Rewarding Learning

ADVANCED
General Certificate of Education
2025

Centre Number

Candidate Number

Physics

Assessment Unit A2 1

assessing
Deformation of Solids, Thermal Physics, Circular Motion, Oscillations and Atomic and Nuclear Physics

APH11

[APH11]
MONDAY 19 MAY, MORNING

TIME

2 hours.

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 and use a dark HB pencil for drawings and graphs.
Do not write with a gel pen.
Answer **all seven** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 100.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.
Quality of written communication will be assessed in Question **4**.
Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.
You may use a scientific calculator.

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1 Energy from the Sun originates from nuclear fusion between nuclei inside the core.

(a) (i) **Equation 1.1** shows a typical nuclear fusion reaction that occurs in the Sun's core. Complete the equation by inserting the correct number in the box.

$${}^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} = {}^{4}_{2}\mathrm{He} + \boxed{}\ {}^{1}_{1}\mathrm{H} + \text{Energy}$$ **Equation 1.1** [1]

The core of the Sun is a hot plasma.

(ii) Define the term plasma.

____

____ [1]

(b) The minimum energy each ${}^{3}_{2}\mathrm{He}$ nucleus requires before fusion can occur is 0.832 MeV.

(i) Why is heat energy required to initiate the fusion of ${}^{3}_{2}\mathrm{He}$ nuclei?

____

____ [1]

(ii) Calculate the temperature required to give a ${}^{3}_{2}\mathrm{He}$ nucleus 0.832 MeV of energy.

Temperature = ____________________ K [4]

[Turn over

(c) Nuclear binding energy is the minimum energy that is required to break up the nucleus.
A graph of the binding energy per nucleon against nucleon number is shown in **Fig. 1.1**.

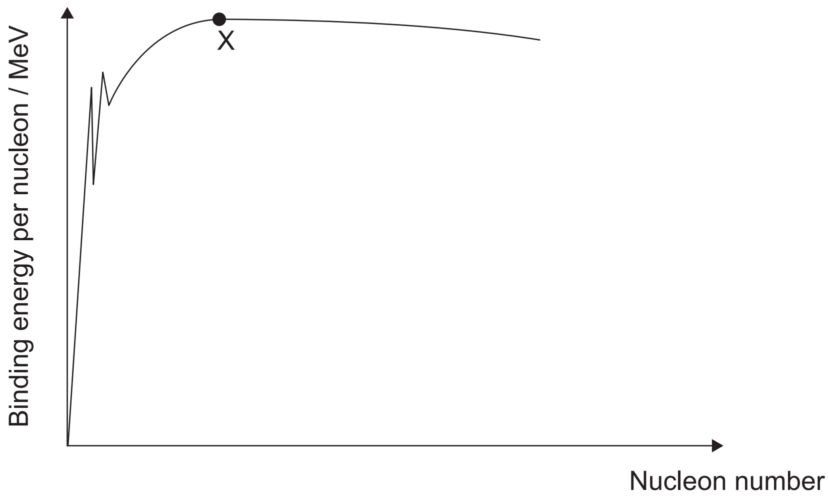

Fig. 1.1

(i) State the x-axis and y-axis values for the point on the graph marked X.

x-axis ___________________

y-axis ___________________ MeV [2]

(ii) Describe how energy is released during the process of nuclear fusion. Make reference to the binding energy per nucleon graph in your answer.

____

____

____

____ [3]

(d) When nuclei undergo fusion there is a mass defect.

(i) Explain what is meant by the term mass defect.

____

____ [1]

(ii) The mass of a proton is 1.00728 u, and the mass of a neutron is 1.00866 u. Given that the mass of a $^{3}_{2}\mathrm{He}$ nucleus is 3.01603 u, calculate the mass defect of a $^{3}_{2}\mathrm{He}$ nucleus. Give your answer to three significant figures.

Mass defect = ____________________ kg [5]

(iii) Calculate the average binding energy per nucleon for a $^{3}_{2}\mathrm{He}$ nucleus.

Energy = ____________________ J [3]

[Turn over

2 A student investigates the oscillations of a pendulum bob attached to a light, inextensible string.

(a) The pendulum bob is pulled to one side by an angle of 10° as shown in **Fig. 2.1**. When released, the pendulum bob oscillates with simple harmonic motion.

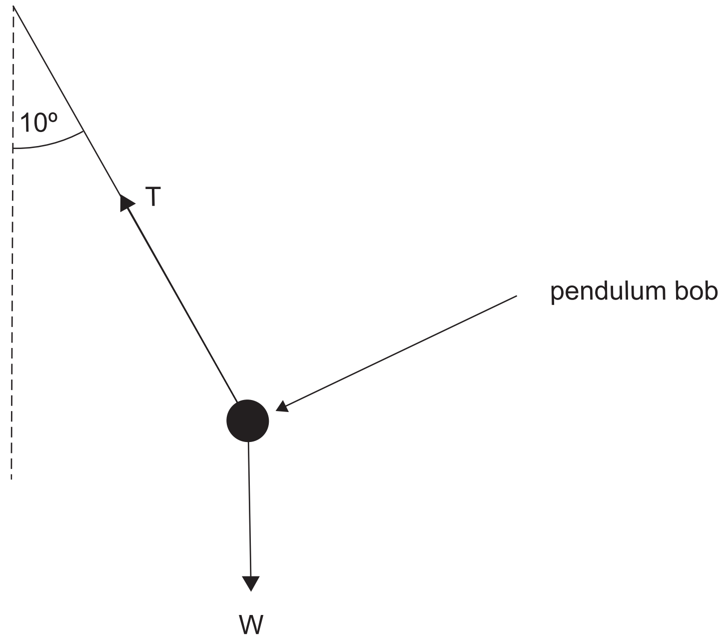

Fig. 2.1

The motion of the pendulum bob is caused by a component of its weight.

(i) On **Fig. 2.1**, draw and label the components of the weight of the pendulum bob perpendicular and parallel to the direction of motion of the pendulum bob. [2]

The tension T in the string varies as the pendulum bob oscillates.

(ii) The mass of the pendulum bob is 0.15 kg. Calculate the minimum value of the tension in the string. State where in the motion this occurs.

Minimum tension = ____________ N

Occurs: ___________________________________ [2]

(iii) The time taken for the pendulum bob to complete 20 oscillations was 14.80 s. Show that the length of the pendulum is approximately 0.14 m.

[3]

(b) The same pendulum of length 0.14 m and pendulum bob mass of 0.15 kg is now made to perform circular motion at a constant speed as shown in **Fig. 2.2**.

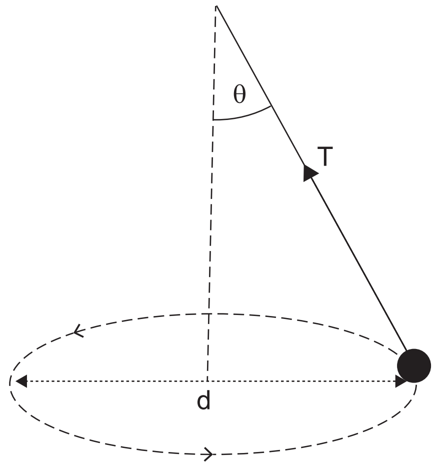

Fig. 2.2

(i) Calculate the diameter d of the circle when the angle θ is 22°.

Diameter = ______________ m [3]

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(ii) The tension in the string in **Fig. 2.2** is 1.59 N. Calculate the linear speed of the pendulum bob.

Linear speed = ____________ m s^{-1} [3]

(iii) How long will it take the pendulum bob to complete 15 revolutions?

Time = ____________ s [4]

3 A passenger on a plane noticed that their sealed crisp packet had a different volume at a high altitude compared to the volume of the packet before take-off. As well as crisps, the packet contains nitrogen gas. At high altitude, the cabin pressure is lower than atmospheric pressure.

(a) (i) Describe and explain the change in volume of the crisp packet when the plane flies at a high altitude.

___

___

___ [3]

(ii) The cabin pressure before take-off was atmospheric pressure, 101 kPa. At an altitude of 9.55 km, the cabin pressure is 25.0 kPa lower than atmospheric pressure.

Before take-off, the volume of the crisp packet was 363 cm^3. The crisps occupy 68% of the volume.

Calculate the volume of the crisp packet at the altitude of 9.55 km.

Assume the temperature of the cabin remains unchanged.

Volume = ____________ cm^3 [6]

(b) The passenger purchased a cup of tea in a Styrofoam cup. The volume of the tea in the cup was 470 cm^3. The passenger added two milk pots to the tea each of volume 12 cm^3. The milk pots were stored at a cabin temperature of 20°C. The temperature of the tea with the added milk was 62°C.

Table 3.1 shows the density and specific heat capacity of the tea and milk.

Table 3.1

	Tea	**Milk**
Density / $g\,cm^{-3}$	1.000	1.035
Specific heat capacity / $J\,g^{-1}\,°C^{-1}$	4.19	3.89

Determine the initial temperature of the tea. Assume the heat transferred to the Styrofoam cup and other heat losses are negligible.

Initial temperature of tea = ________________ °C [6]

[Turn over

4 **Quality of written communication will be assessed in this question.**

ITER, the International Thermonuclear Experimental Reactor, is an international research project whose long-term goal is to explore the possibility of the production of electricity from nuclear fusion commercially.

Write an account of the main elements of ITER. Include a description of the following:

- the method of plasma confinement;
- the three methods used to heat the plasma;
- the requirement of nuclear shielding and how this is achieved; and
- the method by which heat is extracted from the reactor.

[8]

5 (a) The Young modulus of copper is 130 GPa.

(i) Define the Young modulus.

____

____

____ [2]

(ii) Draw a labelled diagram of the arrangement of apparatus that can be used to measure the extension of a length of copper wire for a range of stretching forces.

[4]

(b) **Fig. 5.1** shows a graph of the force applied to a 3.00 m length of copper wire against the extension of the wire up to the limit of proportionality.

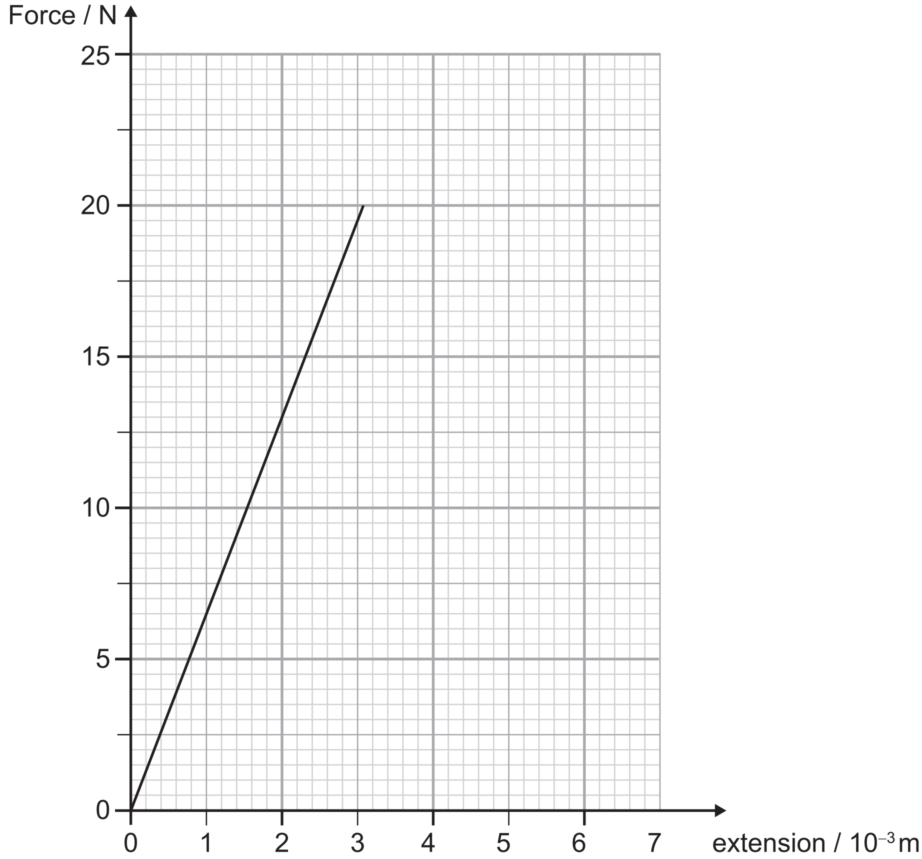

Fig. 5.1

(i) Complete the graph in **Fig. 5.1** to show what happens to the wire when forces larger than 20.0 N are used to extend the wire. [1]

(ii) Draw an X on the graph to represent the elastic limit. [1]

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(iii) Calculate the diameter of the 3.00 m length of copper wire.

Diameter = ____________________ m [7]

6 Shock absorbers are essential components of a car's suspension system. They dampen the vibrations experienced by the driver when a car travels over bumps in the road. Critical damping offers a more comfortable car ride than over-damping. When shock absorbers become worn, their ability to dampen vibrations diminishes and the suspension system provides lighter damping.

(a) **(i)** Outline the characteristics of lightly damped oscillations.

____

____ [2]

(ii) Outline one similarity and one difference between critical damping and over-damping.

____

____

____ [2]

(b) The natural frequency f_o of an oscillating body is 15 Hz.

(i) What is meant by the term natural frequency?

____

____ [1]

(ii) How is resonance achieved in an oscillating system?

____ [1]

(iii) On **Fig. 6.1**, sketch a graph to show how the amplitude of forced oscillations changes with frequency, at frequencies close to f_o. Label this sketch R. [1]

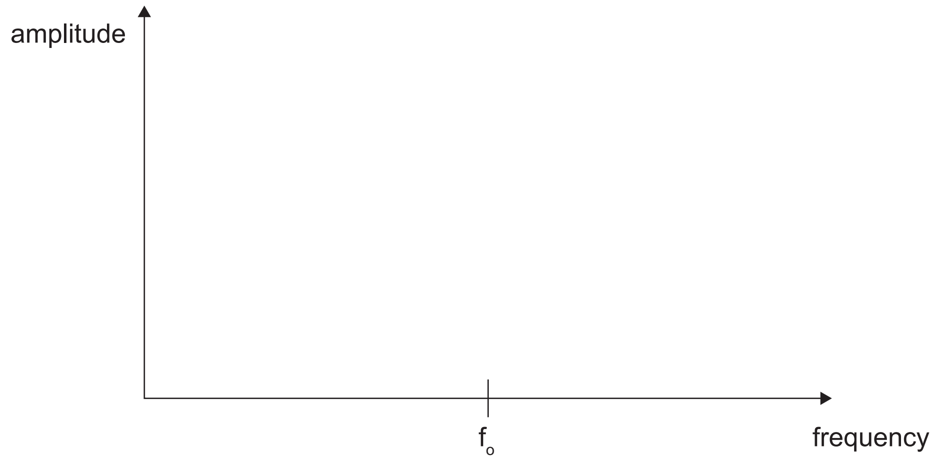

Fig. 6.1

(iv) Add a second sketch to **Fig. 6.1** to demonstrate the effects of damping on the amplitude of forced oscillations. Label this sketch D. [3]

7 (a) The decay constant of americium-241 is $1.60 \times 10^{-3}\,yr^{-1}$.

(i) What is meant by the term decay constant?

____

____ [1]

(ii) Calculate the half-life of americium-241.

Half-life = ____________________ yr [2]

The activity of the americium-241 was measured in the laboratory. The technician recorded the background counts as 149 counts in 500 s. The source was then placed in front of the detector and three different count readings recorded. These are shown in **Table 7.1**.

Table 7.1

Time counts were recorded / seconds	**Number of counts**
60	748
60	751
60	750

(iii) Calculate a reliable value for the activity of the americium-241.

Activity = ____________________ Bq [4]

(iv) If the activity of the americium-241 was measured 25 years earlier, by how much would the activity of the source have changed?

Change in activity = ____________________ Bq [3]

(b) Americium-241 is an alpha source often used in smoke detectors. The alpha particles travel between two electrodes inside the detector and when smoke enters the detector, it disrupts the flow of alpha particles causing an alarm to sound.

State the properties of the alpha radiation emitted by americium-241 and explain how these properties makes americium-241 suitable for use in a smoke detector.

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____ [4]

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For Examiner's use only	
Question Number	**Marks**
1	
2	
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Total Marks	

Examiner Number

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Physics

Assessment Units AS 1 and AS 2

[SPH11/SPH21]

DATA AND FORMULAE SHEET

Data and Formulae Sheet for AS 1 and AS 2

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}$ m s^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
acceleration of free fall on the Earth's surface	$g = 9.81$ m s^{-2}
electron volt	1 eV $= 1.60 \times 10^{-19}$ J
the Hubble constant	$H_0 \approx 2.4 \times 10^{-18}$ s^{-1}

Useful formulae

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

Waves

two-source interference	$\lambda = \frac{ay}{d}$
diffraction grating	$d \sin\theta = n\lambda$

Light

lens equation $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

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

Einstein's equation $\frac{1}{2} m v_{max}^2 = hf - hf_0$

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

Astronomy

red shift $z = \frac{\Delta\lambda}{\lambda}$

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

Hubble's law $v = H_0 d$