Mixed Exam Questions - Set 12

1.

An isotope of polonium-213 ($^{213}_{84}Po$) first decays into an isotope of lead-209 ($^{209}_{82}Pb$) and this lead isotope then decays into the stable isotope of bismuth (Bi).

Fig. 24 shows two arrows on a neutron number *N* against proton number *Z* chart to illustrate these two decays.

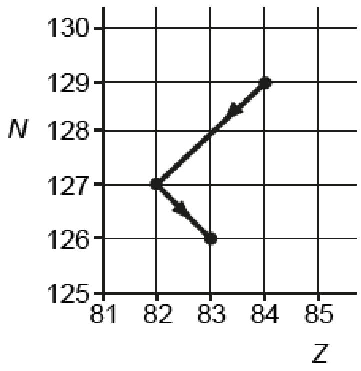

Fig. 24

(a) Complete the nuclear decay equations for

(i) the polonium isotope

$^{213}_{84}Po \longrightarrow ^{209}_{82}Pb$ + ... **[1]**

(ii) the lead isotope.

$^{209}_{82}Pb \longrightarrow ^{\cdots}_{83}Bi + ^{0}_{-1}e$ + ... **[2]**

(b) A pure sample of polonium-213 is being produced in a research laboratory.

The half-life of $^{213}_{84}Po$ is very small compared with the half-life of $^{209}_{82}Pb$.

After a very short time, the ionising radiation detected from the sample is mainly from the beta-minus decay of the lead-209 nuclei.

(i) Briefly describe and explain an experiment that can be carried out to confirm the beta-minus radiation emitted from the lead nuclei.

....

....

....

.... **[2]**

(ii) The activity of the sample of $^{209}_{82}Pb$ after 7.0 hours is 12 kBq.

The half-life of $^{209}_{82}Pb$ is 3.3 hours.

Calculate the initial number of lead-209 nuclei in this sample.

number of nuclei = ... **[4]**

2.

The nuclear reaction below shows how the isotope of fluorine-18 ($^{18}_{9}F$) is made from the isotope of oxygen-18 ($^{18}_{8}O$).

$$^{18}_{8}O + ^{1}_{1}p \rightarrow ^{18}_{9}F + ^{1}_{0}n + \gamma$$

The oxygen-18 nucleus is **stationary** and the proton has kinetic energy of 0.25×10^{-11} J. The binding energy of the $^{18}_{8}O$ nucleus is 2.24×10^{-11} J and the binding energy of the $^{18}_{9}F$ nucleus is 2.20×10^{-11} J. The proton and the neutron have zero binding energy.

(i) Explain why a high-speed proton is necessary to trigger the nuclear reaction shown above.

....

....

....

.... **[2]**

(ii) Estimate the minimum wavelength λ of the gamma ray photon (γ).

λ = ... m **[3]**

3.

(a) Fig. 20.1 shows a positively charged metal sphere and a negatively charged metal plate.

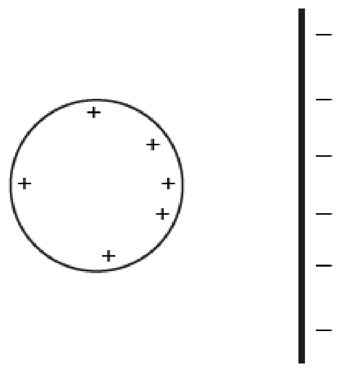

Fig. 20.1

On Fig. 20.1, draw a minimum of **five** electric field lines to show the field pattern between the sphere and the plate. **[2]**

(b) Define *electric potential* at a point in space.

....

.... **[1]**

(c) A metal sphere is given a positive charge by connecting its surface briefly to the positive terminal of a power supply. The electric potential at the surface of the sphere is + 5.0 kV. The sphere has radius 1.5 cm.

(i) Show that the charge Q on the surface of the sphere is 8.3×10^{-9} C.

[2]

(ii) Fig. 20.2 shows the charged sphere from **(i)** suspended from a nylon thread and placed between two oppositely charged vertical plates.

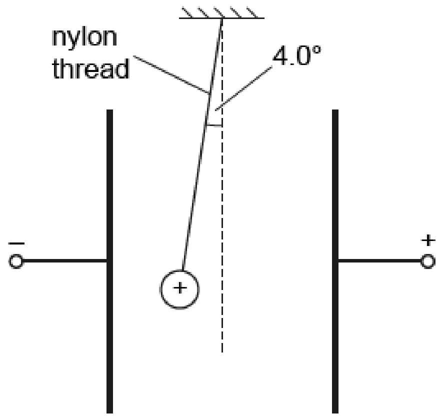

Fig. 20.2 (not to scale)

The weight of the sphere is 1.7×10^{-2} N. The string makes an angle of 4.0° with the vertical.

1. Show that the electric force on the charged sphere is 1.2×10^{-3} N.

[1]

2. Calculate the uniform electric field strength E between the parallel plates.

E = ... $N C^{-1}$ **[2]**

4.

Stars produce energy by nuclear fusion.
One particular fusion reaction between two protons ($^{1}_{1}H$) is shown below.

$$^{1}_{1}H + ^{1}_{1}H \rightarrow ^{2}_{1}H + ^{0}_{+1}e + \nu$$

In this reaction 2.2 MeV of energy is released.

(a) Only one of the particles shown in the reaction has binding energy.
Determine the binding energy per nucleon of this particle. Explain your answer.

....

....

.... **[2]**

(b) Explain why high temperatures are necessary for fusion reactions to occur in stars.

....

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....

....

.... **[2]**

(c) A gamma photon in a star can spontaneously create an electron-positron pair.
Calculate the **maximum** wavelength of a gamma photon for this creation event.

maximum wavelength = ... m **[3]**

5.

(a) (i) State **two** situations in which a charged particle will experience no magnetic force when placed in a magnetic field.

first situation ....

....

....

second situation ....

....

....

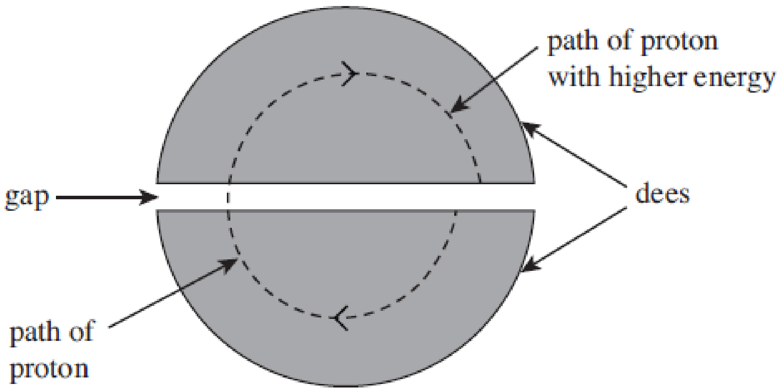
(2 marks)

(a) (ii) A charged particle moves in a circular path when travelling perpendicular to a uniform magnetic field. By considering the force acting on the charged particle, show that the radius of the path is proportional to the momentum of the particle.

(2 marks)

(b) In a cyclotron designed to produce high energy protons, the protons pass repeatedly between two hollow D-shaped containers called 'dees'. The protons are acted on by a uniform magnetic field over the whole area of the dees. Each proton therefore moves in a semi-circular path at constant speed when inside a dee. Every time a proton crosses the gap between the dees it is accelerated by an alternating electric field applied between the dees. **Figure 2** shows a plan view of this arrangement.

Figure 2



(b) (i) State the direction in which the magnetic field should be applied in order for the protons to travel along the semicircular paths inside each of the dees as shown in **Figure 2**.

....

(1 mark)

(b) (ii) In a particular cyclotron the flux density of the uniform magnetic field is 0.48 T. Calculate the speed of a proton when the radius of its path inside the dee is 190 mm.

speed .... $m s^{-1}$

(2 marks)

(b) (iii) Calculate the time taken for this proton to travel at constant speed in a semicircular path of radius 190 mm inside the dee.

time .... s

(2 marks)

(b) (iv) As the protons gain energy, the radius of the path they follow increases steadily, as shown in **Figure 2**. Show that your answer to part (b)(iii) does not depend on the radius of the proton's path.

....

....

....

....

....

....

(2 marks)

(c) The protons leave the cyclotron when the radius of their path is equal to the outer radius of the dees. Calculate the maximum kinetic energy, in MeV, of the protons accelerated by the cyclotron if the outer radius of the dees is 470 mm.

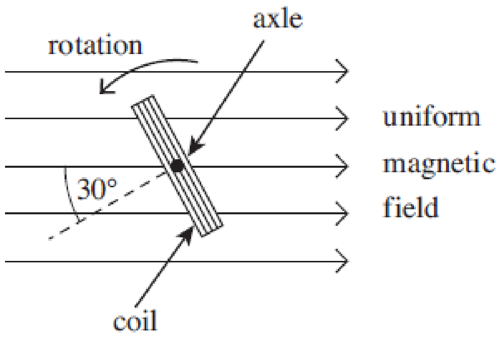
maximum kinetic energy .... MeV
(3 marks)

Question 2 is on the next page.

6.

A rectangular coil is rotating anticlockwise at constant angular speed with its axle at right angles to a uniform magnetic field. **Figure 3** shows an end-on view of the coil at a particular instant.

Figure 3



(a) At the instant shown in **Figure 3**, the angle between the normal to the plane of the coil and the direction of the magnetic field is 30°.

(a) (i) State the minimum angle, in degrees, through which the coil must rotate from its position in **Figure 3** for the emf to reach its maximum value.

angle .... degrees

(1 mark)

(a) (ii) Calculate the minimum angle, in radians, through which the coil must rotate from its position in **Figure 3** for the flux linkage to reach its maximum value.

angle .... radians

(2 marks)

(b) **Figure 4** shows how, starting in a different position, the flux linkage through the coil varies with time.

(b) (i) What physical quantity is represented by the gradient of the graph shown in **Figure 4**?

....

(1 mark)

(b) (ii) Calculate the number of revolutions per minute made by the coil.

revolutions per minute ....

(2 marks)

Figure 4

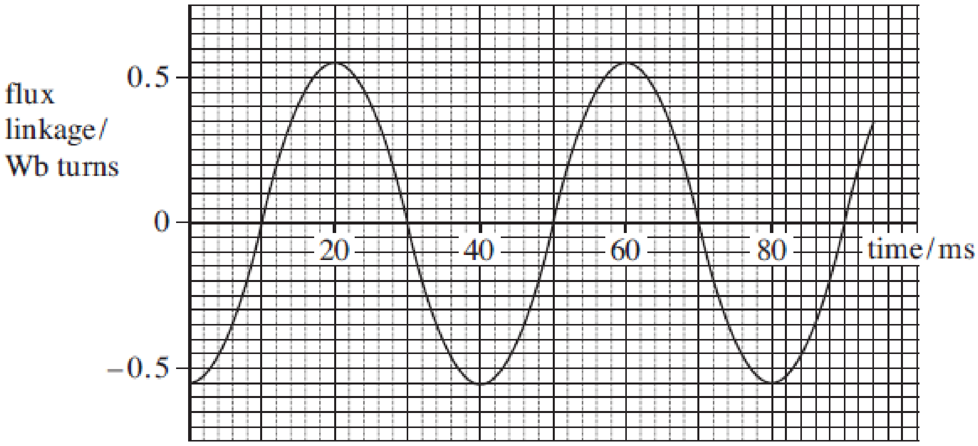
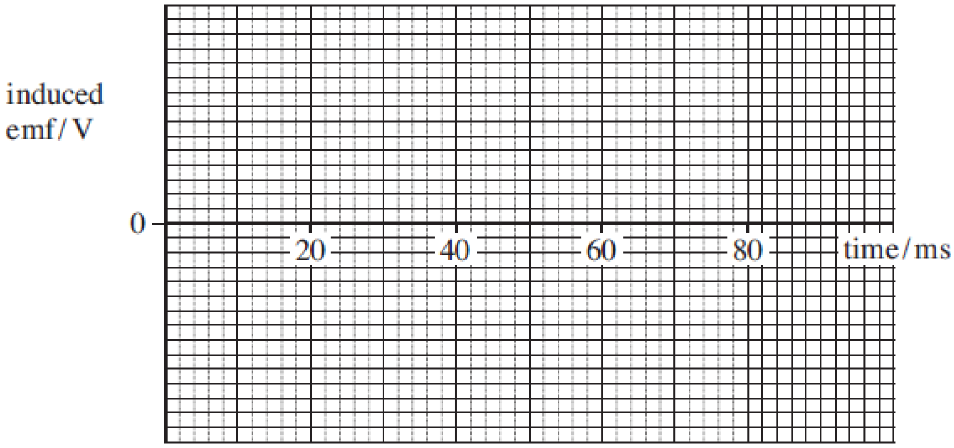


Figure 5



(b) (iii) Calculate the peak value of the emf generated.

peak emf V

(3 marks)

(c) Sketch a graph on the axes shown in **Figure 5** above to show how the induced emf varies with time over the time interval shown in **Figure 4**.

(2 marks)

(d) The coil has 550 turns and a cross-sectional area of $4.0 \times 10^{-3}\,m^2$.

Calculate the flux density of the uniform magnetic field.

flux density .... T
(2 marks)

7.

This question is about the discharge of combinations of capacitors.

In Figs. 4.1 and 4.2, the capacitors are charged through a 10 kΩ resistor from a 10 V d.c. supply when the switch **S** is connected to **X**. They discharge when the switch is moved to **Y**. The ammeters A_1, A_2, A_3 and A_4 monitor the currents in the circuits. Initially, the switch is connected to **X** and the capacitors are fully charged.

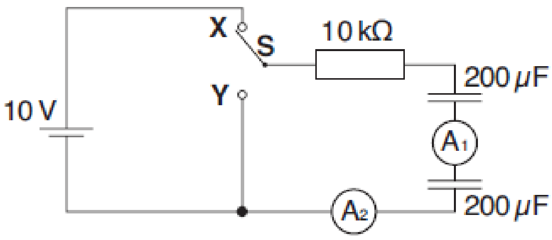


Fig. 4.1

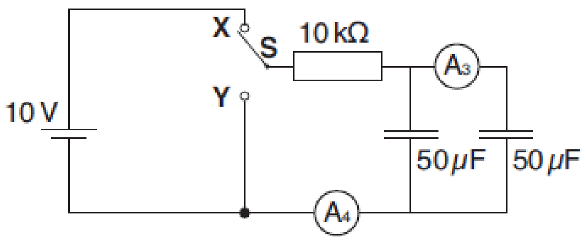


Fig. 4.2

(a) State

(i) the voltage across each capacitor in Fig. 4.1 .... V [1]

(ii) the voltage across each capacitor in Fig. 4.2 .... V [1]

(b) **(i)** Calculate the total charge stored in the circuit of Fig. 4.2.

charge = ... C [2]

(ii) Explain why the total charge stored in the circuit of Fig. 4.1 is the same as in the circuit of Fig. 4.2.

....

....

....

....[2]

(c) Fig. 4.3 shows how the reading I on ammeter A_2 in the circuit of Fig. 4.1 varies with time t as the capacitors discharge, after the switch is moved from **X** to **Y** at $t = 0$.

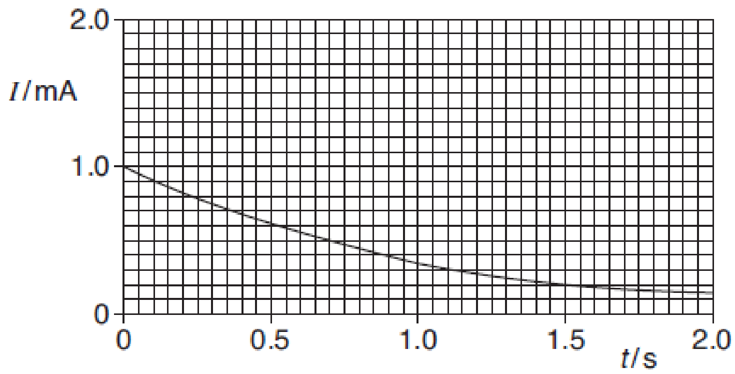


Fig. 4.3

(i) Describe how and explain why the reading on ammeter A_1 varies, if at all, over the same time interval.

....

....

....[2]

(ii) Sketch curves on Fig. 4.3 to show how you expect the readings on ammeters A_3 and A_4 to vary with time from $t = 0$, when the switch is moved from **X** to **Y** in Fig. 4.2. Label your curves **A_3** and **A_4** respectively. [3]