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General Certificate of Education
2012

Centre Number

71	

Candidate Number

Physics

Assessment Unit A2 1

assessing

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

[AY211]

THURSDAY 17 MAY, MORNING

AY211

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.
Answer **all nine** questions.
Write your answers in the spaces provided in this question paper.

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.
Quality of written communication will be assessed in Question **8**.
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 **9** contributes to the synoptic assessment required of the specification.

For Examiner's use only	
Question Number	Marks
1	
2	
3	
4	
5	
6	
7	
8	
9	
Total Marks	

If you need the values of physical constants to answer any questions in this paper they may be found in the Data and Formulae Sheet.

Examiner Only

Marks | Remark

Answer **all nine** questions

1 The specific heat capacities of some substances at room temperature are shown in **Table 1.1**.

Table 1.1

Substance	**Specific heat capacity/J kg^{-1} K^{-1}**
aluminium	9.1×10^2
copper	3.9×10^2
alcohol	2.5×10^3
water	4.2×10^3
mercury	1.4×10^2
glycerine	2.5×10^3

(a) **(i)** From the table the specific heat capacity of water at room temperature is 4.2×10^3 J kg^{-1} K^{-1}.

Explain what is meant by this statement.

____

____

____

____ [1]

(ii) The specific heat capacity of water is large compared to most other substances. Using this fact explain why water is used as a coolant in a car radiator.

____

____

____

____ [1]

Examiner Only	
Marks	Remark

(b) The specific heat capacity of metals may be determined using an electrical method. **Fig. 1.1** shows the experimental apparatus which may be used to find the specific heat capacity of a copper block.

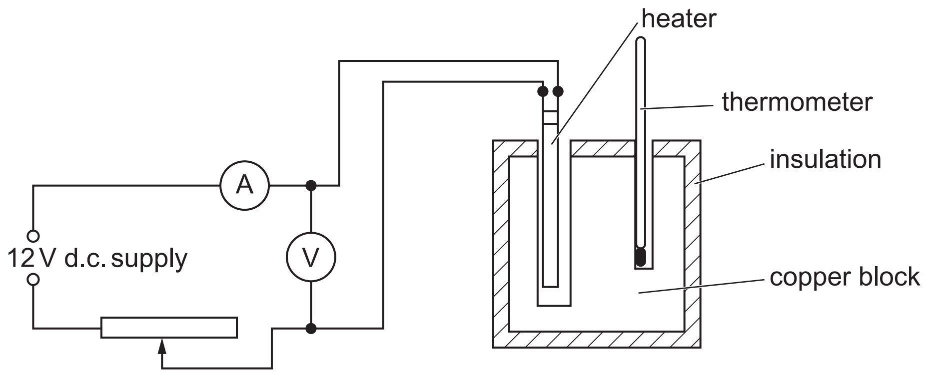

Fig. 1.1

(i) Complete **Table 1.2** by stating the **additional** instruments required and the measurements to be taken with these instruments to allow a value for the specific heat capacity of copper to be determined.

Table 1.2

Instrument used	Measurement to be taken

[2]

(ii) State how **all** the measurements may be used to obtain a value for the specific heat capacity of copper.

____

____

____

______________________________________ [3]

Examiner Only	
Marks	Remark

(c) **(i)** Using information from **Table 1.1**, calculate how much heat is required to raise the temperature of a piece of copper of mass 200 g from 25 °C to 50 °C.

Amount of heat ____________ J [2]

(ii) How long will it take to achieve this temperature rise using an electric heater of power 0.040 kW?

Time ____________ s [2]

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(Questions continue overleaf)

2 (a) (i) State the principle of conservation of momentum.

[2]

(ii) State the principle of conservation of energy.

[1]

(iii) By referring to these principles, compare and contrast elastic and inelastic collisions.

[3]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

(b) A rugby player of mass 110 kg moving at a velocity of 2.00 m s^{-1} collides with an opponent moving with twice the momentum in the opposite direction. After the collision the players move together with a common velocity and total kinetic energy of 115 J.

Calculate the magnitude of the common velocity and state the direction the players move after the collision (with respect to the direction the rugby player of mass 110 kg was originally moving).

Velocity of players after collision = ____________________ m s^{-1}

Direction of players after collision = ____________________ [4]

Examiner Only	
Marks	Remark

3 **(a)** Explain why an object can travel in a circle at a constant speed and yet still have an acceleration.

____

____

____ [2]

(b) **Fig. 3.1** shows a small stone of mass 0.3 kg attached to the end of a string 1.2 m long. The stone is made to revolve in a horizontal circle of radius 0.6 m at an angle θ to the horizontal.

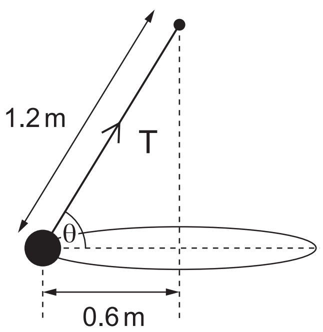

Fig. 3.1

(i) Calculate the tension T in the string.

Tension = ____________ N [2]

(ii) Calculate the period of rotation of the stone.

Period = ____________ s [3]

Examiner Only	
Marks	Remark

(c) The stone is now made to whirl in a vertical circle of radius 1.2 m and at a constant speed of $4.0\,m\,s^{-1}$.

Calculate the maximum and minimum tension in the string.

Maximum tension = ____________ N

Minimum tension = ____________ N [3]

4 **(a)** Define simple harmonic motion.

____

____

____ [1]

(b) **Fig. 4.1** shows a ball attached to the end of a spring which is suspended from a fixed point.

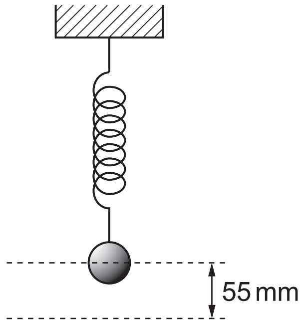

Fig. 4.1

When the spring is extended by a distance of 55 mm and then released it undergoes simple harmonic motion with a period of 0.98 seconds.

(i) Calculate the magnitude of the maximum acceleration of the ball.

Maximum acceleration = ____________ $m\,s^{-2}$ [2]

Examiner Only	
Marks	Remark

Examiner Only: Marks | Remark

(ii) Calculate the distance of the ball from the equilibrium position 0.2 seconds after it is released.

Distance = ____________ m [2]

(c) The ball on the spring eventually stops oscillating.

(i) Explain why the ball stops oscillating.

____

____

____ [1]

(ii) On the axes of **Fig. 4.2** sketch a graph to show the variation of the displacement of the ball with time.

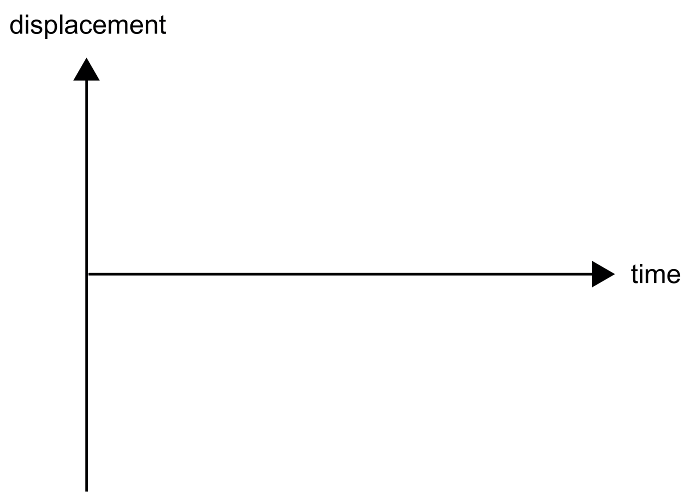

Fig. 4.2

[2]

Examiner Only	
Marks	Remark

5 The results of alpha scattering experiments enabled the structure of the atom to be explained. An arrangement for such an alpha scattering experiment is shown in **Fig. 5.1**.

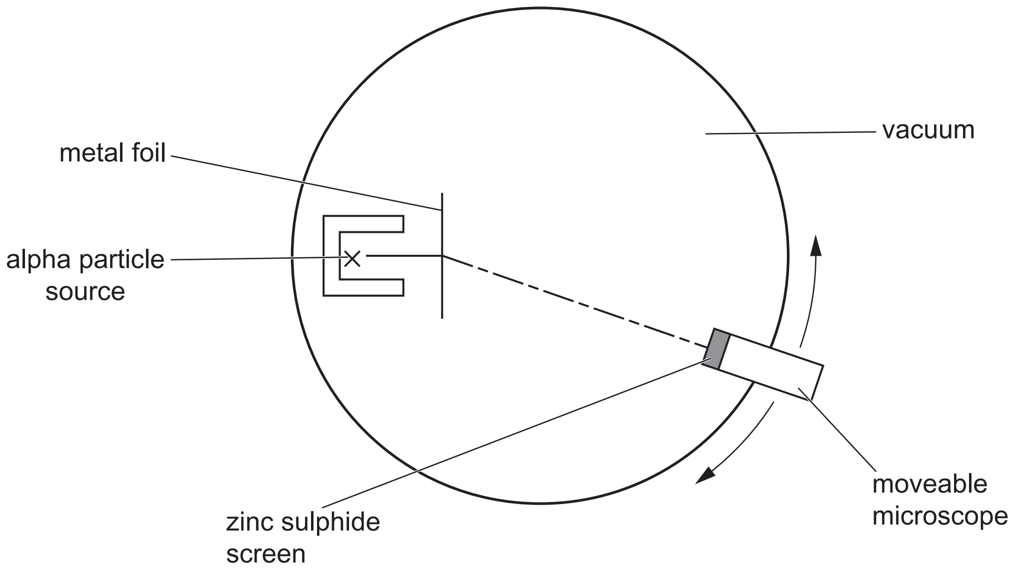

Fig. 5.1

(a) (i) Explain the function of the zinc sulphide screen.

____

____

____ [1]

(ii) Explain why the microscope is moveable.

____

____

____ [1]

(iii) Explain why it was important to perform the experiment in an evacuated chamber.

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____

____ [1]

Examiner Only	
Marks	Remark

(b) Complete **Table 5.1** by stating the experimental observations which led to the following conclusions.

Table 5.1

Experimental conclusions	**Experimental observations**
The atomic nucleus is very small	
The atomic nucleus is positively charged	

[2]

(c) The nucleus of an element is represented with the chemical symbol of the element and two numbers. **Fig. 5.2** shows how iron and neon are represented.

$^{56}_{26}Fe \qquad ^{20}_{10}Ne$

Fig. 5.2

Describe the composition of the nuclei of iron (Fe) and neon (Ne) represented in **Fig. 5.2**.

Iron ____

Neon ____ [1]

Examiner Only	
Marks	Remark

(d) **Equation 5.1** can be used to estimate the density of nuclear matter:

$$r = r_0 A^{\frac{1}{3}} \qquad \textbf{Equation 5.1}$$

(i) Use **Equation 5.1** to find the volume of a nucleus of an iron atom. Take $r_0 = 1.2\,\text{fm}$ and the volume of a sphere as $\frac{4}{3}\pi r^3$.

Volume = ____________ m^3 [2]

(ii) Calculate the nuclear density of iron.

Density of a nucleus of iron = ____________ $\text{kg}\,\text{m}^{-3}$ [2]

(iii) Explain how the nuclear density of neon compares with your answer in **(d)(ii)** for the nuclear density of iron.

____

____

____ [1]

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(Questions continue overleaf)

Examiner Only	
Marks	Remark

6 Radioactive elements disintegrate to form new elements emitting particles in the process.

(a) (i) Complete the following which is part of the uranium decay series.

$$^{238}_{92}\text{U} \xrightarrow[\alpha\text{-emission}]{} {}^{\square}_{\square}\text{Th} \xrightarrow[\beta\text{-emission}]{} {}^{\square}_{\square}\text{Pa}$$

[2]

(ii) Radioactive elements are often described by their activity and half-life. Define these terms.

Activity: ____

____ [1]

Half-life: ____

____ [1]

(b) A sample of a radioactive isotope contains 2.4×10^{24} radioactive atoms and has a decay constant of $2.31 \times 10^{-2}\,\text{s}^{-1}$.

(i) Calculate the activity of the sample.

Activity = ____________ s^{-1} [1]

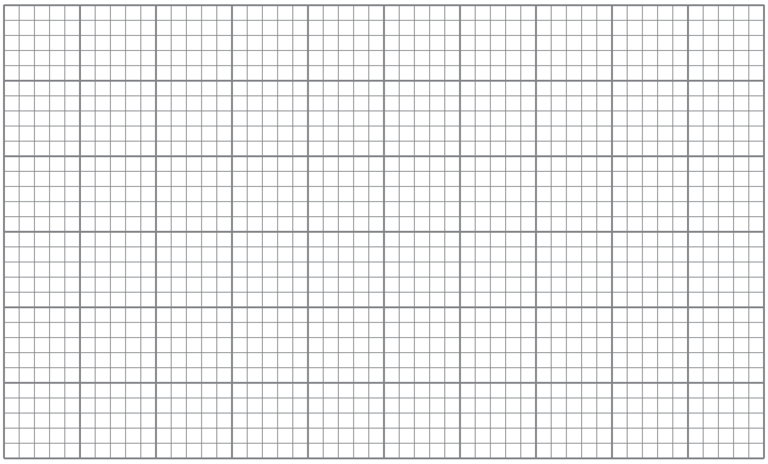
(ii) Calculate the half-life of the sample.

Half-life = ____________ s [1]

Examiner Only
Marks | Remark

(iii) On **Fig. 6.1** draw a graph to show how the number of radioactive atoms decreases with time. Include at least 3 half-lives on your graph.

Number of radioactive atoms



Time/s

Fig. 6.1

[2]

(iv) Calculate the number of radioactive atoms remaining after 30 minutes.

Number of radioactive atoms remaining = ____________________ [2]

Examiner Only	
Marks	Remark

7 **(a)** Explain what is meant by the mass defect of an atomic nucleus.

____

____ [1]

(b) **(i)** Calculate the mass defect of a helium-4 nucleus in kg, using the following information:

mass of helium nucleus = 4.0015 u
mass of proton = 1.0073 u
mass of neutron = 1.0087 u

Mass defect = ____________ kg [2]

(ii) Calculate the binding energy per nucleon of the helium-4 nucleus in MeV.

Binding energy/nucleon = ____________ MeV [3]

Examiner Only	
Marks	Remark

(iii) On **Fig. 7.1** sketch the shape of the graph of binding energy per nucleon against mass number and indicate the approximate position of iron-56 on the graph. Explain the relationship between the position of the nucleus on the curve and the stability of the nucleus.

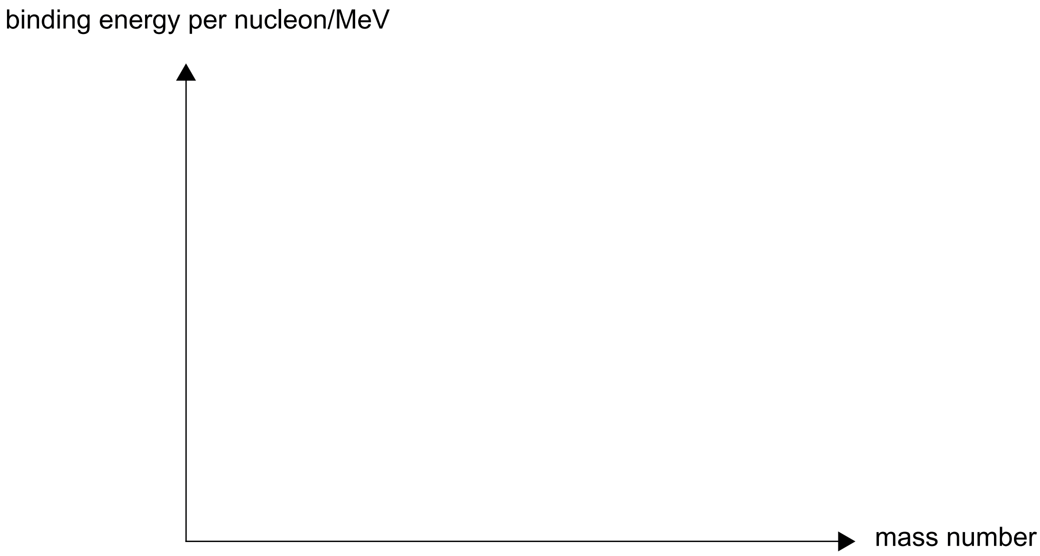


Fig. 7.1

Explanation:

____

____

____ [2]

Examiner Only	
Marks	Remark

In this question you will be assessed on the quality of your written communication. You are advised to answer in continuous prose.

8 **(a)** Explain what is meant by nuclear fusion.

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____ [1]

(b) Explain why plasma confinement and high particle kinetic energy are required for nuclear fusion to take place.

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____ [2]

(c) Briefly describe three methods of plasma confinement in nuclear fusion.

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____ [4]

Quality of written communication [2]

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(Questions continue overleaf)

Examiner Only	
Marks	Remark

9 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.

Standing waves in air pipes

When a vibrating tuning fork is held over the end of a pipe closed at one end, the air in the pipe vibrates. If the frequency of the tuning fork matches the fundamental frequency of the pipe, the air inside resonates with large amplitude and a loud note of the same frequency as the fork is heard. A standing wave is set up with an antinode at the open end of the pipe and a node at the closed end. The speed of sound is to be measured using a resonance tube with a vibrating tuning fork held over the end of a cylindrical tube which is placed inside a container of water. This arrangement, shown in **Fig. 9.1**, allows the length of the air column to be varied.

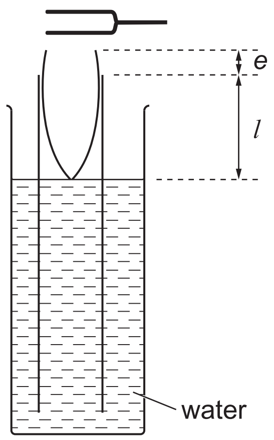

Fig. 9.1

It is found that the air vibrations at the open end of the resonance tube extend a short distance *e* into the air outside the tube. This is called the end-correction. The antinode of the standing wave set up by the tuning fork is a distance *e* above the top of the tube.

A vibrating tuning fork is held over the end of the resonance tube and the tube is raised from its lowest position until a very loud note is obtained. This is the fundamental resonance position. *e* is the end-correction and *l* is the length from the water level to the top of the tube.

The length *l* is measured and recorded along with the frequency of the tuning fork causing the vibrations. This process is repeated for several tuning forks of different frequencies.

Examiner Only	
Marks	Remark

As a quarter of a wave is formed at the fundamental resonance position the following equation is correct:

$$l + e = \frac{\lambda}{4} \qquad \textbf{Equation 9.1}$$

The wave equation is:

$$v = f\lambda \qquad \textbf{Equation 9.2}$$

The speed of sound v and the end correction e, which can both be taken as constants, are to be found using a linear graph of $\frac{1}{f}$ (f = frequency) plotted on the y-axis against l on the x-axis.

(a) Use **Equation 9.1** and **Equation 9.2** to form an expression which will show the relationship between the frequency f of the tuning fork and the length l of the air column and which can be used to plot this linear graph. Use your expression to complete **Equation 9.3** which is in the form of the straight line equation y = mx + c.

$$\frac{1}{f} = \square\, l + \square \qquad \textbf{Equation 9.3}$$

[3]

Examiner Only	
Marks	Remark

Table 9.1 gives data for the length of the air column, l, and the frequency of the tuning fork, f, obtained for this experiment.

Table 9.1

f/Hz	l/mm	$\frac{1}{f}$ / ____
256	314	
288	278	
320	249	
341	233	
384	205	
456	171	
512	151	

(b) Use the blank column in **Table 9.1** to calculate $\frac{1}{f}$ *to* the correct number of significant figures. Include the unit. [3]

(c) **(i)** On the grid of **Fig. 9.2** draw the linear graph of $\frac{1}{f}$ against l. [3]

(ii) Using the gradient and intercept of your graph, find values for the speed of sound v and the end-correction e.

v = ____________ $m\,s^{-1}$ [2]

e = ____________ mm [2]

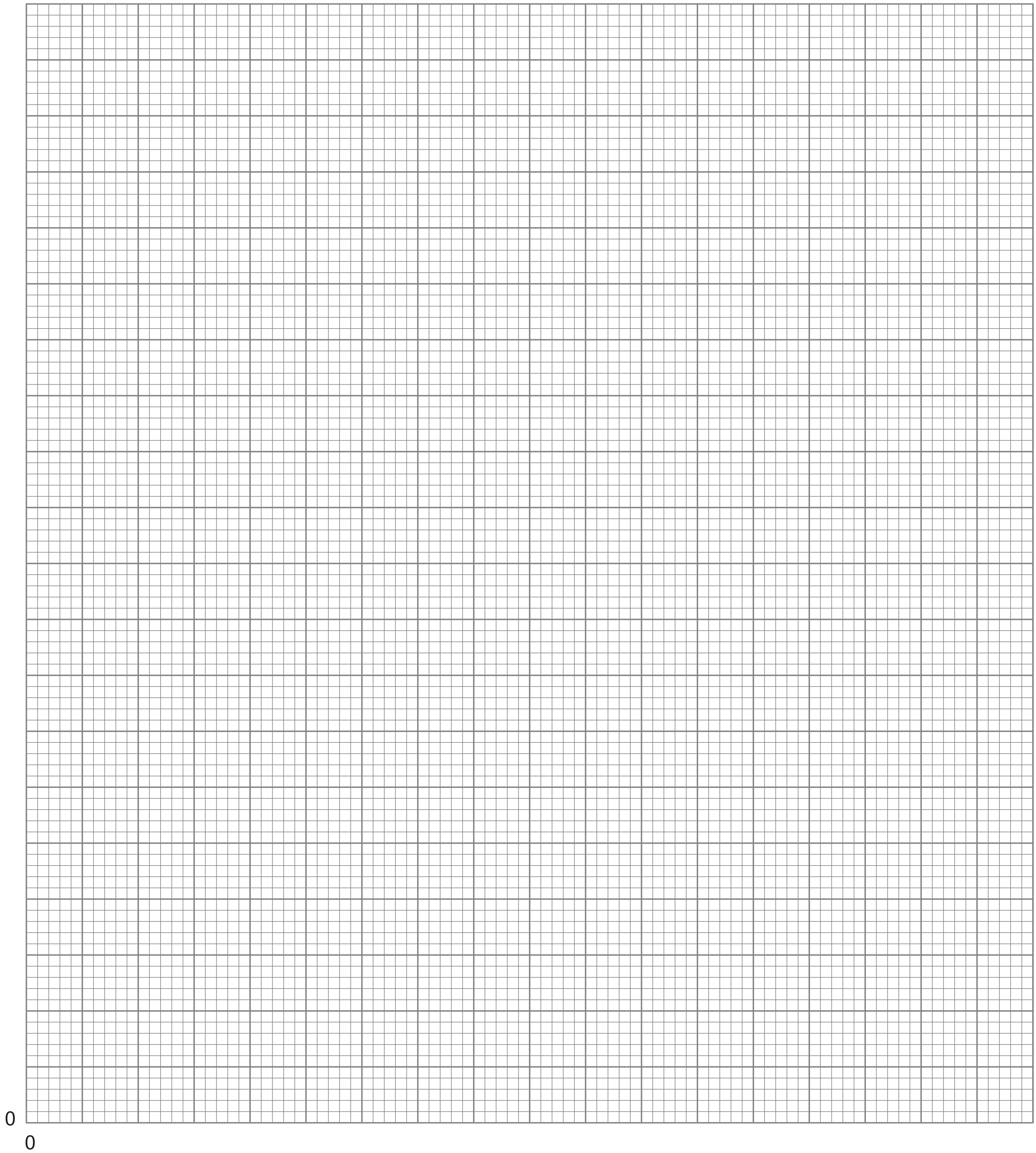

Fig. 9.2

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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	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$
	$\left(\dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{F}^{-1}\ \text{m}\right)$
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	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$

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

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