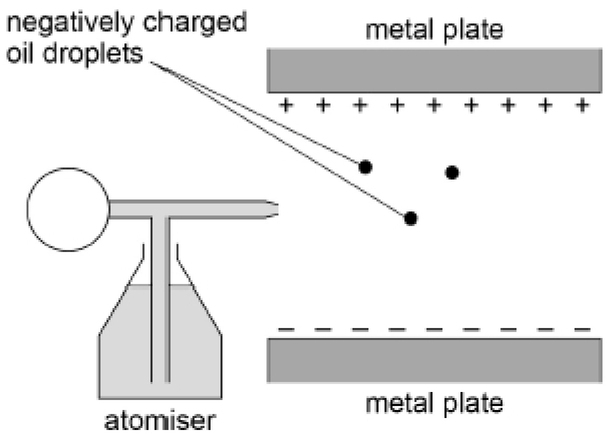
1. The diagram shows an experiment to measure the charge of the electron.



Negatively charged oil droplets are sprayed from the atomiser into the gap between the two horizontal metal plates. A potential difference is applied between the metal plates.

One of the droplets remains stationary.

(a) Identify the forces acting on the stationary droplet.
In your answer you should state the relationship between the forces.

The upthrust on the droplet due to the air it displaces is negligible.

____

____

____

____

____

____

(2)

(b) The potential difference between the plates is changed to zero and the droplet falls at a terminal velocity of 1.0×10^{-4} m s^{-1}.

The density of the oil is 880 kg m^{-3}
The viscosity of air is 1.8×10^{-5} N s m^{-2}

Show that the radius of the droplet is about 1×10^{-6} m.

Assume that the droplet is spherical.

(3)

(c) The potential difference between the plates is restored to its initial value and the droplet becomes stationary.

The charge on the droplet is -4.8×10^{-19} C.

A student suggests that, if the droplet splits into two spheres of equal size, both spheres would remain stationary.

Deduce whether this suggestion is correct.

___

___

___

___

___

___

___

___

___

___

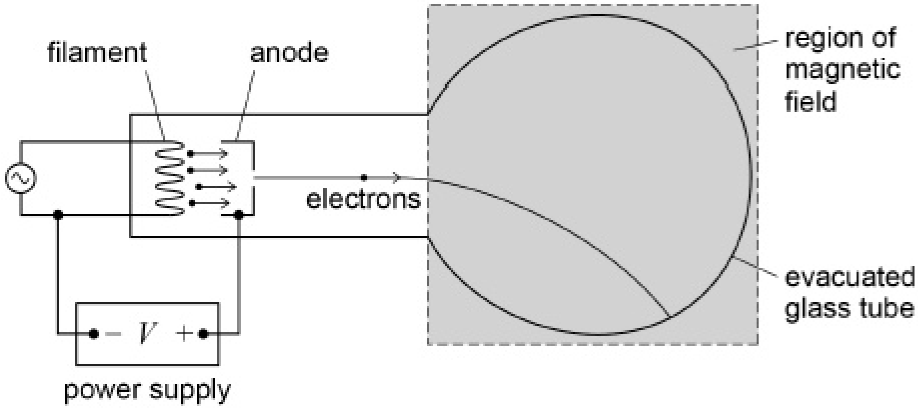
___

___

(3)

(Total 8 marks)

2. 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.

____

____

____

____

____

____

____

____

____

____

(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 $\frac{2V}{B^2r^2}$

(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.

specific charge of the electron = ____________________ 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.

___

___

___

___

___

___

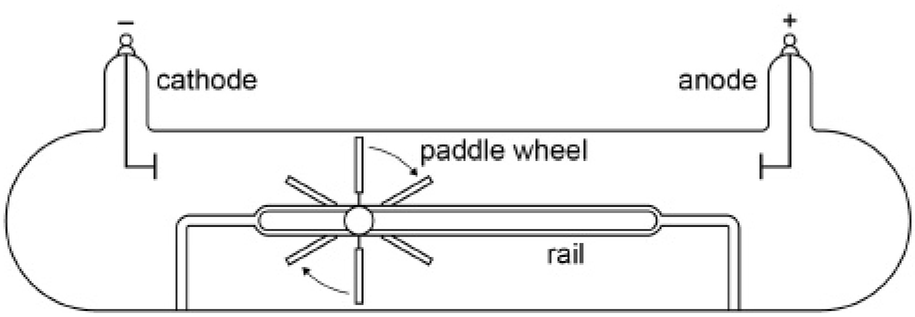
___

___

(2)
(Total 9 marks)

3. The diagram shows a gas discharge tube devised by William Crookes in one of his investigations.

When a large potential difference is applied between the cathode and anode the paddle wheel is seen to rotate and travel along the rail towards the anode.



(a) Explain how this experiment led Crookes to conclude that cathode rays are particles and that these particles caused the movement of the paddle.

____

____

____

____

____

____

(2)

(b) Later experiments showed that cathode rays are electrons in motion.

Explain how cathode rays are produced in a gas discharge tube.

____

____

____

____

____

____

____

____

(3)

(c) In a particular gas discharge tube, air molecules inside the tube are absorbed by the walls of the tube.

Suggest the effect that this absorption may have on the motion of the paddle wheel.

Give a reason for your answer.

____

____

____

____

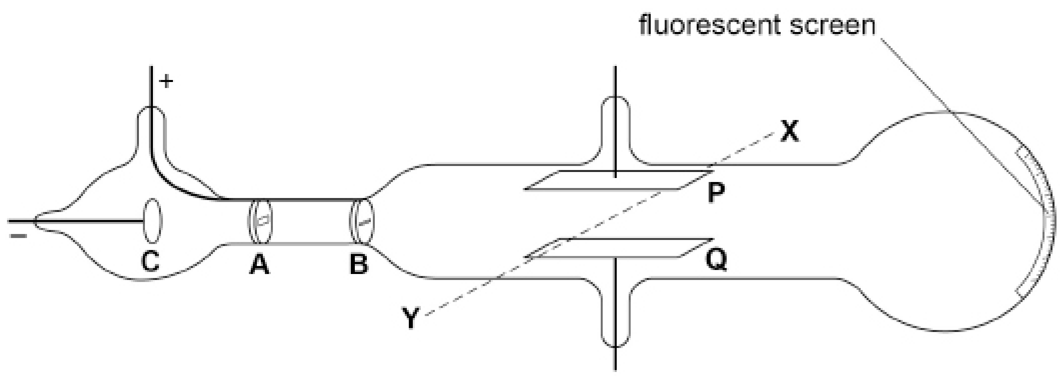
____

____

(2)

(Total 7 marks)

4. The figure shows a diagram of a discharge tube used by JJ Thomson to investigate cathode rays.



The direction **XY** is horizontal and at right angles to the axis of the tube.

(a) When correct connections are made to a high-voltage power supply, a cathode ray is produced. The cathode ray hits the centre of the fluorescent screen.

Describe how a cathode ray is produced in the discharge tube in the figure above.

____

____

____

____

____

____

(2)

(b) **P** and **Q** are metal plates that can be attached to a second power supply.

In an experiment, a potential difference (pd) is applied across **P** and **Q** so that **P** is positively charged and **Q** is negatively charged. This deflects the cathode ray.

Then a magnetic field is applied between the plates so that the cathode ray follows its original path to the centre of the screen.

What is the direction of the magnetic field?
Tick (✓) **one** box.

from **P** to **Q** ☐

from **Q** to **P** ☐

from **X** to **Y** ☐

from **Y** to **X** ☐

(1)

(c) Changes are made to the apparatus so that the particles in the cathode ray travel with a greater speed as they pass between plates **P** and **Q**.

Explain how the cathode ray is restored to its original path by adjusting:

- only the electric field strength between **P** and **Q**
- only the magnetic flux density.

electric field strength only ____

____

____

____

____

magnetic flux density only ____

____

____

____

____

(3)

(d) Using the apparatus in the figure above, Thomson determined the specific charge of the particles in the cathode rays. Thomson compared this result with the specific charge of the hydrogen ion.

Discuss the significance of Thomson's results for the particles in cathode rays, when compared with the specific charge of the hydrogen ion.

____

____

____

____

____

____

(2)

(Total 8 marks)