EUNOIA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS 2024
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME	

CIVICS GROUP	2	3	-			REGISTRATION NUMBER		

PHYSICS

9749/02

Structured Questions

September 2024

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
The use of an approved scientific calculator is expected where appropriate.
Answer **all** questions.

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use paper clips, highlighters, glue or correction fluid.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Q1	10
Q2	10
Q3	10
Q4	8
Q5	6
Q6	6
Q7	10
Q8	20
s.f.	
P2 Total	80

This document consists of **23** printed pages and **1** blank page.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$\left(1/\left(36\pi\right)\right) \times 10^{-9}$ F m^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_e = 9.11 \times 10^{-31}$ kg
rest 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,	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{Gm}{r}$
temperature,	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\, \omega \sqrt{\left(x_0^2 - x^2\right)}$
electric current,	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 n I$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 **(a)** State the two conditions necessary for a system to be in equilibrium.

(i) ……………………………………………………………………………………………….

(ii) ……………………………………………………………………………………………….[2]

(b) Explain what is meant by the *centre of gravity* of a body.

……………………………………………………………………………………………..... [1]

(c) A rod AB is hinged to a wall at A. The rod is held horizontally by means of a cord BD, attached to the rod at end B and to the wall at D, as shown in Fig. 1.1.

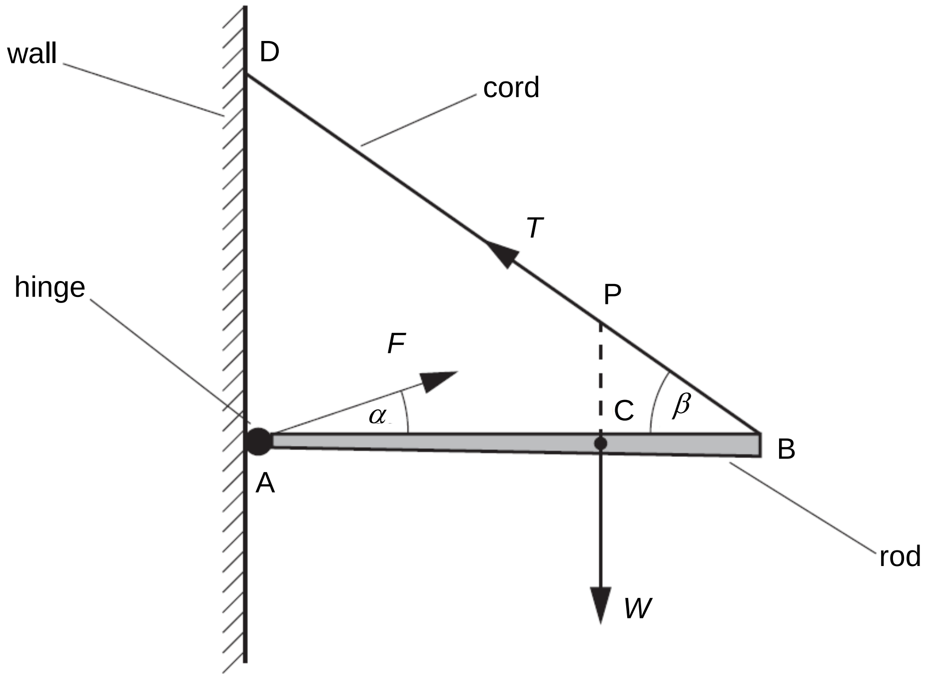

Fig. 1.1

The rod has weight W and the centre of gravity of the rod is at C.

The rod is held in equilibrium by a force T in the cord and a force F produced at the hinge.

(i) The line of action of the weight W of the rod passes through the cord at point P.

Explain why, for the rod to be in equilibrium, the force F produced at the hinge must also pass through point P.

……………………………………………………………………………………………….

……………………………………………………………………………………………….

……………………………………………………………………………………………….[2]

(ii) It is given that W = 10 N, β = 30° and length AC = $\frac{2}{3}$AB.

Calculate
1. tension T, and

T = ……………………………….. N [2]

2. angle α.

α = ……………………………….. ° [3]

[Total: 10]

2 (a) An object of mass 0.80 kg is placed at a distance r from the centre P of a flat disc rotating horizontally with an angular speed ω. It undergoes circular motion with the disc, as shown in Fig. 2.1.

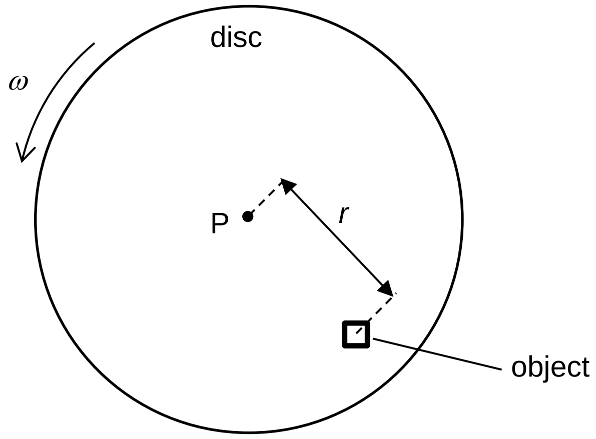

Fig. 2.1 (top view)

To determine the maximum frictional force acting on the object, the angular speed is slowly increased until the object starts to slide. For different values of r, this value of the angular speed is recorded as ω_{max}. The variation with $\frac{1}{r}$ of ω_{max}^2 is shown in Fig. 2.2.

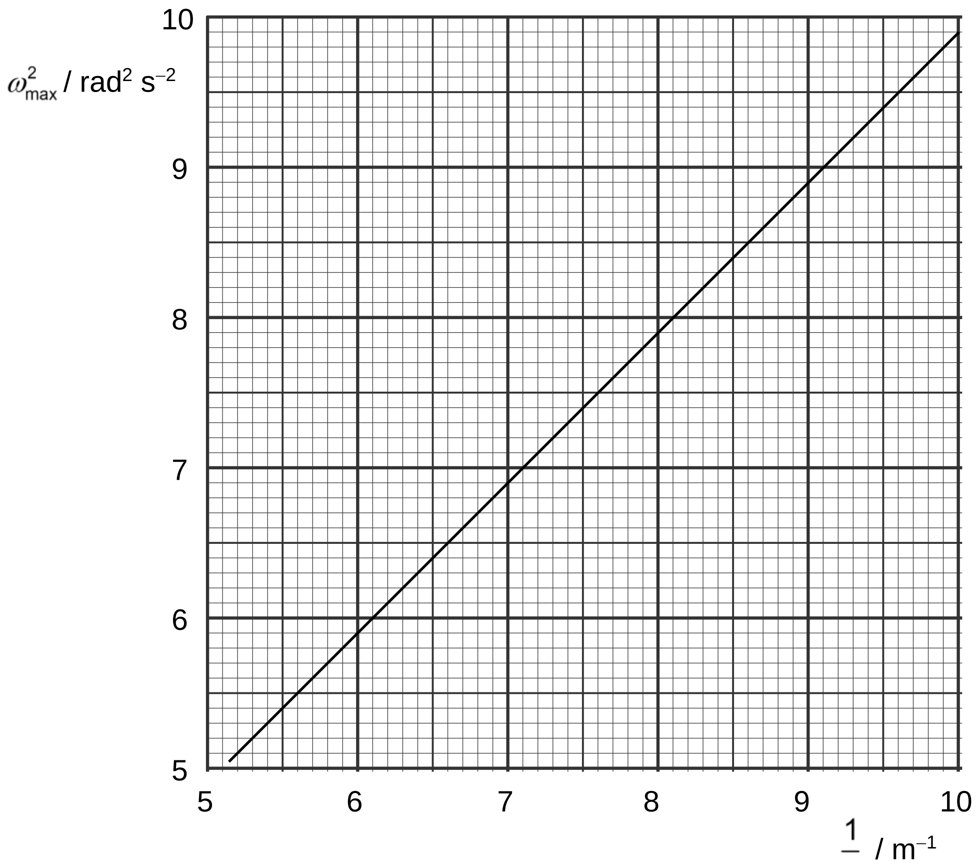

Fig. 2.2

(i) On Fig. 2.1, draw an arrow to show the direction of the frictional force acting on the object at the instant shown. Label this arrow Z. [1]

(ii) Explain the direction of the frictional force in **(a)(i)**.

……………………………………………………………………………………………………….

…………………………………………………………………………………………………… [1]

(b) **(i)** Determine the gradient of the line in Fig. 2.2.

gradient = ……………………………….. [2]

(ii) Suggest the physical significance of the gradient. Show any necessary working.

……………………………………………………………………………………………………….

…………………………………………………………………………………………………… [2]

(c) Determine the maximum frictional force acting on the object.

maximum frictional force = ………………………………..N [2]

(d) Explain why the object starts to slide as angular speed increases.

………………………………………………………………………………………………………..

………………………………………………………………………………………………………..

………………………………………………………………………………………………………..

…………………………………………………………………………………………………… [2]

[Total: 10]

3 **(a)** Explain what is meant by

(i) a free oscillation,

....

.... [1]

(ii) the natural frequency of an oscillating body.

....

.... [1]

(b) A strip of metal is clamped to the edge of a bench and a mass is hung from its free end as shown in Figure 3.1.

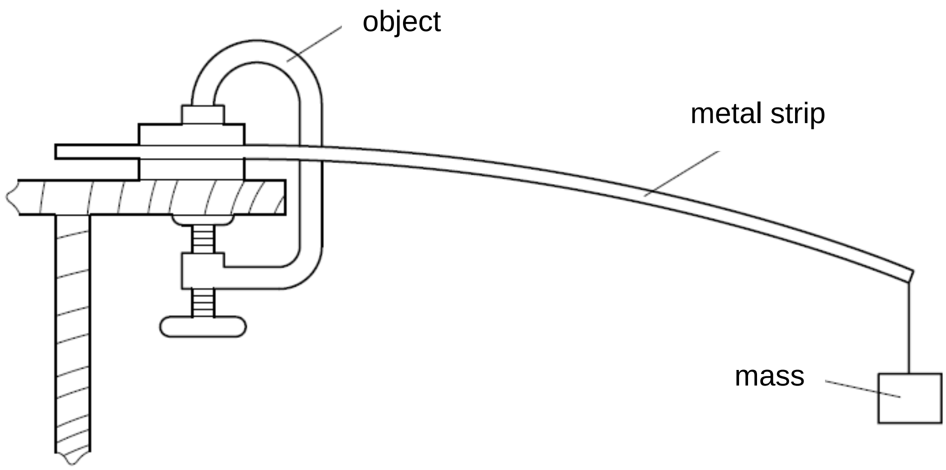

Fig. 3.1

The end of the strip is pulled downwards by 2.0×10^{-3} m and then released.

Fig. 3.2 shows the variation with time t of the displacement y of the end of the strip.

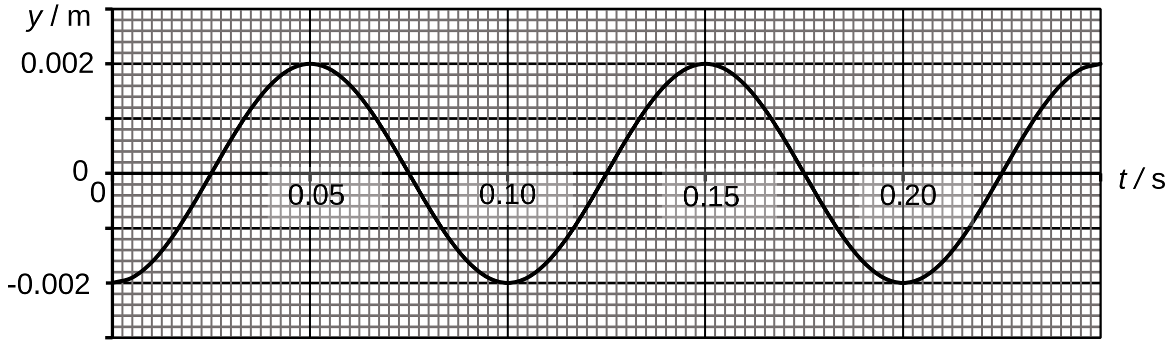

Fig. 3.2

(i) On Fig. 3.3, show the corresponding variation with time t of the potential energy E_p of the vibrating system from t = 0 to t = 0.20 s. Assume the vibrating system to have a mass of 200 g.

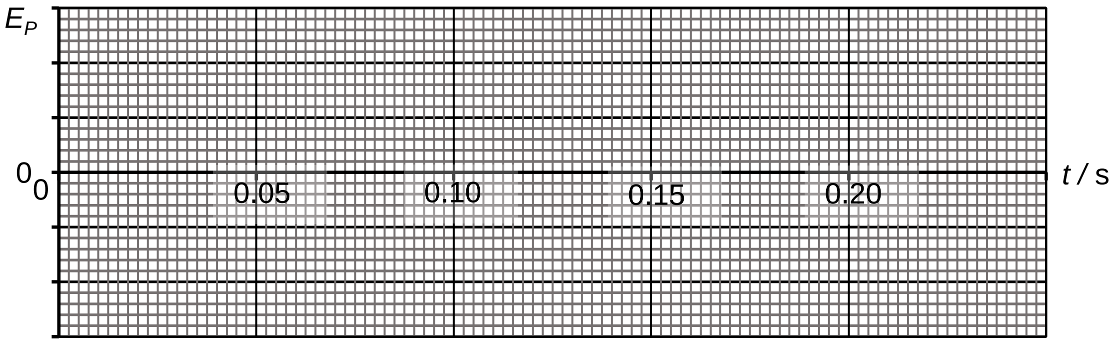

Fig 3.3

[3]

(ii) On Fig. 3.4, sketch the variation with displacement y of the velocity v of the end of the strip.

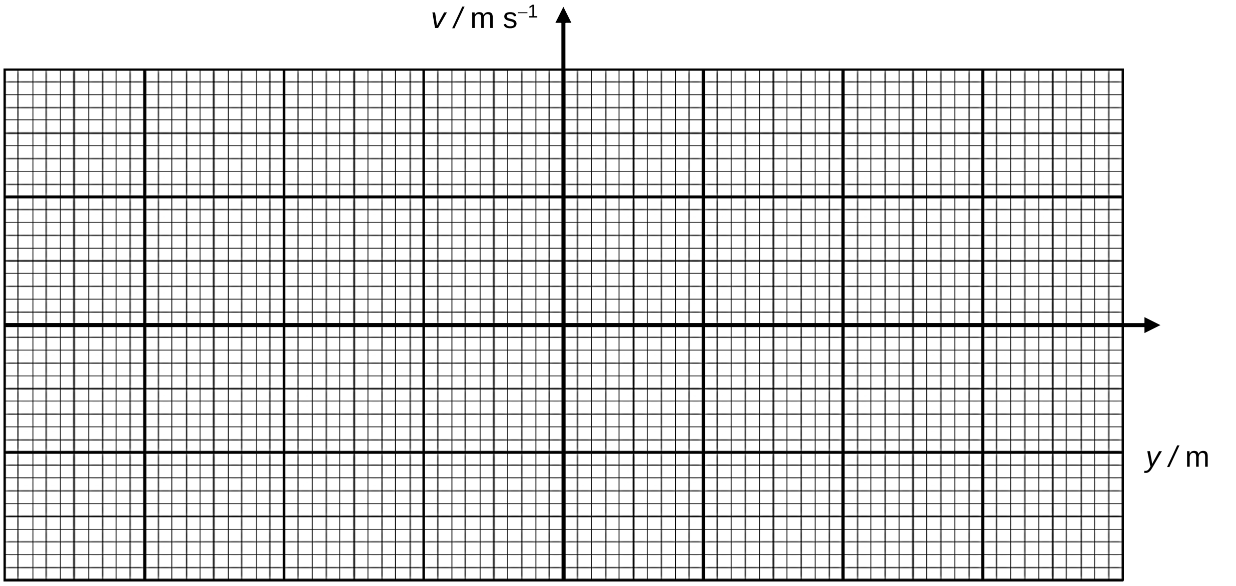

Fig 3.4

[3]

(ii) The string supporting the mass breaks when the end of the strip is at its lowest point in an oscillation.

1. State what change, if any, will occur in the period of the subsequent motion of the end of the strip.

period: ……………………………………………………………………………………

2. State and **explain** the change, if any, on the amplitude of the subsequent motion of the end of the strip.

amplitude: ……………………………………………………………………………………

……………………………………………………………………………………………… [2]

[Total: 10]

4 **(a)** **(i)** State the principle of conservation of linear momentum.

……………………………………………………………………………………………

……………………………………………………………………………………………[1]

(ii) State the relation between force and momentum.

……………………………………………………………………………………………

……………………………………………………………………………………………[1]

(b) A fast-moving neutron of mass m collides head-on with a stationary nitrogen atom of mass $14m$ as illustrated in Fig. 4.1.

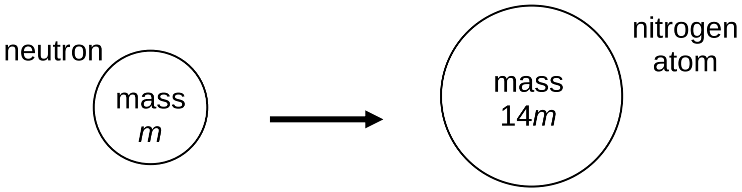

Fig. 4.1

The neutron is captured by the atom to form a heavy isotope of nitrogen of $15m$.

(i) Explain the subsequent motion of the isotope given that the collision is head-on.

……………………………………………………………………………………………

……………………………………………………………………………………………. [1]

(ii) Calculate the ratio of kinetic energy of the heavy isotope of nitrogen to the initial kinetic energy of the neutron.

ratio of kinetic energy = ………………………………….. [3]

(iii) Hence or otherwise, explain whether the collision process whereby the neutron is captured is elastic or inelastic.

……………………………………………………………………………………………..……..

……………………………………………………………………………………………..… [2]

[Total: 8]

5 Fig. 5.1 shows two circular coils X and Y that are fixed in position.

The planes of both coils are parallel and their centres lie along a common axis PQ.

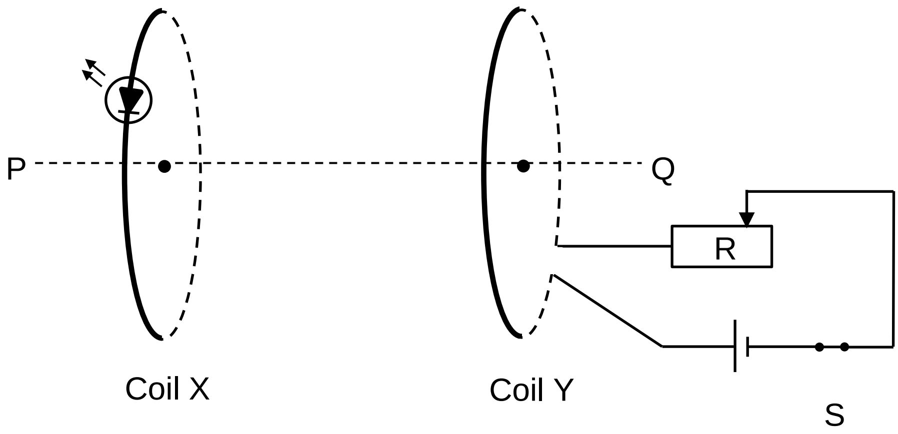

Fig. 5.1

A light emitting diode (LED) is connected to coil X.

Coil Y is connected to a cell, a switch S and a variable resistor R.

R is set to its maximum value and S is closed.

(a) Based on the laws of electromagnetic induction, describe and explain what would be observed of the LED when S is opened.

....

....

....

....

....

....

....

....

....[4]

(b) The cell in Fig. 5.1 is now replaced by an alternating voltage source.

The sinusoidal current flowing through coil Y is shown in Fig. 5.2.

Current flowing in the clockwise direction, when the coils are viewed from Q, is taken as positive.

On the axes of Fig. 5.3, sketch the variation with time t of the current I_X flowing through coil X from t = 0 to t = 0.040 s.

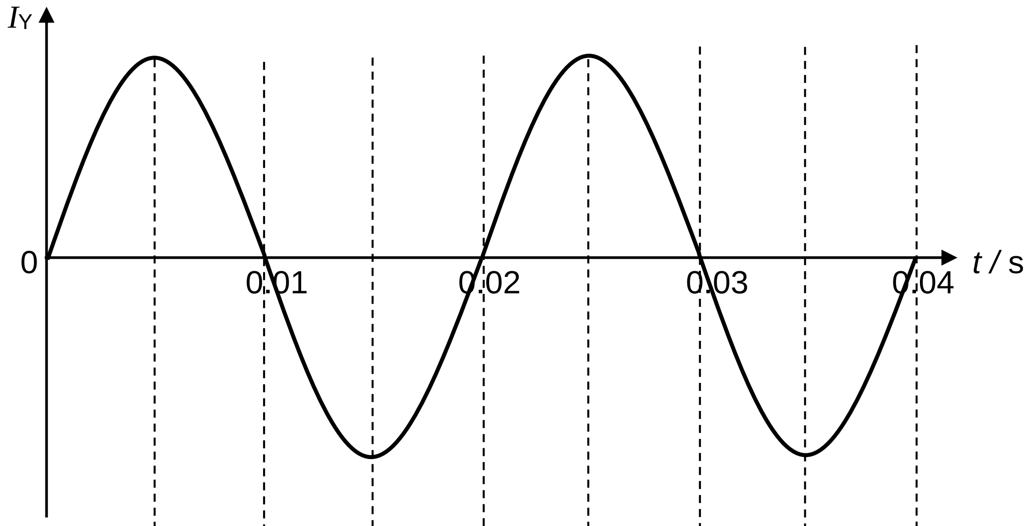

Fig. 5.2

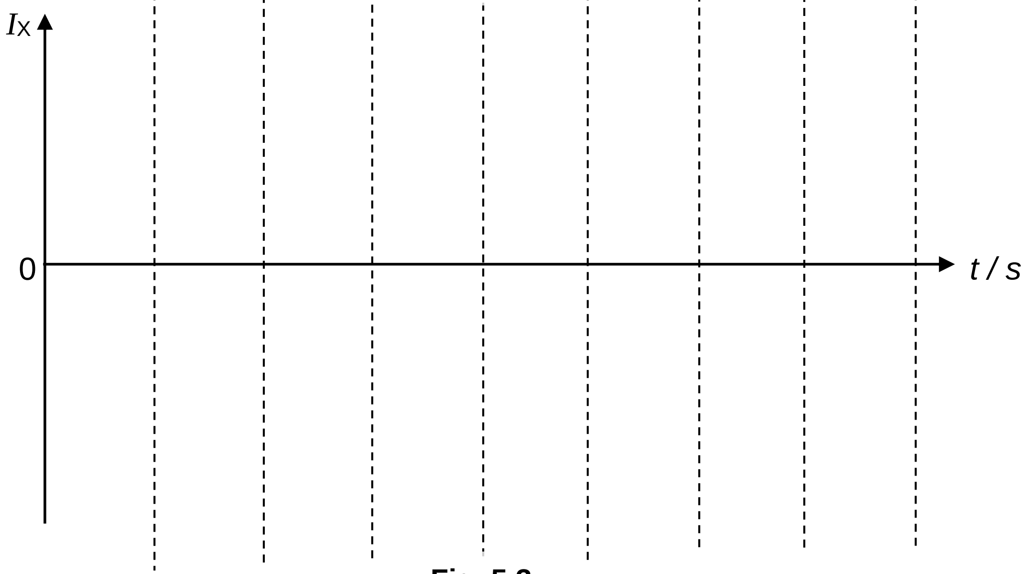

Fig. 5.3

[2]

[Total: 6]

6 **(a)** An ideal iron core transformer is shown in Fig. 6.1.

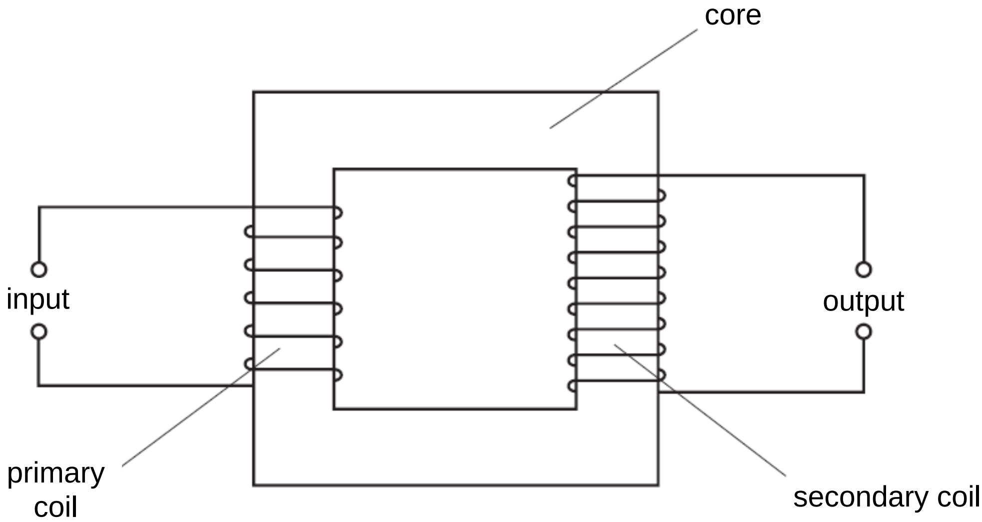

Fig. 6.1

Explain

(i) why the iron core is laminated,

……………………………………………………………………………………………….

……………………………………………………………………………………………….[1]

(ii) why the alternating current in the primary coil of a transformer is not in phase with the alternating e.m.f. induced in the secondary coil.

……………………………………………………………………………………………….

……………………………………………………………………………………………….

……………………………………………………………………………………………….

……………………………………………………………………………………………….[3]

(b) An ideal transformer has 300 turns on the primary coil and 8100 turns on the secondary coil.

The root-mean-square input voltage to the primary coil is 9.0 V.

Calculate the peak voltage across the load resistor connected to the secondary coil.

peak voltage = ………………………….. V [2]

[Total: 6]

7 **(a)** Fig. 7.1 shows the path of a beam of electrons before it passes through a magnetic field.

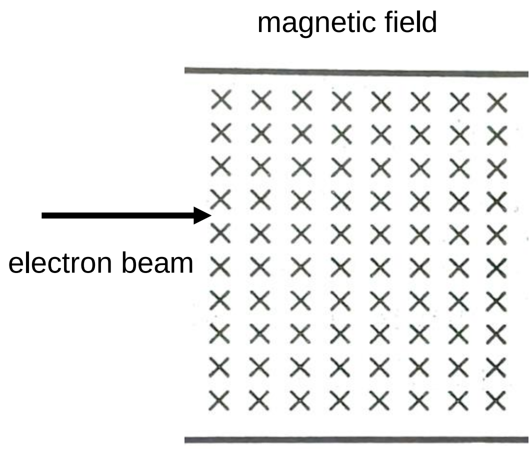

Fig. 7.1

The magnetic flux density in the uniform magnetic field is 0.0050 T. Each electron enters the magnetic field with a speed of $v = 5.0 \times 10^6$ m s^{-1}.

(i) The magnetic force causes the electrons to accelerate in the magnetic field. Explain whether the force does work on the electron.

……………………………..………………………………………………………………

…..……………………………………………………………………………………… [1]

(ii) Determine the magnetic force acting on the electron.

magnetic force = ……………………….N [2]

(iii) Show that the radius of the electrons' path is 5.7 mm.

[2]

(iv) If a proton beam is used instead and the protons travel at the same speed as the electrons, explain qualitatively why this setup may not be practical in a typical school laboratory.

………………………………..………………………………………………………………

…..…………………………………………………………………………………………… [2]

(b) Another beam of electrons enters a uniform electric field between two parallel plates at right angles to the field as shown in Fig. 7.2. The region between the plates is a vacuum.

Each electron has mass *m*, charge *e* and speed *v*.

The length of the plates is *x*, the separation of the plates is *d* and the potential difference across the plates is *V*.

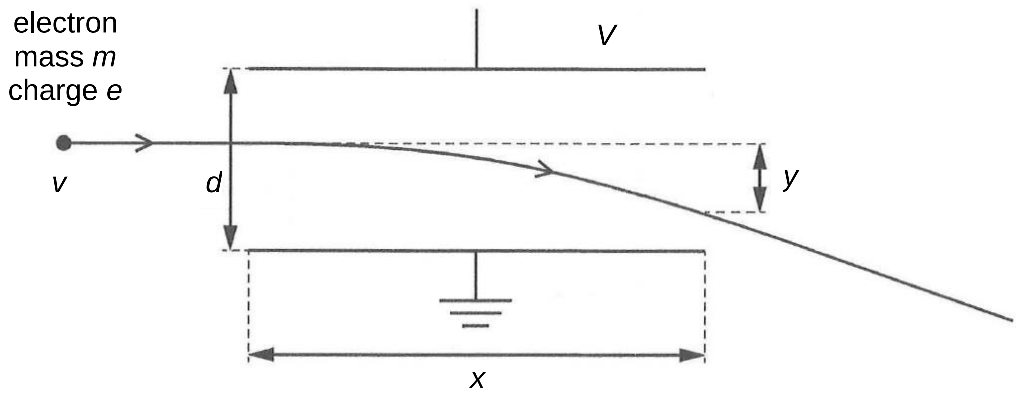

Fig 7.2

The vertical deflection of the electron is *y* at the point where it leaves the region between the plates.

Write down an equation for *y* in terms of *d*, *e*, *m*, *v*, *V,* and *x*. Show your working.

y =…………………………….. [3]

[Total:10]

8 Read the passage below and answer the questions that follow.

Ionizing radiation affects DNA molecules within cells, which are critical in cell reproduction. It has its greatest effect on cells that rapidly reproduce, including most types of cancer. It can induce cancer and cure cancer. It is used routinely for medical diagnostic purposes.

The biological effects of ionizing radiation on living tissue are directly proportional to the amount of ionization produced in the living tissue. The amount of ionization produced is in turn proportional to the energy deposited.

Absorbed dose of a radiation refers to the amount of ionizing radiation energy absorbed per unit mass of tissue. The unit for absorbed dose is the **gray (Gy)**, which is defined to be

$$1 \text{ Gy} = 1 \text{ J kg}^{-1}.$$

The biological effects of ionizing radiation also depend on the type of radiation and the type of tissue. **Dose equivalent** of a radiation considers both the amount of radiation absorbed and the medical effects of that type of radiation. It is calculated by multiplying the absorbed dose in grays by a quality factor called the **relative biological effectiveness (RBE)**, and is measured in **sievert (Sv).**

$$1 \text{ Sv} = 1 \text{ Gy} \times \text{RBE}$$

Table 8.1 gives the RBE values for several types of ionizing radiation.

Type and energy of radiation	**RBE**
X-rays	1
γ rays	1
β rays (> 32 keV)	1
β rays (< 32 keV)	1.7
neutrons, thermal to slow (< 20 keV)	*5
neutrons, fast (1 - 10 MeV)	10 (body), 32 (eyes)
protons (1 - 10 MeV)	10 (body), 32 (eyes)
α rays from radioactive decay	*20
heavy ions from accelerators	*20

*only maximum values provided

Table 8.1

The greater the dose equivalent, the greater the biological effects. If a radiation exposure is spread out over a longer duration, greater doses are needed to cause the same biological effect. This is due to the body’s ability to partially repair the damage.

Laws regulate radiation doses to which people can be exposed. The greatest occupational whole-body dose that is allowed is about 20 to 50 mSv in a year and is rarely reached by medical and nuclear power plant workers.

(a) **(i)** With reference to Table 8.1 and the characteristics of the different ionising radiations, explain the following:

1. α rays have a higher RBE than X-rays, γ rays and energetic β rays.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………[2]

2. Neutrons do not carry any electrical charge but have an RBE greater than 1.

……………………………………………………………………………………………

…………………………………………………………………………………………[1]

(ii) To limit or reduce radiation doses, one general principle is to *limit the time of exposure*. Suggest two other general principles to limit radiation doses.

……………………………………………………………………………………………

…………………………………………………………………………………………[2]

(iii) Calculate the dose absorbed over a period of one year by the lung tissue of a weapons plant employee who inhales and retains plutonium-239 in an accident. The activity of the plutonium-239 inhaled remains approximately constant at 3.70×10^4 Bq over many years.

The mass of the affected lung tissue is 2.00 kg, and each plutonium-239 nucleus decays by emitting a 5.23 MeV α-particle.

dose = ………………………….. Sv [3]

(b) A *radioactive tracer* is a drug that contains radioactive isotopes. It can be injected into a patient. Gamma emitters make good radioactive tracers.

Once the tissues and organs have absorbed the tracer, radiation from the tracer is captured by a special camera outside the body that produces images, allowing doctors to diagnose the condition of the patient.

(i) In addition to being safer since gamma radiation has a lower RBE, suggest one other advantage of using a gamma-emitting tracer in a patient, rather than a beta-emitting tracer.

……………………………………………………………………………………………….

……………………………………………………………………………………………….

……………………………………………………………………………………………….[1]

(ii) Biological half-life is the time taken by the human body to eliminate, by natural excretion, half of the amount of a substance (such as a radioactive material) that has entered the body. The process is approximately exponential.

The effective decrease of radioactivity of a tracer in the body is due to both the physical decay of the tracer and the biologic elimination of the tracer by the body.

The effective decay constant λ_E of the tracer is given by

$$\lambda_E = \lambda_B + \lambda_T$$

where λ_T is the nuclear decay constant of the radioisotope in the tracer,
and λ_B is the biological decay constant of the tracer.

Show that the effective half-life t_E of the tracer is given by

$$t_E = \frac{t_T t_B}{t_T + t_B}$$

where t_T is the nuclear half-life of the radioisotope in the tracer,
and t_B is the biological half-life of the tracer.

[1]

(iii) A patient is given an injection containing 1.0×10^{-12} g of technetium-99m, which has a nuclear half-life of 6.02 hours. The molar mass of technetium-99m is 99 g.

1. Show that the initial activity of the technetium-99m is 1.9×10^{5} Bq.

activity = ………………………….. Bq [2]

2. Calculate the effective half-life of the technetium-99m if its biological half-life in the body is 24 hours.

effective half-life = ………………………….. h [1]

3. Determine the activity of the technetium-99m remaining in the patient 3.0 days after the injection.

activity = ………………………….. Bq [2]

(c) It is often convenient to represent the decay of a radioactive sample with time using a semi-log graph as it produces a straight-line plot.

When a sample contains a mixture of unrelated radioactive nuclides (i.e. no parent-daughter relationships), the total activity A_{total} of the sample is just the sum of the individual activities of the different nuclides.

$$A_{total} = A_1 + A_2 + \ldots$$

where A_1 is the activity due to the first nuclide,
and A_2 is the activity due to the second nuclide, and so on.

In this case, the plot of A_{total} against time will be a curve on the semi-log graph.

Fig.8.1 shows the total activity curve A_{total} for a sample consisting of two unrelated radioactive nuclides. The dashed line A_1 is the activity curve for nuclide 1, which has the longer half-life. Nuclide 2 has an activity of 5 Bq on day 18, indicated by point P.

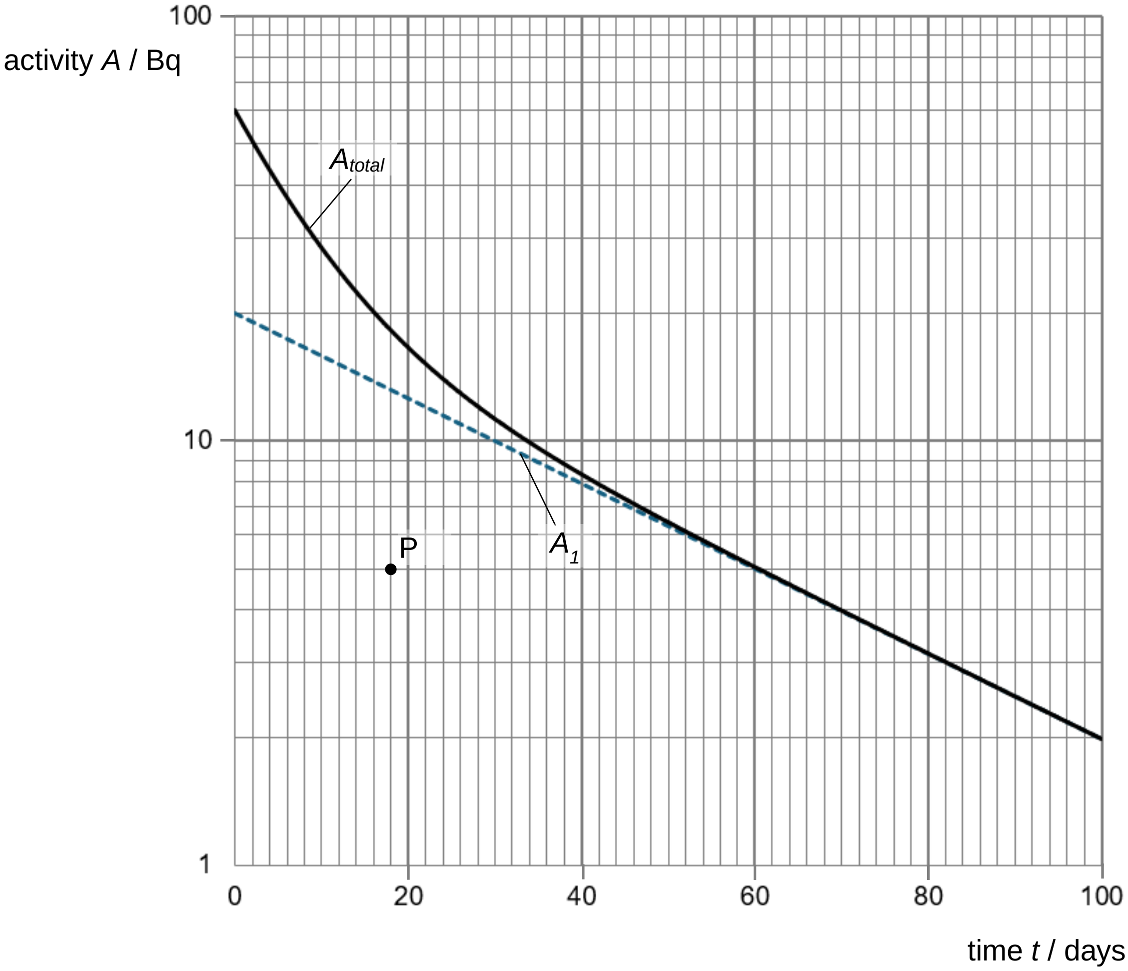

Fig. 8.1

(i) Explain why the slope of the graph of A_{total} against time will eventually follow the slope of the line for the activity of the radioactive nuclide having the longer half-life.

………………………………………………………………………………………………….

……………………………………………………………………………………………[1]

(ii) State the half-life of nuclide 1.

half-life = ………………………….. day [1]

(iii) Determine the initial activity of nuclide 2 at t = 0 day.

activity = ………………………….. Bq [1]

(iv) Draw a line in Fig.8.1 to show the variation with time t of the activity of nuclide 2. Label this line A_2. [1]

(v) Hence or otherwise, determine the half-life of nuclide 2.

half-life = ………………………….. day [1]

[Total: 20]

BLANK