Mixed Exam Questions - Set 11

1.

The radioactive nucleus of plutonium ($^{238}_{94}$Pu) decays by emitting an alpha particle ($^{4}_{2}$He) of kinetic energy 5.6MeV with a half-life of 88 years. The plutonium nucleus decays into an isotope of uranium.

(a) State the number of neutrons in the **uranium** isotope.

..... **[1]**

(b) The mass of an alpha particle is 6.65×10^{-27} kg.

(i) Show that the kinetic energy of the alpha particle is about 9×10^{-13} J.

[1]

(ii) Calculate the speed of the alpha particle.

speed = ... $m\,s^{-1}$ **[2]**

(c) In a space probe, a source containing plutonium-238 nuclei is used to generate 62W for the onboard electronics.

(i) Use your answer to **(b)(i)** to show that the initial activity of the sample of plutonium-238 is about 7×10^{13} Bq.

[1]

(ii) Calculate the decay constant of the plutonium-238 nucleus.

1 year = 3.16×10^{7} s

decay constant = ... s^{-1} **[2]**

(iii) The molar mass of plutonium-238 is 0.24 kg. Calculate

1 the number of plutonium-238 nuclei in the source

number of nuclei = ... **[2]**

2 the mass of plutonium in the source.

mass = ... kg **[1]**

Question 2 is on the next page.

2.

(a)

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

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

[3 marks]

binding energy = _____ MeV

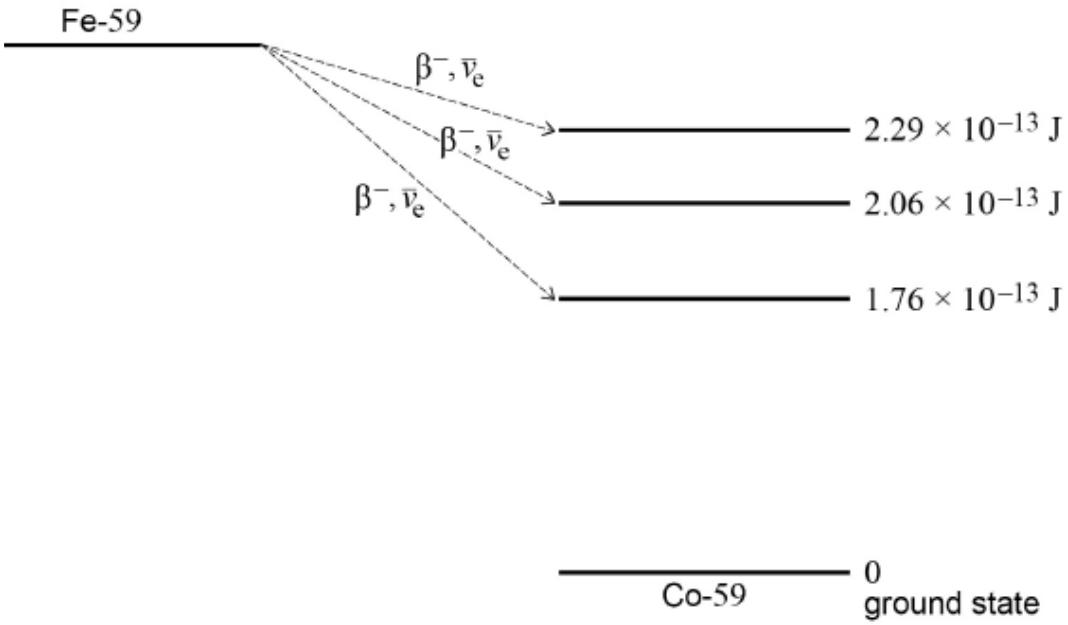
(b)

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 $^{59}_{27}Co$, 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

3.

A spark plug is the device in a petrol engine which ignites the fuel-air mixture, causing an explosion in the cylinder.

(a) A potential difference of 40 kV is needed across a gap of 0.60 mm to produce the spark which ignites the fuel vapour. Calculate the magnitude of the electric field strength in the spark gap just before the spark.

electric field strength = ... unit ..... [3]

(b) The electrical supply in a motor car is 12V. To achieve 40 kV, two coils are wound on the same iron core, shown schematically in Fig. 5.1. The secondary coil is in series with the spark gap. The primary coil is in series with the battery and a switch.

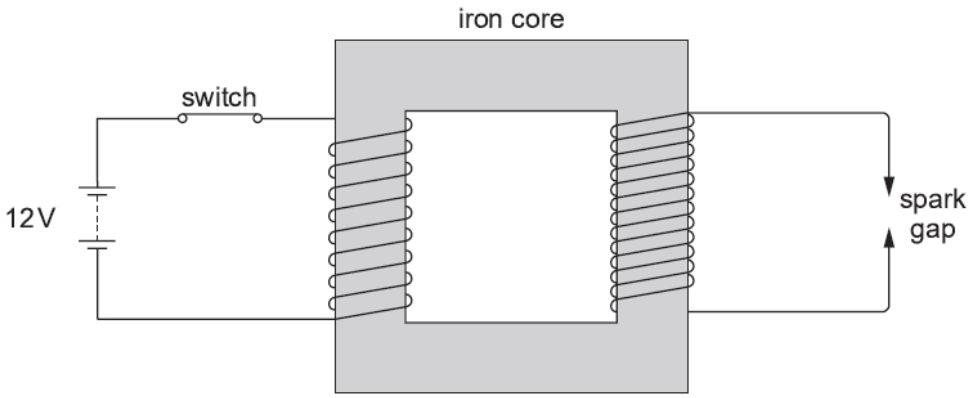


Fig. 5.1

(i) Draw on Fig. 5.1 the complete paths of **two** lines of magnetic flux linked with the current in the primary coil. [2]

(ii) The magnetic flux through both coils is the same but the magnetic flux linkage is not. Explain why.

.....

.....

.....

.....[2]

(iii) Explain why a potential difference is produced across the spark gap as the switch is opened.

.....

.....[1]

(iv) Explain how each of the following factors influences the size of the potential difference across the spark gap:

1 the rate of collapse of the magnetic flux

.....

.....

.....

.....

.....[2]

2 the ratio of the number of turns between the primary and secondary coils.

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.....[2]

4.

Fig. 3.1 shows the variation of the magnetic flux **linkage** with time *t* for a small generator.

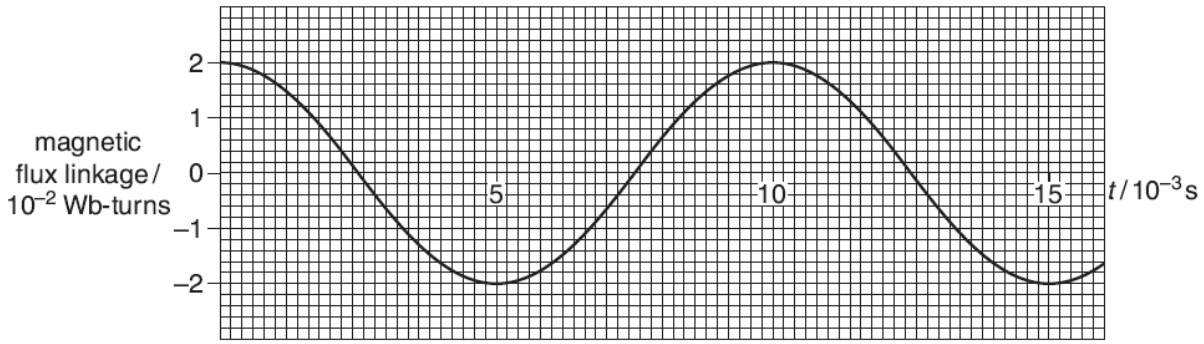

Fig. 3.1

The generator has a flat coil of negligible resistance that is rotated at a steady frequency in a uniform magnetic field. The coil has 400 turns and cross-sectional area $1.6 \times 10^{-3} m^2$. The output from the generator is connected to a resistor of resistance 150 Ω.

(a) Use Fig. 3.1 to

(i) calculate the frequency of rotation of the coil

frequency = ... Hz **[1]**

(ii) calculate the magnetic flux density *B* of the magnetic field

B = ... T **[3]**

(iii) show that the **maximum** electromotive force (e.m.f.) induced in the coil is about 12V.

[3]

(b) Hence calculate the **maximum** power dissipated in the resistor.

power = ... W **[2]**

5.

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

[2 marks]

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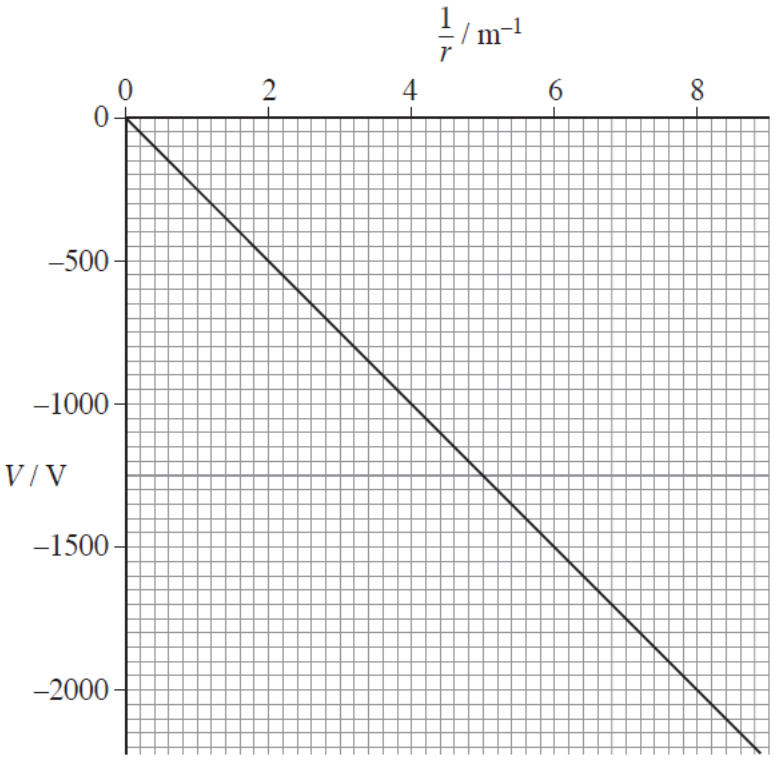
.....

.....

.....

(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.

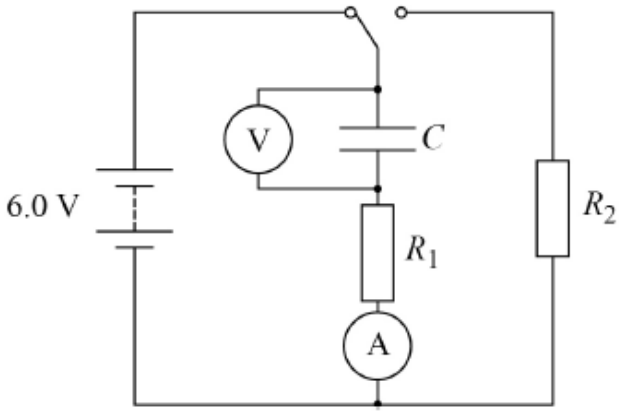
[2 marks]

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

6.

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 V and negligible internal resistance.

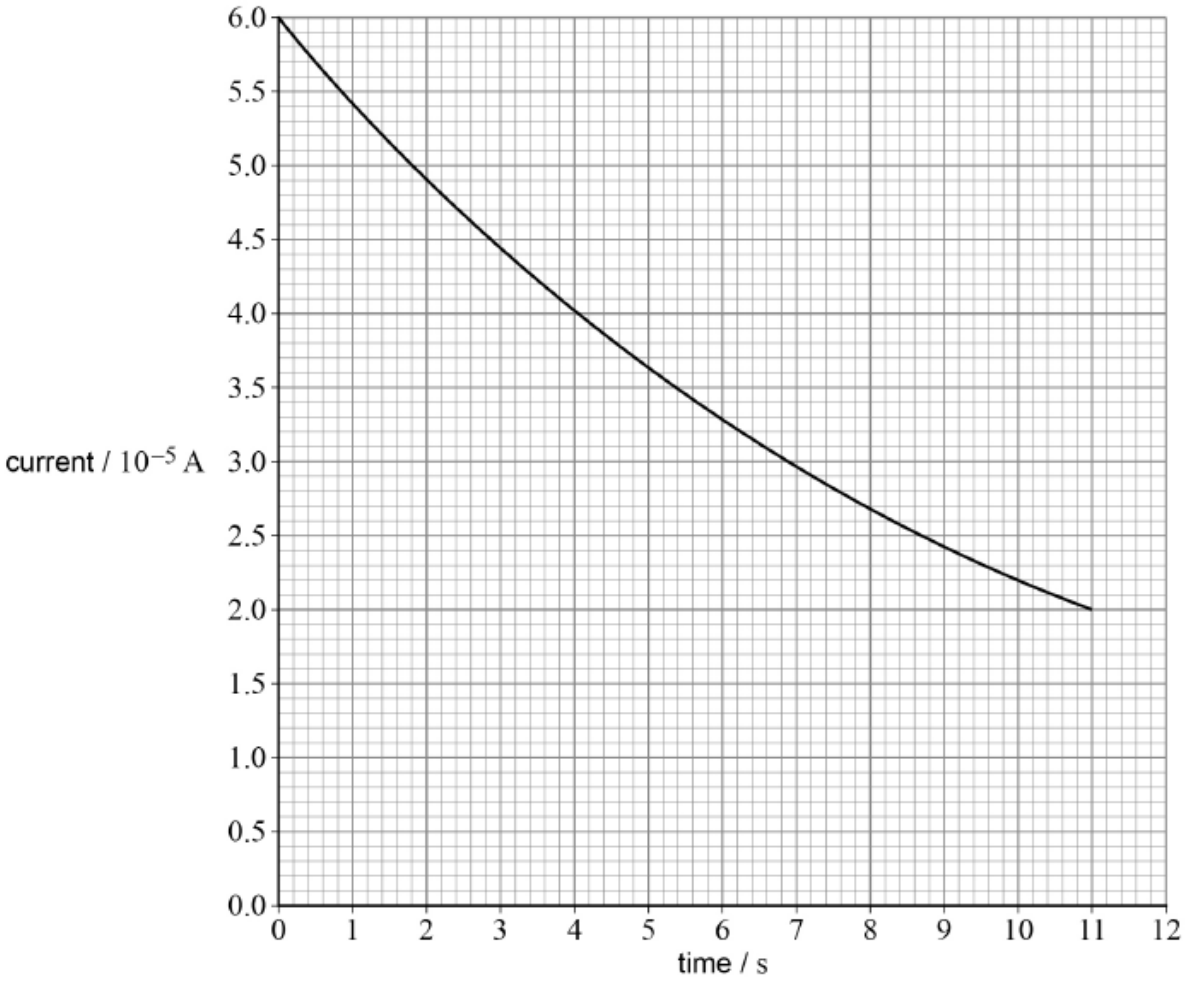
(a)

Show that the time taken for the capacitor to charge from 2.0 V to 4.0 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.

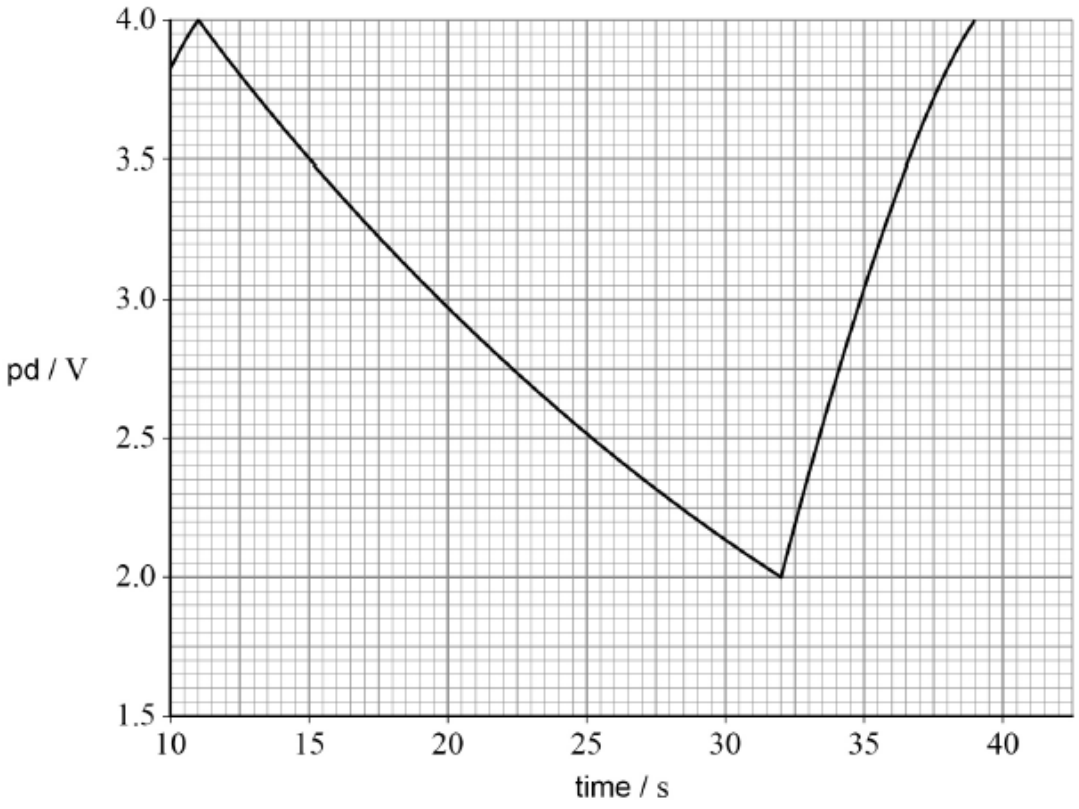
[4 marks]

(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