Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

9345587678

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **February/March 2024**

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **28** pages. Any blank pages are indicated.

DC (PB/FC) 331328/4

Data

acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$
speed of light in free space	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19}\ \text{C}$
unified atomic mass unit	$1\ \text{u} = 1.66 \times 10^{-27}\ \text{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
molar gas constant	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$ $(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

gravitational potential	$\phi = -\dfrac{GM}{r}$
gravitational potential energy	$E_P = -\dfrac{GMm}{r}$
pressure of an ideal gas	$p = \frac{1}{3}\dfrac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm\omega\sqrt{(x_0^{\,2} - x^2)}$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
electrical potential energy	$E_P = \dfrac{Qq}{4\pi\varepsilon_0 r}$
capacitors in series	$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
discharge of a capacitor	$x = x_0 e^{-\frac{t}{RC}}$
Hall voltage	$V_H = \dfrac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 e^{-\lambda t}$
decay constant	$\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$
intensity reflection coefficient	$\dfrac{I_R}{I_0} = \dfrac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}$
Stefan–Boltzmann law	$L = 4\pi\sigma r^2 T^4$
Doppler redshift	$\dfrac{\Delta\lambda}{\lambda} \approx \dfrac{\Delta f}{f} \approx \dfrac{v}{c}$

1 **(a)** Explain why the gravitational potential near to a point mass is negative.

....

....

....

.... [2]

(b) A planet may be assumed to be a uniform sphere. It has gravitational potential ϕ at distance r from the centre of the planet.

The variation with $\frac{1}{r}$ of ϕ is shown in Fig. 1.1.

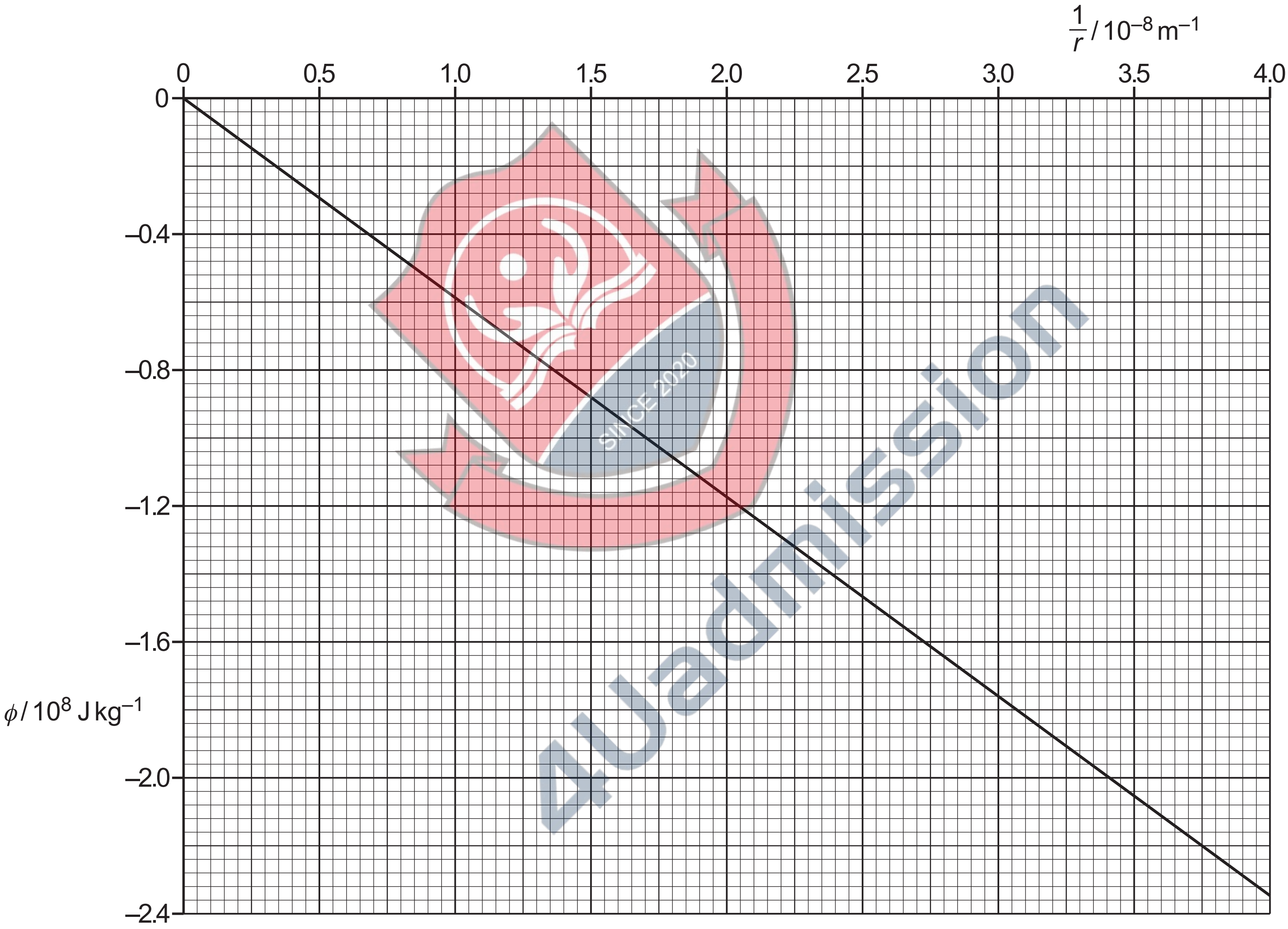

Fig. 1.1

(i) Show that the mass of the planet is 8.8×10^{25} kg.

[2]

(ii) The period of rotation of the planet is 0.72 Earth days.

A satellite in orbit around the planet remains above the same point on the surface of the planet.

Use the mass of the planet in **(b)(i)** to determine the radius *R* of the orbit of the satellite.

R = ... m [3]

(iii) The speed of the satellite in **(b)(ii)** is $8400\,\mathrm{m\,s^{-1}}$. The mass of the satellite is 1200 kg.

Determine the additional energy required to move the satellite from its orbit to infinity.

energy required = ... J [3]

[Total: 10]

2 **(a)** By referring to both kinetic energy and potential energy, explain what is meant by the internal energy of an ideal gas.

....

....

....

.... [2]

(b) A fixed mass of an ideal gas at a temperature of 20 °C is sealed in a cylinder by a piston, as shown in Fig. 2.1.

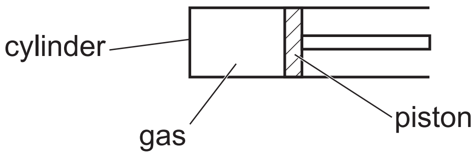

Fig. 2.1

The initial volume of the gas is $1.24 \times 10^{-4}\,m^3$.
Thermal energy is supplied to the gas and its volume increases by $5.20 \times 10^{-5}\,m^3$.

(i) The piston is freely moving so that the gas is always at atmospheric pressure.

Atmospheric pressure is $1.01 \times 10^5\,Pa$.

Calculate the work done by the gas.

work done by gas = ... J [2]

(ii) Calculate the final thermodynamic temperature T of the gas.

T = ... K [2]

(iii) The mass of the gas is 16 g. For this expansion, there is a net transfer of 960 J of thermal energy to the gas.

Calculate the specific heat capacity c of the gas at this pressure.

c = ... $J\,kg^{-1}\,K^{-1}$ [2]

(c) The gas in **(b)** is allowed to return to its starting temperature. The piston is now fixed in position.

Thermal energy is supplied to increase the temperature to the same final temperature as in **(b)**.

Use the first law of thermodynamics to suggest and explain how the specific heat capacity of the gas for this situation compares with the value in **(b)(iii)**.

....

....

....

.... [3]

[Total: 11]

3 A small object of mass 24 g rests on a platform. The platform is attached to an oscillator, as shown in Fig. 3.1.

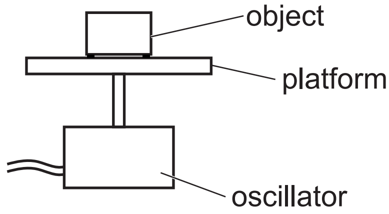

Fig. 3.1

The oscillator moves the platform up and down.

(a) The total energy of the oscillations of the object is 2.2×10^{-4} J.
In one oscillation the object travels a total distance of 14 mm.

Calculate the angular frequency ω of the oscillations.

ω = ... rad s^{-1} [3]

(b) The frequency of the oscillator is fixed, and the amplitude of the oscillations is gradually increased.

(i) Calculate the maximum amplitude of the oscillations so the object does not lose contact with the platform.

amplitude = ... m [2]

(ii) The amplitude of the oscillations is increased so it is greater than the value in **(b)(i)**.

State and explain the position in an oscillation where the object first loses contact with the platform.

....

....

....

.... [2]

[Total: 7]

4 **(a)** Three capacitors are connected as shown in Fig. 4.1.

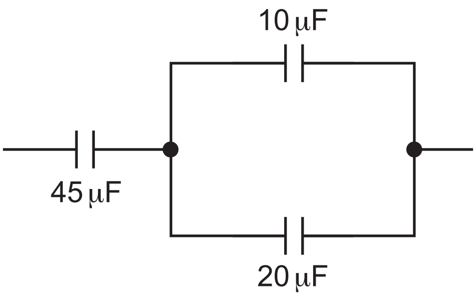

Fig. 4.1

Determine the total capacitance, in μF, of the network of three capacitors.

capacitance = ... μF [2]

(b) A capacitor of capacitance 45 μF is connected to a variable power supply initially set at 8.0 V. The output of the power supply increases so that the potential difference (p.d.) across the capacitor increases to 9.6 V.

Calculate the increase in energy ΔE stored in the capacitor.

ΔE = ... J [2]

(c) A sinusoidal a.c. power supply is connected to the input of a bridge rectifier. The output of the rectifier is connected to a load resistor.

(i) Complete the circuit in Fig. 4.2 by adding a capacitor to smooth the p.d. across the load resistor.

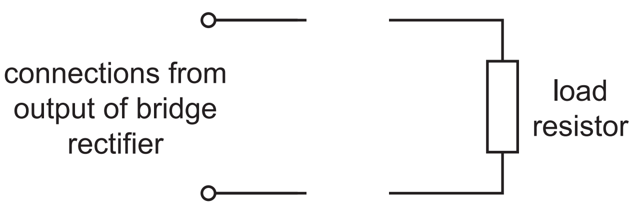

Fig. 4.2

[1]

(ii) The variation with time t of the p.d. V of the smoothed output is shown in Fig. 4.3.

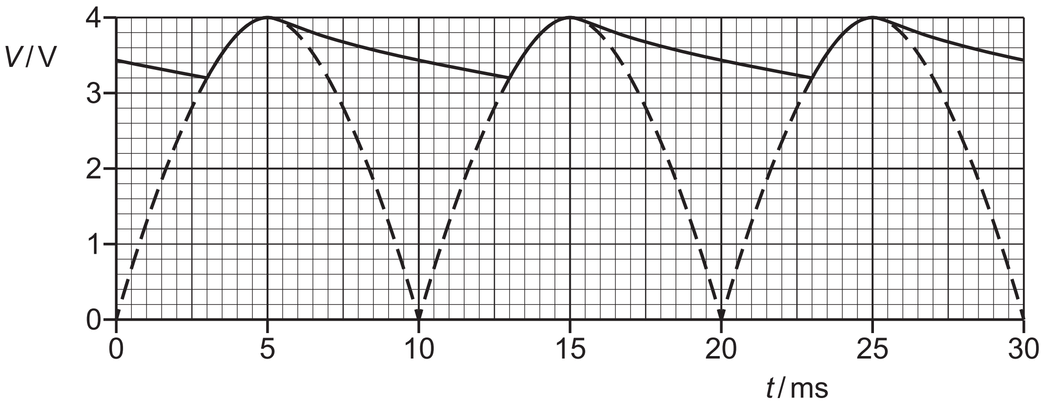

Fig. 4.3

Determine the time constant, in ms, of the smoothing circuit.

time constant = ... ms [3]

(d) A sinusoidal a.c. power supply has a maximum power of 16 W.

State the value of the mean power when the output of the power supply is:

(i) full-wave rectified

mean power = ... W [1]

(ii) half-wave rectified.

mean power = ... W [1]

[Total: 10]

5 **(a)** An object travels in a circle at constant speed.

State the names of **two** quantities that vary during the motion of the object.

1 ....

2 ....
[2]

(b) A charged particle of mass m and with charge q enters a region of uniform magnetic field, perpendicular to the field lines. The magnetic flux density is B.

The particle travels in a circle with period T and radius r.

(i) By considering the magnetic force acting on the particle, show that

$$B = \frac{2\pi m}{qT}.$$

[3]

(ii) The particle is an alpha particle. The period of the circular motion is 2.5 μs.

Calculate B.

B = ... T [2]

(iii) A second alpha particle is in the same uniform field. It travels in a circle of radius $2r$.

State and explain how the periods of the motion of the two particles compare.

....

....

.... [1]

(iv) The speed of the alpha particle in **(b)(ii)** is $1.1 \times 10^6\,\text{m}\,\text{s}^{-1}$. An electric field is applied so that this particle now moves with constant velocity.

Use your answer in **(b)(ii)** to calculate the electric field strength E. Give the unit with your answer.

E = ... unit .... [2]

[Total: 10]

6 **(a)** A small coil C has 64 turns and cross-sectional area $0.71\,cm^2$. The coil is placed inside a solenoid as shown in Fig. 6.1.

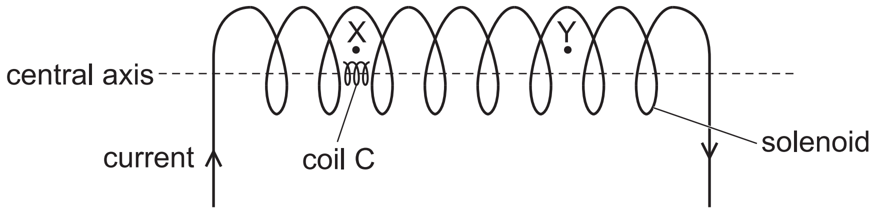

Fig. 6.1

The centre of coil C is on the central axis of the solenoid.

(i) There is a constant current in the solenoid.
Coil C is moved through the solenoid from position X to position Y.

On Fig. 6.2, sketch a line to show the variation of the magnetic flux linkage in coil C with position as it moves from X to Y.

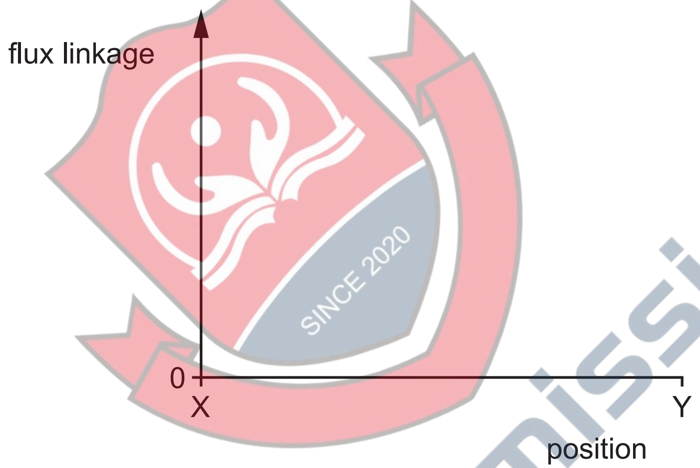

Fig. 6.2

[1]

(ii) Explain the shape of your line in **(a)(i)**.

....

....

....

.... [2]

(iii) Coil C is now held stationary at X. The current in the solenoid varies so that the magnetic flux density B at X varies from time 0 to time $4t$ as shown in Fig. 6.3.

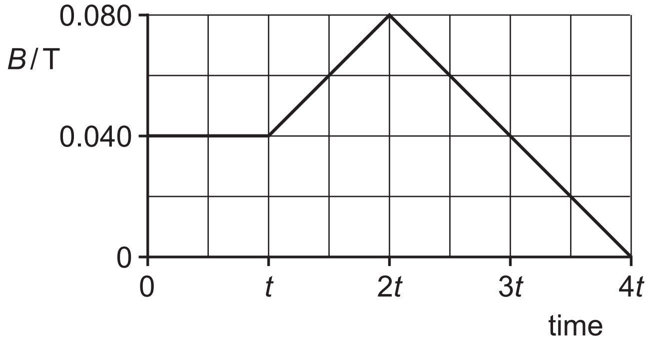

Fig. 6.3

Calculate the maximum magnetic flux linkage in coil C.

flux linkage = ... Wb [2]

(iv) On Fig. 6.4, sketch a line to show the induced electromotive force (e.m.f.) E in coil C from time 0 to time $4t$.

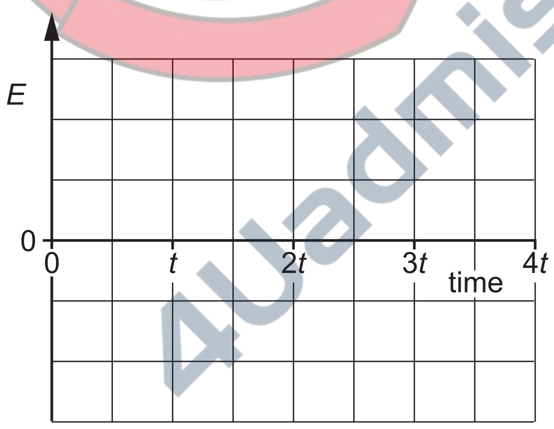

Fig. 6.4

[3]

(b) A metal spring rests on a smooth table. The turns of the spring are equally spaced. The ends of the spring are connected to a d.c. power supply, as shown in Fig. 6.5.

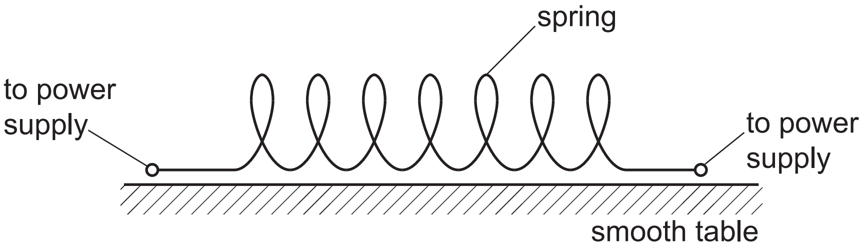

Fig. 6.5

The spring is connected to the d.c. power supply using flexible leads. The spring is not under tension.

With reference to magnetic fields, describe and explain the change in the distance between the turns of the spring when the power supply is first switched on.

....

....

....

....

.... [3]

[Total: 11]

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7 **(a)** A photon has an energy of 3.11×10^{-19} J.

Calculate the momentum of the photon.

momentum = ... N s [2]

(b) A laser beam has a power of 350 mW. The light from the laser has a wavelength of 640 nm.

(i) Determine the number of photons emitted by the laser in a time of 1.0 s.

number = ... [2]

(ii) The laser beam is incident normally on a surface that absorbs all of the photons.

Show that the force F exerted on the surface by the laser beam is given by

$$F = \frac{P}{c}$$

where P is the power of the laser beam and c is the speed of light.

[2]

(c) Light of a single wavelength is incident on the surface of different metals. The work function energy of the metals is given in Table 7.1.

Table 7.1

metal	work function energy / eV
tungsten	4.49
magnesium	3.68
potassium	2.26

(i) Explain the term threshold wavelength.

....

....

.... [1]

(ii) For the metals in Table 7.1, calculate the value of the largest threshold wavelength.

threshold wavelength = ... m [2]

[Total: 9]

8 **(a)** State what is meant by the binding energy of a nucleus.

....

....

.... [2]

(b) A nucleus of uranium-235 absorbs a neutron and becomes unstable. It then undergoes a fission reaction. One possible reaction is

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{142}_{54}Xe + ^{90}_{38}Sr + \text{neutrons.}$$

(i) Determine the number of neutrons produced in this fission reaction.

number = ... [1]

(ii) Data for the binding energies per nucleon for this fission reaction are given in Table 8.1.

Table 8.1

isotope	binding energy per nucleon / MeV
uranium-235	7.59
xenon-142	8.37
strontium-90	8.72

Calculate the energy released, in MeV, from the fission of one nucleus of uranium-235.

energy = ... MeV [2]

(iii) The isotope xenon-142 is unstable. The isotope xenon-132 is stable.

Suggest a reason why xenon-142 is unstable.

....

.... [1]

(iv) Xenon-142 decays into the isotope caesium-142.

A sample initially contains only nuclei of xenon-142. After a time equal to 6.0 s, the ratio

$$\frac{\text{number of decayed nuclei of xenon-142}}{\text{number of undecayed nuclei of xenon-142}}$$

is equal to 31.

Calculate the half-life of xenon-142. Show your working.

half-life = ... s [3]

[Total: 9]

9 (a) Electrons in a vacuum are accelerated through a potential difference of 84 kV. The electrons then strike a metal target and X-rays are produced.

(i) Calculate the minimum wavelength of the X-rays that are produced.

wavelength = ... m [2]

(ii) The melting points of two metals are given in Table 9.1.

Table 9.1

metal	melting point / °C
copper	1090
tungsten	3420

Suggest why the metal target is made from tungsten rather than copper.

....

....

.... [2]

(b) An X-ray beam is incident normally on a sample of soft tissue and bone as shown in Fig. 9.1.

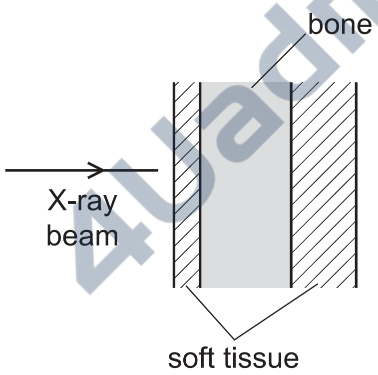

Fig. 9.1

Data for the two materials are given in Table 9.2.

Table 9.2

medium	linear attenuation coefficient μ / cm^{-1}	specific acoustic impedance Z / 10^6 kg m^{-2} s^{-1}
soft tissue	0.22	1.7
bone	3.0	7.8

The total thickness of soft tissue is x. The total thickness of bone is also x.

The incident intensity of the X-ray beam is I_0. The transmitted intensity of the X-ray beam is 13% of the incident intensity.

Determine x, in cm.

x = ... cm [3]

(c) **(i)** Define the specific acoustic impedance of a medium.

....

....

.... [2]

(ii) Use data from Table 9.2 to calculate the percentage of the intensity of ultrasound that is transmitted at a boundary between soft tissue and bone.

percentage transmitted = ... % [2]

(iii) The ultrasound is now incident on the sample of soft tissue and bone shown in Fig. 9.1.

Suggest **two** reasons why the transmitted intensity through the sample is less than the answer in **(c)(ii)**.

1 ....

....

2 ....

....

[2]

[Total: 13]

10 **(a)** The Sun has a surface temperature of 5780 K. The luminosity of the Sun is 3.85×10^{26} W.

(i) Calculate the radius of the Sun.

radius = ... m [2]

(ii) The Earth is a distance of 1.50×10^{11} m from the Sun.

Calculate the radiant flux intensity F of the radiation from the Sun at a distance of 1.50×10^{11} m. Give a unit with your answer.

F = ... unit .... [2]

(iii) The variation with wavelength of the intensity of radiation emitted from the Sun is shown in Fig. 10.1.

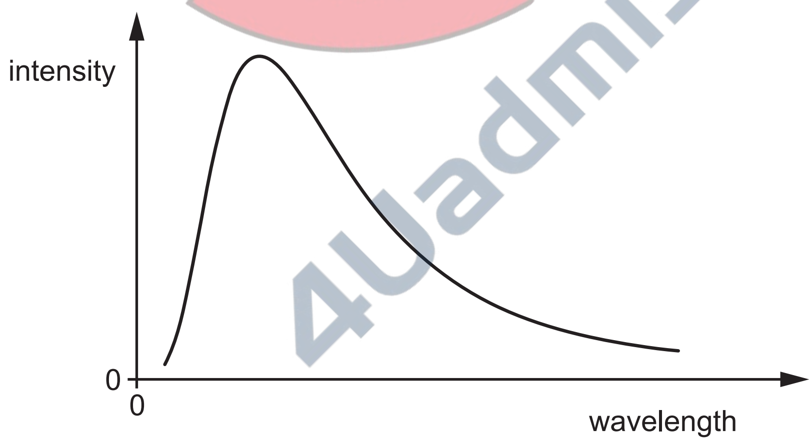

Fig. 10.1

Another star has the same radius as the Sun but has a lower surface temperature.

On Fig. 10.1, sketch a line to show the variation with wavelength of the intensity of the radiation emitted for this star. [2]

(b) A galaxy in the constellation Corona Borealis is moving away from the Earth.

(i) The visible emission spectrum for the Sun is shown in Fig. 10.2.

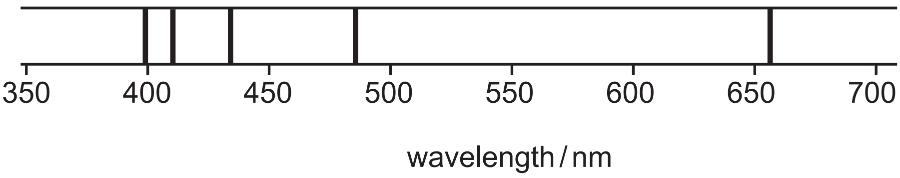

Fig. 10.2

The lines are at wavelengths of 397 nm, 410 nm, 434 nm, 486 nm and 656 nm. The compositions of the Sun and a star in the Corona Borealis galaxy are similar.

On Fig. 10.3, sketch the emission spectrum for the star in the Corona Borealis galaxy as observed from the Earth. No calculations are required.

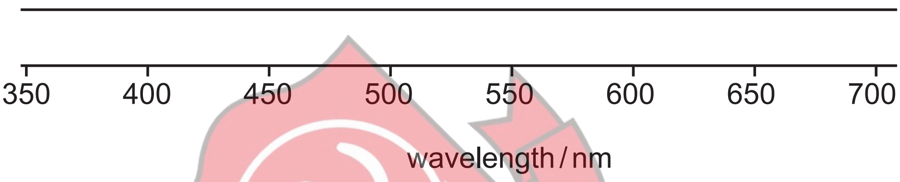

Fig. 10.3

[1]

(ii) The galaxy in Corona Borealis is moving away from the Earth at a speed of 21 400 km s^{-1}.

Use information from **(b)(i)** to calculate, in nm, the observed wavelength of the lowest visible energy emission for the star in the Corona Borealis galaxy.

wavelength = ... nm [2]

(iii) The wavelength in **(b)(ii)** is used to calculate a value for the surface temperature of the star in the Corona Borealis galaxy. The calculation does not give an accurate value.

State and explain whether this value of temperature is too high or too low.

....

....

.... [1]

[Total: 10]

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