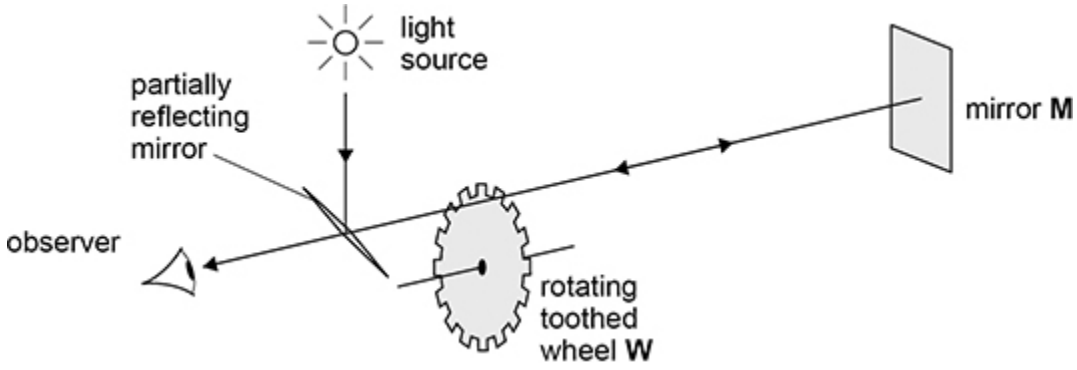
A-Level Physics

Electromagnetic Waves

Question Paper

Time available: 43 minutes
Marks available: 28 marks

1. The figure below shows the arrangement used by Fizeau to determine the speed of light.



The toothed wheel **W** is rotated and the reflected light from a distant mirror **M** is observed.

The speed of light is calculated from the equation

$$c = 4dnf_0$$

where d is the distance from **W** to **M** and
n is the number of teeth on the rotating wheel **W**.

(a) State what f_0 represents in the equation.

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(2)

(b) The experiment is attempted using a rotating wheel with 720 teeth that can be rotated at up to 620 revolutions per minute.
The distance between **W** and **M** is $8.5\ \text{km}$.

Deduce whether the speed of light can be determined with this particular arrangement.

(2)

(c) The determination of the speed of light took on extra significance when Maxwell derived the wave-speed equation

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$

State how ε_0 and μ_0 are related to the types of field in the wave.

ε_0

μ_0

(2)
(Total 6 marks)

2. **Figure 1** shows a modern version of the apparatus used by Hertz to investigate the properties of electromagnetic waves. Electromagnetic waves are continuously emitted from a dipole transmitter. The electromagnetic waves are detected by a dipole receiver.

An oscilloscope is used to display the amplitude of the detected signal at the dipole receiver.

Figure 1

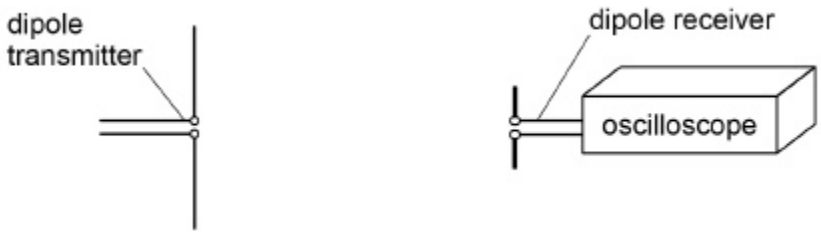
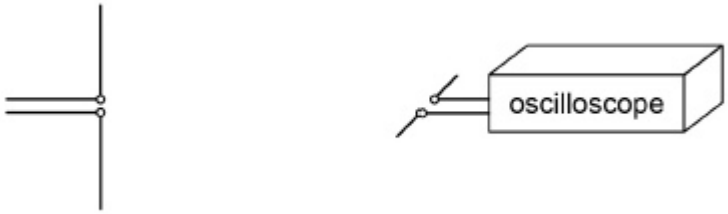


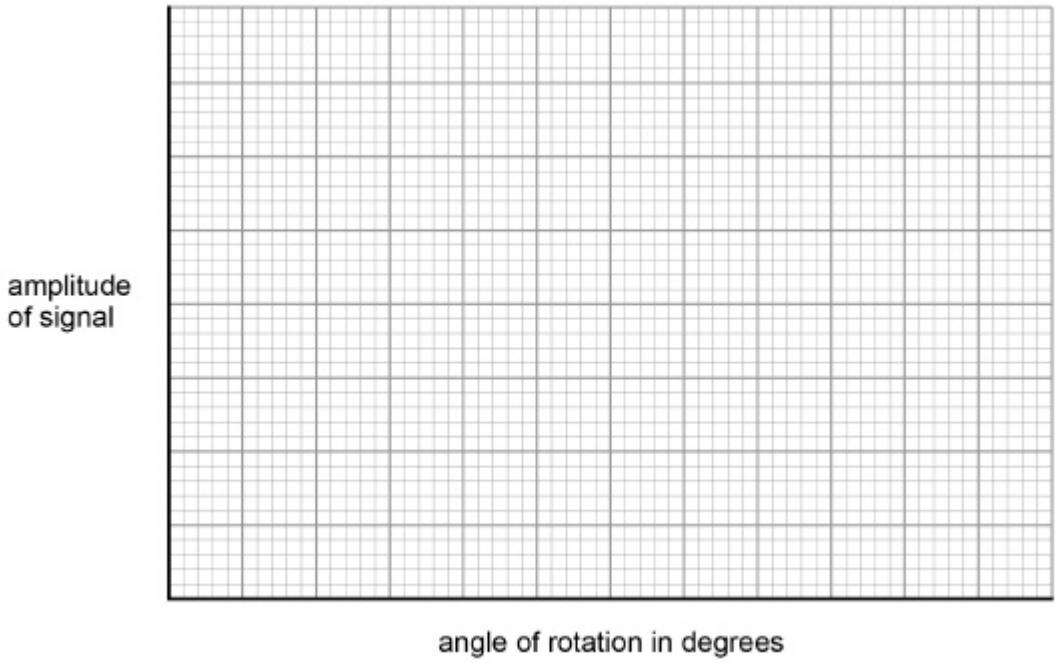
Figure 2 shows the same apparatus when the dipole receiver has been rotated through an angle of 90°

Figure 2



(a) Sketch a graph on **Figure 3** to show how the amplitude detected by the dipole receiver varies with angle of rotation as the receiver is turned through 360°
Start your graph from the position shown in **Figure 1**.

Figure 3



(3)

(b) Maxwell derived the equation $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ for the speed c of electromagnetic waves,

where μ_0 is the permeability of free space and ε_0 is the permittivity of free space.

Explain, using a suitable calculation, why this equation led to the conclusion that light is an electromagnetic wave.

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_____

(2)

(Total 5 marks)

3. In 1864, James Clerk Maxwell published a theory that included an equation for the speed of electromagnetic waves in a vacuum.

(a) Show that Maxwell's theory agrees with the accepted value for the speed of light in a vacuum.
Use information from the Data and Formulae Booklet in your answer.

(2)

Between 1886 and 1889, Heinrich Hertz completed a series of experiments in an attempt to verify Maxwell's theory. **Figure 1** shows a simplified arrangement similar to the one used by Hertz in one of his experiments.

Figure 1

T is a radio wave transmitter with an aerial consisting of two vertical metal rods.
D is a detector that uses a conducting loop aerial.

(b) **T** is switched on so that an oscillating current is produced in the metal rods.
An emf is detected in the conducting loop aerial.

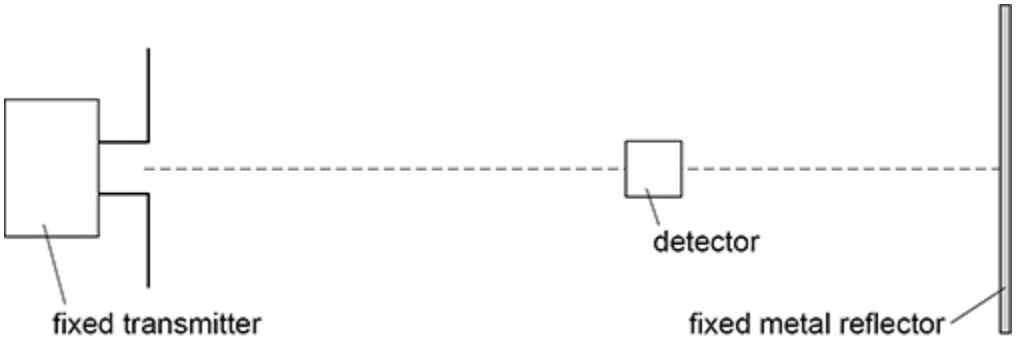
Explain this experiment with reference to Maxwell's model of electromagnetic waves.

(4)

(c) In a different experiment Hertz used stationary waves to determine the speed of radio waves.

Figure 2 shows an experimental arrangement similar to the arrangement Hertz used.

Figure 2



Stationary waves are produced between the fixed transmitter and the fixed metal reflector.

In one experiment the distance between the transmitter and reflector is about 12 m and the transmitter frequency is 75 MHz.

Deduce whether this arrangement can be used to measure the speed of electromagnetic waves suggested by Maxwell's equation.

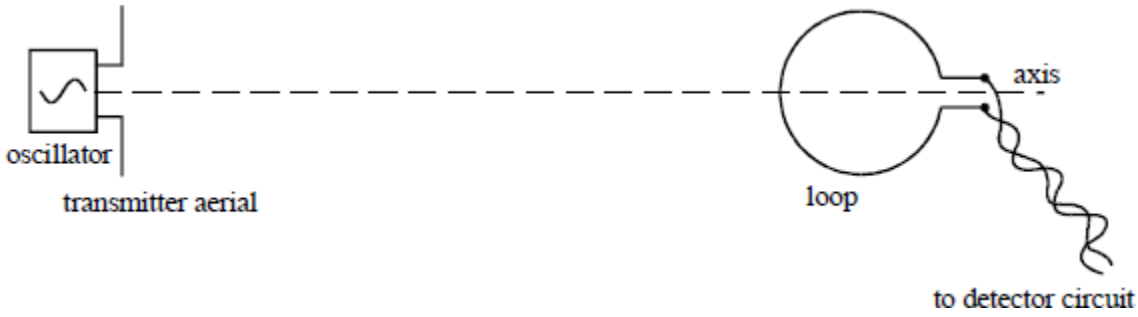
(4)

(Total 10 marks)

4. (a) Describe, with the aid of a diagram, an electromagnetic wave propagating through free space.

(3)

(b) When an alternating potential difference of a suitably high frequency is applied to a transmitter, an alternating emf of the same frequency is induced in a detector loop as shown. The loop and transmitter aerial are in the same vertical plane.



(i) Explain, in terms of electromagnetic waves, why an emf is induced in the loop when in this position.

(ii) The alternating emf decreases to zero when the loop is rotated about the axis through 90° until it is horizontal. Explain why the emf is zero when the loop is horizontal.

(4)

(Total 7 marks)