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**ADVANCED**  
**General Certificate of Education**  
**2018**

Centre Number

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Candidate Number

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# Physics

## Assessment Unit A2 1

*assessing*

Momentum, Thermal Physics,  
 Circular Motion, Oscillations  
 and Atomic and Nuclear Physics



**[AY211]**

\*AY211\*

**MONDAY 4 JUNE, AFTERNOON**

### TIME

1 hour 30 minutes.

### INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

**You must answer the questions in the spaces provided.**

**Do not write outside the boxed area on each page or on blank pages.**

Complete in black ink only. **Do not write with a gel pen.**

Answer **all ten** questions.

### INFORMATION FOR CANDIDATES

The total mark for this paper is 90.

Quality of written communication will be assessed in Question **8(b)**.

Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question.

Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.

You may use an electronic calculator.

Question **10** contributes to the synoptic assessment required of the specification.



- 1 (a) State the principle of conservation of momentum.

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[2]

- (b) In the activity 'zorb' a person is secured inside a large transparent ball which can then be rolled along a surface.  
The word 'zorb' in the question refers to **both** the ball and the person inside.

- (i) Zorb A, of mass 126 kg, is released from rest at the top of a hill. As it rolls down the hill, 20% of the total energy of zorb A is lost due to frictional forces. At the bottom of the hill zorb A has momentum equal to  $2450 \text{ kg m s}^{-1}$ .

Calculate the vertical height of the hill.

Height = \_\_\_\_\_ m [4]



- (ii) At the bottom of the hill zorb A collides with a second zorb, zorb B, of mass 114 kg. Zorb B is travelling towards zorb A at a speed of  $7.5 \text{ m s}^{-1}$ . After the collision zorb B rebounds in the opposite direction to its initial motion with a speed of  $4.6 \text{ m s}^{-1}$ .

Calculate the speed of zorb A after the collision.

Speed = \_\_\_\_\_  $\text{m s}^{-1}$  [3]



2 (a) Boyle's law relates the pressure of a gas to its volume under certain conditions.

(i) Draw a clearly labelled diagram to show how suitable apparatus is set up to take a series of measurements that will verify Boyle's Law.

[3]

(ii) State two factors that must be controlled in the experiment.

1. \_\_\_\_\_

2. \_\_\_\_\_ [2]

(iii) State the relationship between the pressure of a gas and its volume provided the factors in (ii) are constant.

\_\_\_\_\_

\_\_\_\_\_ [1]



- (b) Fig. 2.1 shows an airship with an envelope containing helium gas at a pressure of  $1.03 \times 10^5$  Pa.



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Fig. 2.1

- (i) The envelope of the airship has a volume of  $8230 \text{ m}^3$ . If the temperature of the gas is  $14^\circ\text{C}$ , calculate the mass of helium in the envelope of the airship.

The molar mass of helium =  $4.003 \times 10^{-3} \text{ kg mol}^{-1}$ .

Mass of helium = \_\_\_\_\_ kg [3]

- (ii) Calculate the root mean square speed of the helium gas atoms in the envelope of the airship.

Root mean square speed = \_\_\_\_\_  $\text{m s}^{-1}$  [3]

[Turn over



- 3 (a) Walking barefoot across hot coals is part of a religious ritual in some cultures. One of the properties of the burning material that needs to be considered is the specific heat capacity.

- (i) Define specific heat capacity.

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[1]

- (ii) The specific heat capacities of two types of rock that could be used as the hot coals are shown in **Table 3.1**.

**Table 3.1**

Type of Rock	Specific heat capacity / $\text{J g}^{-1} \text{ } ^\circ\text{C}^{-1}$
Pumice	0.87
Anthracite	1.32

Based on the values of specific heat capacity, explain which type of rock would be more suitable to use to prevent burns on the feet of the walker.

Type of rock \_\_\_\_\_

Explanation

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[1]



- (b) (i) A kettle with a 2700 W heating element is used to boil 750 cm<sup>3</sup> of water. The water is initially at a temperature of 18°C. Calculate the time taken for the water to boil.

The specific heat capacity of water is 4.187 J g<sup>-1</sup> °C<sup>-1</sup> and its density is 1 g cm<sup>-3</sup>.

Time = \_\_\_\_\_ s [3]

- (ii) Explain why it is likely that when the kettle is used it will take longer to boil than the time you have calculated in (i).

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ [1]

[Turn over

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- 4 (a) Fig. 4.1 shows a fairground carousel where the horses move in a horizontal circle at a constant speed.



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Fig. 4.1

A 136 kg horse on the outside of the carousel travels in a circle of diameter 12.0 m. It takes 42 seconds for the horse to complete one full rotation.

- (i) Use the definition of acceleration to explain why there must be a resultant force on the horse.

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[3]

- (ii) Calculate the magnitude of the resultant force on the horse.

Force = \_\_\_\_\_ N [3]



- (b) On another fairground ride, the rollercoaster, a carriage and passengers of combined mass 1200 kg approaches a vertical circular section as shown in Fig. 4.2. The diameter of the circle is 38 m.

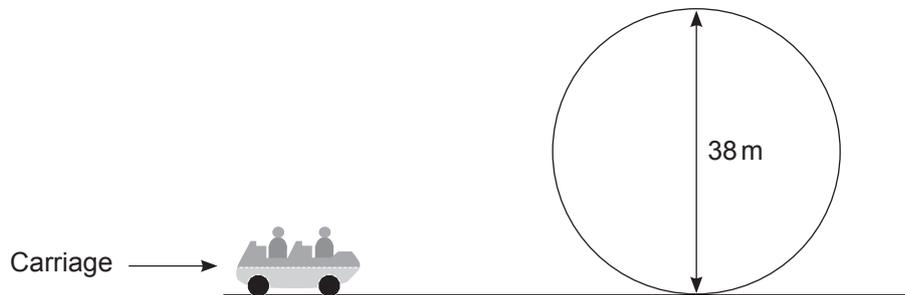


Fig. 4.2

- (i) What is the minimum speed of the rollercoaster carriage for the passengers to feel weightless at the top of the loop?

Speed = \_\_\_\_\_ m s<sup>-1</sup> [2]

- (ii) Describe what happens to the rollercoaster carriage if the speed is less than that calculated in (i).

\_\_\_\_\_  
 \_\_\_\_\_ [1]

- (iii) If the rollercoaster carriage has fewer passengers and therefore less mass than in (i) how will the speed at which weightlessness is experienced be affected?

\_\_\_\_\_  
 \_\_\_\_\_ [1]

[Turn over]



- 5 A mass on the end of a spring is pulled down a distance of 3 cm **below** equilibrium position and released so that it oscillates with simple harmonic motion. A graph of how the displacement of the mass varies with time is shown in Fig. 5.1.

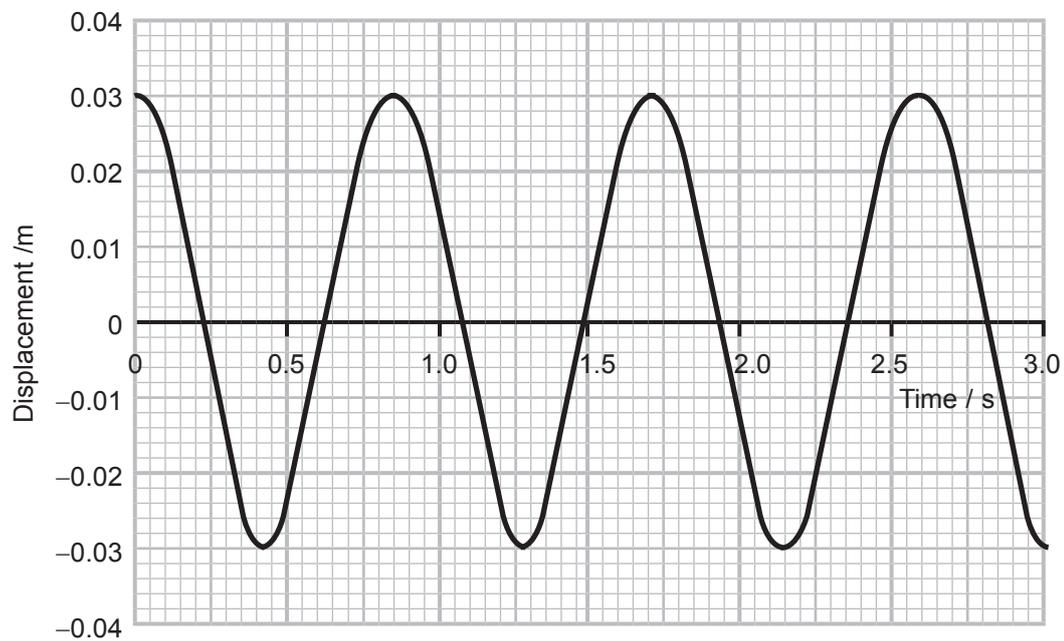


Fig. 5.1

- (a) Calculate the displacement of the mass at a time of 12.5 seconds and state whether the mass is above or below the equilibrium position at this time.

Displacement = \_\_\_\_\_ m

Position relative to equilibrium position = \_\_\_\_\_

[5]



(b) Describe how the maximum velocity of the mass could be determined from Fig. 5.1.

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[2]

(c) (i) Describe how the mass on the spring could be forced to resonate.

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[1]

(ii) How can you tell that the mass on the spring is resonating?

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[1]

[Turn over



- 6 (a) Gold foil was used in the historic alpha particle scattering experiment conducted by Geiger and Marsden. Gold has atomic number 79 and mass number 199. Calculate the radius of the nucleus of a gold atom. State your answer in metres.  
( $r_0 = 1.2 \text{ fm}$ )

Radius of gold atom = \_\_\_\_\_ m [2]

- (b) Fig. 6.1 shows an overhead view of part of the apparatus used in the alpha particle scattering experiment.

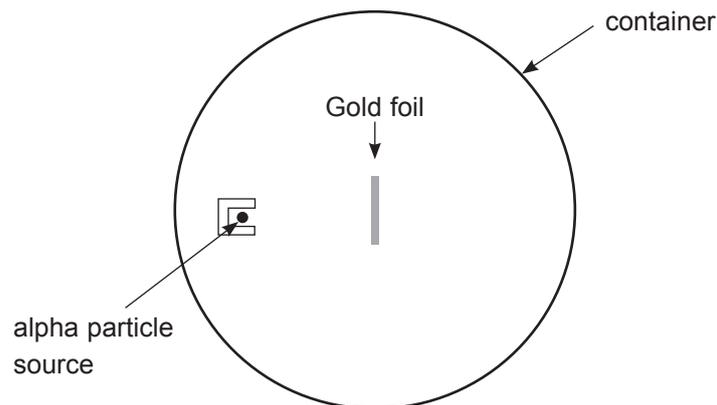


Fig. 6.1

- (i) Complete Fig. 6.1 by drawing and labelling any additional apparatus that was used when Geiger and Marsden carried out the experiment. [2]
- (ii) Indicate, with the letter **P**, the position in which most alpha particles were detected in the experiment. [1]



(iii) Explain why the diameter of the container can be larger than 5 cm even though the range of alpha particles in air is less than 5 cm.

[1]

(c) Fig. 6.2 shows the path of an alpha particle as it approaches a nucleus.

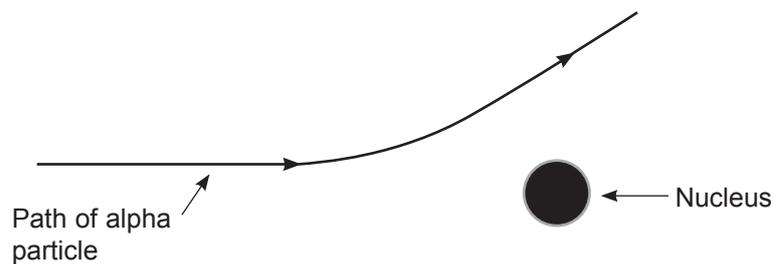


Fig. 6.2

The nucleus is replaced with one with a larger atomic number. On Fig. 6.2, sketch the new path taken by the alpha particle.

[2]

[Turn over

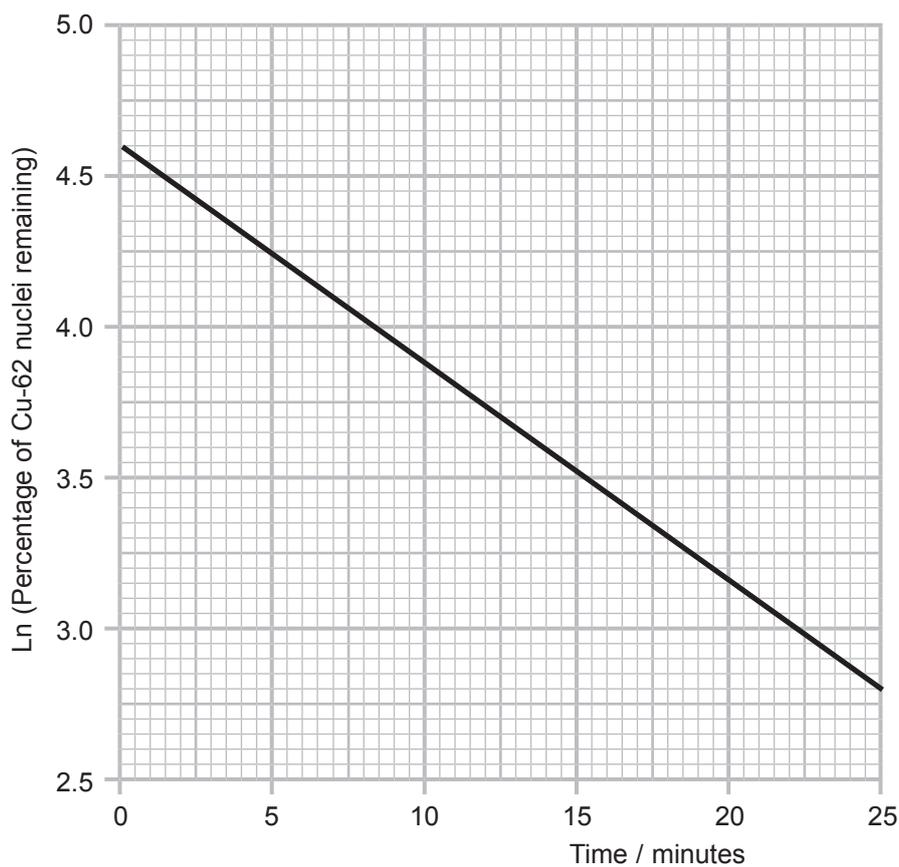


- 7 **Equation 7.1** shows the relationship between the number of radioactive nuclei  $N$  left after time  $t$ .  $\lambda$  is the decay constant and  $N_0$  is the initial number of radioactive nuclei.

$$N = N_0 e^{-\lambda t} \quad \text{Equation 7.1}$$

One isotope of copper, Cu-62, can be used for medical imaging.

**Fig. 7.1** shows a graph of the natural logarithm,  $\text{Ln}$ , of the percentage of radioactive Cu-62 nuclei remaining with time.



**Fig. 7.1**



(a) Use Fig. 7.1 to calculate the half-life of Cu-62.

Half-life = \_\_\_\_\_ minutes [3]

(b) After two hours the activity of the source has dropped to 0.46 Bq. Calculate the initial activity of the source.

Initial activity = \_\_\_\_\_ Bq [2]

[Turn over



8 Your answer to part (b) of this question should be in continuous prose. You will be assessed on the quality of your written communication.

- (a) The graph in Fig. 8.1 shows how the binding energy per nucleon varies with the number of nucleons in the nucleus. Complete Fig. 8.1 by adding appropriate numerical values to the axes of the graph. [2]

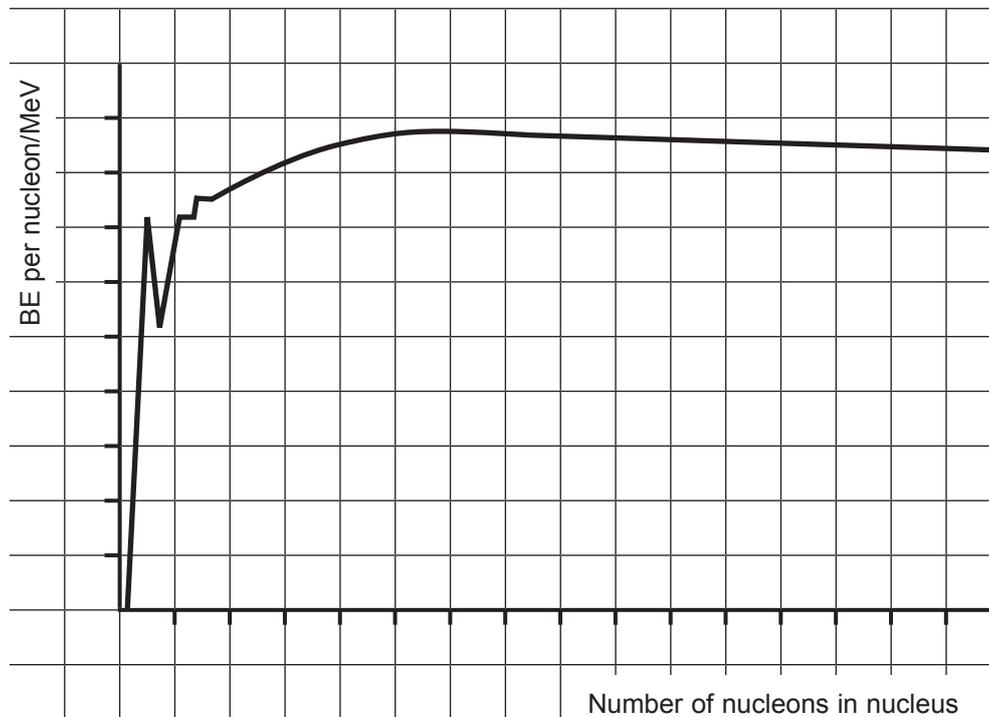


Fig. 8.1





- 9 (a) The functions of two components in a fission reactor are shown in **Table 9.1**. Complete **Table 9.1** with the name of each component and a suitable material from which it can be made.

**Table 9.1**

Component	Function	Material
	Slow down neutrons	
	Absorb neutrons	

[2]

- (b) (i) **Equation 9.1** shows an incomplete equation to describe a fission reaction. The number of neutrons that are released has been omitted.



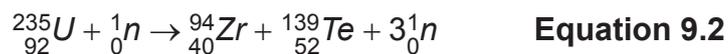
How many neutrons are released in the reaction?

Number of neutrons = \_\_\_\_\_

[1]



(ii) **Equation 9.2** is another example of a fission reaction.



The mass of each nucleus and a neutron are given in **Table 9.2**.

**Table 9.2**

Nucleus	Mass / u
U-235	235.0439
Zr-94	93.9063
Te-139	138.9347
n	1.0086

Calculate the number of U-235 nuclei that need to undergo fission by the reaction in **Equation 9.2** to produce 1 joule of energy.

Number of nuclei = \_\_\_\_\_

[4]

[Turn over



## 10 Data Analysis Question

This question contributes to the synoptic requirement of the specification. In your answer, you will be expected to bring together and apply principles and concepts from different areas of physics, and to use the skills of physics in the particular situation described.

When electrons in a metal are given enough energy they can escape from the surface of the metal. This energy can be supplied in different ways.

- (a) Name a piece of apparatus that uses heat energy to cause thermionic emission of electrons from the surface of a metal.

[1]

- (b) In the photoelectric effect the energy is supplied by photons. The relationship between the kinetic energy  $E$  of the emitted electrons and the frequency  $f$  of the incident radiation is given by **Equation 10.1**

$$E + W = hf \quad \text{Equation 10.1}$$

where  $h$  is the Planck constant and  $W$  is the work function of the metal.

- (i) Use **Equation 10.1** and the equation of a straight line graph to show that a graph of  $v^2$  against  $f$  will be a straight line that does not go through the origin, where  $v$  is the velocity of an emitted electron.

[2]





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**Table 10.1** shows the velocities of the emitted electrons at different frequencies.

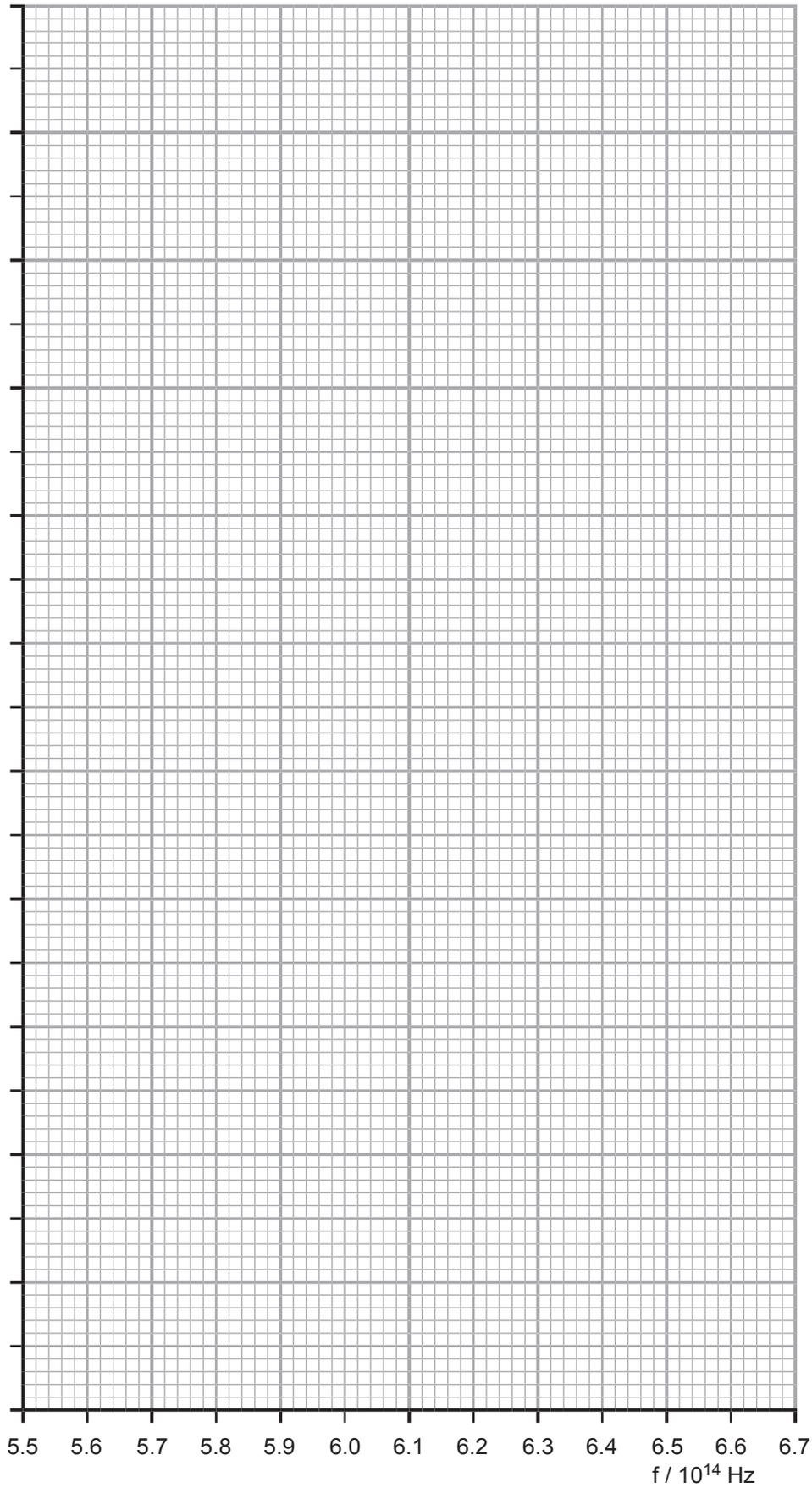
**Table 10.1**

$f / 10^{14} \text{ Hz}$	$v / 10^5 \text{ m s}^{-1}$	$v^2 / \text{_____}$
5.52	1.81	
5.86	2.87	
6.20	3.64	
6.42	4.12	
6.65	4.45	

- (ii) Use the blank column to record values of  $v^2$  to an appropriate number of significant figures. Complete the column heading appropriately. [3]
- (iii) On the axes of **Fig. 10.1** plot a graph of  $v^2$  against  $f$ . The x axis has been labelled and scaled for you. [4]
- (iv) Use your graph to calculate a value for the work function of the metal in eV.

Work function = \_\_\_\_\_ eV [5]





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Fig. 10.1



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For Examiner's use only		
Question Number	Marks	Remark
1		
2		
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## GCE Physics

## Data and Formulae Sheet for A2 1 and A2 2

## Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permittivity of a vacuum	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
	$\left( \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ F}^{-1} \text{ m} \right)$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
(unified) atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall on the Earth's surface	$g = 9.81 \text{ m s}^{-2}$
electron volt	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$

The following equations may be useful in answering some of the questions in the examination:

### Mechanics

Conservation of energy  $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$  for a constant force

Hooke's Law  $F = kx$  (spring constant  $k$ )

### Simple harmonic motion

Displacement  $x = A \cos \omega t$

### Sound

Sound intensity level/dB  $= 10 \lg_{10} \frac{I}{I_0}$

### Waves

Two-source interference  $\lambda = \frac{ay}{d}$

### Thermal physics

Average kinetic energy of a molecule  $\frac{1}{2}m\langle c^2 \rangle = \frac{3}{2}kT$

Kinetic theory  $pV = \frac{1}{3}Nm\langle c^2 \rangle$

Thermal energy  $Q = mc\Delta\theta$

### Capacitors

Capacitors in series  $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

Capacitors in parallel  $C = C_1 + C_2 + C_3$

Time constant  $\tau = RC$

**Light**

Lens formula  $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Magnification  $m = \frac{v}{u}$

**Electricity**

Terminal potential difference  $V = E - Ir$  (e.m.f.  $E$ ; Internal Resistance  $r$ )

Potential divider  $V_{\text{out}} = \frac{R_1 V_{\text{in}}}{R_1 + R_2}$

**Particles and photons**

Radioactive decay  $A = \lambda N$

$$A = A_0 e^{-\lambda t}$$

Half-life  $t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

de Broglie equation  $\lambda = \frac{h}{p}$

**The nucleus**

Nuclear radius  $r = r_0 A^{\frac{1}{3}}$

