Contents

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MASTERING DOT POINT PHYSICS

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The Electromagnetic Spectrum

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7.1 James Clerk Maxwell

Investigate Maxwell's contribution to the classical theory of electromagnetism, including unification of electricity and magnets, prediction of electromagnetic waves and prediction of velocity.

James Clerk Maxwell

1862 – Maxwell

Influenced by the work of Michael Faraday in the 1830s, proposed that the speed of an electromagnetic wave would be the same as the speed of light.

Proposed that light was a transverse wave in the same medium as electric and magnetic waves – this was known as the aether.

Developed a set of 20 simultaneous equations containing 20 variables that showed that electric and magnetic fields are two complementary components of electromagnetic fields.

1864 – Maxwell

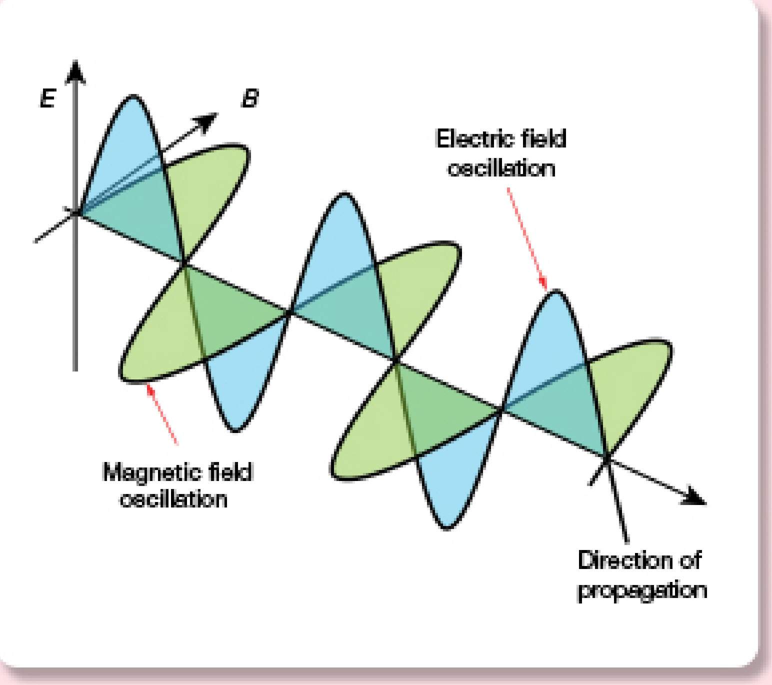
Puts forward his theory of electromagnetic radiation.

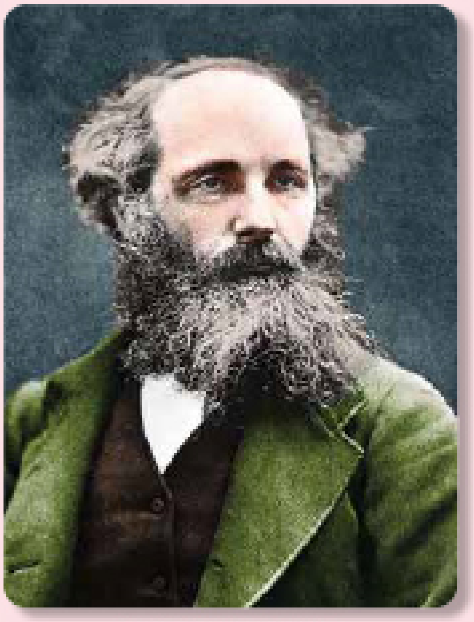
Electricity, magnetism, and light could all be explained using the same theory in physics.

Light was propagated by alternating electric and magnetic fields, which he believed would vibrate perpendicular to one another.

1867 – Maxwell

Made the first prediction that there would be a continuous range of electromagnetic radiations which extended beyond the visible spectrum at both ends.





James Clerk Maxwell (1831-1879).

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Sample Questions

1. Complete the sentences below to summarise Maxwell's contributions to electromagnetic radiation by placing one word in each box.

(a) Around 1862, Maxwell proposed that the speed of propagation of an electromagnetic was [ ] [ ] as the speed of [ ].

(b) Maxwell proposed that light must be a [ ] in a medium which was the same medium carrying electrical and magnetic waves.

(c) In the 1830s Michael Faraday converted [ ] [ ] into [ ] energy using an insulated wire and a galvanometer.

(d) Faraday used the results of his experiment to derive electric and magnetic equations to describe [ ] and [ ].

(e) Maxwell understood the significance of Faraday's work and, in 1864 proposed a theory connecting [ ], [ ] and [ ] into a single theory.

(f) Maxwell's theory proposed that electricity, magnetism, and light could all be explained using the [ ] theory in physics.

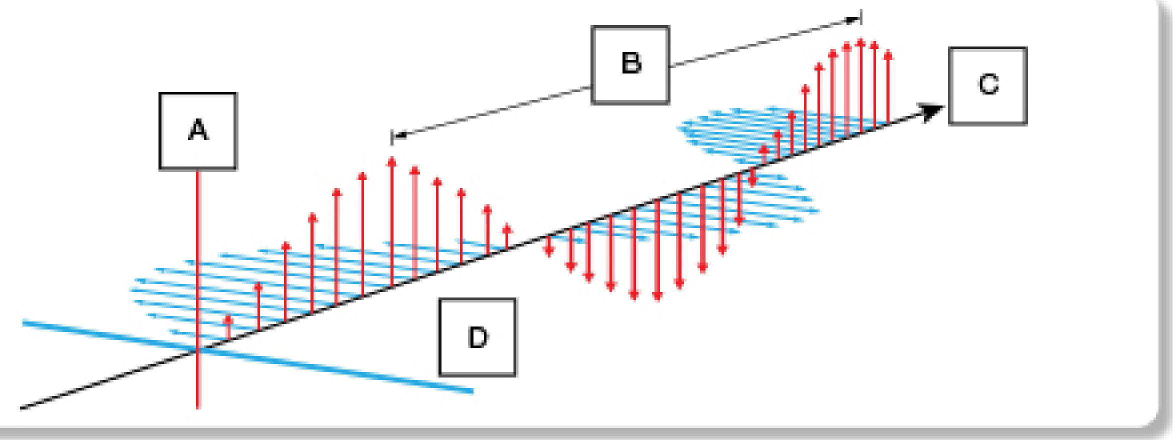
(g) Maxwell's theory also proposed that light was [ ] by alternating electric and magnetic fields.

(h) Maxwell believed that the alternating electric and magnetic fields would vibrate [ ] to one another.

(i) In 1867 Maxwell predicted that there was a [ ] [ ] of electromagnetic radiations.

(j) This was the first prediction of a continuous [ ] of electromagnetic radiation.

2. Identify the labelled parts of the diagram of an electromagnetic wave.



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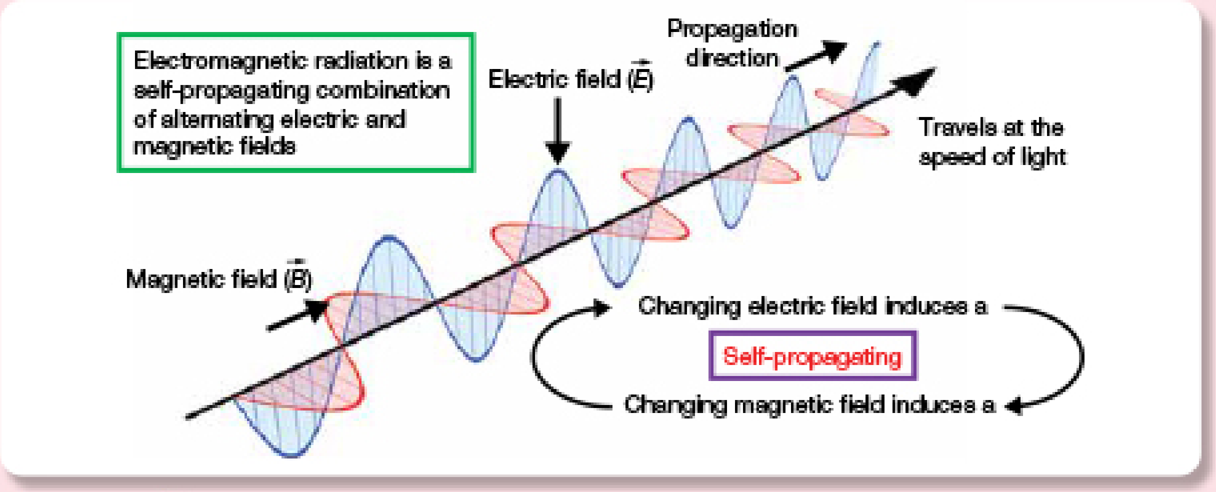
7.2 Transverse Electromagnetic Waves

Describe the production and propagation of electromagnetic waves and relate these processes qualitatively to the predictions made by Maxwell's electromagnetic theory.

Transverse electromagnetic waves

Electromagnetic waves

- Are self-propagating alternating induced electric and magnetic fields travelling through space at the speed of light, 3×10^8 m s^{-1}, slower through denser mediums.



Electromagnetic waves

- Can travel through a vacuum.
- Classified as transverse waves because the changing magnetic and electric fields are at right angles to the direction in which they carry energy.
- The **wavelength**, (λ), of an electromagnetic wave is the distance between the peaks of successive magnetic or electric field pulses.
- The **period**, (T), of an EMR is the time for one wavelength to pass a given point.
- The **frequency**, (f), is the number of wavelengths that pass a point each second. Frequency is measured in hertz (Hz).

- The energy carried by each EMR photon is directly proportional to the frequency of the radiation as given by Planck's quantum theory equation, $E = hf$, where f is the frequency of the wave and h is Planck's constant (see later).
- Note that the energy of an electromagnetic radiation photon is dependent on its frequency, *not* the amplitude of the electric and magnetic field oscillations.
- We refer to the **intensity**, (I), of an electromagnetic wave rather than to its amplitude. The intensity of an electromagnetic wave depends on the number of photons in the beam. Each photon will have energy dependent on its frequency. The more photons in a beam, the greater the intensity and the higher the total energy.

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Sample Questions

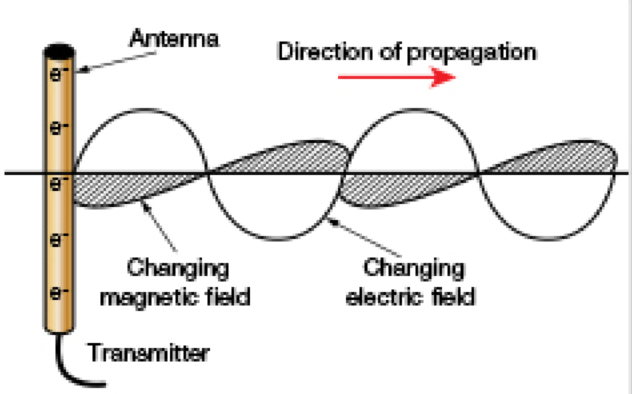
1. (a) What is an electromagnetic wave?

(b) State three ways in which an electromagnetic wave differs from transverse matter waves.

(c) Given that transverse waves are defined in terms of the relative direction of their particle oscillation, and that electromagnetic waves do not propagate through particle oscillation, why are they referred to as transverse waves?

2. Sheldon and his friends reflected a laser beam with speed 3×10^8 m s^{-1} off the Moon and received the reflected signal back on Earth 2.5 s later. According to this information, what is the distance between the Moon and the Earth?

3. The diagram shows an antenna emitting EMR.



In what way do the electrons in the antenna produce the EMR?

(A) By moving at constant speed upwards, only.

(B) By moving at constant speed downwards, only.

(C) By moving at constant speed alternatively upwards and downwards.

(D) By accelerating upwards and downwards alternatively.

4. What is the same for all EMR?

(A) Their amplitude.

(B) Their frequency.

(C) Their speed.

(D) Their wavelength.

5. What is the same for blue and yellow light?

(A) They have the same energy.

(B) They have the same frequency.

(C) They have the same speed.

(D) They have the same wavelength.

6. The Sun's rays travel through space:

(A) At the speed of sound.

(B) At twice the speed of sound.

(C) At half the speed of light.

(D) At the speed of light.

7. Which statement is true regarding mechanical and electromagnetic waves?

(A) Both types require a medium.

(B) Neither type requires a medium.

(C) A mechanical wave requires a medium, but an electromagnetic wave does not.

(D) EMR speed is affected by a medium, but the speed of a mechanical wave is not.

8. How does visible EMR from the Sun differ from the non-visible EMR from the Sun?

(A) It has different amplitudes.

(B) It travels a different distance.

(C) It travels at a different speed.

(D) It has different wavelengths.

9. What is the relationship between the wavelength (λ), and frequency (f), of an EMR?

(A) If λ increases, f increases.

(B) If f decreases, λ increases.

(C) If f remains constant, λ increases.

(D) If λ remains constant, f increases.

10. The range of electromagnetic waves placed in a certain order is called the:

(A) Electromagnetic spectrum.

(B) Electromagnetic wavelength.

(B) Electromagnetic frequency.

(B) Electromagnetic field.

11. What determines the energy carried by electromagnetic waves?

(A) Their amplitude.

(B) Their frequency.

(C) Their speed.

(D) The medium they travel through.

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7.3 Measuring the Speed Of Light

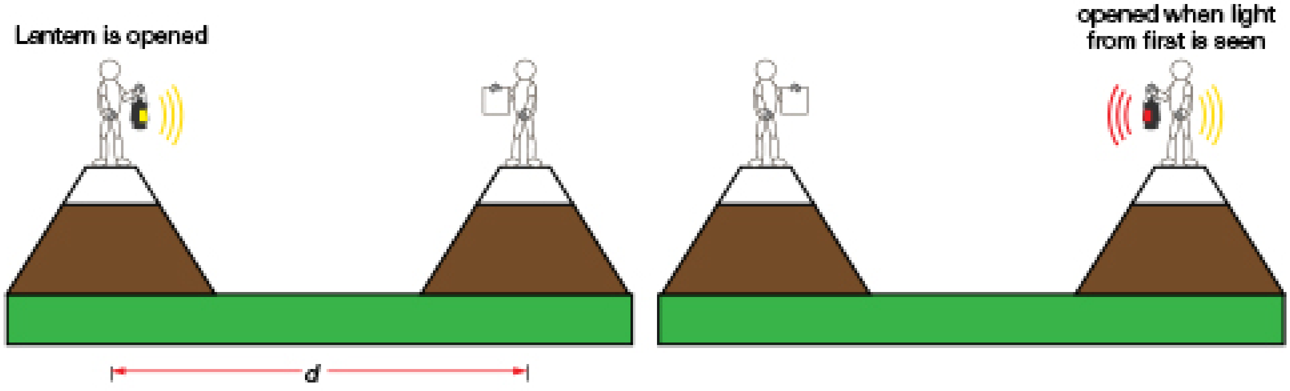
Conduct investigations of historical and contemporary methods used to determine the speed of light and its current relationship to the measurement of time and distance.

Historical measurements of the speed of light

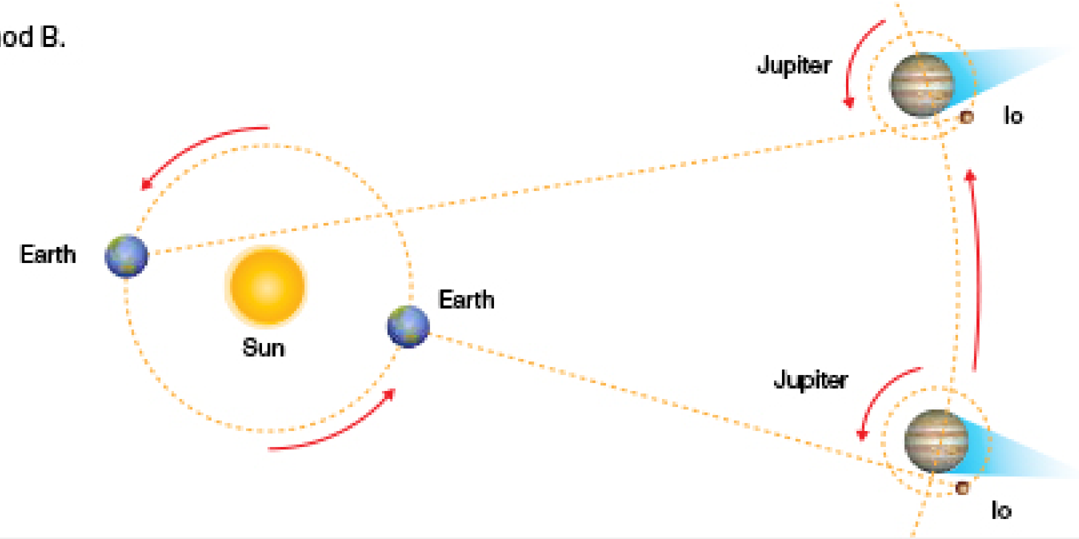
Sample Questions

1. Each of the diagrams below represents one of the early methods used by scientists to measure the speed of light. Your task for each diagram is to:
   - Determine which scientist used this method, and when he used it.
   - Briefly describe the physics behind the method used.
   - Indicate the answer he got and its degree of error taking the accepted value today (set in 1983) as 299 792 458 m s^{-1}. (Note the values you research will vary across resources.)

(a) Method A.



(b) Method B.



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