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General Certificate of Education
2015

Centre Number

Candidate Number

Physics

Assessment Unit A2 1
assessing
Momentum, Thermal Physics,
Circular Motion, Oscillations
and Atomic and Nuclear Physics

AY211

[AY211]

TUESDAY 19 MAY, MORNING

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 seven** 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 **3(a)**.
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 **7** contributes to the synoptic assessment required of the specification.

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

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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 seven** questions

1 A child of mass 45 kg stands on the edge of a playground roundabout of radius 2.5 m. A force is applied to keep the roundabout rotating at a constant speed.

(a) A stopclock is used to find the time taken for the roundabout to complete 5 revolutions and the results are recorded in **Table 1.1**.

Table 1.1

Time taken for 5 revolutions/s	28.6	30.1	29.4

(i) Use the results to calculate an accurate value for the angular velocity of the roundabout.

Angular velocity = ____________________ rad s^{-1} [3]

(ii) Calculate the linear velocity of the child.

Linear velocity = ____________________ m s^{-1} [2]

(b) When the child is directly opposite point A, as shown in **Fig. 1.1**, he throws a ball of mass 1.1 kg straight towards A at a horizontal speed of 6.2 m s^{-1}.

Examiner Only	
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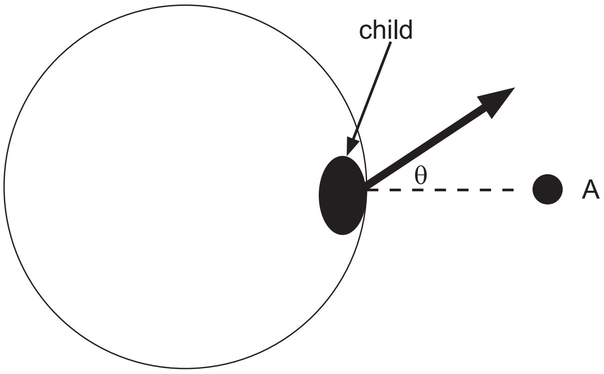

Fig. 1.1

Explain why the ball will not move straight towards point A but will travel at an angle θ as shown on **Fig. 1.1**.

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____ [2]

Examiner Only

Marks	Remark

(c) **(i)** State the principle of conservation of momentum.

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____ [2]

(ii) The ball, thrown in **(b)**, is caught by another child of mass 25 kg who is stationary on a swing.

Use the principle of conservation of momentum to calculate the magnitude of the initial velocity that this child will move at as a result of catching the ball. Ignore any change in the speed of the ball caused by it falling vertically under gravity.

Velocity = ____________ $m\,s^{-1}$ [4]

2 **(a)** State the ideal gas equation, identify the terms and use it to explain why putting an aerosol container onto a fire could cause it to explode.

Examiner Only	
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____ [5]

(b) A cylindrical can containing a gas at standard temperature and pressure has diameter of 5.0 cm and height 15.0 cm, as shown in **Fig. 2.1**.

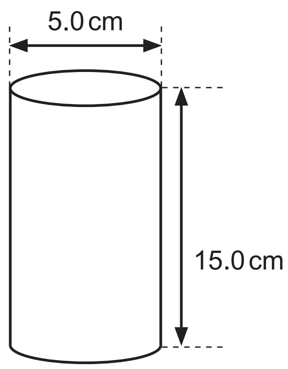

Fig. 2.1

(i) One mole of an ideal gas occupies a volume of 22.4×10^{-3} m^3 at standard temperature and pressure. Calculate the number of moles of the gas inside the can, assuming the gas is ideal.

Number of moles = ____________________ [3]

Examiner Only	
Marks	Remark

(ii) If the can will withstand a maximum pressure of 396 kPa, calculate the temperature of the gas, in °C, at which the can will explode.

Temperature = ___________________ °C [3]

(iii) Calculate the total kinetic energy of the gas molecules in the can at this temperature.

Total kinetic energy = ___________________ J [3]

Where appropriate in this question you should answer in continuous prose. You will be assessed on the quality of your written communication.

Examiner Only	
Marks	Remark

3 A mass–spring system consists of a mass oscillating in a vertical plane on the end of a spring as shown in **Fig. 3.1**. Such a system is often used to demonstrate simple harmonic motion.

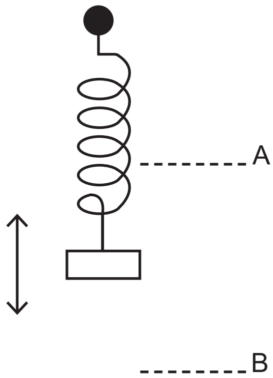

Fig. 3.1

(a) Identify the forces acting on the mass and describe how the magnitude and direction of the resultant of these forces changes as it moves from position A through the equilibrium position to B. At points A and B the mass is at maximum displacement from its equilibrium position.

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____ [3]

Quality of written communication [2]

Examiner Only	
Marks	Remark

(b) In a system undergoing simple harmonic motion, at a time t = 0.6 s, the acceleration, a is –0.74 m s^{-2} and the displacement, x is 0.3 m. Calculate the period and the amplitude of the motion and use your values to draw an accurate graph for the motion of the object on the grid of **Fig. 3.2**. At time t = 0, the system is at maximum displacement. On your graph show at least 2 complete cycles of the motion.

Period = ________________ s

Amplitude = ________________ m

Fig. 3.2

[7]

(c) State one similarity and one difference between a system that is critically damped and one that is overdamped.

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____ [2]

Examiner Only	
Marks	Remark

4 (a) An early use of alpha particles when they were first discovered was in the alpha scattering experiment to prove the existence of a concentration of mass in a small core, later called a nucleus. What happened to the alpha particles in this experiment that led to the conclusion that the nucleus was small and positively charged?

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____ [2]

(b) A more recent use of alpha particles is in cancer treatments. One example is the alpha decay of radium-223 which can be used to kill cancer cells on bone surfaces. Radium-223 has a half-life of 11.4 days.

A sample of radium with an activity of 93 kBq per kg of body mass is required for a particular patient. The patient has a mass of 76 kg and is due for treatment at 9 a.m. Calculate the initial activity required if the sample is prepared at 3 p.m. the previous day.

Initial activity = ____________________ Bq [4]

(c) It is important that the half-life of the isotope is found accurately so that the previous calculation does not result in an incorrect dose being received by the patient.

One method used to determine the half-life of a radioactive isotope is to measure the activity over a period of time and plot a graph of activity against time. The time taken for the activity to halve can be read directly from the graph for more than one value and the results averaged.

(i) **Fig. 4.1** shows an activity against time graph for a sample of radium-223. Scale the time axis of **Fig. 4.1**. [1]

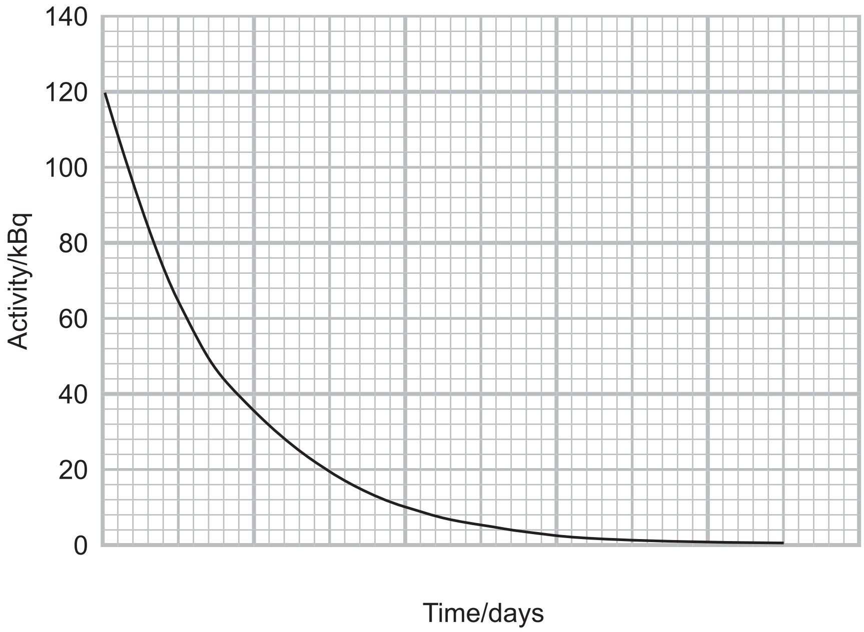

Fig. 4.1

(ii) Describe an alternative graphical method that could be used to find a value for the half-life, given a series of readings of activity and time.

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____ [3]

5 **(a)** Explain what is meant by nuclear fission.

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____ [2]

(b) **Equation 5.1** shows one example of a fission reaction.

$$n + {}^{235}_{92}U \rightarrow X \rightarrow {}^{137}_{55}Cs + {}^{95}_{37}Rb + 4n \qquad \textbf{Equation 5.1}$$

(i) The nucleus X represents an intermediate step in the reaction. State the number of neutrons and number of protons in the nucleus X.

Number of neutrons = ____________________

Number of protons = ____________________ [2]

(ii) The rest mass of each of the particles in **Equation 5.1** is shown in **Table 5.1**.

Table 5.1

Particle	Rest mass/u
U-235	235.0439
Cs-137	136.9070
Rb-95	94.9290
n	1.0087

Calculate the energy released in this fission reaction in eV.

Energy released = ____________________ eV [5]

Examiner Only	
Marks	Remark

(iii) How many of these reactions must take place per second to provide a typical power of 478 MW?

Number of reactions = ____________________ [2]

(c) (i) In many fission reactors, heavy water is used instead of water as the coolant. The specific heat capacity of water is 4.182 kJ kg^{-1} K^{-1} while heavy water has a specific heat capacity of 4.228 kJ kg^{-1} K^{-1}.

Explain why it is an advantage to use heavy water rather than water as the coolant.

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____ [1]

(ii) Calculate the change in temperature of 1 kg of heavy water that would result from **one** of the nuclear fission reactions in **Equation 5.1**.

Change in temperature = ____________________ K [2]

Examiner Only

Marks	Remark

6 **(a)** **(i)** State two **potential** benefits of using nuclear fusion to generate electricity rather than nuclear fission.

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____ [2]

(ii) Explain why these benefits are described as 'potential'. Other than plasma confinement, state one difficulty that needs to be overcome to change this.

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____ [2]

(b) **(i)** The JET reactor uses magnetic confinement to contain the plasma formed as part of the fusion process. What property do the particles of the plasma have that allows them to be controlled by a magnetic field?

____ [1]

(ii) State the shape of the vessel in which the plasma is contained in the JET reactor.

____ [1]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

(c) (i) Another method of confinement is gravitational confinement. Why is it not considered a possibility for use in a fusion reactor on Earth?

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____ [1]

(ii) Research is underway into a third method of confinement for possible use in a fusion reactor. State the name of this method of confinement and explain how it works.

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____ [3]

7 An object was heated to a temperature of 90 °C and left to cool in an area with a controlled, constant temperature of 0 °C. The temperature, θ, of the object was recorded over a time period of 150 seconds and the results plotted on the grid of **Fig. 7.1**.

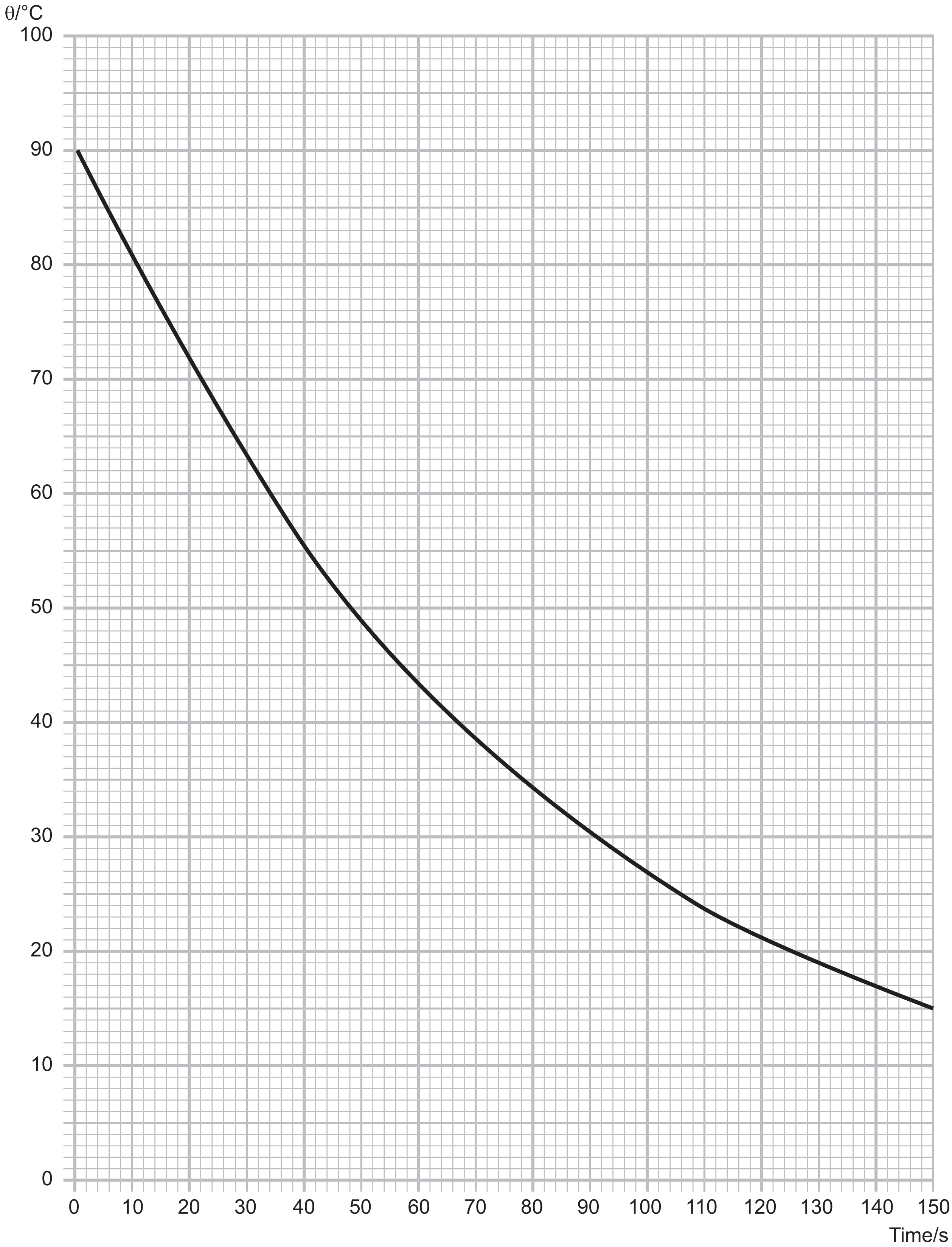

Fig. 7.1

Examiner Only

Marks	Remark

(a) The magnitude of the **rate of change of** temperature, ϕ, of the object at a range of temperatures, θ, is shown in **Table 7.1**.

Table 7.1

θ/°C	ϕ/°C s^{-1}
70	0.83
60	0.74
50	0.61
40	
30	0.37
20	0.26

(i) Use the graph of **Fig. 7.1** to calculate the missing value for ϕ at a temperature of 40 °C and record it in **Table 7.1**.

Show your working out in the space below.

[3]

(ii) Newton's law of cooling states that the rate of change of temperature, ϕ, of an object is proportional to the temperature difference between the object and the external environment.

Write down an equation that describes Newton's law of cooling defining each term that you use.

[2]

(iii) Use the grid of **Fig. 7.2** to plot a suitable graph from the results in **Table 7.1** that can confirm whether or not the object obeys Newton's law of cooling. [5]

(iv) Does the graph confirm that the object obeys Newton's law of cooling? Explain your conclusion.

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____ [1]

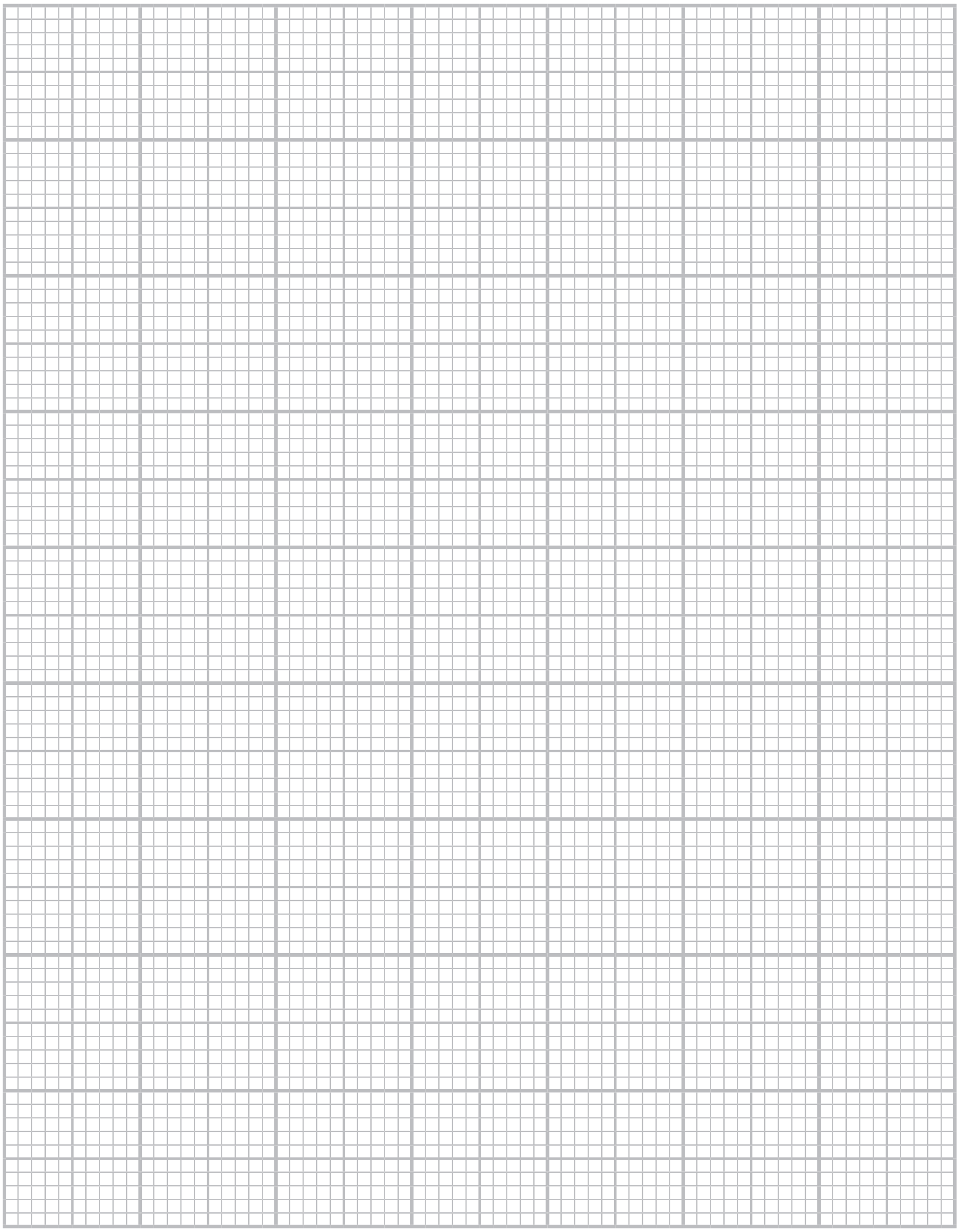

Fig. 7.2

Examiner Only	
Marks	Remark

(b) **Equation 7.1** describes the graph shown in **Fig. 7.1**. On the axis of **Fig. 7.3** sketch a graph of ln θ against time, t. Include values for intercepts on the x and y axes.

$$\theta = 90e^{-0.012t}$$ **Equation 7.1**

Fig. 7.3

[4]

Examiner Only	
Marks	Remark

THIS IS THE END OF THE QUESTION PAPER

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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	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permittivity of a vacuum	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$\left(\dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{F^{-1}\,m}\right)$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
(unified) atomic mass unit	$1\ \mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$
acceleration of free fall on the Earth's surface	$g = 9.81\,\mathrm{m\,s^{-2}}$
electron volt	$1\,\mathrm{eV} = 1.60 \times 10^{-19}\,\mathrm{J}$

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	$x = \mathrm{A} \cos \omega t$

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