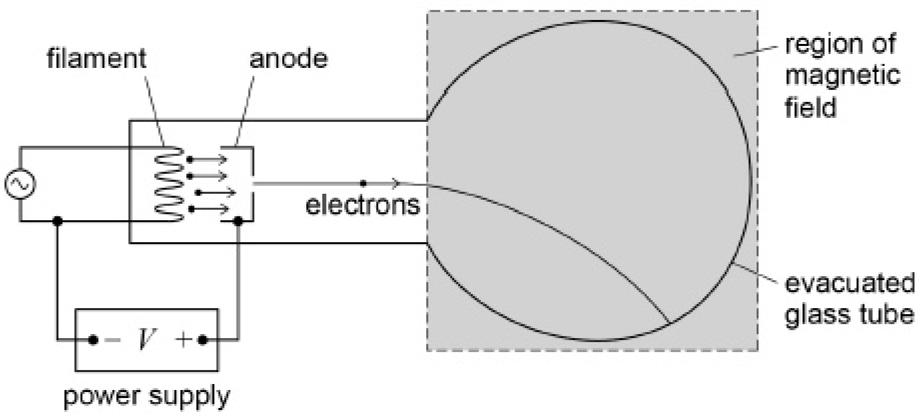
**3** The diagram shows apparatus which can be used to determine the specific charge of an electron.




Electrons are emitted from the filament and accelerated by a potential difference between the filament and anode to produce a beam. The beam is deflected into a circular path by applying a magnetic field perpendicular to the plane of the diagram.

(a) Describe the process that releases the electrons emitted at the filament.

electons gain energy via collisions as current flows
temperature of the filament rises
electrons are boiled off - thermionic emission

**(3)**

(b) The table shows the data collected when determining the specific charge of the electron by the method shown in the diagram.

| | |
|---|---|
| potential difference $V$ that accelerates the electrons | 320 V |
| radius $r$ of circular path of the electrons in the magnetic field | 4.0 cm |
| flux density $B$ of the applied magnetic field | 1.5 mT |

Show that the specific charge of the electron is given by the expression $\frac{2V}{B^2 r^2}$

$F = \frac{mv^2}{r} = Bev \Rightarrow r = \frac{mv}{Be}$ ... (2)

$\frac{1}{2}mv^2 = eV \Rightarrow mv^2 = 2eV \Rightarrow v^2 = \frac{2eV}{m}$ ... (1)

Now (1) → (2)

$r = \frac{m}{Be}\sqrt{\frac{2eV}{m}} \Rightarrow r^2 = \frac{m^2}{B^2e^2}\frac{2eV}{m} \Rightarrow r^2 = \frac{m\,2V}{B^2 e}$

want $\frac{e}{m}$

$\Rightarrow \frac{e}{m} = \frac{2V}{r^2 B^2}$

**(2)**

(b) Use one of $\frac{1}{2}mv^2 = eV$ and $r = \frac{mv}{Be}$ or $\frac{mv^2}{r} = Bev$

To arrive at

$\frac{Ber}{m} = v$ or $v = \sqrt{\frac{2eV}{m}}$ or $v^2 = \frac{2eV}{m}$

or $\frac{e}{m} = \frac{v}{Br}$ or $\frac{e}{m} = \frac{v^2}{2V}$ ✓

Substitution in the other equation and manipulates correctly and clearly to give $\frac{e}{m} = \frac{2V}{B^2r^2}$

(c) Using data from the table, calculate a value for the specific charge of the electron. Give your answer to an appropriate number of significant figures.

$$\frac{e}{m} = \frac{2 \times 320}{(1.5\times10^{-3})^2 \times (4\times10^{-2})^2} = 1.7 \times 10^{11}$$

2 s f

specific charge of the electron = 1.8 C kg$^{-1}$

**(2)**

(d) At the time when Thomson measured the specific charge of the particles in cathode rays, the largest specific charge known was that of the hydrogen ion.

State how Thomson's result for the specific charge of each particle within a cathode ray compared with that for the hydrogen ion and explain what he concluded about the nature of the particles.

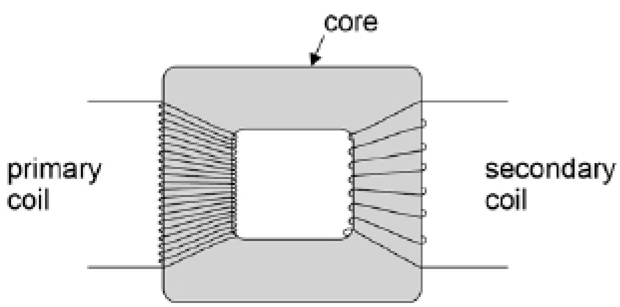
specific charge for a hydrogen ion was about 2000 times smaller
this suggested that either the charge was a lot bigger or the mass was a lot smaller for cathode rays (or some combination gave this bigger figure)

**(2)**

**(Total 9 marks)**

**6** **Figure 1** shows a step−down transformer used in a laptop power supply.

**Figure 1**




(a) Explain the purpose of the core in the transformer.

the core directs the magnetic flux lines around to the secondary

**(1)**

(b) Describe and explain **two** features of the core that improve the efficiency of the transformer.

1. it is a large mass of soft iron which is a very magnetic material and can be magentised/demagnetised very easily

2. the coil is laminated - iron is intersperced with Ithink layers of a non electrical conductor which acts to reduce eddy currents

**(2)**

(c) Explain why transformers only work continuously when supplied with an alternating current.

$\mathcal{E} \propto N \frac{\Delta \phi}{\Delta t}$

therefore you need a constantly changing magnetic flux which is eaily created with an ac

**(1)**

(d) The primary coil of the transformer is connected to a 230 $V_{rms}$ ac supply. The current in the primary coil is 0.30 $A_{rms}$. The secondary coil has 300 turns and provides an output of 20 $V_{rms}$ and a power of 65 W.

Calculate the number of turns on the primary coil.

$\frac{N_p}{N_s} = \frac{V_p}{V_s} \Rightarrow N_p = \frac{N_s V_p}{V_s} = \frac{300 \times 230}{20}$

number of turns on primary = 3450

**(1)**

(e) Calculate the efficiency of the transformer.

$\frac{\text{Power out}}{\text{power in}} \quad \frac{V_s I_s}{V_p I_p} = \frac{65W}{230 \times 0.3} = 94\%$

efficiency ______________________

**(2)**

**(Total 7 marks)**

**7** Two charged particles, **$P_1$** and **$P_2$**, follow circular paths as they move at right angles to the same uniform magnetic field. Both particles are travelling at the same speed.

The radius of the path travelled by **$P_1$** is twice the radius of the path travelled by **$P_2$**.

The mass of **$P_1$** is $m$ and its charge is $q$.

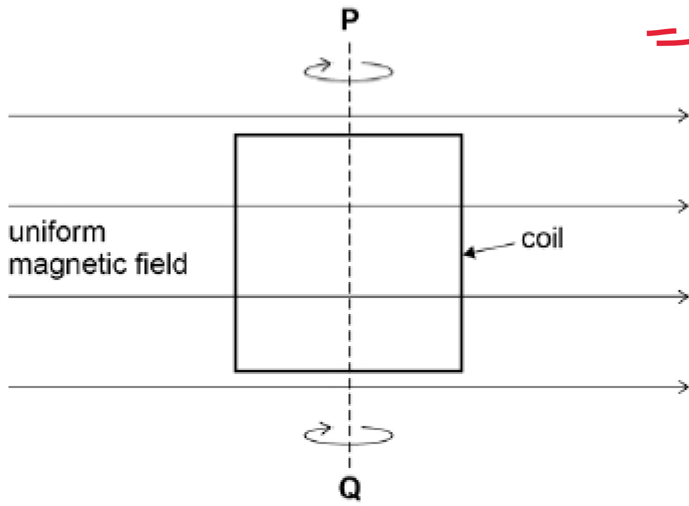
What is the mass of **$P_2$** and the charge of **$P_2$**?

| | **Mass of $P_2$** | **Charge of $P_2$** | |
|---|---|---|---|
| **A** | $2m$ | $q$ | |
| **B** | $2m$ | $2q$ | |
| **C** | $\sqrt{2}\,m$ | $\sqrt{2}\,q$ | |
| **D** | $m$ | $2q$ | |

**(Total 1 mark)**

**8** A rectangular coil of area $A$ has $N$ turns of wire. The coil is in a uniform magnetic field of flux density $B$ with its plane parallel to the field lines.

Initial flux linked = 0




The coil is then rotated through an angle of 30° about axis **PQ**.

What are the correct initial value and correct final value of the magnetic flux linkage?

| | **Initial magnetic flux linkage** | **Final magnetic flux linkage** | |
|---|---|---|---|
| **A** | 0 | $\frac{1}{2}BAN$ | |
| **B** | 0 | $BAN$ | |
| **C** | $BAN$ | $\frac{1}{2}BAN$ | |
| **D** | $BAN$ | $BAN$ | |

**(Total 1 mark)**

Initial flux linkage is 0 and angle is 90 degrees
turn through 30 means the angle is now 60

$N\Phi = BAN\cos\theta = BAN\cos 60$

**9** Charged particles, each of mass $m$ and charge $Q$, travel at a constant speed in a circle of radius $r$ in a uniform magnetic field of flux density $B$.

Which expression gives the frequency of rotation of a particle in the beam?

**A** $\frac{BQ}{2\pi m}$ ☐

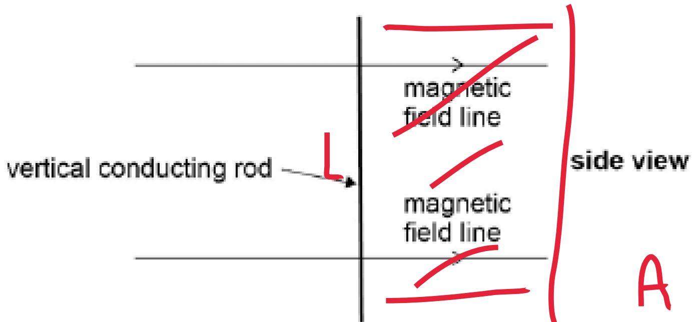
**B** $\frac{BQ}{m}$ ☐

**C** $\frac{BQ}{\pi m}$ ☐

**D** $\frac{2\pi BQ}{m}$ ☐

**(Total 1 mark)**

**10** A vertical conducting rod of length $l$ is moved at a constant velocity $v$ through a uniform horizontal magnetic field of flux density $B$.




Which of the rows gives a correct expression for the induced emf between the ends of the rod for the stated direction of the motion of the rod?

| | Direction of motion | Induced emf | |
|---|---|---|---|
| **A** | Vertical | $\frac{B}{lv}$ | ☐ |
| **B** | Horizontal at right angles to the field | $Blv$ | ☐ |
| **C** | Vertical | $Blv$ | ☐ |
| **D** | Horizontal at right angles to the field | $\frac{B}{lv}$ | ☐ |

**(Total 1 mark)**