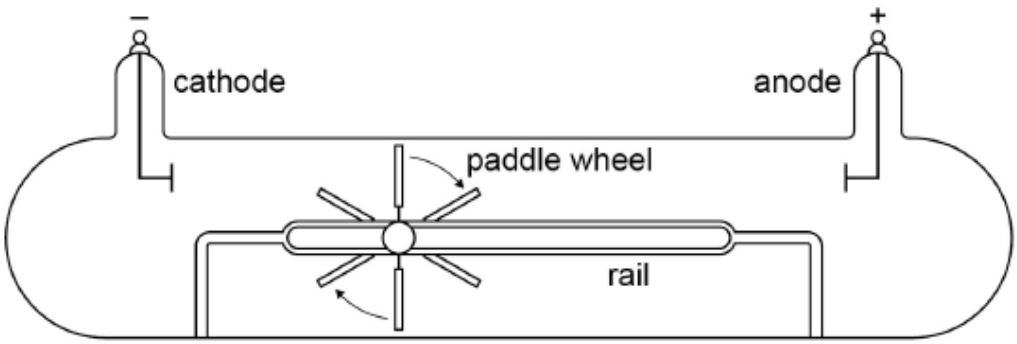
Turning Points in Physics - 1

1.

Figure 1 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.

Figure 1



(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 marks]

(b)

Later experiments showed that cathode rays are electrons in motion.

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

[3 marks]

(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.

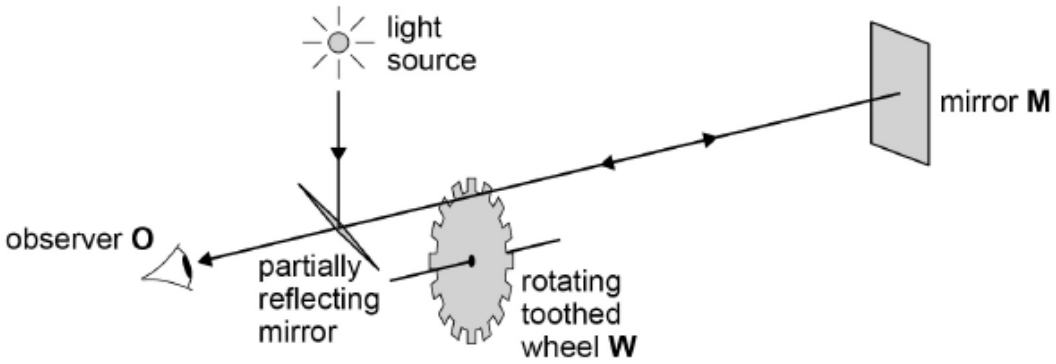
Give a reason for your answer.

[2 marks]

2.

Figure 2 shows the apparatus Fizeau used to determine the speed of light.

Figure 2



The following observations are made.

A When the speed of rotation is low the observer sees the light returning after reflection by the mirror **M**.

B When the speed of the wheel is slowly increased the observer continues to see the light until the wheel reaches a certain speed. At this speed the observer cannot see the light.

(a)

Explain these observations.

[2 marks]

Observation A

Observation B

(b)

Table 1 shows data from Fizeau's experiment at the instant when observation B is made.

Table 1

d, distance from **M** to **W**	8.6 km
f, number of wheel revolutions per second	12
n, number of teeth in the wheel	720

It can be shown that the speed of light c is given by the equation

$$c = 4dnf$$

Discuss whether the data in **Table 1** are consistent with the present accepted value for the speed of light.

[2 marks]

(c)

The speed of the wheel is further increased.

Deduce the value of f when the observer would next be unable to see light returning from the mirror.

[2 marks]

(d)

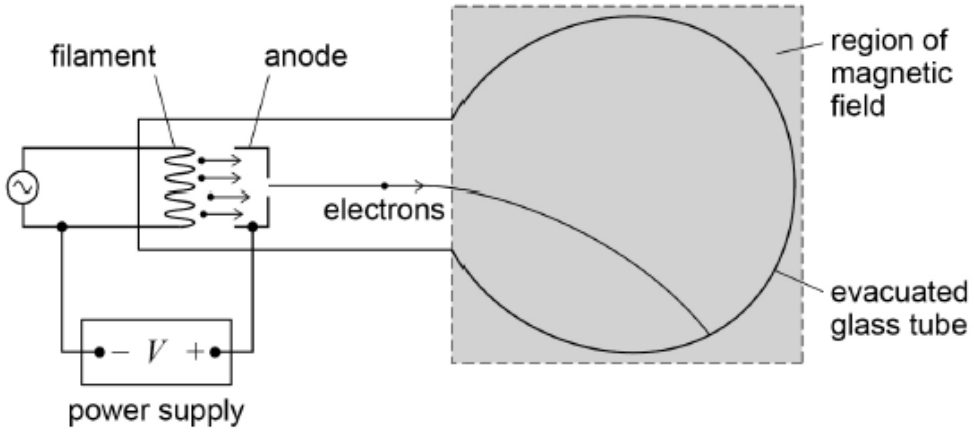
Explain how the nature of light is implied by Maxwell's theory of electromagnetic waves and Fizeau's result.

[3 marks]

3.

Figure 1 shows apparatus which can be used to determine the specific charge of an electron.

Figure 1



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 marks]

(b)

Table 1 shows the data collected when determining the specific charge of the electron by the method shown in **Figure 1**.

Table 1

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 marks]

(c)

Using data from **Table 1**, calculate a value for the specific charge of the electron.
Give your answer to an appropriate number of significant figures.

[2 marks]

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

(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.

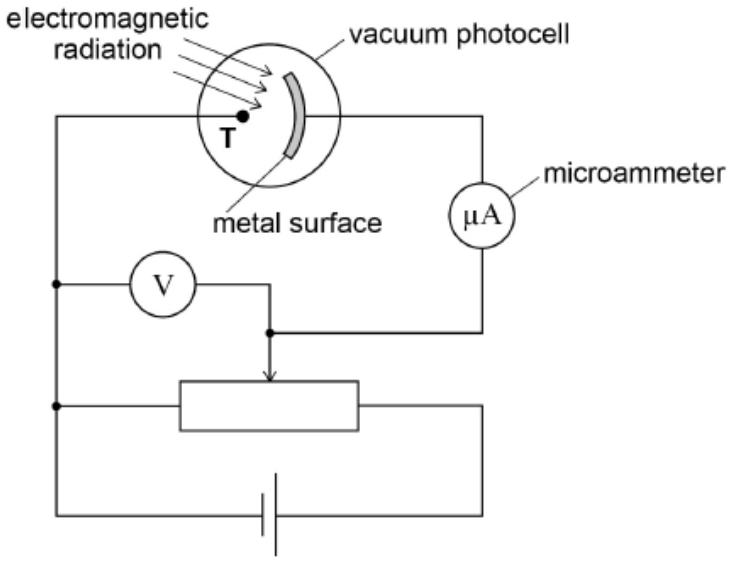
State how Thomson's result for the specific charge of each particle within a cathode ray compared with that for the hydrogen ion and explain what he concluded about the nature of the particles.

[2 marks]

4.

Figure 5 shows a vacuum photocell in which a metal surface is illuminated by electromagnetic radiation of a single wavelength. Electrons emitted from the metal surface are collected by terminal **T** in the photocell. This results in a photocurrent, ***I***, which is measured by the microammeter.

Figure 5



The potential divider is adjusted until the photocurrent is zero.

The potential difference shown on the voltmeter is 0.50 V

The work function of the metal surface is 6.2 eV

(a)

Calculate the wavelength, in nm, of the electromagnetic radiation incident on the metal surface.

[3 marks]

wavelength = _____ nm

(b)

The intensity of the electromagnetic radiation is increased. No adjustment is made to the potential divider.

The classical wave model and the photon model make different predictions about the effect on the photocurrent.

Explain the effect on the photocurrent that each model predicts and how experimental observations confirm the photon model.

[3 marks]

(c)

The potential divider in **Figure 5** is returned to its original position so that a photocurrent is detected by the microammeter.
The potential divider is then adjusted to increase the potential difference shown on the voltmeter.

Explain why the photocurrent decreases when this adjustment to the potential divider is made.

[2 marks]

(d)

The apparatus shown in **Figure 5** is used to investigate three different metal surfaces **A**, **B** and **C**.

Table 2 shows, for each of the three surfaces, a voltmeter reading V and the corresponding photocurrent I. The same source of electromagnetic radiation is used throughout the investigation.

Table 2

	V/V	I/μA
Metal surface **A**	1.5	56
Metal surface **B**	2.5	56
Metal surface **C**	2.5	78

Which conclusion about the relationship between the work functions of **A**, **B** and **C** is correct?

Tick (✓) the correct box.

[1 mark]

A > B > C ☐

A < B < C ☐

B > A > C ☐

B < A < C ☐