negative	positive
C	negative	positive	negative
D	negative	negative	negative
E	positive	positive	positive

11. Which of the following statements describes a spontaneous nuclear fission reaction?

A $^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{144}_{56}\mathrm{Ba} + {}^{90}_{36}\mathrm{Kr} + 2\,{}^{1}_{0}\mathrm{n}$

B $^{7}_{3}\mathrm{Li} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{4}_{2}\mathrm{He}$

C $^{3}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$

D $^{226}_{88}\mathrm{Ra} \rightarrow {}^{222}_{86}\mathrm{Rn} + {}^{4}_{2}\mathrm{He}$

E $^{216}_{84}\mathrm{Po} \rightarrow {}^{216}_{84}\mathrm{Po} + \gamma$

12. The following statement describes a fission reaction.

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{139}_{57}\mathrm{La} + {}^{95}_{42}\mathrm{Mo} + 2\,{}^{1}_{0}\mathrm{n} + 7\,{}^{0}_{-1}e$$

The total mass of the particles before the reaction is $391{\cdot}848 \times 10^{-27}$ kg.

The total mass of the particles after the reaction is $391{\cdot}478 \times 10^{-27}$ kg.

The energy released in the reaction is

A $3{\cdot}53 \times 10^{-8}$ J

B $3{\cdot}52 \times 10^{-8}$ J

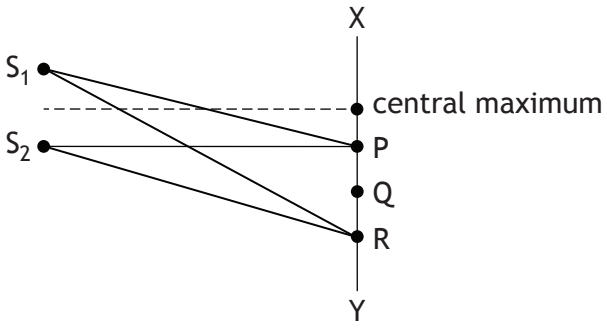
C $3{\cdot}33 \times 10^{-11}$ J

D $1{\cdot}67 \times 10^{-11}$ J

E $1{\cdot}11 \times 10^{-19}$ J.

13. S_1 and S_2 are sources of coherent waves.

An interference pattern is obtained between X and Y.



The first order maximum occurs at P, where $S_1P = 200$ mm and $S_2P = 180$ mm.

For the third order maximum, at R, the path difference ($S_1R - S_2R$) is

A 20 mm

B 30 mm

C 40 mm

D 50 mm

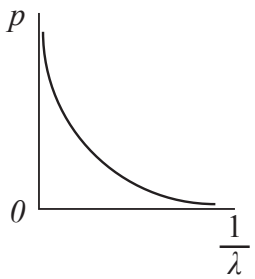
E 60 mm.

14. All particles exhibit wave properties.

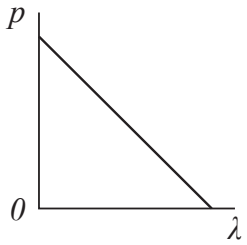
The momentum p of a particle is inversely proportional to its wavelength λ.

Which of the following graphs shows the relationship between p and λ?

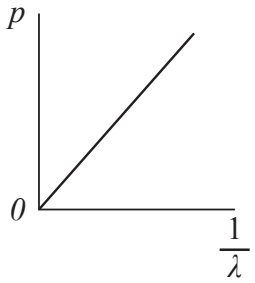
A



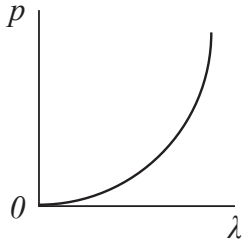
B



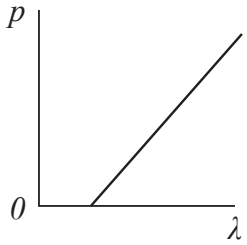
C



D



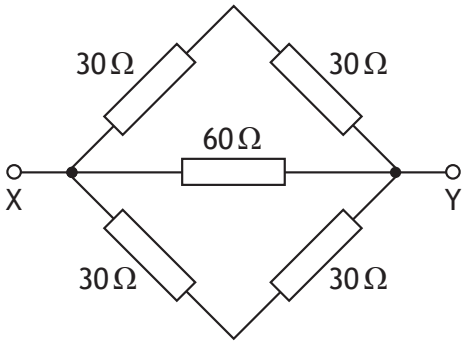
E



15. Which of the following lists the particles in order of size from smallest to largest?

A helium nucleus; electron; proton
B helium nucleus; proton; electron
C proton; helium nucleus, electron
D electron; helium nucleus, proton
E electron; proton; helium nucleus

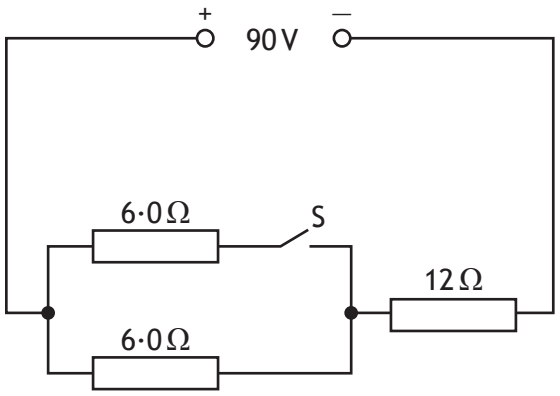
16. Five resistors are connected as shown.



The resistance between X and Y is

A 12 Ω
B 20 Ω
C 30 Ω
D 60 Ω
E 180 Ω.

17. A circuit is set up as shown.

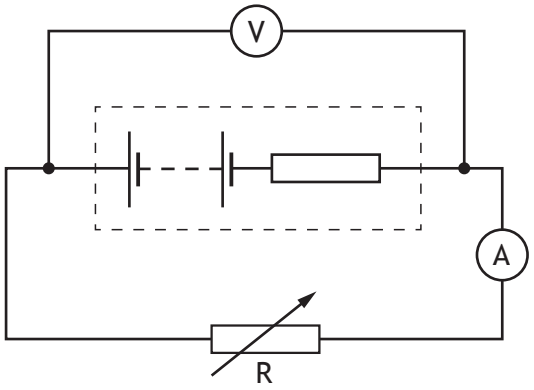


The internal resistance of the supply is negligible.

Which row in the table shows the potential difference (p.d.) across the 12 Ω resistor when switch S is open and when S is closed?

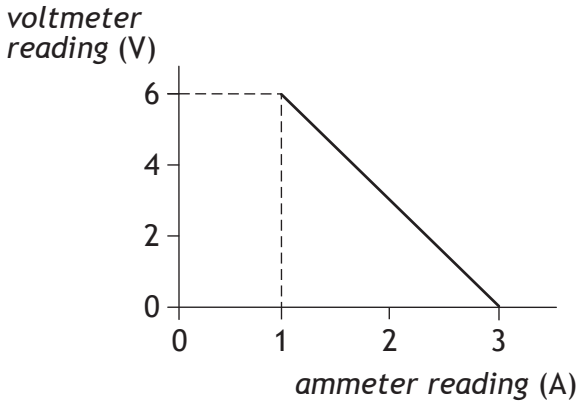
	p.d. across 12 Ω *resistor when S is open* (V)	*p.d. across* 12 Ω *resistor when S is closed* (V)
A	30	18
B	45	45
C	60	45
D	60	72
E	72	60

18. A circuit is set up as shown.



The variable resistor R is adjusted and a series of readings taken from the voltmeter and ammeter.

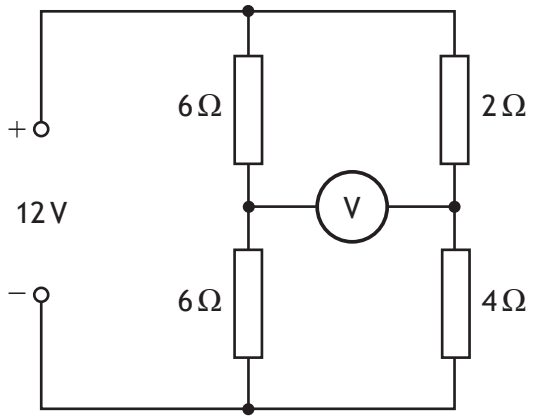
The graph shows how the voltmeter reading varies with the ammeter reading.



Which row in the table shows the values for the e.m.f. and internal resistance of the battery in the circuit?

	e.m.f. (V)	*internal resistance* (Ω)
A	6	2
B	6	3
C	9	2
D	9	3
E	9	6

19. The following circuit is set up.



The reading on the voltmeter is

A 0 V

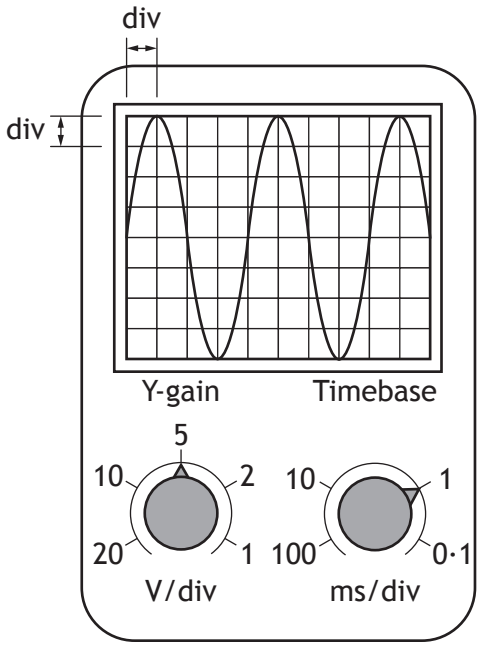
B 2 V

C 6 V

D 8 V

E 12V.

20. An alternating voltage is displayed on an oscilloscope screen. The Y-gain and the timebase settings are shown.



Which row in the table gives the values for the peak voltage and frequency of the signal?

	Peak voltage (V)	*Frequency* (Hz)
A	10	100
B	10	250
C	20	250
D	10	500
E	20	1000

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

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EP37/H/11

Physics
Relationships Sheet

Date — Not applicable

EP37H11

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** 2,8,18,32,32,8,2 Nobelium	103 **Lr** 2,8,18,32,32,9,2 Lawrencium

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Mark

EP37/H/01

Physics
Section 1 – Answer Grid and Section 2

Date — Not applicable

Duration — 2 hours 30 minutes

* E P 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

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 EP37/H/02 and to the Relationship Sheet EP37/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 EP37/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.

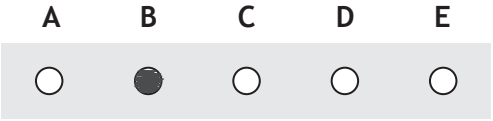
3. Any rough work must be written in the additional space for answers and rough work at the end of this booklet.

Sample Question

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

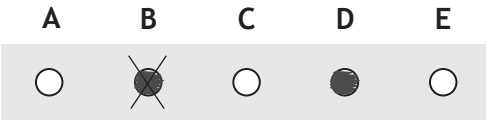
A ampere
B kilowatt-hour
C watt
D coulomb
E volt.

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

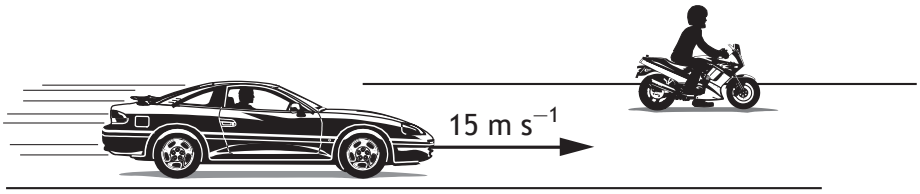
	A	B	C	D	E
1	○	○	○	○	○
2	○	○	○	○	○
3	○	○	○	○	○
4	○	○	○	○	○
5	○	○	○	○	○
6	○	○	○	○	○
7	○	○	○	○	○
8	○	○	○	○	○
9	○	○	○	○	○
10	○	○	○	○	○
11	○	○	○	○	○
12	○	○	○	○	○
13	○	○	○	○	○
14	○	○	○	○	○
15	○	○	○	○	○
16	○	○	○	○	○
17	○	○	○	○	○
18	○	○	○	○	○
19	○	○	○	○	○
20	○	○	○	○	○

SECTION 2 — 110 marks

Attempt ALL questions

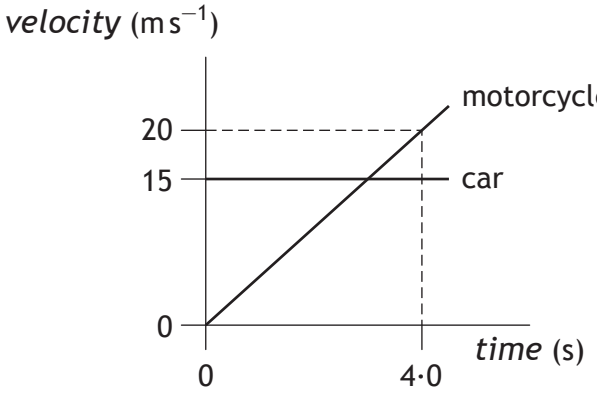
1. A car is travelling at a constant speed of $15\,m\,s^{-1}$ along a straight, level road.

It passes a motorcycle which is stationary at the roadside.



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

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



(a) Show that the initial acceleration of the motorcycle is $5{\cdot}0\,m\,s^{-2}$. **2**

Space for working and answer

1. (continued)

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

Space for working and answer

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

(i) Calculate the frictional force acting on the motorcycle at this time. **3**

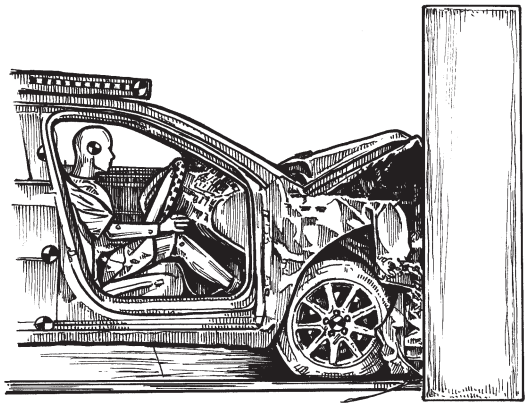
Space for working and answer

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

MARKS | DO NOT WRITE IN THIS MARGIN

2. The force applied by a seat belt on a crash test dummy is being investigated. The crash test dummy is placed in a car.

The car then travels along a test track at a speed of $13{\cdot}4\,m\,s^{-1}$, collides with a wall and comes to rest.



(a) State the law of conservation of linear momentum. **2**

(b) The total mass of the car and dummy is 1200 kg.

Calculate the change in momentum of the car and dummy in the collision. **3**

Space for working and answer

2. (continued)

(c) The crash test dummy has a mass of 75 kg and is wearing a seat belt. During the collision the dummy travels a distance of 0·48 m while coming to rest.

Calculate the average force exerted on the dummy by the seat belt. **4**

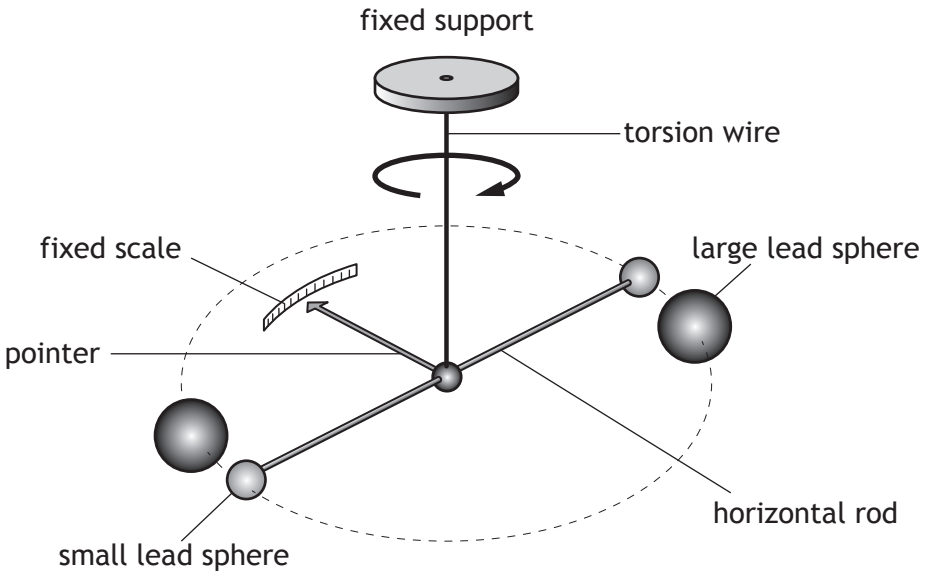
Space for working and answer

(d) This seatbelt is designed to stretch slightly during the collision.

Explain, in terms of forces, an advantage of this design. **3**

3. A student carries out an experiment to measure the Universal Constant of Gravitation.

The apparatus consists of a horizontal rod with small lead spheres at each end. The rod is suspended from its centre by a thin torsion wire. The student places a large lead sphere near each of the small spheres. The gravitational attraction between each pair of large and small spheres causes the torsion wire to twist. The angle of twist is indicated on a fixed scale by the position of a pointer attached to the rod.



The torsion wire twists by one degree when each small lead sphere experiences a force of $1{\cdot}56 \times 10^{-9}$ N.

(a) (i) The student measures the angle of twist to be 0·45°.

Show that the gravitational force between one pair of large and small spheres is $7{\cdot}0 \times 10^{-10}$ N. **1**

Space for working and answer

3. (a) (continued)

(ii) The small lead spheres each have a mass of 0·0148 kg.

The large lead spheres each have a mass of 1·52 kg.

The student measures the distance from the centre of mass of each of the large spheres to the centre of mass of its adjacent small sphere to be 46·5 mm.

Determine the value for the Universal Constant of Gravitation the student obtains from these results. **3**

(b) The manufacturer of the apparatus claims that this experiment can achieve an accuracy to within ±2·5% of the accepted value for the Universal Constant of Gravitation.

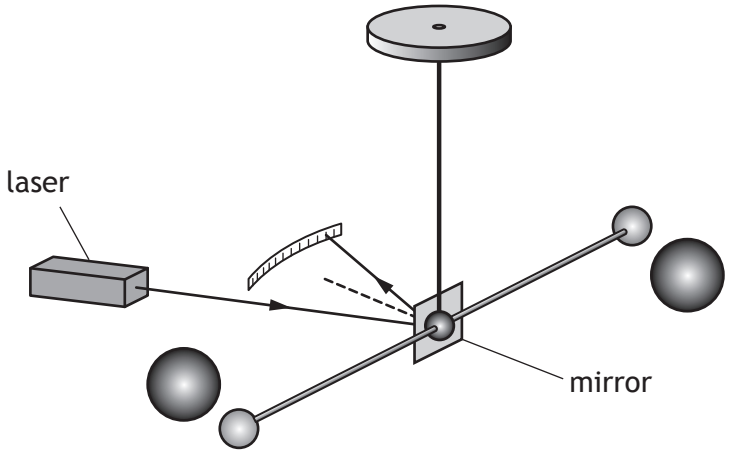
State whether or not the student's value for the Universal Constant of Gravitation agrees with this claim.

You must justify your answer by calculation. **3**

Space for working and answer

3. (continued)

(c) The student now decides to replace the pointer on the horizontal rod with a small mirror. A laser beam is then directed at the mirror in such a way that the beam is reflected onto the scale as shown.



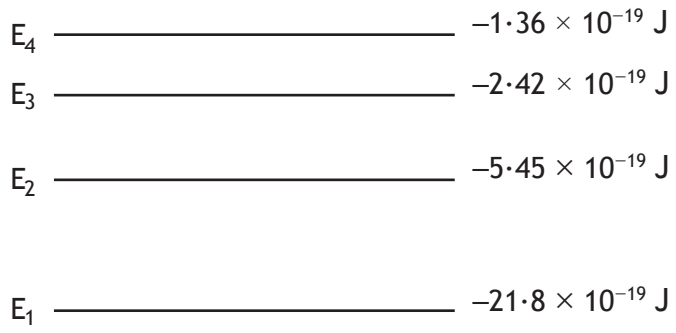
Explain how this modification improves the accuracy of the experiment. **2**

4. A binary star is a star system consisting of two stars orbiting around each other.

One of the techniques astronomers use to detect binary stars is to examine the spectrum of light emitted by the stars. In particular they look for the changes in wavelength of a specific spectral line, called the hydrogen alpha line, over a period of time.

Accurate measurements of the wavelength of the hydrogen alpha line on Earth have determined it to be 656·28 nm.

(a) The following diagram shows some of the energy levels for the hydrogen atom.



Radiation is emitted when electrons make transitions from higher to lower energy levels.

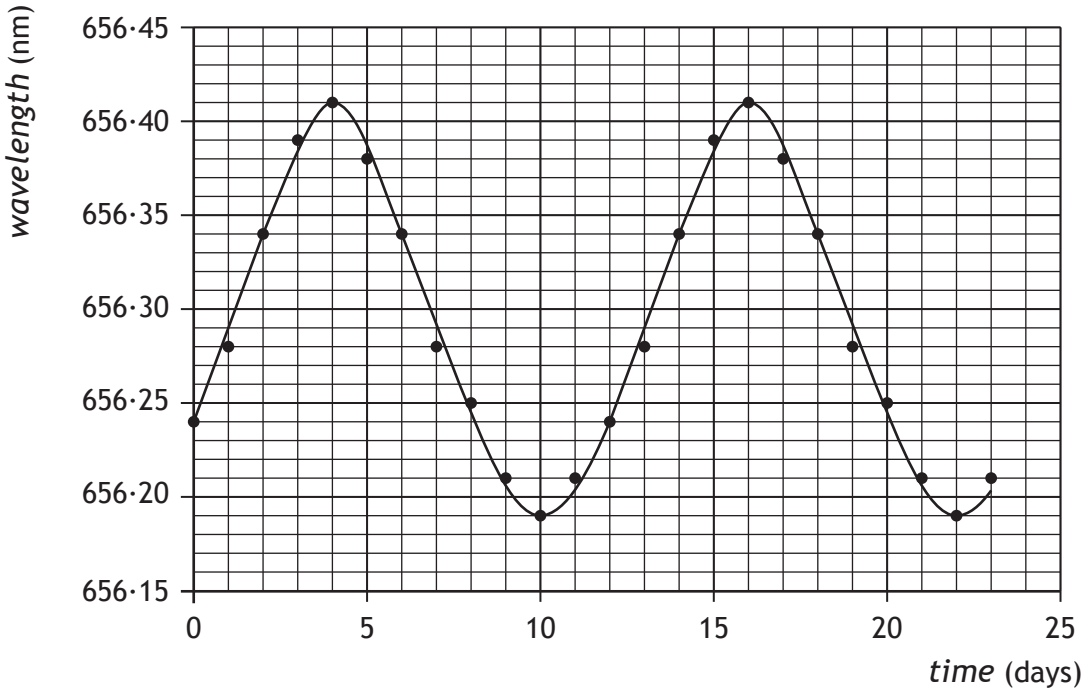
Identify the transition, between these energy levels, that produces the hydrogen alpha line.

Justify your answer by calculation. **5**

Space for working and answer

4. (continued)

(b) The graph shows how the wavelength of the hydrogen alpha line for one of the stars in a binary pair varies with time, as observed on Earth.



Using information from the graph:

(i) determine the period of orbit of this star; **1**

(ii) calculate the maximum recessional velocity of the star; **5**

Space for working and answer

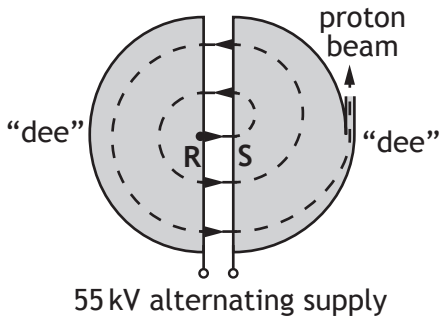
4. (b) (continued)

(iii) explain how the maximum approach velocity of the star compares to its maximum recessional velocity. **2**

MARKS | DO NOT WRITE IN THIS MARGIN

5. A cyclotron is used in a hospital to accelerate protons that are then targeted to kill cancer cells.

The cyclotron consists of two D-shaped, hollow metal structures called "dees", placed in a vacuum. The diagram shows the cyclotron viewed from above.



Protons are released from rest at **R** and are accelerated across the gap between the "dees" by a voltage of 55 kV.

(a) Show that the work done on a proton as it accelerates from **R** to **S** is $8{\cdot}8 \times 10^{-15}$ J. **2**

Space for working and answer

(b) Inside the "dees" a uniform magnetic field acts on the protons.

Determine the direction of this magnetic field. **1**

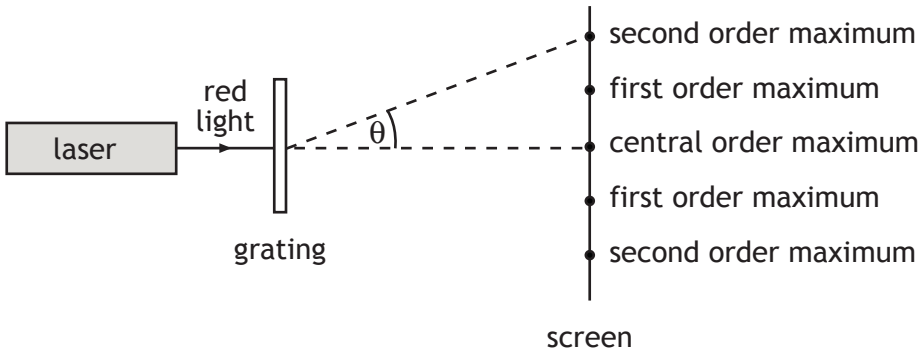
(c) Explain why an alternating voltage is used in the cyclotron. **2**

6. A laser produces a narrow beam of monochromatic light.

MARKS

DO NOT WRITE IN THIS MARGIN

(a) Red light from a laser passes through a grating as shown.



A series of maxima and minima is observed.

Explain in terms of waves how a **minimum** is produced. **1**

(b) The laser is now replaced by a second laser, which emits blue light.

Explain why the observed maxima are now closer together. **2**

Space for working and answer

(c) The wavelength of the blue light from the second laser is $4{\cdot}73 \times 10^{-7}$ m.

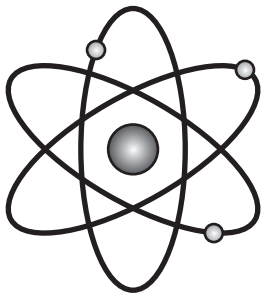
The spacing between the lines on the grating is $2{\cdot}00 \times 10^{-6}$ m.

Calculate the angle between the central maximum and the second order maximum. **3**

Space for working and answer

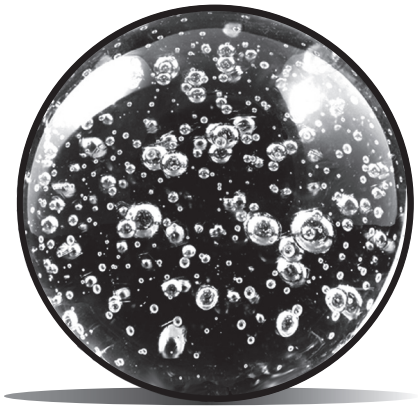
MARKS | DO NOT WRITE IN THIS MARGIN

7. A science textbook contains the following diagram of an atom.



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

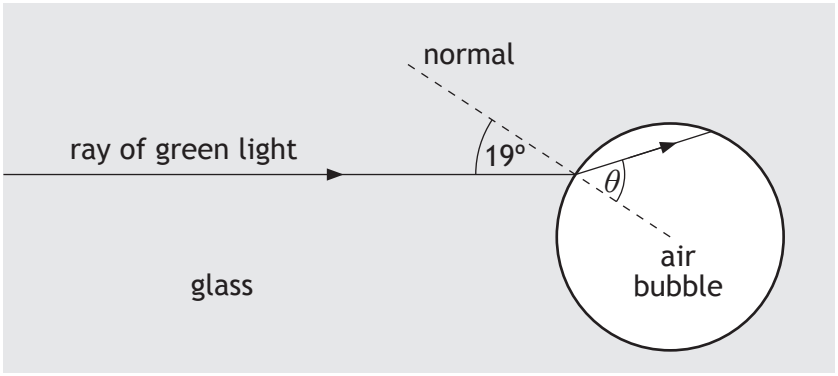
8. A student places a glass paperweight containing air bubbles on a sheet of white paper.



The student notices that when white light passes through the paperweight, a pattern of spectra is produced.

The student decides to study this effect in more detail by carrying out an experiment in the laboratory.

A ray of green light follows the path shown as it enters an air bubble inside glass.



not to scale

The refractive index of the glass for this light is 1·49.

(a) Calculate the angle of refraction, θ, inside the air bubble. **3**

Space for working and answer

8. (continued)

(b) Calculate the maximum angle of incidence at which a ray of green light can enter the air bubble. **3**

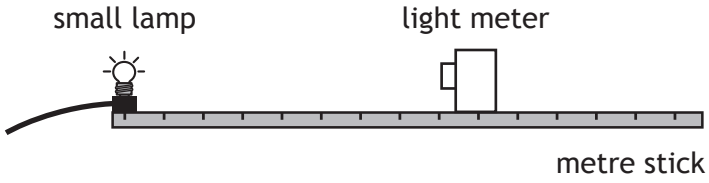
Space for working and answer

(c) The student now replaces the ray of green light with a ray of white light.

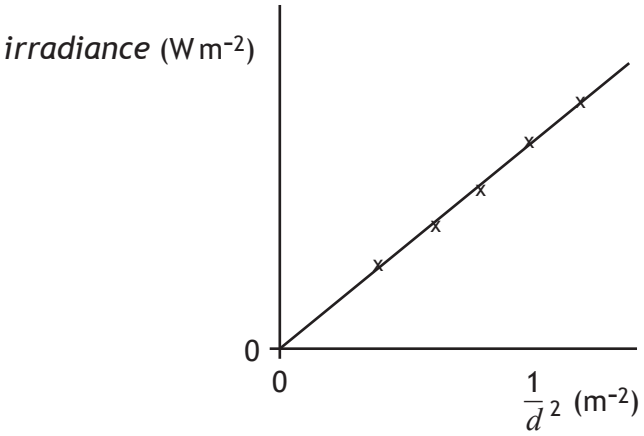
Explain why a spectrum is produced. **1**

9. A student investigates how irradiance I varies with distance d from a small lamp.

The following apparatus is set up in a darkened laboratory.



The results are used to produce the following graph.



(a) Explain why this graph confirms the relationship $I = \frac{k}{d^2}$. **1**

(b) The irradiance of light from the lamp at a distance of 1·6 m is 4·0 W m^{-2}.

Calculate the irradiance of the light at a distance of 0·40 m from the lamp. **3**

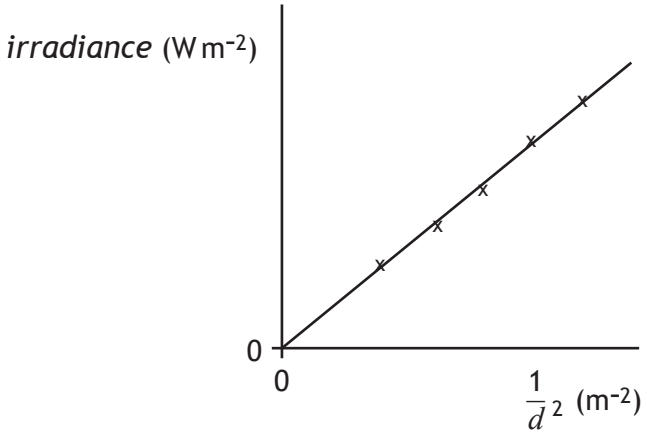
Space for working and answer

9. (continued)

(c) The experiment is repeated with the laboratory lights switched on.

On the graph below, draw another line to show the results of the second experiment. **1**

Additional graph (if required) is provided on *Page twenty-nine*.



MARKS | DO NOT WRITE IN THIS MARGIN

10. Physicists study subatomic particles using particle accelerators.

Pions are subatomic particles made up of two quarks.

There are three types of pion:

π^+ particles which have a charge of $+1$;
π^- particles which have a charge of -1;
and π^0 particles which have a zero charge.

The π^+ particle is made up of an up quark and an anti-down quark.

(a) State whether a pion is classed as a baryon or a meson.

Justify your answer. **2**

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

Determine the charge on an anti-down quark. **1**

(c) The π^- particle is the antiparticle of the π^+ particle.

State the names of the quarks that make up an π^- particle. **1**

10. (continued)

(d) π^+ particles have a mean lifetime of $2{\cdot}6 \times 10^{-8}$ s in their own frame of reference.

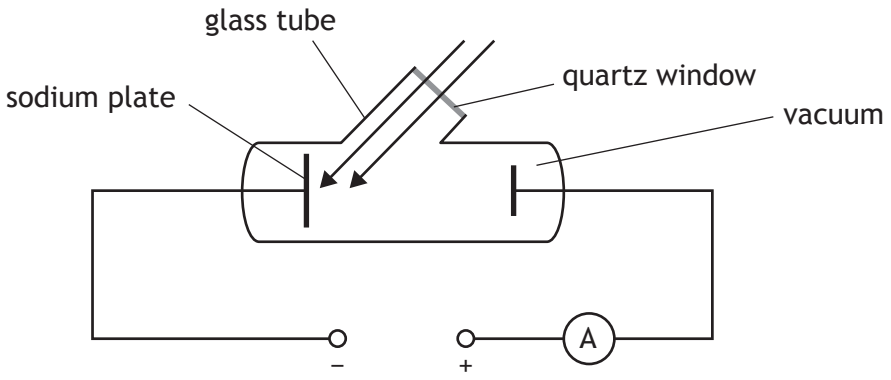
In an experiment in a particle accelerator, π^+ particles are accelerated to a velocity of $0{\cdot}9c$.

Calculate the mean lifetime of these π^+ particles relative to a stationary observer. **3**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

11. The following apparatus is set up in a physics laboratory to investigate the photoelectric effect.



constant voltage supply

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

Light of frequency $6{\cdot}74 \times 10^{14}$ Hz is incident on the sodium plate and photoelectrons are emitted.

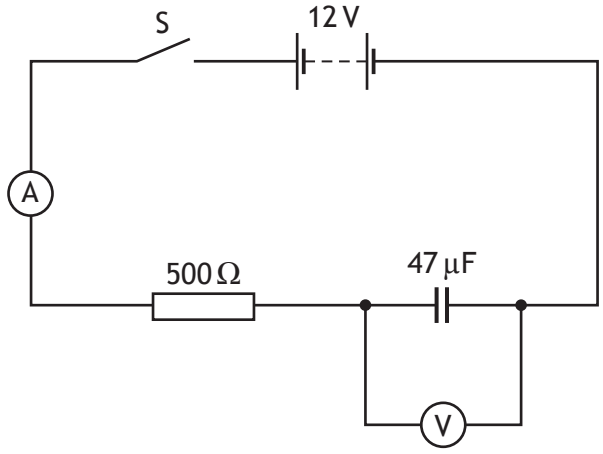
(a) Calculate the maximum kinetic energy of a photoelectron just as it is emitted from the sodium plate. **3**

Space for working and answer

(b) Calculate the maximum velocity of a photoelectron just as it is emitted from the sodium plate. **3**

Space for working and answer

12. A 12 volt battery of negligible internal resistance is connected in a circuit as shown.



The capacitor is initially uncharged. Switch S is then closed and the capacitor starts to charge.

(a) Sketch a graph of the current against time from the instant switch S is closed.

Numerical values are not required. **1**

(b) At one instant during the charging of the capacitor the reading on the ammeter is 5·0 mA.

Calculate the reading on the voltmeter at this instant. **4**

Space for working and answer

12. (continued)

(c) (i) Calculate the maximum charge stored on the capacitor. **3**

Space for working and answer

(ii) Calculate the **maximum** energy stored in the capacitor in this circuit. **3**

Space for working and answer

(d) The 500 Ω resistor is now replaced with a 2·0 kΩ resistor.

What effect, if any, does this have on the maximum energy stored in the capacitor?

Justify your answer. **2**

MARKS | DO NOT WRITE IN THIS MARGIN

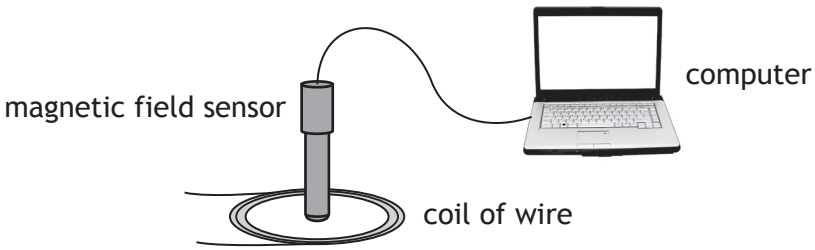
13. Recent innovations in capacitor technology have led to the development of "ultracapacitors". Ultracapacitors of a similar size to standard AA rechargeable cells are now available with ratings of around 100 F with a maximum working voltage of 2·7 V.

By comparison, AA rechargeable cells operate at 1·5 V and can store up to 3400 mA h of charge.
(*charge* in mA h = *current* in mA × *time* in hours)

Use your knowledge of physics to compare the advantages and/or disadvantages of using ultracapacitors and rechargeable cells. **3**

14. A student is investigating how the magnetic field strength at the centre of a coil of wire depends on the direct current in the coil.

The strength of the magnetic field is measured with a magnetic field sensor placed in the centre of the coil. The sensor is connected to a computer as shown.



The computer displays values of magnetic field strength. The unit of magnetic field strength is the tesla (T).

(a) The student designs a circuit to vary and measure the current in the coil of wire.

The circuit symbol for a coil of wire is shown.

Draw a circuit diagram to show how the current in the coil could be varied and measured. **2**

MARKS

DO NOT WRITE IN THIS MARGIN

(b) The following results are obtained.

Current in coil (A)	*Magnetic field strength* (T)
0·20	$1{\cdot}4 \times 10^{-4}$
0·40	$2{\cdot}4 \times 10^{-4}$
0·60	$3{\cdot}0 \times 10^{-4}$
0·80	$3{\cdot}6 \times 10^{-4}$
1·00	$4{\cdot}6 \times 10^{-4}$

Using the square-ruled paper on *Page thirty-one*, plot a graph of magnetic field strength against current. **3**

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

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

(d) The magnetic field strength B at the centre of a coil of wire is given by the relationship

$$B = 6{\cdot}3 \times 10^{-7} \frac{NI}{r}.$$

where B is the magnetic field strength in tesla
N is the number of turns in the coil
I is the current in the coil in amperes
r is the radius of the coil in metres.

The number of turns in the coil used by the student is 30.

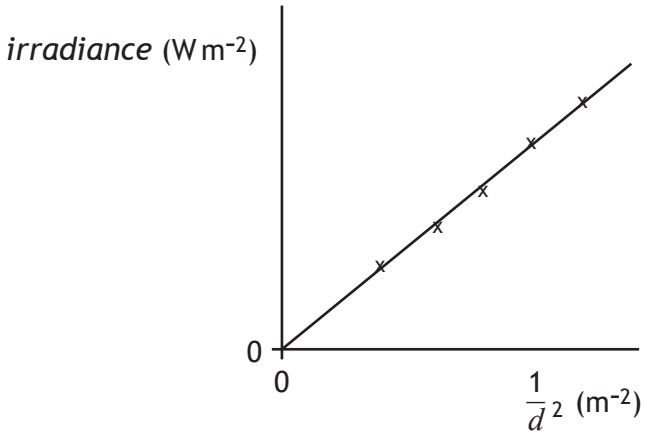
Use this relationship and the gradient of your graph to calculate the radius of the coil. **4**

Space for working and answer

[END OF EXEMPLAR QUESTION PAPER]

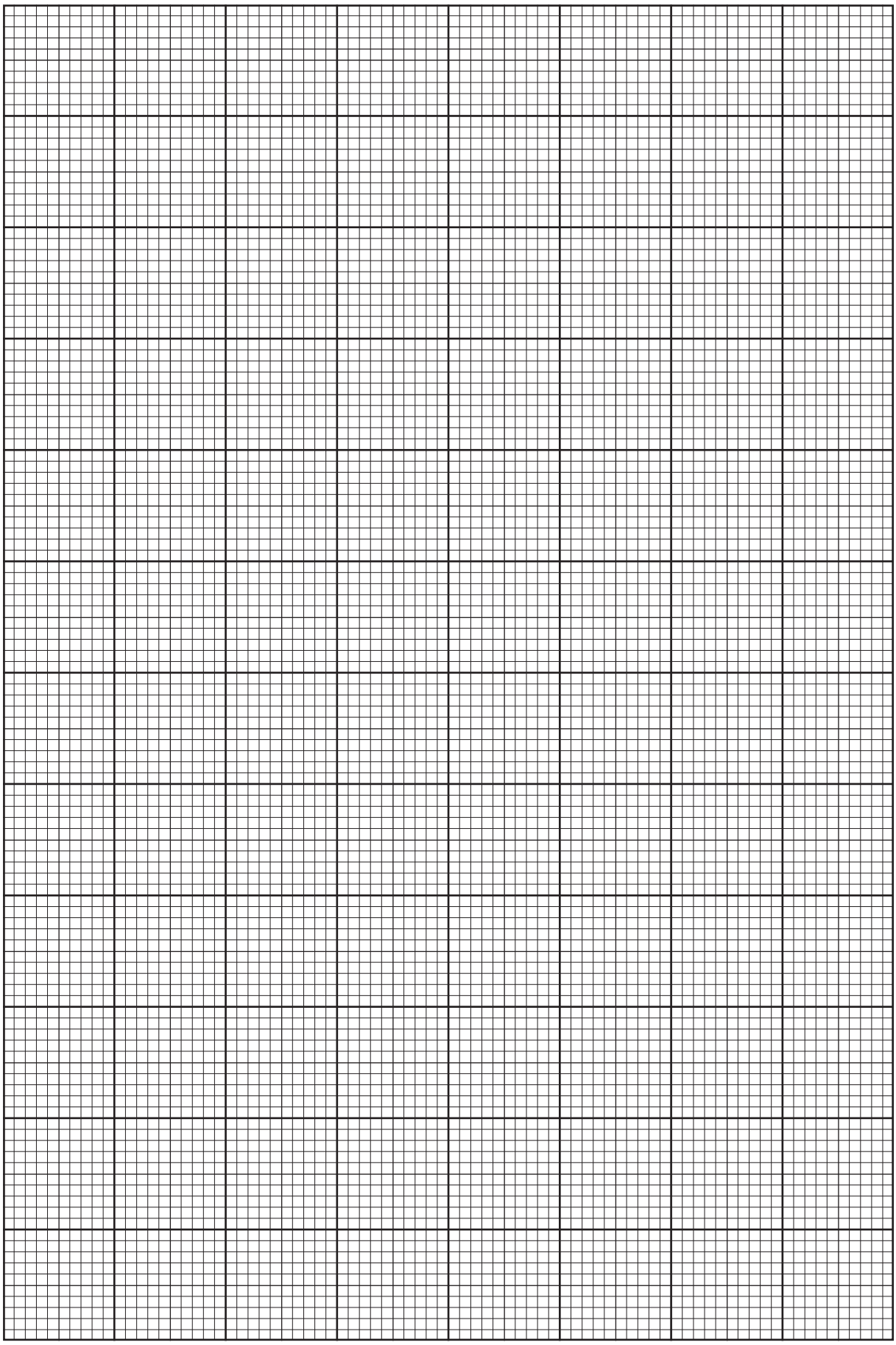
ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

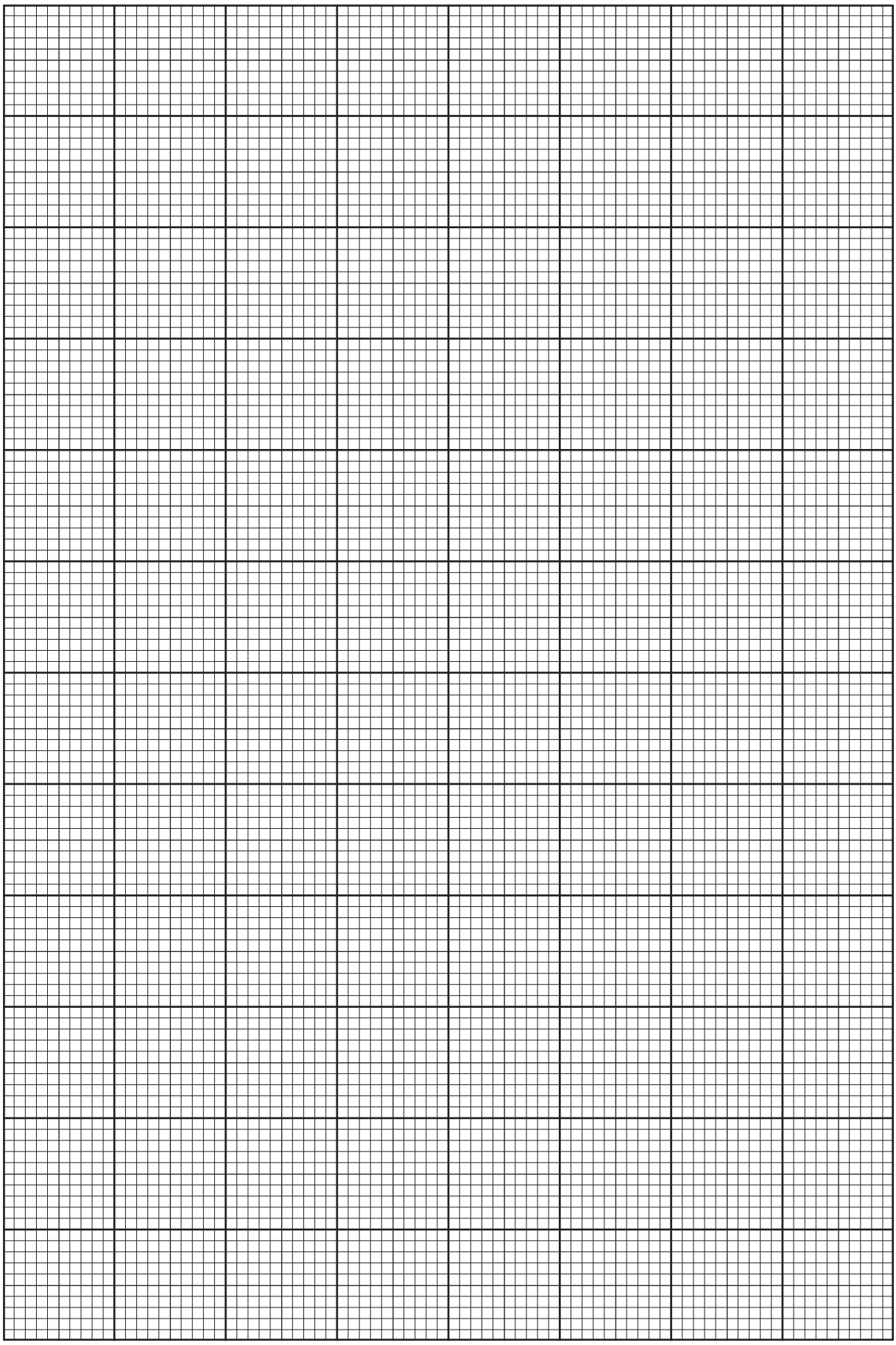
Additional graph for Question 9(c)



MARKS | DO NOT WRITE IN THIS MARGIN

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK





National
Qualifications
EXEMPLAR PAPER ONLY

EP37/H/02 **Physics**

Marking Instructions

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

SQA ©

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 <u>always</u> 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.

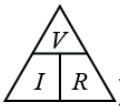
(d) Where a wrong answer to part of a question is carried forward and the wrong answer is then used correctly in the following part, the candidate should be given credit for the subsequent part or "follow on".

(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:

- **describe**, they must provide a statement or structure of characteristics and/or features;
- **determine** or **calculate**, they must determine a number from given facts, figures or information;
- **estimate**, they must determine an approximate value for something;
- **explain**, they must relate cause and effect and/or make relationships between things clear;
- **identify**, **name**, **give**, or **state**, they need only name or present in brief form;
- **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.
- **predict**, they must suggest what may happen based on available information;
- **show that**, they must use physics [and mathematics] to prove something, eg a given value — *all steps, including the stated answer, must be shown*;
- **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

Detailed Marking Instructions for each question

SECTION 1

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

SECTION 2

Question			Expected response	Max mark	Additional guidance
1	a		Must start with a formula or (**0**) $v = u + at$ **(1)** $20 = 0 + 4a$ **(1)** $a = 5 \cdot 0 \text{ m s}^{-2}$ Award a maximum of (**1**) mark if final answer (including units) is not shown.	**2**	*u* and *v* wrong way round, (**1**) **max for formula** Gradient method is okay: $a = \frac{\Delta v}{t} = \frac{20}{4} = 5 \text{ m s}^{-2}$ ***a=v/t* not acceptable**
1	b		car motorcycle $d = v \times t$ $s = ut + ½ at^2$ **(1)** $d = 15 \times 4$ $s = ½ \times 5 \times 16$ $d = 60$ $s = 40$ **(1)** **(1)** Extra distance = 60 – 40 = 20 m **(1)** ***Can also use $v^2 = u^2 + 2as$*** ***$20^2 = 0 + 2 \times 5 \times s$ for motorcycle*** '(**1**)' for both formulae **or** '(**1**)' for both area formulae	**4**	or, by area under graph; car motorcycle $A = l \times b$ $A = ½ b \times h$ (**1**) $A = 15 \times 4$ $A = ½ \times 4 \times 20$ $A = 60$ m (**1**) $A = 40$ m (**1**)
1	c	i	$F_{(resultant)} = ma$ $= 290 \times 5$ **(1)** $= 1450 \text{ (N)}$ **(1)** Frictional force = 1450 - 1800 = (-)350 N **(1)**	**3**	Note: this is not a standard 3-mark question.
1	c	ii	The *faster it goes*, the greater the *air resistance*. (**1**) or ***frictional forces/friction/drag*** ***then*** ***F(drive)*** constant, the *unbalanced* force would decrease. **or** Increasing ***F(drive)*** keeps the *unbalanced* force constant. **or** ***overall/net force* — (1)**	**2**	**Must be explanation involving force. This mark is conditional upon mark 1.**
2	a		total momentum before a collision is equal to total momentum after collision, **(1)** in the absence of external forces, **(1)**	**2**	**Must have total and collision or interaction** **and** "absence of external forces" **or** "for an isolated/**closed** system".

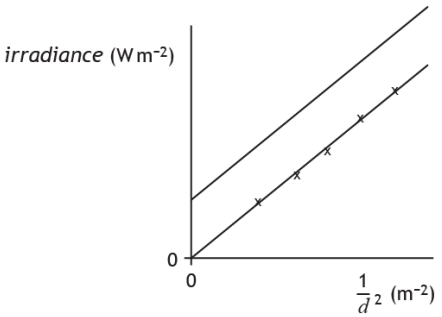
2	**b**		$\Delta mv = mv - mu$ **(1)** **Values in line 2 must be final - initial** $\Delta mv = 1200 \times 0 - 1200 \times 13 \cdot 4$ **(1)** $= -16080 \text{ kg m s}^{-1}$ $= -1 \cdot 6 \times 10^4 \text{ kg m s}^{-1}$ **(1)**	**3**	**ie** if u and v wrong way round, formula 1 only **must have change in momentum, ie "*mv*" or "*p*" = 16080 kg m s^{-1} gets 0 marks**
2	**c**		$v^2 = u^2 + 2as$ $0 = 13 \cdot 4^2 + 2 \times a \times 0 \cdot 48$ $a = -187 \cdot 04 \text{ (m s}^{-2})$ **(1)** $F = ma$ **(1)** $F = 75 \times (-)187 \cdot 04$ **(1)** $F = (-)14028 \text{ N} \quad F = 1 \cdot 4 \times 10^4 \text{ N}$ **(1)** Note: 1 mark for both formulae	**4**	**OR,** $E_k = \frac{1}{2} mv^2$ $= \frac{1}{2} \times 75 \times 13 \cdot 4^2$ $= 6733 \cdot 5 \text{ (J)}$ **(1)** $E_w = F \times d$ **(1)** $6733 \cdot 5 = F \times 0 \cdot 48$ **(1)** $\Rightarrow F = 1 \cdot 4 \times 10^4 \text{ N}$ **(1)** **OR,** $s = \frac{(u+v)t}{2}$ $0 \cdot 48 = \frac{(13 \cdot 4 + 0)t}{2}$ $t = 0 \cdot 072 \text{ (s)}$ **(1)** $Ft = m(v-u)$ **(1)** $F \times 0 \cdot 072 = 75(0 - 13 \cdot 4)$ **(1)** $F = 1 \cdot 4 \times 10^4 \text{ N}$ **(1)** Accept 1×10^4, $1 \cdot 40 \times 10^4$, and $1 \cdot 403 \times 10^4$
2	**d**		(Average) force (acting on dummy/passenger) is decreased/**reduced/smaller** **(1)** Time (of collision) increased **(1)** **change in momentum is the same** **(1)**	**3**	**Look for "smaller force" first. 0 marks if this is not there.** **Do not accept arrows for "increases" or "decreases".** An alternative approach using $W = F \times d$ is also acceptable: Distance travelled during collision increased (**1**) Loss in kinetic energy the same (**1**) So (average) force acting reduced (**1**)
3	**a**	**i**	Force $= 1 \cdot 56 \times 10^{-9} \times 0 \cdot 45$ **(1)** $= 7 \cdot 0 \times 10^{-10} \text{ N}$	**1**	Must show multiplication If final answer is **not** shown as **7·0 × 10^{-10}** award **0** marks.

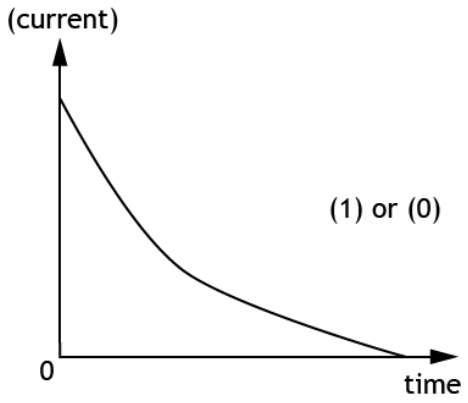
3	**a**	**ii**	$F = \frac{GMm}{r^2}$ **(1)** $7{\cdot}0 \times 10^{-10} = \frac{G \times 1{\cdot}52 \times 0{\cdot}0148}{0{\cdot}0465^2}$ **(1)** $\therefore G = 6{\cdot}7 \times 10^{-11}\ \text{m}^3\,\text{kg}^{-1}\,\text{s}^{-2}$ **(1)** [or $\text{N m}^2\,\text{kg}^{-2}$]	**3**	Accept $6{\cdot}728 \times 10^{-11}$ $6{\cdot}73 \times 10^{-11}$ 7×10^{-11}
3	**b**		$\pm 2{\cdot}5\%$ of $6{\cdot}67 \times 10^{-11} = \pm 1{\cdot}7 \times 10^{-12}$ **(1)** [or $\pm 0{\cdot}17 \times 10^{-11}$] claim between $6{\cdot}50 \times 10^{-11}$ **(1)** (and $6{\cdot}84 \times 10^{-11}$) [or between $6{\cdot}5 \times 10^{-11}$ (and $6{\cdot}8 \times 10^{-11}$)] within range so OK **(1)**	**3**	If answer to (a)(ii) is wrong, but answer to (b) is consistent, give full marks. arithmetic mistake, maximum of 2 value for *G* must be at least 2 sig fig, otherwise 0 marks no justification, 0 marks could do by finding 6·7 as a percentage of 6·67 and showing within 2·5%
3	**c**		reflection would result in increased/double the reading on the (fixed) scale **(1)** smaller <u>percentage</u> uncertainty **(1)**	**2**	**For (1) mark, accept an answer saying that the reading is more precise as the laser light hits the scale rather than having the gap between the pointer and the scale.**
4	**a**		$f = \frac{v}{\lambda}$ **(1)** $= \frac{3 \times 10^8}{656{\cdot}28 \times 10^{-9}}$ **(1)** $= 4{\cdot}57 \times 10^{14}$ (Hz) $E = hf$ **(1)** $= 4{\cdot}57 \times 10^{14} \times 6{\cdot}63 \times 10^{-34}$ **(1)** $= 3{\cdot}03 \times 10^{-19}$ (J) transition from E_3 to E_2 **(1)** or $E_3 \rightarrow E_2$ But **not:** E_3—E_2 **OR** $E_2 \rightarrow E_3$	**5**	**anywhere** **anywhere** **- this mark stands alone**
4	**b**	**i**	**12 days**	**1**	(**1**) or (**0**), no tolerance

4	**b**	**ii**	$z = \dfrac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$ **(1)** $= \dfrac{656 \cdot 41 - 656 \cdot 28}{656 \cdot 28}$ **(1)** $= 1 \cdot 9809 \times 10^{-4}$ $v = cz$ **(1)** $= 3 \cdot 00 \times 10^{8} \times 1 \cdot 98 \times 10^{-4}$ **(1)** $= 5 \cdot 94 \times 10^{4}\ \text{m s}^{-1}$ **(1)**	**5**	anywhere **must be 656·41** anywhere **accept:** 5·9, 5·943 or 5·9426 (plus units)
4	**b**	**iii**	blueshift is less than redshift **(1)** approach velocity is less **(1)**	**2**	independent marks **or "the difference in wavelength for approach is less than for recession"** **by calculation;** **(1) for magnitude of** less **(1) for *v* less** **(tolerate the dropping of the negative sign)**
5	**a**		$E_w = QV$ **(1)** $= 1 \cdot 60 \times 10^{-19} \times 55000$ **(1)** $= 8 \cdot 8 \times 10^{-15}\ \text{J}$	**2**	**This is a** 'Show' question, so must state formula. Maximum of **(1)** if last line not shown.
5	**b**		Into the page or down**/downwards** **(1)**	**1**	**Do not accept "down the page".**
5	**c**		to ensure that the accelerating potential is in the correct direction for the particles motion **(1)** **OR** the direction of the force acting on the particle is reversed **(1)**	**2**	
6	**a**		waves *meet* out of phase or crest meets trough **(1)** or path difference = $\left(n + \tfrac{1}{2}\right)\lambda$	**1**	Must have waves meeting/combining.
6	**b**		λ blue light is shorter (than λ red light) **(1)** and $n\lambda = d \sin\theta$ **(1)** **OR** $\sin\theta = \dfrac{n\lambda}{d}$	**2**	Explanation involving diffraction, 0 marks.

6	**c**		$n\lambda = d\sin\theta$ **(1)** $2\times 4\cdot 73\times 10^{-7} = 2\cdot 00\times 10^{-6}\sin\theta$ **(1)** $\theta = 28\cdot 2^{\circ}$ **(1)**	**3**	Accept 28, 28·23 and 28·229
7			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.	**3**	This open-ended question requires comment on a diagram of an atom. Candidate responses are expected to include one or more of: problems with planetary model; Bohr; energy levels; subatomic particles; wave particle; quantum model; Heisenberg.
			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.

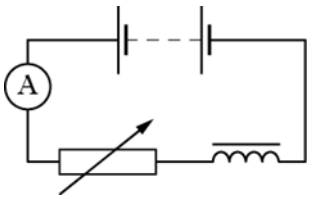
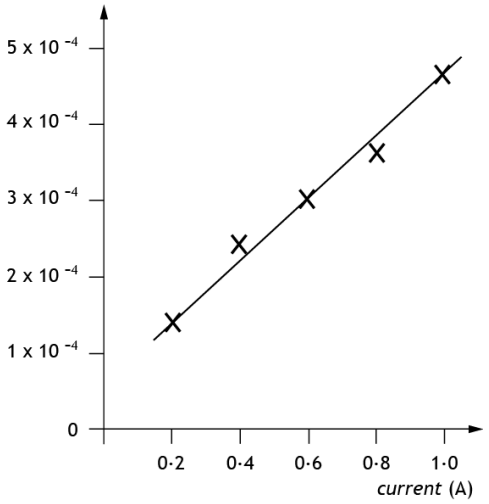
			2 marks: The candidate has demonstrated a **reasonable** understanding of the physics involved, showing that the problem/situation is understood. This type of response might make some statement(s) that is/are relevant to the problem/situation, for example, a statement of relevant principle(s) or identification 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 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.		In response to this question, a **limited** 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 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.
8	**a**		$n = \frac{\sin\theta_1}{\sin\theta_2}$ **(1)** $1{\cdot}49 = \frac{\sin\theta_{air}}{\sin 19^\circ}$ **(1)** $\theta_{air} = 29^\circ$ **(1)**	**3**	

8	**b**		$n = \frac{1}{\sin\theta_c}$ **(1)** $1{\cdot}49 = \frac{1}{\sin\theta_c}$ **(1)** $\theta_c = 42{\cdot}2^\circ$ **(1)**	**3**	Accept 42, 42·16, 42·155
8	**c**		Different frequencies/colours are <u>refracted</u> through different angles **OR** The <u>refractive index</u> is different for different frequencies/colours **(1)**	**1**	**Do not accept: — "bending" on its own, but ignore it if follows "refraction".** **a correct answer followed by "diffract" or "defract", 0 marks.**
9	**a**		Since graph is <u>straight line</u> through the <u>origin</u> **(1)**	**1**	"straight line" is **not** sufficient
9	**b**		$I_1 d_1^2 = I_2 d_2^2$ **(1)** $4{\cdot}0 \times 1{\cdot}6^2 = I_2 \times 0{\cdot}40^2$ **(1)** $I_2 = 64\ \text{W m}^{-2}$ **(1)**	**3**	
9	**c**			**1**	Second line must be both parallel to and above original graph line.
10	**a**		meson **(1)** quark/antiquark pair **(1)** **OR** made of 2 quarks	**2**	**must have "meson" before the second (1) can be awarded.**
10	**b**		$\pi^+ = \text{u} + \overline{\text{d}}$ $+1 = \frac{2}{3} + \overline{\text{d}}$ charge on anti-down $= +\frac{1}{3}$ **(1)**	**1**	
10	**c**		anti-up and down **(1)**	**1**	both required, (**1**) or (**0**) not "anti-anti-down"
10	**d**		$t' = \frac{t}{\sqrt{1-\frac{v^2}{c^2}}}$ **(1)** $= \frac{2{\cdot}6 \times 10^{-8}}{\sqrt{1-\frac{(0{\cdot}9c)^2}{c^2}}}$ **(1)** $= 6{\cdot}0 \times 10^{-8}$ s **(1)**	**3**	accept: 6×10^{-8} s $5{\cdot}96 \times 10^{-8}$ s $5{\cdot}965 \times 10^{-8}$ s

11	**a**		$E_k = hf - hf_0$ **(1)** $= \left(6{\cdot}63\times10^{-34} \times 6{\cdot}74\times10^{14}\right) - 3{\cdot}78\times10^{-19}$ **(1)** $= 6{\cdot}89\times10^{-20}\,\text{J}$ **(1)**	**3**	"$E = hf$" on its own (0) Accept: $6{\cdot}9 \times 10^{-20}$ J $6{\cdot}886 \times 10^{-20}$ J $6{\cdot}8862 \times 10^{-20}$ J Accept $6{\cdot}90\times10^{-20}$ J here ie using $E = hf$ $= 4{\cdot}47\times10^{-19}$ J
11	**b**		$E_k = \frac{1}{2}mv^2$ **(1)** $v^2 = \dfrac{2\times6{\cdot}89\times10^{-20}}{9{\cdot}11\times10^{-31}}$ **(1)** $v = 3{\cdot}89\times10^{5}\ \text{m s}^{-1}$ **(1)**	**3**	Or consistent with (a) **The max number of sig figs is five, but this depends on the candidate's substitution for *E*.**
12	**a**			**1**	
12	**b**		$V_R = IR$ $= 5\times10^{-3}\times500$ **(1)** $= 2{\cdot}5\ (\text{V})$ **(1)** $V_C = 12 - 2{\cdot}5$ **(1)** $= 9{\cdot}5\ \text{V}$ **(1)**	**4**	
12	**c**	**i**	$Q = CV$ **(1)** $= 47\times10^{-6}\times12$ **(1)** $= 5{\cdot}64\times10^{-4}\ \text{C}$ **(1)**	**3**	

12	**c**	**ii**	$E = \frac{1}{2}CV^2$ **(1)** $= 0{\cdot}5 \times 47 \times 10^{-6} \times 12^2$ **(1)** $= 3{\cdot}4 \times 10^{-3}$ J **(1)**	**3**	**Must use 12 V — otherwise max 1 for correct formula.** **Alternative:** $Q = CV$ $= 47 \times 10^{-6} \times 12$ $= 5{\cdot}64 \times 10^{-4}$ (C) $E = \frac{1}{2}QV$ $= \frac{1}{2} \times 5{\cdot}64 \times 10^{-4} \times 12$ $= 3{\cdot}4 \times 10^{-3}$ J **(1) for both formulae** **(1) for both substitutions**
12	**d**		Max energy the same/"no effect" **(1)** Values for "C" **and** "V" are the same as before **(1)**	**2**	
13			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.	**3**	This open-ended question requires comment on the advantages and/or disadvantages of using "ultracapacitors" and rechargeable cells. Candidate responses are expected to include one or more of: voltage rating, energy storage, recharge rate, delivering energy surges, etc.
			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 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.		In response to this question, a **limited** 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 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.
14	**a**		Suitable components selected and circuit symbols correct **(1)** suitable circuit (ie it would work) **(1)**, eg  **resistor must be variable (unless variable supply used).**	**2**	Values not required Accept  **OR** 
14	**b**		*magnetic field strength* (T)  	**3**	**3 marks for a fully correct graph.** **Axes labels must have both the name of the quantity and its unit.** **Each point must be plotted to within ± a half scale division.** **There must be a single, straight, best-fit line through the points.** **A non-linear scale on either axis is wrong and prevents access to any marks.**
14	**c**		(the graph is a straight line that) does not pass through origin **OR** **(1)** the magnetic field strength is not zero when the current is zero	**1**	
14	**d**		$\text{gradient} = 6{\cdot}3\times10^{-7}\,\frac{N}{r}$ **(1)** $3{\cdot}8\times10^{-4} = 6{\cdot}3\times10^{-7}\,\frac{30}{r}$ **(1)** $r = 0{\cdot}05\ \text{m}$ **(1)** gradient of graph = $3{\cdot}8 \times 10^{-4}$ (TA^{-1}) **(1)**	**4**	**Accept:** **$3{\cdot}6 \times 10^{-4}$ to $4{\cdot}0 \times 10^{-4}$** **If <u>values</u> of B and I (from the table or the graph line) are used in the formula, 0 marks.** **0·0497 m; 0·04974 m**

[END OF EXEMPLAR MARKING INSTRUCTIONS]