Selected Questions – Set 7

1.

(a) Fig. 3.1 shows two charged horizontal plates.

Fig. 3.1

The potential difference across the plates is 60V. The separation of the plates is 5.0mm.

(i) On Fig. 3.1 draw the electric field pattern between the plates. **[2]**

(ii) Calculate the electric field strength between the plates.

electric field strength = ... $V m^{-1}$ **[1]**

(b) Positive ions are accelerated from rest in the horizontal direction through a potential difference of 400V. The charged plates in **(a)** are then used to deflect the ions in the vertical direction. Fig. 3.2 shows the path of these ions.

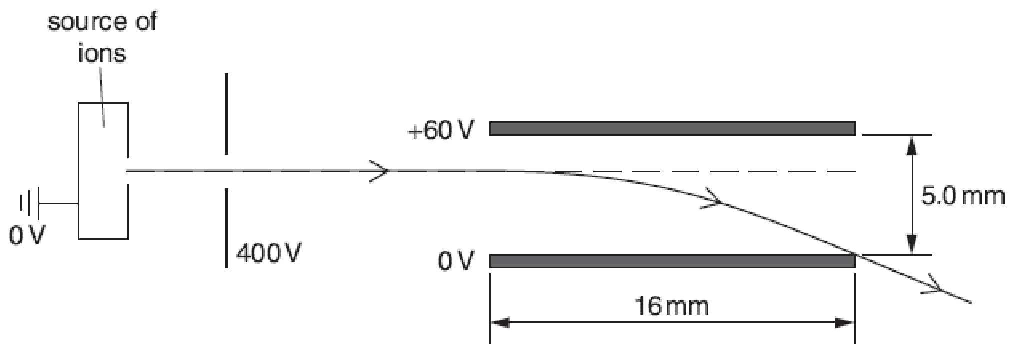


Fig. 3.2

Each ion has a mass of 6.6×10^{-27} kg and a charge of 3.2×10^{-19} C.

(i) Show that the horizontal velocity of an ion after the acceleration by the 400 V potential difference is $2.0 \times 10^{5}\,\mathrm{m\,s^{-1}}$.

[2]

(ii) The ions enter at right angles to the uniform electric field between the plates. Calculate the vertical acceleration of an ion due to this electric field.

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

(iii) The length of each of the charged plates is 16 mm.

1 Show that an ion takes about 8.0×10^{-8} s to travel through the plates.

[1]

2 Calculate the vertical deflection of an ion as it travels through the plates.

deflection = ... m **[2]**

(c) A uniform magnetic field is applied in the region between the plates in Fig. 3.2. The magnetic field is perpendicular to both the path of the ions and the electric field between the plates.

Calculate the magnitude of the magnetic flux density of field needed to make the ions travel horizontally through the plates.

magnetic flux density = ... T **[3]**

(d) Ions of the same charge but greater mass are accelerated by the potential difference of 400V described in **(b)**. Describe and explain the effect on the deflection of the ions after they have travelled between the plates using the same electric and magnetic fields of **(c)**.

....

....

....

.... **[2]**

2.

(a) State, in words, Coulomb's law.

[2 marks]

....

....

....

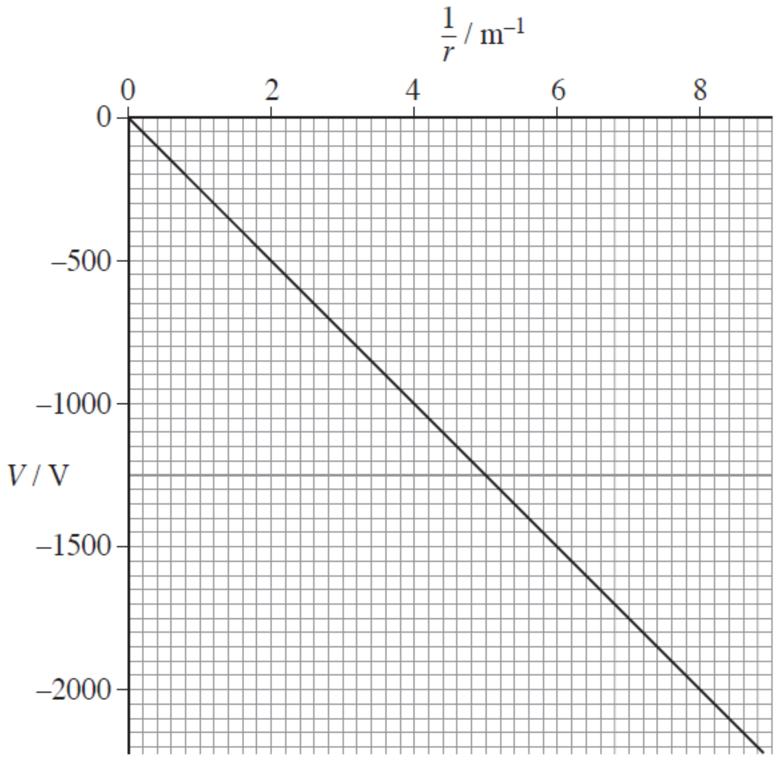
....

....

....

(b) **Figure 3** shows how the electric potential, V, varies with $\frac{1}{r}$, where r is the distance from a point charge Q.

Figure 3



State what can be deduced from the graph about how V depends on r and explain why all the values of V on the graph are negative.

[2 marks]

....

....

....

....

(c) (i) Use data from the graph (**Figure 3**) to show that the magnitude of Q is about 30 nC.

[2 marks]

(c) (ii) A $+60$ nC charge is moved from a point where $r = 0.20$ m to a point where $r = 0.50$ m. Calculate the work done.

[2 marks]

work done .... J

(c) (iii) Calculate the electric field strength at the point where $r = 0.40$ m.

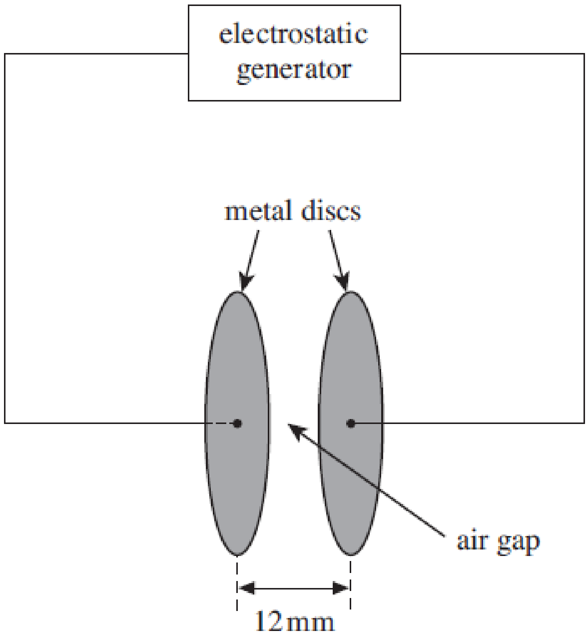
[2 marks]

electric field strength .... V m^{-1}

3.

Figure 1 shows an arrangement to demonstrate sparks passing across an air gap between two parallel metal discs. Sparks occur when the electric field in the gap becomes large enough to equal the breakdown field strength of the air. The discs form a capacitor, which is charged at a constant rate by an electrostatic generator until the potential difference (pd) across the discs is large enough for a spark to pass. Sparks are then produced at regular time intervals whilst the generator is switched on.

Figure 1



(a) The electrostatic generator charges the discs at a constant rate of 3.2×10^{-8} A on a day when the minimum breakdown field strength of the air is 2.5×10^{6} V m^{-1}. The discs have a capacitance of 3.7×10^{-12} F.

(a) (i) The air gap is 12 mm wide. Calculate the minimum pd required across the discs for a spark to occur. Assume that the electric field in the air gap is uniform.

pd V

(1 mark)

(a) (ii) Calculate the time taken, from when the electrostatic generator is first switched on, for the pd across the discs to reach the value calculated in part (a)(i).

time .... s

(2 marks)

(b) The discs are replaced by ones of larger area placed at the same separation, to give a larger capacitance.

State and explain what effect this increased capacitance will have on:

(b) (i) the time between consecutive discharges,

....

....

....

....

....

(2 marks)

(b) (ii) the brightness of each spark.

....

....

....

....

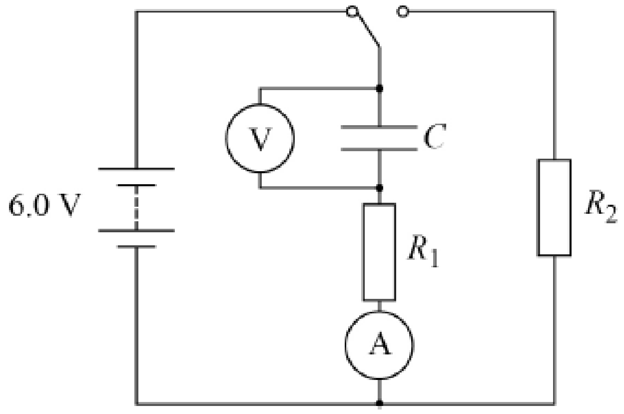
....

(2 marks)

4.

Figure 8 shows a circuit used to investigate the charge and discharge of a capacitor of capacitance C using resistors of resistances R_1 and R_2.

Figure 8



The battery has an emf of $6.0\ \mathrm{V}$ and negligible internal resistance.

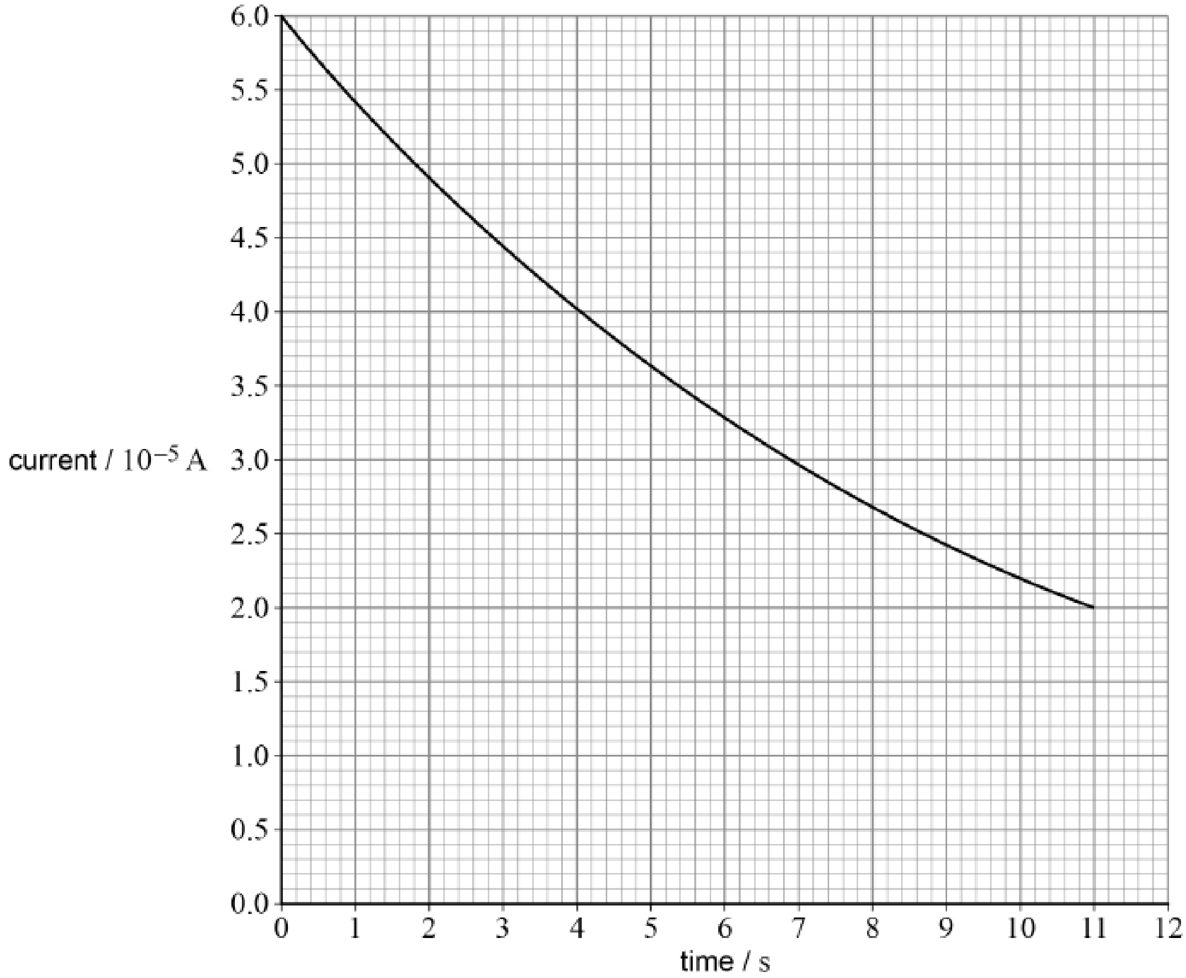
(a)

Show that the time taken for the capacitor to charge from $2.0\ \mathrm{V}$ to $4.0\ \mathrm{V}$ is approximately $0.7R_1C$.

[3 marks]

The capacitor is fully discharged.
The capacitor is then charged until the potential difference (pd) across it is 4.0 V.
Figure 9 shows the variation with time of the ammeter reading as the capacitor is charged.

Figure 9



(b)

Show that the capacitance of the capacitor is about 1×10^{-4} F.

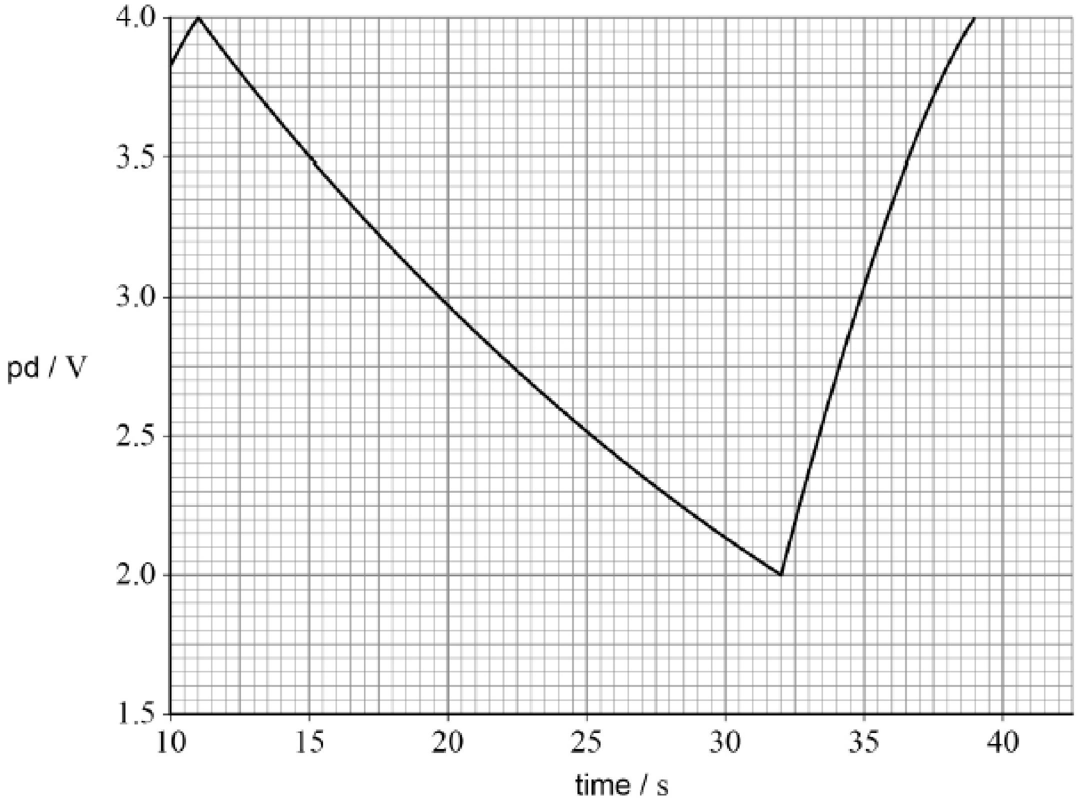
[4 marks]

(c)

When the pd reaches 4.0 V the switch is immediately set to discharge the capacitor. When the pd reaches 2.0 V the switch is immediately set to charge the capacitor.

Figure 10 shows how the pd across the capacitor varies with time.

Figure 10



Determine the value of R_2.

[3 marks]

$R_2 =$ ______________________ Ω

5.

(a)

Calculate the binding energy, in MeV, of a nucleus of ${}^{59}_{27}\mathrm{Co}$.

nuclear mass of ${}^{59}_{27}\mathrm{Co} = 58.93320\ \mathrm{u}$

[3 marks]

binding energy = ______________________________ MeV

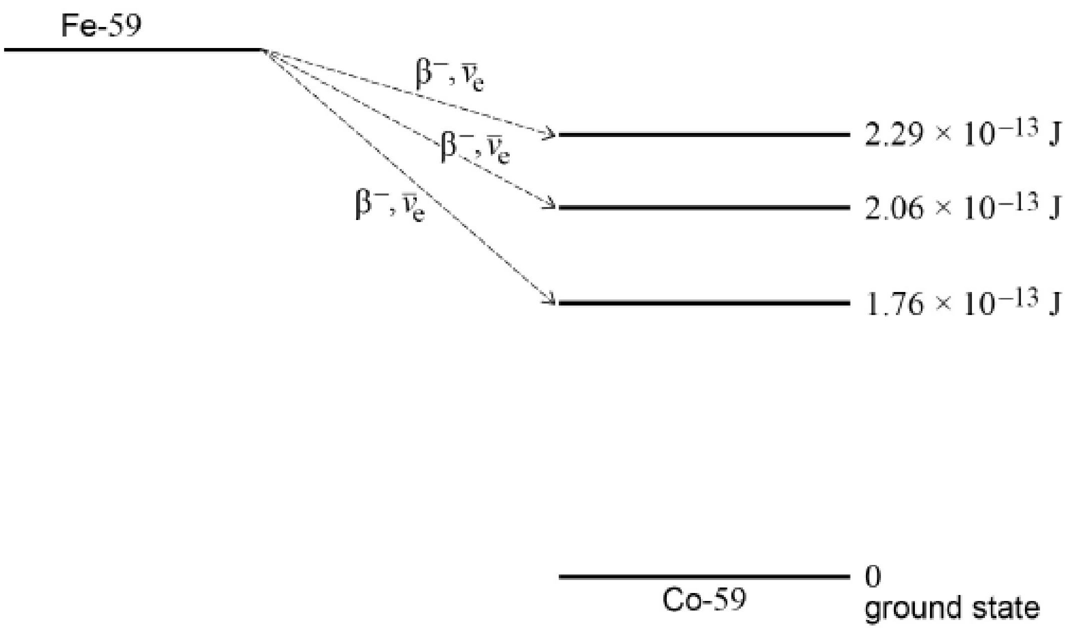
(b)

A nucleus of iron Fe-59 decays into a stable nucleus of cobalt Co-59. It decays by β^- emission followed by the emission of γ-radiation as the Co-59 nucleus de-excites into its ground state.

The total energy released when the Fe-59 nucleus decays is 2.52×10^{-13} J.

The Fe-59 nucleus can decay to one of three excited states of the cobalt-59 nucleus as shown in **Figure 5**. The energies of the excited states are shown relative to the ground state.

Figure 5



Calculate the maximum possible kinetic energy, in MeV, of the β^- particle emitted when the Fe-59 nucleus decays into an excited state that has energy above the ground state.

[2 marks]

(c)

Following the production of excited states of $^{59}_{27}\mathrm{Co}$, γ-radiation of discrete wavelengths is emitted.

State the maximum number of discrete wavelengths that could be emitted.

[1 mark]

maximum number = ______________________________

(d)

Calculate the longest wavelength of the emitted γ-radiation.

[3 marks]

longest wavelength = ______________________________ m

6.

(a) State and describe **one** way in which X-ray photons interact with matter.

....

....

....

.... **[2]**

(b) The intensity of a collimated beam of X-rays is reduced to 10% of its initial value after passing through 3.0 mm of soft tissue. Calculate the thickness of soft tissue that reduces the intensity to 50% of its initial value.

thickness = ... mm **[3]**

(c) X-rays are used to image internal body structures.

(i) Explain how image intensifiers are used to improve the quality of the X-ray image.

In your answer, you should explain clearly the process involved which makes the image brighter.

....

....

....

....

.... **[3]**

(ii) Explain how contrast media are used to improve the quality of the X-ray image.

....

....

....

.... **[2]**