Rewarding Learning

ADVANCED
General Certificate of Education
2023

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]
THURSDAY 25 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 only. **Do not write with a gel pen.**
Answer **all nine** 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 **7(a)(iii)**.
Your attention is drawn to the Data and Formulae sheet which is inside this question paper.
You may use an electronic calculator.

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1 The nucleus of an atom is considered to be a sphere of volume $V = \frac{4}{3}\pi r^3$ where its radius r is given by **Equation 1.1**.

$$r = r_o A^{\frac{1}{3}} \qquad \textbf{Equation 1.1}$$

where $r_o = 1.2 \times 10^{-15}$ m

(a) Complete **Table 1.1** by identifying the symbols.

Table 1.1

Symbol	Quantity
r_o	
A	

[2]

(b) The atomic number of rhodium is 45. The volume of a nucleus of rhodium is 7.46×10^{-43} m^3.

Calculate the number of **neutrons** in the nucleus of rhodium.

Number of neutrons = ______________________ [3]

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2 In July 2020, the UK government pledged more funding to speed up the development of smaller nuclear fission reactors which only produce enough energy to power a city of medium size.

(a) The following equation shows a typical nuclear fission reaction. Complete the equation by inserting appropriate numbers in the boxes.

$$^{236}_{92}\mathrm{U} \rightarrow {}^{144}_{\square}\mathrm{Ba} + {}^{90}_{36}\mathrm{Kr} + \square\,{}^{1}_{0}\mathrm{n} + \frac{\square}{\square}\,\gamma$$

[4]

(b) **(i)** State and explain the purpose of a moderator in a thermal nuclear fission reactor.

____

____

____ [2]

(ii) A nuclear fission reactor requires a critical size of fuel to be present in the core. What is meant by the term critical size?

____

____

____ [2]

(iii) An uncontrolled chain reaction occurs in an atomic bomb, whereas a controlled chain reaction occurs in a nuclear power station. How is an uncontrolled reaction prevented in a reactor?

____

____ [2]

(c) Evaluate and compare the carbon footprint of the production of electricity when using coal and uranium as resources.

____

____

____

____

____

____ [3]

(d) An estimate of the available energy in a nuclear fuel can be made using the data in **Table 2.1**.

Table 2.1

Percentage of uranium-235 in the nuclear fuel	**0.7%**
Energy release per nuclear decay of uranium-235	**200 MeV**

(i) Calculate the number of uranium-235 atoms in 1 kg of the fuel.

Number of uranium-235 atoms = ______________________ [3]

(ii) Calculate the total available energy in 1 kg of the fuel.

Energy = ____________________ J [3]

3 **(a)** A hacksaw blade, as shown in **Fig. 3.1a**, is clamped between two wooden blocks. It can be made to oscillate by pulling the blade back slightly and releasing. The motion of the blade during an oscillation is shown in **Fig. 3.1b**.

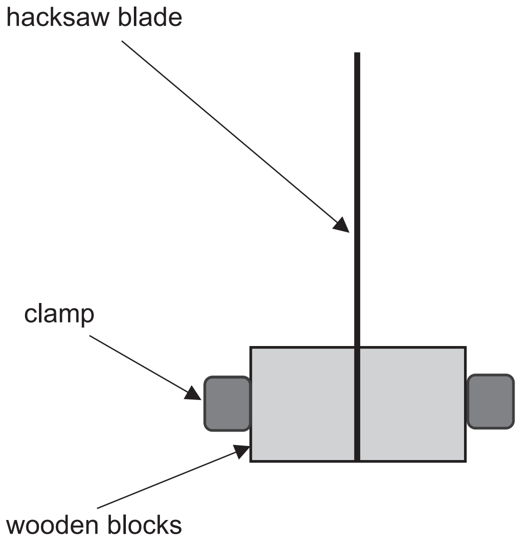

Fig. 3.1a

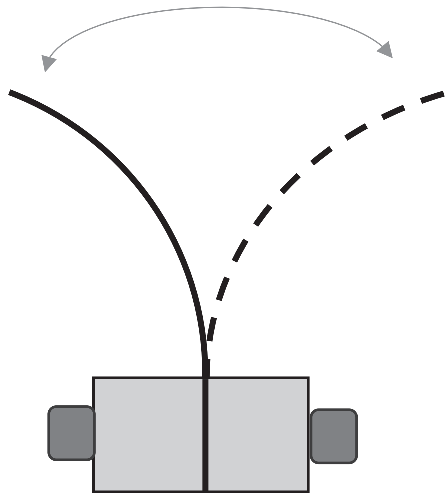

Fig. 3.1b

(i) On **Fig. 3.2** sketch a graph to show how the **amplitude** of the hacksaw blade changes with time if the blade experiences light damping.

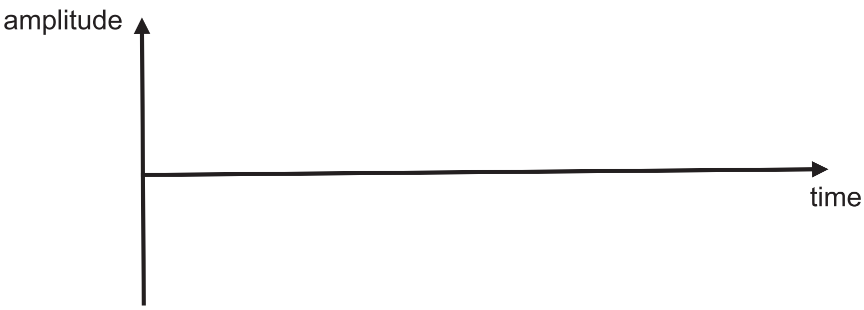

Fig. 3.2

[2]

(ii) A student displaces the hacksaw blade and records a time of 4.55 s for 12 complete oscillations. Calculate the natural frequency of the oscillations of the hacksaw blade.

Frequency = ______________________ Hz [3]

The hacksaw blade can be made to vibrate at different frequencies using a vibration generator connected to a signal generator as shown in **Fig. 3.3**.

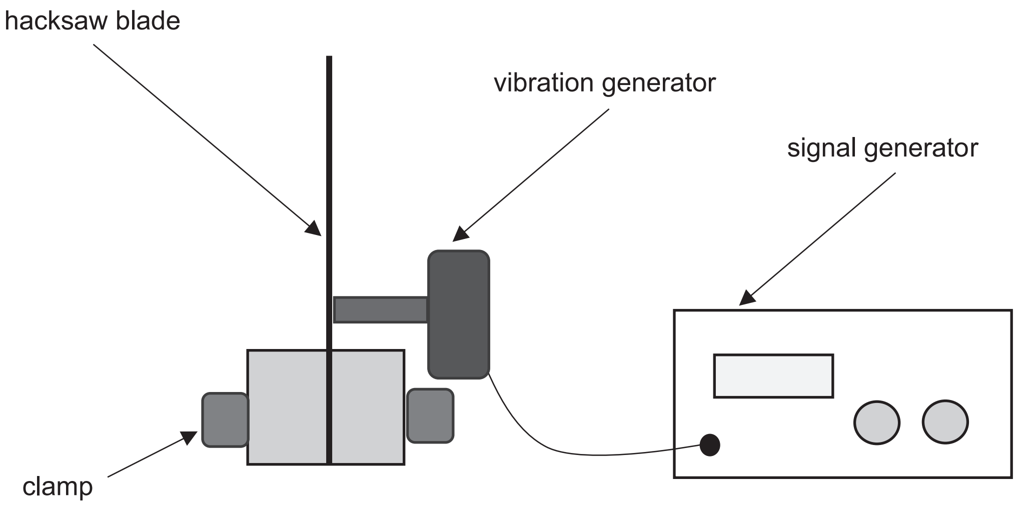

Fig. 3.3

(iii) Describe how the amplitude of the oscillation of the hacksaw blade changes as the frequency on the signal generator is increased slowly from 0 Hz to 4 Hz.

____

____

____

____ [2]

[Turn over

(b) The frequency of the signal generator in **Fig. 3.3** is increased and a different stationary wave is formed on the hacksaw blade, as shown in **Fig. 3.4**. The nodal and antinodal positions along the stationary wave are labelled N and A respectively.

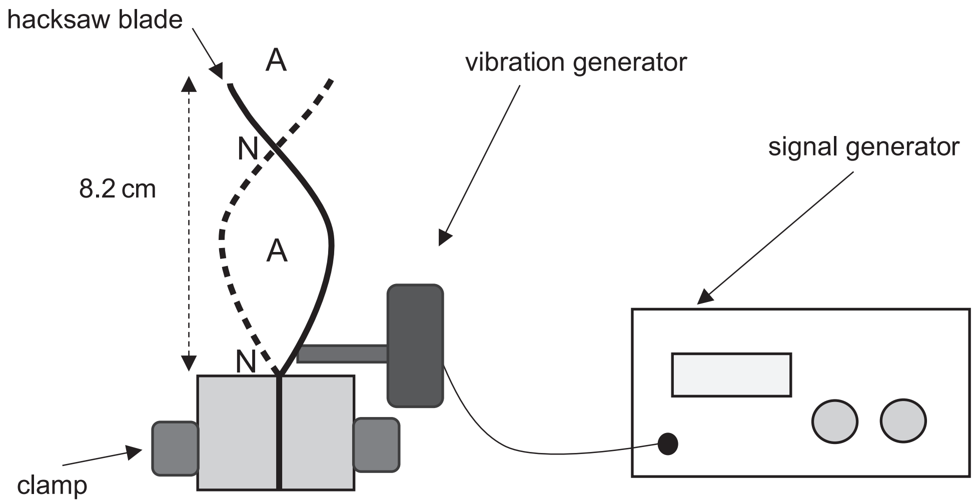

Fig. 3.4

(i) Distinguish between nodes and antinodes.

____

____

____ [2]

(ii) The length of the hacksaw blade is 8.2 cm. Calculate the wavelength of the stationary wave formed on the hacksaw blade.

Wavelength = ____________________ cm [2]

4 The displacement x of an object performing simple harmonic motion is given by **Equation 4.1**.

$$x = 0.57\cos\left(\frac{\pi}{4}t\right) \qquad \textbf{Equation 4.1}$$

(a) On **Fig. 4.1**, sketch a graph of the acceleration a of the object against x for **all** values of the displacement. Include appropriate numerical values on the x-axis.

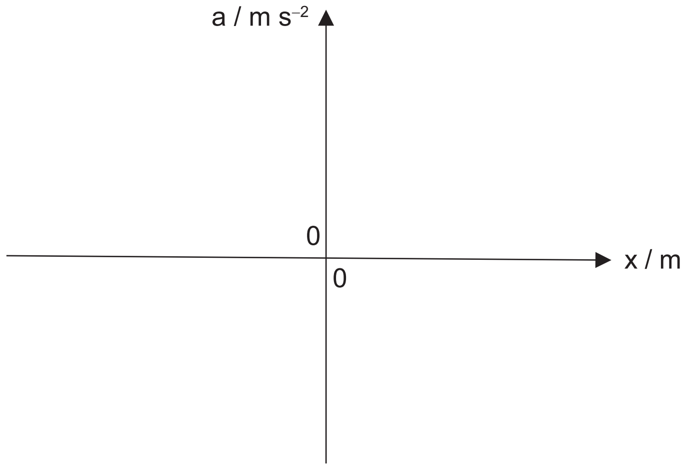

Fig. 4.1

[3]

(b) Calculate the maximum value of the acceleration.

Maximum acceleration = ____________________ m s^{-2} [3]

5 In a fairground ride called the Gravitron people lean against a rotating wall and the force generated by the motion of the Gravitron keeps the people suspended in an elevated position against the wall, as shown in **Fig. 5.1**.

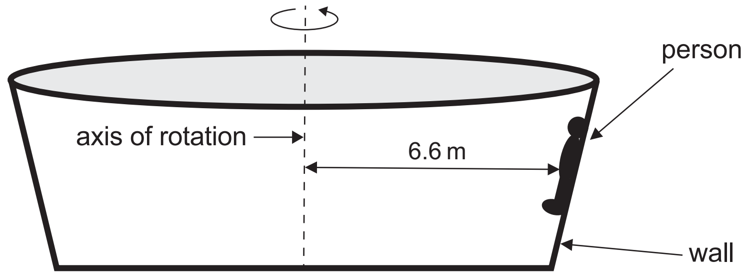

Fig. 5.1

(a) A centripetal force acts on a person when the Gravitron is rotating. What is a centripetal force?

____

____ [1]

Fig. 5.2 shows a simplified diagram of the forces acting on the person in the Gravitron when it is moving.

F is the frictional force, R is the reaction force from the wall on the person and W is the weight of the person.

The mass of the person riding the Gravitron is 65 kg.

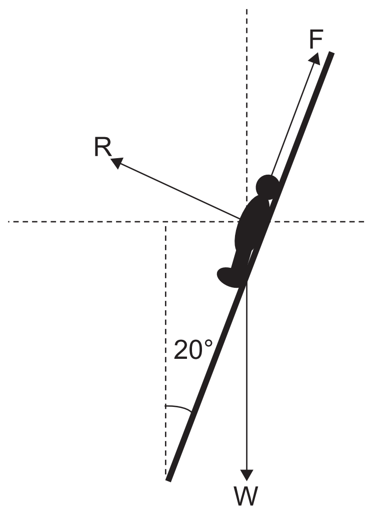

Fig. 5.2

(b) The radius of the Gravitron is 6.60 m as shown in **Fig. 5.1**.

(i) Calculate the linear speed of the Gravitron when R is 1106 N and F is 277 N.

Linear speed = ____________________ $m\ s^{-1}$ [4]

(ii) Calculate the number of revolutions per minute of the Gravitron when it is spinning with the linear speed calculated in part **(b)(i)**.

Revolutions per minute = ____________________ [3]

[Turn over

6 Tennis strings were originally made of natural gut which is very elastic but not durable. A manufacturer wants to compare alternative materials including nylon, polyester and kevlar.

Table 6.1 shows some of the properties of these materials.

Table 6.1

Material	Young modulus / GPa	Elastic limit / GPa
nylon	2.70	0.0483
polyester	0.920	0.0138
kevlar	76.0	2.41

(a) **(i)** Define the term Young modulus of a material.

____

____ [2]

(ii) What is meant by the elastic limit of a material?

____

____ [2]

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(b) A typical diameter of a tennis string is 1.30 mm and 12.0 m of string is used per racket. Strings of this diameter and length are made from the materials in **Table 6.1**.

(i) When the same tension force is applied, which material will produce the largest extension? Explain your answer.

Material: ____

____

____ [2]

(ii) Calculate the extension of the nylon string with a diameter of 1.30 mm for a tension force of 50.0 N applied to the 12.0 m length of string.

Extension = ______________________ m [6]

(iii) The kevlar string with the same dimensions as the nylon string in **(ii)**, stretches 5.93 mm for the same 50.0 N force. Calculate the strain energy stored in the kevlar string.

Strain energy = ______________________ J [2]

[Turn over

In (a)(iii) of this question you will be assessed on the quality of your written communication.

7 A student is to carry out an experiment to verify the relationship between the pressure and the temperature of a gas.

(a) **(i)** State the relationship between the pressure and the temperature of a gas.

____

____

____ [3]

(ii) In the space below, draw a labelled diagram of the apparatus which should be used by the student.

[4]

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(iii) Describe how the apparatus drawn in **(ii)** would be used and outline how the results are used to verify the relationship.

[6]

(b) Therapists can use suction cups to treat muscle aches. The air inside the suction cup is heated and the cup is placed on the skin where it makes an air-tight seal. As the air in the cup cools, the skin tissue is drawn inside the suction cup.

The air in one cup is heated to 65 °C and applied to the skin. It cools to 23 °C and the volume of air in the cup reduces by one sixth.

Calculate the percentage change in the pressure of the air in the suction cup.

Percentage change in pressure = ____________________ % [6]

8 (a) (i) What is meant by the internal energy of a real gas?

____

____ [1]

(ii) State the difference between the internal energy of an ideal gas and a real gas.

____ [1]

(b) (i) A container of volume 50 cm^3 contains oxygen molecules at a pressure of 15 Pa at a temperature of 373 K. Calculate the number of moles of oxygen in the container.

Number of moles = ______________________ [4]

(ii) Calculate the root mean square speed of the oxygen molecules in the container. The mass of one oxygen molecule is 5.30×10^{-26} kg.

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

[Turn over

9 (a) Radioactive nuclei disintegrate **spontaneously** and **randomly**.

What is meant by the words in bold above?

Spontaneously: ____

____

Randomly: ____

____ [2]

(b) (i) The law of radioactive decay is described using the equation $A = -\lambda N$, where A is the activity and λ is the decay constant. In terms of nuclei, define the activity and the decay constant.

Activity: ____

____

Decay constant: ____

____ [2]

(ii) **Fig. 9.1** shows a graph of ln A against time in **seconds** for a radioactive sample with a half-life of 14.4 days.

The initial activity was recorded as 80,000 Bq.

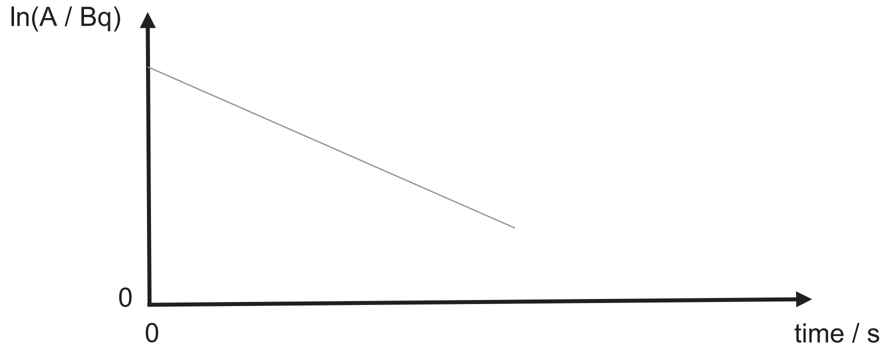

Fig. 9.1

Calculate the intercept on the ln A axis and calculate the magnitude of the gradient of the graph shown in **Fig. 9.1**. Include units where appropriate with your answers.

Intercept = ____________________________

Gradient = ____________________________ [5]

THIS IS THE END OF THE QUESTION PAPER

DO NOT WRITE ON THIS PAGE

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

Examiner Number

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General Certificate of Education

Physics

Assessment Units A2 1 and A2 2

[APH11/APH21]

DATA AND FORMULAE SHEET

Data and Formulae Sheet for A2 1 and A2 2

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}$ m s^{-1}
permittivity of a vacuum	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$\left(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ F^{-1}\ m\right)$
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
(unified) atomic mass unit	$1\ u = 1.66 \times 10^{-27}$ kg
mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
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
Hooke's Law	$F = kx$ (spring constant k)
strain energy	$E = \frac{1}{2}\mathrm{F}\mathrm{x} = \frac{1}{2}kx^2$

Uniform circular motion

centripetal Force	$F = \frac{mv^2}{r}$

Simple harmonic motion

displacement	$x = A\cos\omega t$
simple pendulum	$T = 2\pi\sqrt{\frac{l}{g}}$
loaded spiral spring	$T = 2\pi\sqrt{\frac{m}{k}}$

Waves

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

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	$\tau = RC$
capacitor discharge	$Q = Q_0 e^{\frac{-t}{CR}}$
	or $V = V_0 e^{\frac{-t}{CR}}$
	or $I = I_0 e^{\frac{-t}{CR}}$

Light

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

Electricity

terminal potential difference	$V = E - Ir$
	(e.m.f., E; Internal Resistance, r)
potential divider	$V_{out} = \frac{R_1 V_{in}}{R_1 + R_2}$
a.c. generator	$E = BAN\omega \sin\omega t$

Nuclear Physics

nuclear radius	$r = r_0 A^{\frac{1}{3}}$
radioactive decay	$A = -\lambda N, \quad A = A_0 e^{-\lambda t}$
half-life	$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

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	$v = H_0 d$