Rewarding Learning

ADVANCED
General Certificate of Education
2024

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]
FRIDAY 24 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 questions 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.
You may use a scientific calculator.
Quality of written communication will be assessed in Question **7**.
A Data and Formulae Sheet is included inside this question paper.

14215

1 **(a)** State Hooke's law.

____

____

____ [2]

(b) **Fig. 1.1** shows a toy horse on a spring, found in a playground.

Source: © Getty Images

Fig. 1.1

The mass of the horse is 70 kg. When a child of mass 27 kg sits on the horse, the spring compresses by a further 2.9 cm.

(i) Assuming the spring is still obeying Hooke's law, calculate the spring constant.

Spring constant = ____________________ N cm^{-1} [3]

(ii) The length of the spring is 45 cm before the child sits on the horse. Calculate the original length of the spring before the toy horse is attached to the top of the spring.

Length = ___________________ cm [3]

(iii) Calculate the total strain energy stored in the spring when the child sits on the horse.

Strain energy = ___________________ J [4]

[Turn over

2 **(a)** Use the definition of acceleration to explain why an object, moving in a circle at a constant speed, must have a resultant force acting on it.

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____ [4]

(b) An object is placed on a turntable that is rotating at a constant angular velocity of 3.8 rad s^{-1}.

(i) Calculate the number of revolutions the object will complete in 20 s.

Number of revolutions = ____________________ [4]

(ii) The maximum frictional force between the object and the turntable is 6.2 N. The object begins to slide when it is placed 0.15 m from the centre of the turntable. Calculate the mass of the object.

Mass = ____________________ kg [3]

3 The most frequent failure of an X-ray tube occurs when the heat generated during normal operation is not dissipated adequately.

An X-ray tube produces a beam of high speed electrons with a power of 50 W. When the electrons collide with the metal anode they cause the release of X-ray photons. 99.2% of the kinetic energy of the electron beam is lost in the form of heat at the anode.

(a) Calculate how many joules of heat energy per second are produced at the surface of the anode.

Heat energy per second = ____________________ J [2]

(b) (i) The anode is a metal cylinder of diameter 5.7 cm and height 0.06 cm. The density of the metal used to make the anode is 19.25 g cm^{-3} and it has a specific heat capacity of 0.135 J $g^{-1}K^{-1}$.

Calculate the rate of increase in temperature of the anode per second.

Rate of increase of temperature = ____________________ K s^{-1} [6]

(ii) Explain why it is a benefit for the anode to rotate.

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____ [1]

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4 To predict the weather, meteorologists need to know the conditions in the upper atmosphere. To do this they release weather balloons, filled with helium, carrying measuring instruments into the upper atmosphere.

As the balloon rises its volume increases and the material of the balloon stretches until the balloon bursts and the measuring instruments fall to the ground.

(a) (i) Explain why the Young modulus of the material used to make the weather balloon is an important property to be considered.

____

____ [1]

(ii) A strip of a material being tested for use as a weather balloon has a cross-sectional area of 3.2 cm^2 and a length of 0.50 m. When a load of 30 N is applied to it, the length becomes 0.55 m. Calculate the Young modulus of the material and state its unit.

Young modulus = ____________________

Unit: ____________________ [6]

[Turn over

(b) A weather balloon has a volume of 5.3 m^3 when it is released. The temperature at the surface of the earth is 15°C. After an hour, the balloon has risen to a height of 30.5 km where the temperature is –44°C.

Fig. 4.1 shows how the pressure P of the air varies as the height h above the surface of the earth increases.

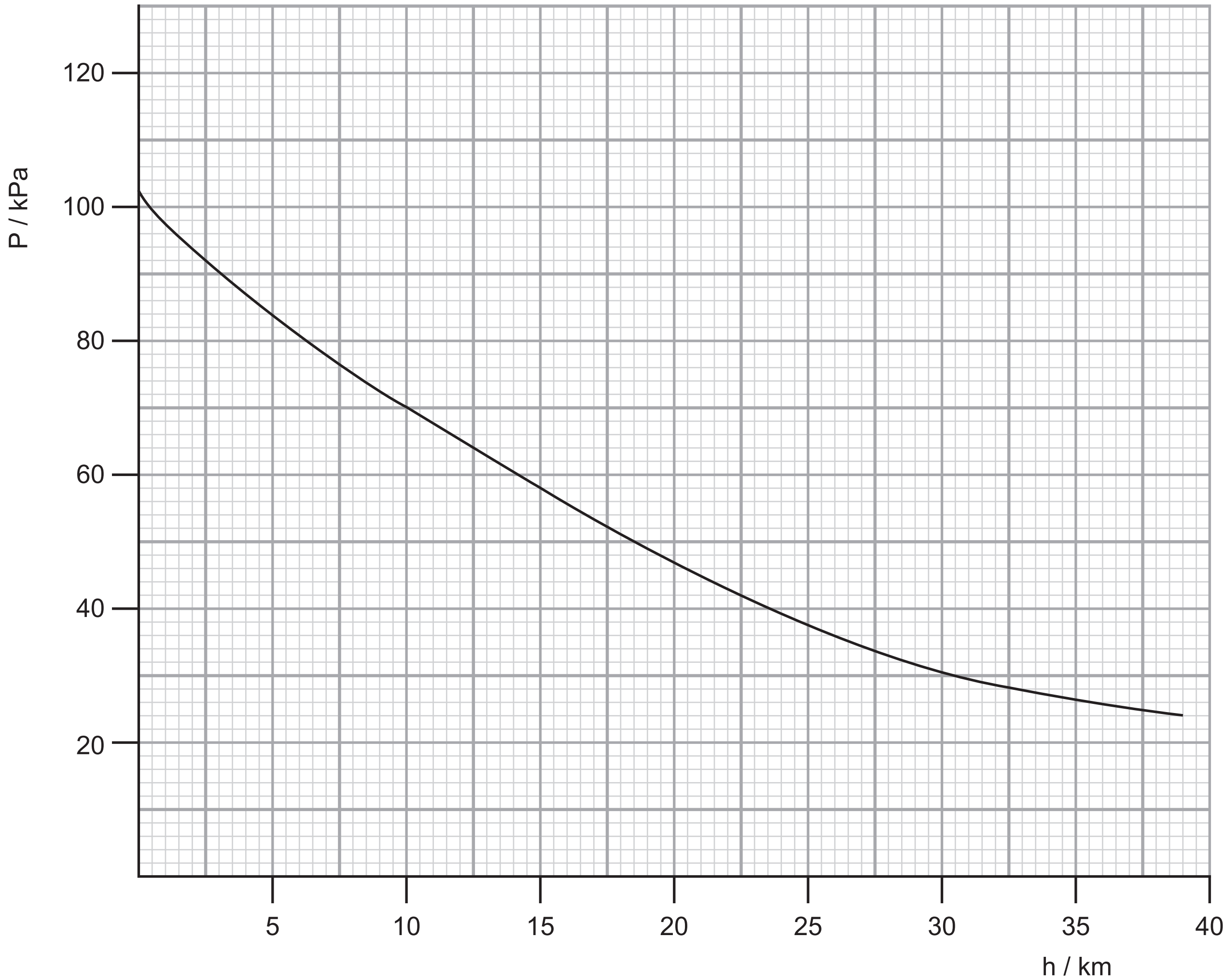

Fig. 4.1

The balloon bursts at 30.5 km allowing the measuring instruments to fall back to earth.

(i) Calculate the volume of the balloon just before it bursts.

Volume = ________________ m^3 [5]

(ii) In reality, as the balloon rises some of the helium gas escapes from the balloon. Will this make the balloon reach a higher, lower, or the same height before it bursts? Tick the box beside the correct statement and explain your choice.

The balloon will reach a higher height ☐

The balloon will reach a lower height ☐

The height reached by the balloon will be the same ☐

Explanation:

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____ [3]

[Turn over

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5 In the early 1900's, paint which contained a mixture of radium-226 and zinc sulfide was used in wristwatches to make the numbers and hands of the watch glow. The radioactive decay of the radium-226 released the energy to allow the zinc sulfide to emit light.

The equation for the decay of radium-226 is shown in **Equation 5.1**.

$$^{226}_{88}\text{Ra} \rightarrow {}^{\square}_{\square}\text{Rn} + {}^{\square}_{\square}\text{He}$$ **Equation 5.1**

(a) (i) Complete **Equation 5.1** by inserting the correct value in each of the four empty boxes. [2]

(ii) Describe the structure of the radium-226 nucleus in terms of its component parts.

____

____ [2]

(iii) Calculate the radius of the radium-226 nucleus given that $r_o = 1.2$ fm.

r = ____________________ m [3]

[Turn over

(b) The paint was applied by workers using a paintbrush which they often licked to dampen it. Many of the workers developed radiation poisoning.

(i) Explain why the workers were affected by radiation poisoning but the people who wore the wristwatches were not.

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____ [3]

(ii) Radium-226 has a half-life of 1600 years. The initial activity of the radium used in a watch was 3.42×10^8 Bq. The activity of this radium when it was tested for age in January 2022 was 3.26×10^8 Bq. Calculate the year in which the watch was manufactured.

Year = ____________________ [5]

(iii) Calculate the number of radium-226 nuclei in the paint in the watch when it was tested in 2022.

Number of nuclei = ____________________ [3]

[Turn over

6 (a) On the axes of **Fig. 6.1**, sketch a graph to show how the acceleration a of an object moving with simple harmonic motion varies with its displacement x. [3]

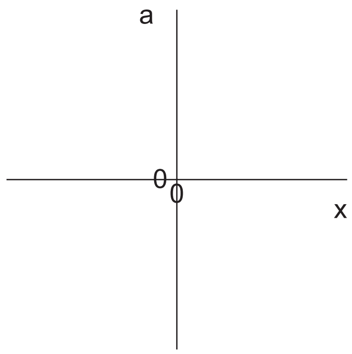

Fig. 6.1

(b) (i) A pendulum of length 0.75 m oscillates with simple harmonic motion. Calculate the period of oscillation of the pendulum.

Period = ____________________ s [2]

(ii) If the pendulum was taken to a place where the acceleration of free fall g was lower, describe and explain what would happen to the period of the pendulum.

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____ [2]

(c) A graph of displacement x against time t for a pendulum is shown in **Fig. 6.2**.

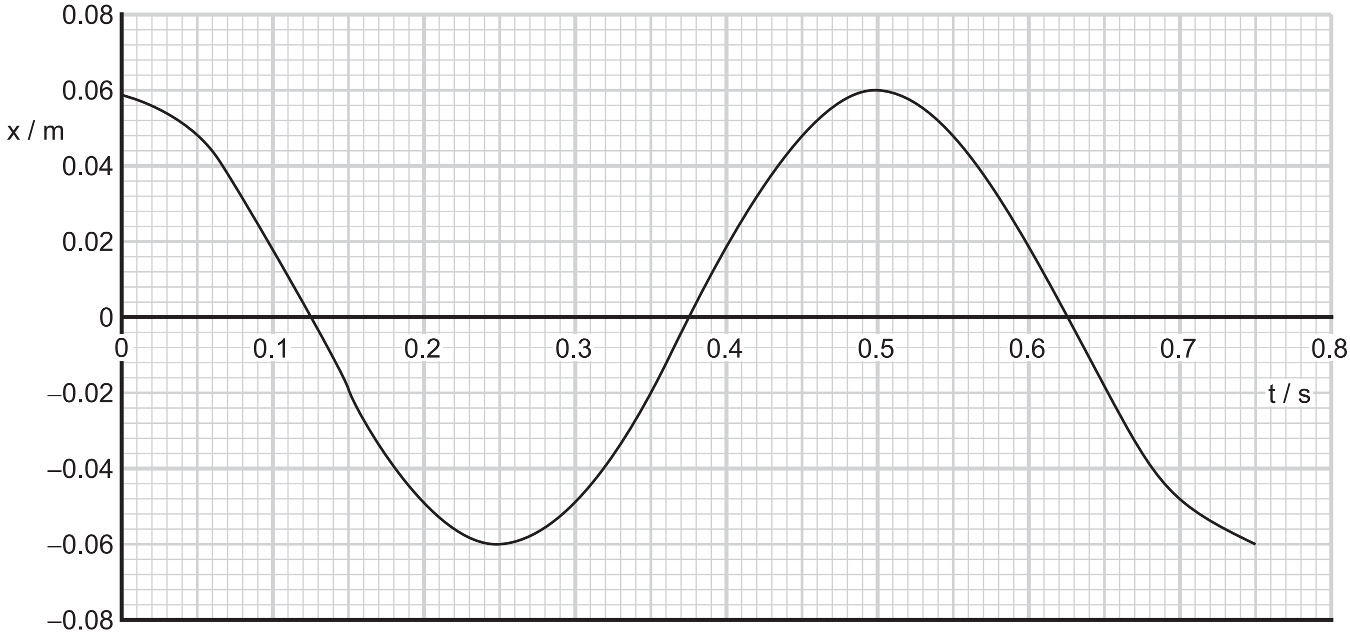

Fig. 6.2

Use the graph to calculate the velocity of the pendulum at a time of 0.3 s.

Velocity = ______________________ $m\ s^{-1}$ [3]

[Turn over

In this question you will be assessed on the quality of your written communication skills, including the use of specialist scientific terms.

7 **(a)** **(i)** What is meant by nuclear fission?

____

____ [2]

(ii) Inside a nuclear fission reactor, neutrons interact with three different components of the reactor. These are:

- the nuclei of the uranium-235 fuel,
- the control rods,
- the moderator.

Describe what happens when a neutron interacts with each of these components and explain why each interaction is necessary.

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____ [6]

(b) The nuclear fusion reaction most likely to work commercially is the fusion of deuterium and tritium nuclei.

Tritium nuclei can be produced by bombarding lithium nuclei with neutrons.

This reaction is shown in **Equation 7.1**.

$$^{6}_{3}\mathrm{Li} + \mathrm{n} \rightarrow {}^{3}_{1}\mathrm{H} + {}^{4}_{2}\mathrm{He} \qquad \textbf{Equation 7.1}$$

The mass of each of the nuclei in **Equation 7.1** is shown in **Table 7.1**.

Table 7.1

Nucleus	Lithium-6	Tritium-3	Helium-4	neutron
Mass / u	6.015122	3.016049	4.002603	1.008665

(i) Calculate the energy, in J, released in the reaction shown in **Equation 7.1**.

Energy = ____________________ J [5]

[Turn over

(ii) The fusion reaction between a tritium nucleus produced by the reaction in **Equation 7.1** and a deuterium nucleus produces an energy of 17.6 MeV.

Calculate the ratio: $\dfrac{\text{energy released from deuterium–tritium fusion}}{\text{energy released by reaction in } \textbf{Equation 7.1}}$

Ratio = ______________________ [4]

(c) (i) Explain why an extremely high temperature is required to achieve nuclear fusion in a plasma of tritium and deuterium nuclei.

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____ [2]

(ii) State the names of two methods in which this heating of the plasma is achieved and describe each method.

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____ [4]

(iii) State the names of two methods of plasma confinement that could potentially be used on earth.

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____________________ [2]

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For Examiner's use only	
Question Number	Marks
1	
2	
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5	
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Total Marks	

Examiner Number

APH11/6
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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}
	$\left(\dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{F}^{-1}\ \text{m}\right)$
elementary charge	$e = 1.60 \times 10^{-19}$ 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 e$V = 1.60 \times 10^{-19}$ 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	$E = \frac{1}{2}\mathrm{Fx} = \frac{1}{2}kx^2$

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 $v = H_0\, d$