* 0019655342201 *

Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

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PHYSICS **9702/42**

Paper 4 A Level Structured Questions **May/June 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 **24** pages. Any blank pages are indicated.

DC (SL/SW) 329808/2

Data

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

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	$f_o = \dfrac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

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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)** Define the radian.

....

.... [1]

(b) A circular metal disc spins horizontally about a vertical axis, as shown in Fig. 1.1.

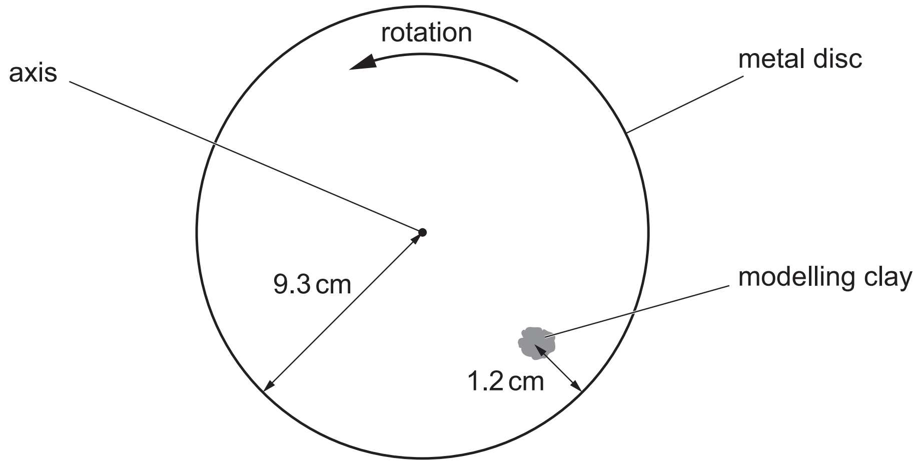

Fig. 1.1 (not to scale)

A piece of modelling clay is attached to the disc.

For the instant when the piece of modelling clay is in the position shown, draw on Fig. 1.1:

(i) an arrow, labelled V, showing the direction of the velocity of the modelling clay [1]

(ii) an arrow, labelled A, showing the direction of the acceleration of the modelling clay. [1]

(c) The metal disc in Fig. 1.1 has a radius of 9.3 cm.
The centre of gravity of the modelling clay is 1.2 cm from the rim of the disc and moves with a speed of 0.68 m s^{-1}.

(i) Calculate the angular speed ω of the disc.

ω = ... rad s^{-1} [2]

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(ii) Calculate the acceleration a of the centre of gravity of the modelling clay.

a = ... $\mathrm{m\,s^{-2}}$ [2]

(d) A second piece of modelling clay is attached to the disc in the position shown in Fig. 1.2.

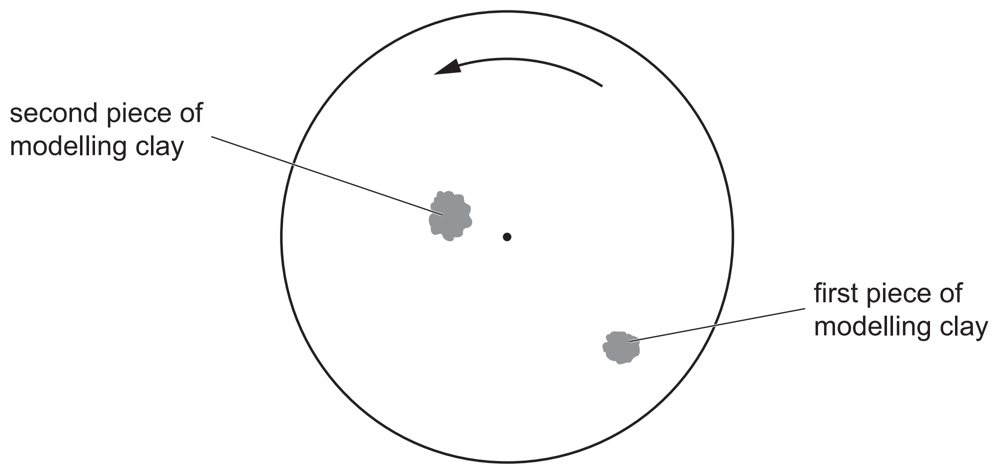

Fig. 1.2

The second piece of modelling clay has a larger mass than the first piece.

By placing **one** tick (✓) in each row, complete Table 1.1 to show how the quantities indicated compare for the two pieces of modelling clay.

Table 1.1

quantity	less for second piece than first piece	same for both pieces	greater for second piece than first piece
angular speed			
linear speed			
acceleration			

[3]

[Total: 10]

2 **(a)** With reference to thermal energy, state what is meant by two objects being in thermal equilibrium.

....

....

.... [1]

(b) Two cylinders X and Y each contain a sample of an ideal gas. The samples are in thermal equilibrium with each other.

X has a volume of $0.0260\,m^3$ and contains 0.740 mol of gas at a pressure of $1.20 \times 10^5\,Pa$. Y has a volume of $0.0430\,m^3$ and contains gas at a pressure of $2.90 \times 10^5\,Pa$. Data for the two cylinders are shown in Fig. 2.1.

Fig. 2.1

(i) Show that the temperature of the gas in X is 234 °C.

[3]

(ii) Determine the number *N* of molecules of the gas in Y. Explain your reasoning.

N = ... [3]

(iii) The gas in X consists of molecules that each have a mass that is four times the mass of a molecule of the gas in Y.

Explain how the root-mean-square (r.m.s.) speed of the molecules in X compares with the r.m.s. speed of the molecules in Y.

....

....

....

....

.... [3]

[Total: 10]

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3 **(a)** State what is meant by the internal energy of a system.

....

....

.... [2]

(b) With reference to molecular kinetic and potential energies, describe and explain how the internal energy of the system changes when:

(i) a gas is heated at constant volume so that its temperature increases

....

....

....

....

.... [3]

(ii) a wire is stretched within its elastic limit at constant temperature.

....

....

....

....

.... [3]

[Total: 8]

4 A block of mass *m* oscillates vertically on a spring, as shown in Fig. 4.1.

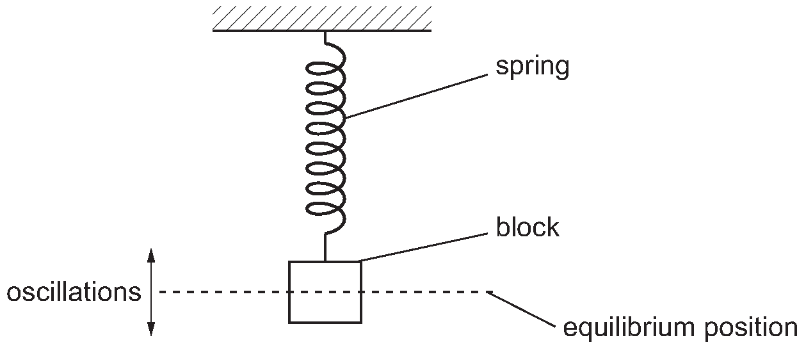

Fig. 4.1

The acceleration *a* of the block varies with displacement *x* from its equilibrium position, as shown in Fig. 4.2.

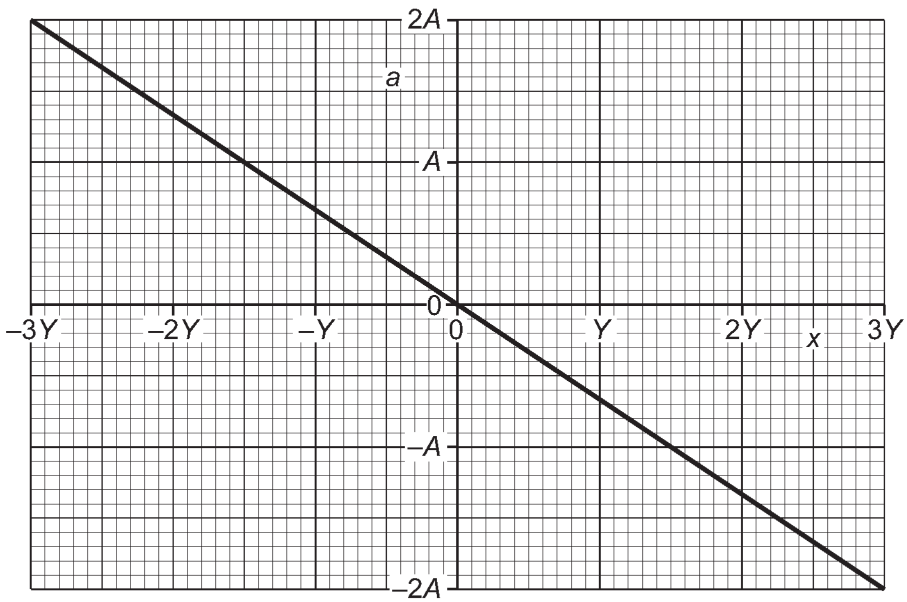

Fig. 4.2

The amplitude of the oscillations is $3Y$ and the maximum acceleration is $2A$.

(a) Explain how Fig. 4.2 shows that the oscillations of the block are simple harmonic.

....

....

.... [2]

(b) Deduce expressions, in terms of some or all of *m*, *A* and *Y*, for:

(i) the angular frequency ω of the oscillations

ω = ... [1]

(ii) the maximum speed v_0 of the oscillations

v_0 = ... [2]

(iii) the energy *E* of the oscillations.

E = ... [2]

(c) The period of the oscillations is 0.75 s and the value of 3*Y* is 1.8 cm.

Determine an expression for *x* in terms of time *t*, where *x* is in cm and *t* is in seconds.

x = ... [2]

[Total: 9]

5 **(a)** Define electric potential at a point.

....

....

.... [2]

(b) Two isolated charged metal spheres X and Y are near to each other in a vacuum. The centres of the spheres are 1.2 m apart, as shown in Fig. 5.1.

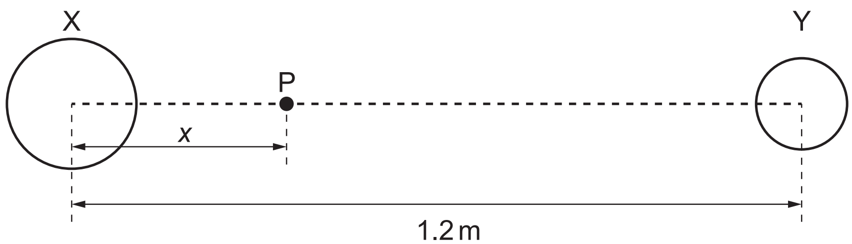

Fig. 5.1 (not to scale)

Point P is on the line joining the centres of spheres X and Y and is at a variable distance x from the centre of X.

Fig. 5.2 shows the variation with x of the total electric potential V due to the two spheres.

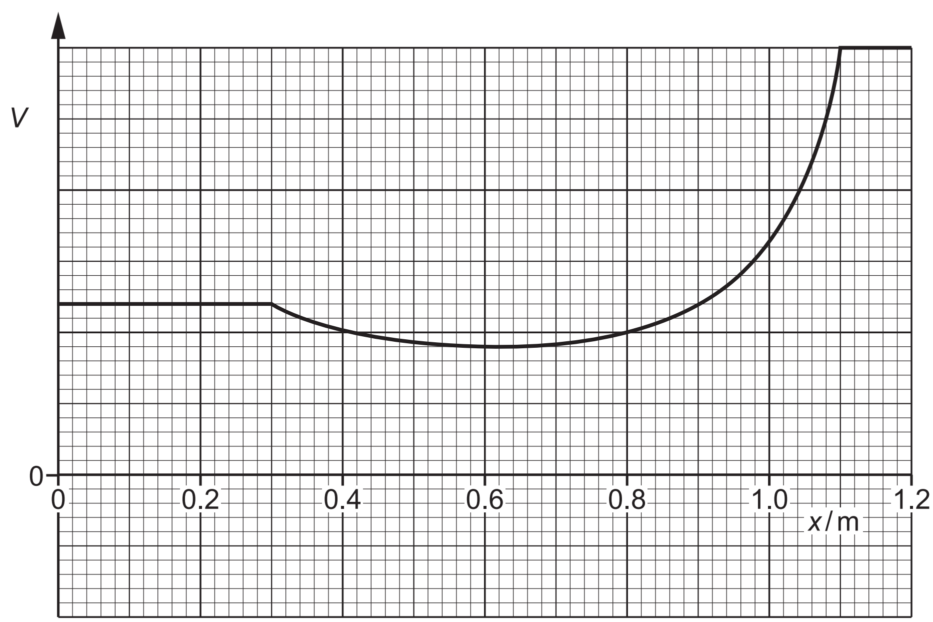

Fig. 5.2

State **three** conclusions that may be drawn about the spheres from Fig. 5.2. The conclusions may be qualitative or quantitative.

1 ....

....

2 ....

....

3 ....

....
[3]

(c) A proton is held at rest on the line joining the centres of the spheres in **(b)** at the position where x = 0.60 m.

The proton is released.

Describe and explain, without calculation, the subsequent motion of the proton.

....

....

.... [2]

[Total: 7]

6 **(a)** Two capacitors X and Y are connected in series to a power supply of voltage V, as shown in Fig. 6.1.

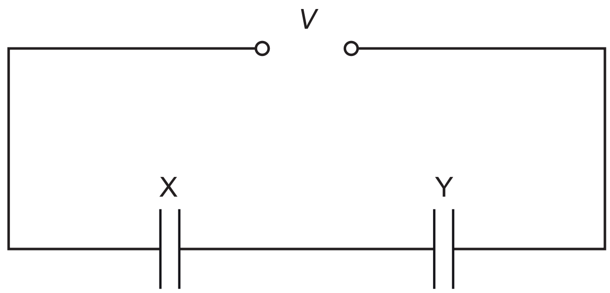

Fig. 6.1

The capacitance of X is C_X and the capacitance of Y is C_Y.

Derive an expression, in terms of C_X and C_Y, for the combined capacitance C_T of the capacitors in this circuit.
Explain your reasoning.

[3]

(b) Two capacitors P and Q are connected in parallel to a power supply of voltage V.
The capacitance of P is 200 μF. The capacitance C_Q of Q can be varied between 0 and 400 μF.
When $C_Q = 0$, the total energy stored in the capacitors is 2.5 mJ.

(i) Show that the supply voltage V is 5.0 V.

[2]

(ii) Calculate the total energy, in mJ, stored in the capacitors when C_Q has its maximum value.

total energy = ... mJ [3]

(iii) On Fig. 6.2, sketch the variation of the total energy E stored in the capacitors with C_Q, as C_Q varies from 0 to 400 μF.

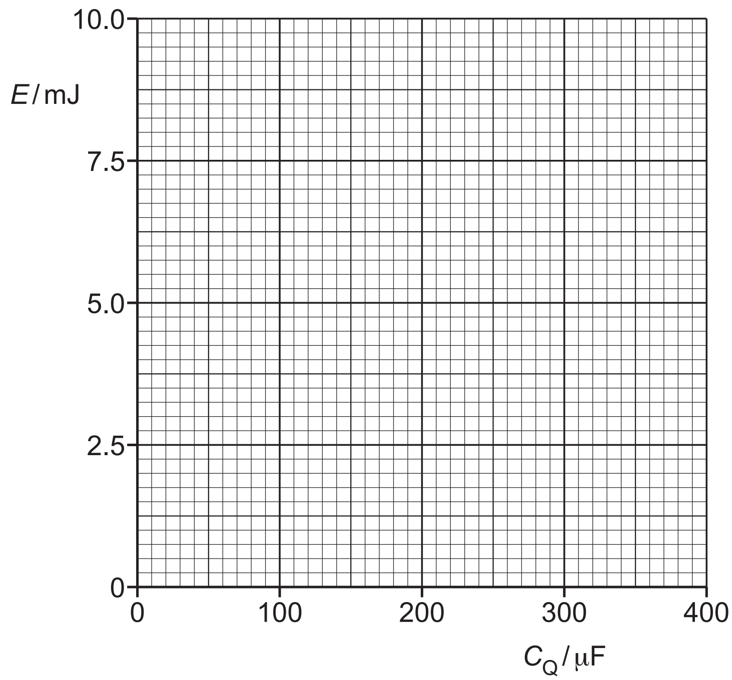

Fig. 6.2

[2]

[Total: 10]

7 **(a)** State Faraday's law of electromagnetic induction.

....

....

.... [2]

(b) Fig. 7.1 shows a coil at rest in a uniform magnetic field that is parallel to the axis of the coil.

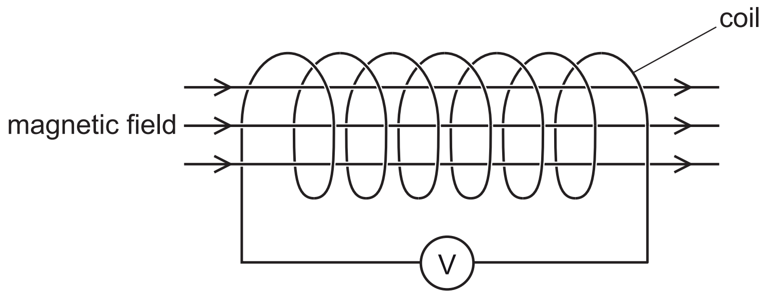

Fig. 7.1

The coil is connected to a centre-zero voltmeter.

The flux density *B* of the uniform magnetic field varies with time *t* as shown in Fig. 7.2.

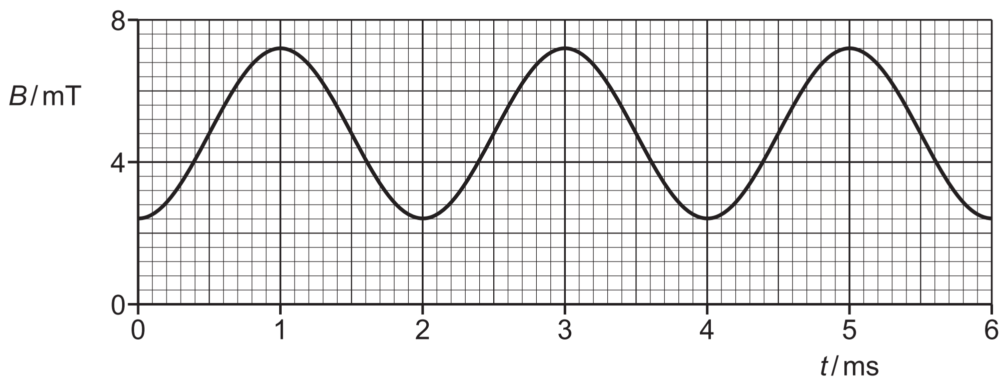

Fig. 7.2

The coil consists of 340 turns, each of cross-sectional area $3.2 \times 10^{-4}\,m^2$.

(i) Calculate the maximum magnetic flux through **one** turn of the coil.

maximum magnetic flux = ... Wb [2]

(ii) Determine the maximum rate of change of magnetic flux linkage in the coil.

maximum rate of change of flux linkage = ... $Wb\,s^{-1}$ [3]

(iii) State the maximum electromotive force (e.m.f.) V_0 induced across the coil.

V_0 = ... V [1]

(iv) On Fig. 7.3, sketch the variation of the e.m.f. V induced across the coil with t from t = 0 to t = 6.0 ms.

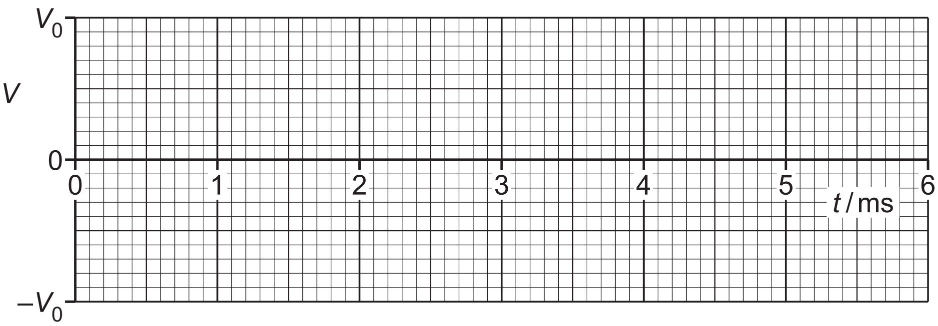

Fig. 7.3

[3]

(v) The variation of V with t can be described by

$$V = A \sin Bt$$

where A and B are constants.

Determine the values of A and B. Give units with your answers.

A = ... unit ....

B = ... unit ....

[3]

[Total: 14]

8 Fig. 8.1 shows part of the emission spectrum of visible radiation emitted by hydrogen gas in a star in a distant galaxy.

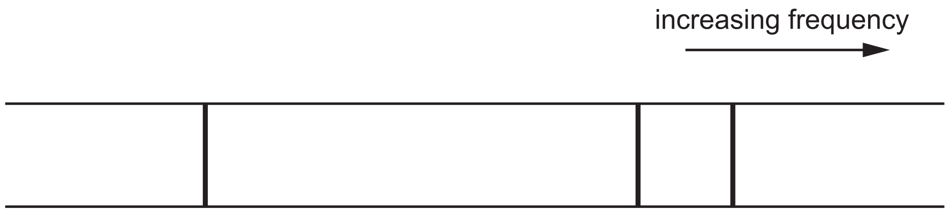

Fig. 8.1

The galaxy is moving away from the Earth at a speed of $6.2 \times 10^6\,\text{m}\,\text{s}^{-1}$.

(a) **(i)** Explain how the positions of the lines in the emission spectrum seen by an observer on the Earth differ from the positions shown in Fig. 8.1.

....

....

.... [2]

(ii) On Fig. 8.1, draw the three lines in possible positions in the spectrum seen by the observer. [2]

(b) The lines in Fig. 8.1 correspond to electron transitions down to the energy level –3.40 eV. One of the lines represents emitted radiation of wavelength 488 nm.

(i) Calculate the energy of a photon of this radiation.

photon energy = ... J [2]

(ii) Determine the energy, in eV, of the energy level from which the electron transition originates to cause the emission of this radiation.

energy level = ... eV [2]

(iii) Determine the wavelength, in nm, of this radiation as detected by the observer on the Earth.

wavelength = ... nm [2]

(c) A value for the Hubble constant is $2.3 \times 10^{-18}\,s^{-1}$.

Determine the distance of the galaxy from the Earth.

distance = ... m [2]

[Total: 12]

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

....

....

.... [2]

(b) Table 9.1 shows the masses of two sub-atomic particles and a polonium-212 ($^{212}_{84}Po$) nucleus.

Table 9.1

	mass / u
proton	1.007 276
neutron	1.008 665
polonium-212 nucleus	211.942 749

For the polonium-212 nucleus, determine:

(i) the mass defect Δm, in kg

Δm = ... kg [3]

(ii) the binding energy

binding energy = ... J [2]

(iii) the binding energy per nucleon.

binding energy per nucleon = ... J [1]

(c) **(i)** On Fig. 9.1, sketch the variation with nucleon number *A* of binding energy per nucleon for values of *A* from 1 to 250.

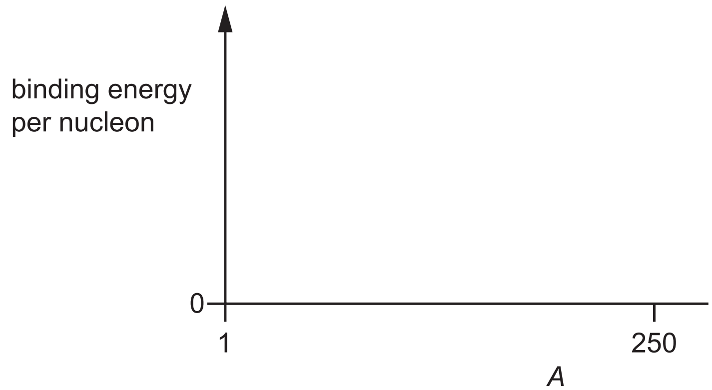

Fig. 9.1

[2]

(ii) On your line in Fig. 9.1, draw an X to show the approximate position of polonium-212. [1]

(iii) Polonium-212 is radioactive and undergoes alpha-decay.

Suggest and explain, with reference to Fig. 9.1, why the alpha-decay of polonium-212 results in a release of energy.

....

....

.... [2]

[Total: 13]

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10 (a) Describe how reflected ultrasound pulses may be used to obtain diagnostic information about internal structures.

....

....

....

.... [2]

(b) (i) Define specific acoustic impedance of a medium.

....

....

.... [2]

(ii) Table 10.1 shows some data for water and for glass.

Table 10.1

	density / $kg\,m^{-3}$	speed of sound / $m\,s^{-1}$
water	1000	1420
glass	2500	4560

Determine the intensity reflection coefficient for ultrasound that is incident on a water–glass boundary.

intensity reflection coefficient = ... [3]

[Total: 7]

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