CHAPTER:-
ELECTROMAGNETIC WAVES

PREVIOUS YEARS

Question 1:

E and B represent the electric and the magnetic field of an electromagnetic wave, respectively. The direction of propagation of the wave is along

- (a) $\mathbf{B}$
- (b) $\mathbf{E}$
- (c) $\mathbf{E} \times \mathbf{B}$
- (d) $\mathbf{B} \times \mathbf{E}$

Detailed Solution:

In an electromagnetic wave, the electric field ($\mathbf{E}$) and the magnetic field ($\mathbf{B}$) oscillate perpendicular to each other and to the direction in which the wave propagates. The direction of wave propagation can be determined using the right-hand rule applied to the cross product of these two fields.

- If you point your index finger in the direction of $\mathbf{E}$ and your middle finger in the direction of $\mathbf{B}$, then your thumb will point in the direction of $\mathbf{E} \times \mathbf{B}$, which is the direction of wave propagation.

Thus, the correct answer is:

Correct Answer: (c) $\mathbf{E} \times \mathbf{B}$

Question 2:

An electromagnetic wave is produced by a charge

- (a) moving with a constant velocity
- (b) moving with a constant speed parallel to a magnetic field
- (c) moving with an acceleration
- (d) at rest

Detailed Solution:

Electromagnetic waves are generated by accelerating charges. When a charge is at rest, it creates an electric field. When it moves with a constant velocity, it creates a magnetic field. However, it is only when the charge is accelerating (changing its velocity) that both the electric and magnetic fields vary with time, and these variations propagate outward as an electromagnetic wave.

- For example, oscillating electrons in an antenna create varying electric and magnetic fields, which propagate as radio waves.

Thus, the correct answer is:

Correct Answer: (c) moving with an acceleration

Question 3:

The ratio of the magnitude of the electric field and magnetic field of a plane electromagnetic wave is equal to

- (a) the speed of light
- (b) the reciprocal of the speed of light
- (c) one
- (d) zero

Detailed Solution:

In a plane electromagnetic wave, the relationship between the magnitudes of the electric field (E) and the magnetic field (B) is governed by the speed of light (c) in the medium. The magnitude of these fields is related by:

$$\frac{E}{B} = c$$

where c is the speed of light in vacuum, approximately 3×10^8 m/s.

- This relationship comes from Maxwell's equations and reflects the intrinsic connection between electric and magnetic fields in an electromagnetic wave.

Thus, the correct answer is:

Correct Answer: (a) the speed of light

Question 4:

The electromagnetic waves used in RADAR systems are

- (a) Infrared waves
- (b) Ultraviolet rays
- (c) Microwaves
- (d) X-rays

Detailed Solution:

RADAR (Radio Detection and Ranging) systems are used for detecting the position, velocity, and characteristics of distant objects such as aircraft, ships, or weather formations. The electromagnetic waves used in RADAR are typically in the microwave range.

- Microwaves have wavelengths short enough to provide detailed resolution but long enough to penetrate through the atmosphere, making them ideal for RADAR.

Thus, the correct answer is:

Correct Answer: (c) Microwaves

Question 5:

The electromagnetic radiations used to kill germs in water purifiers are called

- (a) Infrared waves
- (b) Gamma rays
- (c) X-rays
- (d) Ultraviolet rays

Detailed Solution:

Ultraviolet (UV) light is commonly used in water purification systems to kill or inactivate microorganisms. UV light has enough energy to damage the DNA and RNA of bacteria, viruses, and other pathogens, preventing them from reproducing and causing disease.

- Unlike gamma rays and X-rays, which are more penetrating, UV light is ideal for targeting the surfaces and immediate layers of contaminants in water.

Thus, the correct answer is:

Correct Answer: (d) Ultraviolet rays

Question 6:

Which one of the following electromagnetic radiations has the least wavelength?

- (a) Gamma rays
- (b) Microwaves
- (c) Visible light
- (d) X-rays

Detailed Solution:

Electromagnetic radiation covers a wide spectrum, with different types of waves varying in wavelength and frequency. Here's a brief overview:

- **Gamma rays** have the shortest wavelengths in the electromagnetic spectrum, ranging from about 10^{-12} meters or less.
- **X-rays** have wavelengths shorter than UV light but longer than gamma rays, typically in the range of 10^{-11} to 10^{-9} meters.
- **Visible light** has wavelengths that range from approximately 400 nm (violet) to 700 nm (red).
- **Microwaves** have much longer wavelengths, ranging from about 1 mm to 1 m.

Since the question asks for the radiation with the least (shortest) wavelength, the correct answer is:

Correct Answer: (a) Gamma rays

Question 7:

Which of the following statements is not true about the properties of electromagnetic waves?

- (a) These waves do not require any material medium for their propagation.
- (b) Both electric and magnetic field vectors attain the maxima and minima at the same time.
- (c) The energy in electromagnetic waves is divided equally between electric and magnetic fields.
- (d) Both electric and magnetic field vectors are parallel to each other.

Detailed Solution:

Let's examine each statement:

- **(a) True**: Electromagnetic waves can propagate through a vacuum, meaning they do not require a material medium.
- **(b) True**: In an electromagnetic wave, the electric and magnetic fields oscillate in phase, meaning their maxima and minima occur simultaneously.
- **(c) True**: The energy carried by an electromagnetic wave is indeed divided equally between the electric and magnetic fields.
- **(d) False**: In an electromagnetic wave, the electric and magnetic field vectors are **perpendicular** to each other and to the direction of wave propagation.

Thus, the correct answer is:

Correct Answer: (d) Both electric and magnetic field vectors are parallel to each other.

Question 12:

Give the ratio of velocity of the two light waves of wavelengths 4000 Å and 8000 Å travelling in vacuum.

Detailed Solution:

In a vacuum, all electromagnetic waves, regardless of their wavelength, travel at the same speed, which is the speed of light $c = 3 \times 10^8$ m/s.

- Therefore, the velocity ratio of the two light waves, regardless of their wavelength, will be $1 : 1$.

Correct Answer: The ratio is $1 : 1$.

Question 13:

An AC source with variable frequency is connected to a parallel plate capacitor. How will the displacement current be affected with the decrease in frequency of the source?

Detailed Solution:

The displacement current I_d in a capacitor is related to the rate of change of the electric field, which depends on the frequency f of the applied AC voltage:

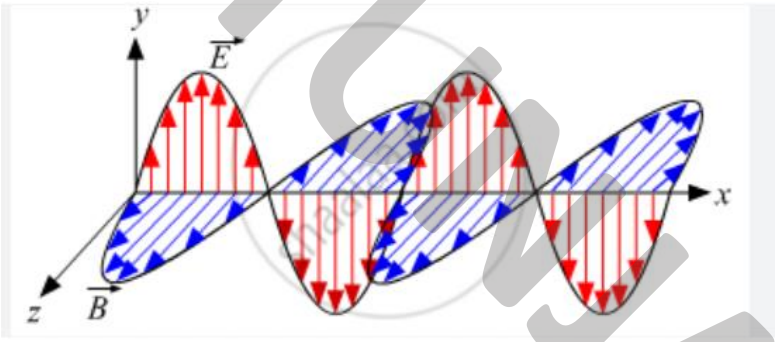
$$I_d \propto \frac{dE}{dt} \propto f$$

- As the frequency of the AC source decreases, the rate of change of the electric field also decreases. Therefore, the displacement current will decrease.

Correct Answer: The displacement current decreases with a decrease in frequency.

Question 14:

Depict the field diagram of an electromagnetic wave propagating along the positive X-axis with its electric field vector along the Y-axis.



Question 15:

Name the electromagnetic waves that are widely used as a diagnostic tool in medicine.

Detailed Solution:

- **X-rays** are widely used in medical diagnostics. They can penetrate body tissues and are used to create images of bones and internal organs.
- **Ultrasound** waves, while not electromagnetic, are also commonly used in medical diagnostics, especially for imaging soft tissues.

Correct Answer: X-rays.

Question 16:

Name the current which can flow even in the absence of electric charge.

Detailed Solution:

- The current that can flow in the absence of a physical charge carrier is known as **displacement current**. It arises in regions where the electric field changes over time, such as between the plates of a capacitor in an AC circuit.

Correct Answer: Displacement current.

Question 17:

Which part of the electromagnetic spectrum is used in RADAR? Give its frequency range.

Detailed Solution:

- **Microwaves** are used in RADAR systems. These waves are particularly useful because of their ability to penetrate the atmosphere and their appropriate wavelength for detecting objects.
- The frequency range for microwaves used in RADAR is typically from **1 GHz to 100 GHz**.

Correct Answer: Microwaves; frequency range: 1 GHz to 100 GHz.

Question 18:

How are electromagnetic waves produced by accelerating charges?

Detailed Solution:

- When a charge accelerates, it disturbs the electric and magnetic fields around it. This disturbance propagates away from the charge as an electromagnetic wave. The oscillating electric field generates a magnetic field and vice versa, leading to the propagation of the wave through space.

Correct Answer: Electromagnetic waves are produced by accelerating charges that cause time-varying electric and magnetic fields.

Question 19:

Name the electromagnetic radiations used for (i) water purification, and (ii) eye surgery.

Detailed Solution:

- **(i) Water purification: Ultraviolet (UV) rays** are used to kill germs and microorganisms in water, making it safe for consumption.
- **(ii) Eye surgery: Lasers** (which can be in the visible, UV, or infrared range) are commonly used in eye surgeries such as LASIK.

Correct Answer:

- (i) Ultraviolet rays
- (ii) Lasers

Question 20:

Do electromagnetic waves carry energy and momentum?

Detailed Solution:

- Yes, electromagnetic waves carry both energy and momentum. The energy is stored in the oscillating electric and magnetic fields, and momentum is associated with the wave's ability to exert pressure (radiation pressure) on objects.

Correct Answer: Yes, electromagnetic waves carry energy and momentum.

Question 21:

How is the speed of electromagnetic waves in vacuum determined by the electric and magnetic fields?

Detailed Solution:

- The speed of electromagnetic waves in vacuum, c, is determined by the permittivity ϵ_0 and permeability μ_0 of free space:

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

- This relationship shows that the speed of light is a fundamental constant related to the properties of electric and magnetic fields in a vacuum.

Correct Answer: The speed of electromagnetic waves in vacuum is determined by the relation $c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$.

Question 22:

In which directions do the electric and magnetic field vectors oscillate in an electromagnetic wave propagating along the X-axis?

Detailed Solution:

- In an electromagnetic wave propagating along the X-axis:
  - The electric field vector $\mathbf{E}$ oscillates perpendicular to the X-axis, say along the Y-axis.
  - The magnetic field vector $\mathbf{B}$ oscillates perpendicular to both the X-axis and the direction of the electric field, say along the Z-axis.

Correct Answer: The electric field oscillates along the Y-axis, and the magnetic field oscillates along the Z-axis.

Question 23:

Why are microwaves considered suitable for RADAR systems used in aircraft navigation?

Detailed Solution:

- Microwaves are suitable for RADAR systems because they have wavelengths that are small enough to detect objects with fine detail and long enough to penetrate through the atmosphere without significant attenuation.
- Additionally, microwaves can reflect off solid objects, making them ideal for detecting and tracking aircraft, weather formations, and other objects in the sky.

Correct Answer: Microwaves are suitable for RADAR systems because they penetrate the atmosphere effectively, have appropriate wavelengths for detailed detection, and can reflect off objects for accurate tracking.

Question 24:

The charging current for a capacitor is 0.25 A. What is the displacement current across its plates?

Detailed Solution:

- Displacement current I_d is the current that occurs in the region between the plates of a capacitor when the electric field changes. According to Maxwell's equations, the displacement current is equal to the charging current in the circuit.

Since the charging current is given as 0.25 A, the displacement current I_d will also be:
Correct Answer: 0.25 A.

Question 25:

To which part of the electromagnetic spectrum does a wave of frequency 5×10^{19} Hz belong?

Detailed Solution:

- The electromagnetic spectrum ranges from radio waves (with the lowest frequencies) to gamma rays (with the highest frequencies).
- The given frequency 5×10^{19} Hz falls within the range of **X-rays** and **gamma rays**. Generally, X-rays have frequencies from 10^{16} Hz to 10^{19} Hz, and gamma rays have frequencies above 10^{19} Hz.

Given that 5×10^{19} Hz is near the boundary, this frequency belongs to the **gamma rays** part of the spectrum.

Correct Answer: Gamma rays.

Question 26:

To which part of the electromagnetic spectrum does a wave of frequency 3×10^{13} Hz belong?

Detailed Solution:

- Infrared waves have frequencies ranging from about 10^{12} Hz to 10^{14} Hz.
- The frequency 3×10^{13} Hz falls squarely within the **infrared** region of the electromagnetic spectrum.

Correct Answer: Infrared waves.

Question 27:

Arrange the following electromagnetic waves in order of increasing frequency: gamma rays, microwaves, infrared rays, ultraviolet rays.

Detailed Solution:

- **Microwaves** have the lowest frequency.
- **Infrared rays** come next, with higher frequency.
- **Ultraviolet rays** have even higher frequency.
- **Gamma rays** have the highest frequency.

Thus, the order of increasing frequency is:
Correct Answer: Microwaves < Infrared rays < Ultraviolet rays < Gamma rays.

Question 28:

Welders wear special goggles or face masks with glass windows to protect their eyes from electromagnetic radiation. Name the radiations and write the range of their frequencies.

Detailed Solution:

- **Ultraviolet (UV) radiation** is primarily what welders need protection from, as the arc welding process emits intense UV light which can cause eye damage.

  Frequency range:

  - **Ultraviolet (UV) radiation:** 10^{15} Hz to 10^{17} Hz.

Welders may also be exposed to **visible light** and **infrared radiation**, but UV radiation is the most hazardous.

Correct Answer: Ultraviolet radiation, with frequency range 10^{15} Hz to 10^{17} Hz.

Question 29:

A capacitor has been charged by a DC source. What are the magnitudes of conduction and displacement currents, when it is fully charged?

Detailed Solution:

- **Conduction current:** When the capacitor is fully charged, there is no further movement of charge onto the plates, so the conduction current I_c is zero.
- **Displacement current:** Displacement current I_d exists only when the electric field between the plates is changing. Once fully charged, the electric field becomes steady, so the displacement current I_d is also zero.

Correct Answer: Both conduction current and displacement current are zero when the capacitor is fully charged.

Question 30:

What are the directions of electric and magnetic field vectors relative to each other and relative to the direction of propagation of electromagnetic waves?

Detailed Solution:

- In an electromagnetic wave, the electric field ($\mathbf{E}$) and magnetic field ($\mathbf{B}$) vectors are perpendicular to each other.
- Both the $\mathbf{E}$ and $\mathbf{B}$ fields are also perpendicular to the direction of propagation of the wave.
- If the wave is propagating in the X-direction:
  - $\mathbf{E}$ might be in the Y-direction.
  - $\mathbf{B}$ will then be in the Z-direction.

Correct Answer: The electric and magnetic field vectors are perpendicular to each other and to the direction of propagation of the wave.

Question 31:

Name the electromagnetic waves which (i) maintain the earth's warmth and (ii) are used in aircraft navigation.

Detailed Solution:

- **(i) Infrared radiation:** Infrared waves maintain the Earth's warmth by being absorbed and re-radiated by the Earth's surface and atmosphere.
- **(ii) Microwaves:** Microwaves are used in RADAR systems for aircraft navigation.

Correct Answer:

- (i) Infrared radiation.
- (ii) Microwaves.

Question 32:

A plane electromagnetic wave travels in vacuum along the Z-direction. What can you say about the direction of electric and magnetic field vectors?

Detailed Solution:

- If the wave is traveling in the Z-direction, the electric and magnetic fields must be perpendicular to the direction of propagation and to each other.
  - The electric field ($\mathbf{E}$) could be along the X-axis.
  - The magnetic field ($\mathbf{B}$) would then be along the Y-axis.

Correct Answer: The electric field is along the X-axis and the magnetic field is along the Y-axis, with the wave propagating along the Z-axis.

Question 33:

How are radio waves produced?

Detailed Solution:

- **Radio waves** are produced by accelerating electrons in an antenna. When an alternating current (AC) flows through the antenna, it causes the electrons to oscillate back and forth. This oscillation of charge generates a time-varying electric and magnetic field, which propagates as a radio wave.

Correct Answer: Radio waves are produced by accelerating electrons in an antenna, typically through an alternating current.

Question 34:

Write two uses of microwaves.

Detailed Solution:

- **(1) Communication:** Microwaves are used in satellite communications and mobile networks because they can penetrate the atmosphere and travel long distances.
- **(2) Cooking:** Microwaves are used in microwave ovens to heat food. The microwaves excite water molecules in the food, causing them to heat up.

Correct Answer: Communication (e.g., satellite communications) and cooking (e.g., microwave ovens).

Question 35:

Write two uses of infrared rays.

Detailed Solution:

- **(1) Thermal imaging:** Infrared rays are used in thermal imaging cameras to detect heat emitted by objects. This is useful in night vision equipment and for detecting heat leaks in buildings.
- **(2) Remote controls:** Infrared rays are commonly used in remote controls for televisions, air conditioners, and other appliances.

Correct Answer: Thermal imaging and remote controls.

Question 36:

Write two uses of X-rays.

Detailed Solution:

- **(1) Medical imaging:** X-rays are used to create images of bones and internal organs in medical diagnostics.
- **(2) Security scanning:** X-rays are used in security systems at airports to scan luggage for concealed items.

Correct Answer: Medical imaging and security scanning.

Question 37:

What is the frequency of electromagnetic waves produced by oscillating charge of frequency $v = 10^5$ Hz?

Detailed Solution:

- The frequency of the electromagnetic waves produced by an oscillating charge is the same as the frequency of the charge's oscillation.

Correct Answer: The frequency is 10^5 Hz.

Question 38:

How are infrared waves produced? What is the range of their wavelength?

Detailed Solution:

- **Production:** Infrared waves are produced by the thermal motion of atoms and molecules. Objects at room temperature and above emit infrared radiation.
- **Wavelength Range:** The wavelength range of infrared waves is typically from 700 nm (near infrared) to 1 mm (far infrared).

Correct Answer: Infrared waves are produced by the thermal motion of atoms and molecules. Their wavelength ranges from 700 nm to 1 mm.

Question 39:

Which of the following has the shortest wavelength? Microwaves, Ultraviolet rays, X-rays.

Detailed Solution:

- **Microwaves** have the longest wavelength, followed by **ultraviolet rays**, and **X-rays** have the shortest wavelength among the options provided.

Correct Answer: X-rays.

Question 40:

Name the part of the electromagnetic spectrum whose wavelength lies in the range of 10^{-10} m. Give its one use.

Detailed Solution:

- Wavelengths in the range of 10^{-10} meters correspond to **X-rays**.
- **Use:** One use of X-rays is in **medical imaging** to view the internal structure of the human body, particularly bones.

Correct Answer: X-rays; use in medical imaging.

Question 41:

Arrange the following in descending order of wavelength: X-rays, radio waves, blue light, infrared light.

Detailed Solution:

To arrange these in descending order of wavelength, we need to understand the electromagnetic spectrum:

- **Radio waves** have the longest wavelengths.
- **Infrared light** comes next, with shorter wavelengths than radio waves.
- **Blue light** has shorter wavelengths than infrared.
- **X-rays** have the shortest wavelengths among the given options.

Order in Descending Wavelength:

Correct Answer: Radio waves > Infrared light > Blue light > X-rays.

Question 42:

Which part of the electromagnetic spectrum has the largest penetrating power?

Detailed Solution:

- **Gamma rays** have the highest energy and hence the largest penetrating power in the electromagnetic spectrum. They can pass through most materials, which is why they are used in medical treatments and for sterilizing equipment.

Correct Answer: Gamma rays.

Question 43:

Which part of the electromagnetic spectrum is absorbed from sunlight by the ozone layer?

Detailed Solution:

- The ozone layer in the Earth's atmosphere absorbs **Ultraviolet (UV) rays** from sunlight. This absorption is crucial for protecting living organisms from harmful UV radiation.

Correct Answer: Ultraviolet (UV) rays.

Question 44:

Which part of the electromagnetic spectrum is used in RADAR systems?

Detailed Solution:

- **Microwaves** are used in RADAR systems. Their wavelength is suitable for detecting objects and their range allows for effective radar communication.

Correct Answer: Microwaves.

Question 45:

Name the electromagnetic radiation used to destroy cancer cells and write its frequency range.

Detailed Solution:

- **Gamma rays** are used to destroy cancer cells through a process known as radiation therapy.

  Frequency Range:

  - Gamma rays have frequencies greater than 10^{19} Hz.

Correct Answer: Gamma rays; frequency range above 10^{19} Hz.

Question 46:

Which part of the electromagnetic spectrum is used in satellite communication?

Detailed Solution:

- **Microwaves** are used in satellite communication. Their frequency range allows them to travel long distances and penetrate the Earth's atmosphere effectively.

Correct Answer: Microwaves.

Question 47:

In what way are the directions of the electric and magnetic field vectors representing an electromagnetic wave related to each other?

Detailed Solution:

- In an electromagnetic wave, the electric field ($\mathbf{E}$) and magnetic field ($\mathbf{B}$) vectors are perpendicular to each other and both are perpendicular to the direction of wave propagation.

Correct Answer: The electric and magnetic field vectors are perpendicular to each other and to the direction of propagation.

Question 48:

Express the velocity of propagation of an electromagnetic wave in terms of the peak value of the electric and magnetic fields.

Detailed Solution:

- The velocity v of an electromagnetic wave in vacuum is given by the relation:

$$v = \frac{E_0}{B_0}$$

where E_0 is the peak value of the electric field and B_0 is the peak value of the magnetic field.

Correct Answer: $v = \frac{E_0}{B_0}$.

Question 49:

How are infrared waves produced? Why are these waves referred to as heat waves? Give any two uses of infrared waves.

Detailed Solution:

- **Production:** Infrared waves are produced by the thermal motion of atoms and molecules. Any object at a temperature above absolute zero emits infrared radiation.
- **Heat Waves:** Infrared waves are referred to as heat waves because they are primarily responsible for the heat we feel from sunlight and other sources. They increase the kinetic energy of molecules, which we perceive as heat.
- **Uses:**
    1. **Thermal imaging:** Infrared waves are used in night vision devices and thermal cameras.
    2. **Remote controls:** Infrared waves are commonly used in remote controls for televisions, air conditioners, and other electronic devices.

Correct Answer:

- Infrared waves are produced by thermal motion of atoms and molecules.
- They are called heat waves because they increase molecular kinetic energy, causing heat.
- Uses: Thermal imaging, remote controls.

Question 50:

How are X-rays produced? Give any two uses of these.

Detailed Solution:

- **Production:** X-rays are produced when high-energy electrons strike a metal target (such as tungsten). The sudden deceleration of these electrons as they hit the target emits X-rays.
- **Uses:**
    1. **Medical imaging:** X-rays are used to produce images of bones and other structures inside the body.
    2. **Security screening:** X-rays are used in airport security to scan luggage and detect prohibited items.

Correct Answer:

- X-rays are produced by the sudden deceleration of high-energy electrons hitting a metal target.
- Uses: Medical imaging, security screening.

Question 51:

Identify the electromagnetic radiation and write its wavelength range, which is used to kill germs in water purifiers. Name the two sources of these radiations.

Detailed Solution:

- **Radiation: Ultraviolet (UV) radiation** is used to kill germs in water purifiers.

  Wavelength Range: UV radiation has a wavelength range of approximately 10 nm to 400 nm.

  Sources:
    1. **Mercury vapor lamps:** These are commonly used in water purifiers to emit UV-C light.
    2. **UV LEDs:** Modern water purifiers may use UV LEDs as a source of UV radiation.

Correct Answer:

- Ultraviolet (UV) radiation; wavelength range 10 nm to 400 nm.
- Sources: Mercury vapor lamps, UV LEDs.

Question 52:

Write any two characteristics of an electromagnetic wave. Why are microwaves used in RADAR systems?

Detailed Solution:

- **Characteristics of Electromagnetic Waves:**
  1. They do not require a medium for propagation and can travel through a vacuum.
  2. The electric and magnetic fields are perpendicular to each other and to the direction of wave propagation.
- **Microwaves in RADAR:** Microwaves are used in RADAR systems because they can penetrate the atmosphere, have appropriate wavelengths for detecting objects, and can reflect off solid surfaces for accurate measurement.

Correct Answer:

- Characteristics: No medium required for propagation; perpendicular electric and magnetic fields.
- Microwaves are used in RADAR because they penetrate the atmosphere and reflect off objects.

Question 53:

What is a displacement current? How is it different from a conduction current?

Detailed Solution:

- **Displacement Current:** Displacement current is the current that appears in regions where the electric field is changing with time, such as in the space between the plates of a charging capacitor. It is given by:

$$I_d = \epsilon_0 \frac{d\Phi_E}{dt}$$

  where Φ_E is the electric flux.
- **Difference from Conduction Current:**
  - **Conduction current** is the flow of real electric charges, such as electrons, through a conductor.
  - **Displacement current** does not involve the actual movement of charges but is related to the time-varying electric field.

Correct Answer:

- Displacement current arises from time-varying electric fields, different from conduction current which involves the flow of charge.

Question 54:

What is meant by the term 'displacement current'? Briefly explain how this current is different from a conduction current.

Detailed Solution:

- **Displacement Current:** Displacement current is a concept introduced by Maxwell to account for the changing electric field in regions where there is no actual charge movement, such as between the plates of a capacitor during charging.
- **Difference from Conduction Current:** Conduction current involves the flow of charge through a conductor, whereas displacement current is a result of a changing electric field, with no actual charge carriers moving through the space.

Correct Answer:

- Displacement current is associated with time-varying electric fields, differing from conduction current which involves actual charge flow.

Question 55:

Identify the electromagnetic wave whose wavelength range is from about 10^{-12} m to about 10^{-8} m. Write one use of each.

Detailed Solution:

- **Electromagnetic Wave:** The wavelength range 10^{-12} m to 10^{-8} m corresponds to **X-rays** and **Gamma rays**.

  Uses:

  - **X-rays** (10^{-10} m to 10^{-8} m): Used in medical imaging to view the internal structure of the body.
  - **Gamma rays** (10^{-12} m to 10^{-10} m): Used in cancer treatment (radiotherapy) and sterilization of medical equipment.

Correct Answer:

- X-rays (10^{-10} m to 10^{-8} m): Used in medical imaging.
- Gamma rays (10^{-12} m to 10^{-10} m): Used in cancer treatment.

Question 56:

Gamma rays and radio waves travel with the same velocity in free space. Distinguish between them in terms of their origin and the main application.

Detailed Solution:

- Gamma Rays:
  - **Origin:** Gamma rays originate from nuclear reactions, such as radioactive decay, and from certain astronomical events like supernovae.
  - **Main Application:** Gamma rays are primarily used in medical treatments, such as in cancer radiotherapy, and in sterilizing medical equipment.
- Radio Waves:
  - **Origin:** Radio waves are generated by oscillating electrical charges, such as those in radio transmitters and antennas.
  - **Main Application:** Radio waves are widely used in communication systems, including radio and television broadcasting, and mobile phone networks.

Correct Answer:

- **Gamma Rays:** Origin—nuclear reactions; Application—medical treatments (radiotherapy).
- **Radio Waves:** Origin—oscillating electrical charges; Application—communication systems.

Question 57:

Compare the following:
(i) Wavelengths of the incident solar radiation absorbed by the earth's surface and the radiation re-radiated by the earth.
(ii) Tanning effect produced on the skin by UV radiation incident directly on the skin and that coming through glass window.

Detailed Solution:

- (i) Wavelength Comparison:
  - **Incident Solar Radiation:** The wavelengths of solar radiation absorbed by the Earth's surface are primarily in the visible light range (approximately 400 nm to 700 nm) and some infrared (700 nm to 1 mm).
  - **Radiation Re-radiated by Earth:** The Earth re-radiates energy in the form of infrared radiation, which has longer wavelengths (typically around 10 μm or 10,000 nm).
- (ii) Tanning Effect:
  - **Direct UV Radiation:** UV radiation incident directly on the skin can cause a significant tanning effect, as it penetrates the skin and stimulates melanin production.
  - **UV Radiation Through Glass:** UV radiation that passes through a glass window is significantly reduced, as glass blocks most UV-B and UV-C rays. As a result, the tanning effect is much less pronounced.

Question 58:

How is the equation for Ampere's circuital law modified in the presence of displacement current? Explain.

Detailed Solution:

- **Original Ampere's Law:**

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{\text{enc}}$$

This equation states that the line integral of the magnetic field $\mathbf{B}$ around a closed loop is proportional to the current I_{enc} enclosed by the loop.

- **Modified Ampere-Maxwell Law:**
In the presence of a time-varying electric field, which gives rise to a displacement current, the law is modified as:

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 \left(I_{\text{enc}} + \epsilon_0 \frac{d\Phi_E}{dt} \right)$$

where $\epsilon_0 \frac{d\Phi_E}{dt}$ represents the displacement current. This modification allows the law to account for the changing electric fields in regions where there is no actual current flow.

Question 59:

How are electromagnetic waves produced by oscillating charges? What is the source of the energy associated with the EM waves?

Detailed Solution:

- **Production of Electromagnetic Waves:** When a charge oscillates (i.e., moves back and forth), it creates a changing electric field. This changing electric field generates a magnetic field, which in turn changes and generates another electric field. This self-propagating system of alternating electric and magnetic fields travels through space as an electromagnetic wave.
- **Source of Energy:** The energy of the electromagnetic waves comes from the energy provided to oscillate the charge. In practical terms, this could be the energy from a power supply or an oscillator circuit that causes the charge to move.

Correct Answer:

- Electromagnetic waves are produced by oscillating charges, creating time-varying electric and magnetic fields.
- The source of the energy is the power or work done to oscillate the charge.

Question 60:

A capacitor made of two parallel plates, each of area A and separation d, is charged by an external DC source. Show that during charging, the displacement current inside the capacitor is the same as the current charging the capacitor.

Detailed Solution:

- **Conduction Current:** When the capacitor is being charged, the conduction current I_c flows through the circuit and causes a buildup of charge on the plates.
- **Displacement Current:** Inside the capacitor, even though no physical charge moves across the gap, the changing electric field due to the increasing voltage across the plates generates a displacement current I_d.
- **Relationship Between I_c and I_d:**
  - The conduction current I_c charging the capacitor is related to the rate of change of charge Q on the capacitor:

$$I_c = \frac{dQ}{dt}$$

  - The displacement current I_d is given by:

$$I_d = \epsilon_0 \frac{d\Phi_E}{dt}$$

where Φ_E is the electric flux through the area A.

Since $Q = \epsilon_0 E \cdot A$, where E is the electric field, we have:

$$I_d = \epsilon_0 \cdot \frac{d}{dt}\left(\frac{Q}{\epsilon_0 A}\right) \cdot A = \frac{dQ}{dt} = I_c$$

Thus, the displacement current inside the capacitor is equal to the conduction current charging the capacitor.

Question 61:

(i) Why are infrared waves often called heat waves? Explain.
(ii) What do you understand by the statement, "electromagnetic waves transport momentum"?

Detailed Solution:

- **(i) Infrared Waves as Heat Waves:**
  - Infrared waves are often called heat waves because they are absorbed by molecules in substances, increasing the kinetic energy of those molecules, which manifests as heat. This is why infrared radiation is associated with warmth.
- **(ii) Electromagnetic Waves Transport Momentum:**
  - Electromagnetic waves carry momentum because they exert pressure on objects when they are absorbed or reflected. This phenomenon is known as radiation pressure. The momentum carried by EM waves is proportional to their energy, given by $p = \frac{E}{c}$, where p is the momentum, E is the energy, and c is the speed of light.

Correct Answer:

- **(i)** Infrared waves are called heat waves because they increase the kinetic energy of molecules, causing heat.
- **(ii)** Electromagnetic waves transport momentum, exerting pressure on objects upon absorption or reflection.

Question 62:

(i) Give one use of electromagnetic radiations obtained in nuclear disintegrations.
(ii) Give one example each to illustrate the situation where there is (i) displacement current but no conduction current and (ii) only conduction current but no displacement current.

Detailed Solution:

- **(i) Use of Electromagnetic Radiation in Nuclear Disintegration:**
  - Gamma rays, which are emitted during nuclear disintegration, are used in **radiotherapy** for treating cancer by targeting and killing cancerous cells.
- **(ii) Examples:**
  - **Displacement Current but No Conduction Current:** This occurs in the region between the plates of a capacitor during charging. There is no physical movement of charges across the gap, but the changing electric field produces a displacement current.
  - **Conduction Current but No Displacement Current:** In a direct current (DC) circuit with a steady current, charges flow through the circuit (conduction current) without any changing electric field, so there is no displacement current.

Question 63:

Identify the electromagnetic waves whose wavelengths vary as (i) $10^{-12}\,\mathrm{m} < \lambda < 10^{-8}\,\mathrm{m}$ (ii) $10^{-3}\,\mathrm{m} < \lambda < 10^{-1}\,\mathrm{m}$. Write one use for each.

Detailed Solution:

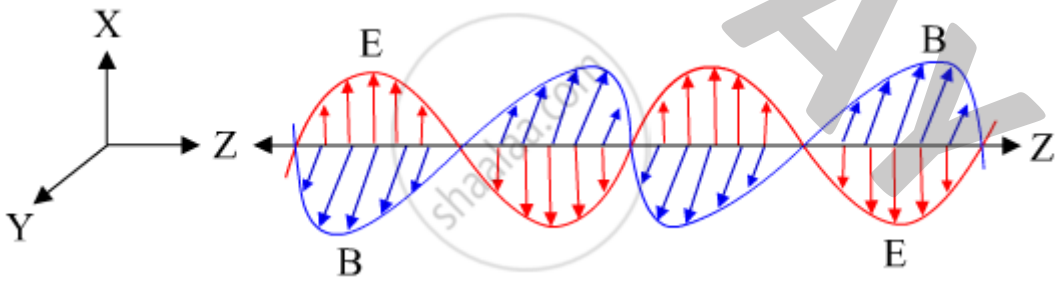
- (i) Wavelength Range $10^{-12}\,\mathrm{m} < \lambda < 10^{-8}\,\mathrm{m}$:
  - **X-rays** and **Gamma rays** fall within this wavelength range.
  - **Use:** X-rays are used in medical imaging to view the internal structure of the body.
- (ii) Wavelength Range $10^{-3}\,\mathrm{m} < \lambda < 10^{-1}\,\mathrm{m}$:
  - **Microwaves** fall within this wavelength range.
  - **Use:** Microwaves are used in microwave ovens to heat food.

Question 64:

(i) How does oscillating charge produce electromagnetic waves?
(ii) Sketch a schematic diagram depicting oscillating electric and magnetic fields of an EM wave propagating along positive Z-direction.

Detailed Solution:

- (i) Production of Electromagnetic Waves by Oscillating Charge:
  - When a charge oscillates, it creates a time-varying electric field. This changing electric field induces a time-varying magnetic field. These alternating fields propagate through space as an electromagnetic wave.



Question 65:

(i) How are electromagnetic waves produced?

(ii) How do you convince yourself that electromagnetic waves carry energy and momentum?

Detailed Solution:

- **(i) Production of Electromagnetic Waves:**
  - Electromagnetic waves are produced by accelerating charges. When a charge accelerates, it generates a time-varying electric field, which in turn induces a time-varying magnetic field, resulting in the propagation of an electromagnetic wave.
- **(ii) Evidence of Energy and Momentum in Electromagnetic Waves:**
  - **Energy:** The energy carried by electromagnetic waves is evident from their ability to heat objects (e.g., sunlight warming the Earth) and perform work (e.g., driving a solar cell).

Electromagnetic waves, like light, are made up of tiny particles called photons. Even though photons don't have mass, they carry both energy and momentum. The momentum p of a photon is given by the formula:

$$p = \frac{E}{c}$$

where E is the energy of the photon and c is the speed of light.

This means that when light hits something, it can exert a tiny force because of the momentum it carries. The energy carried by photons is what causes effects like warming when sunlight hits your skin. So, this explains how light, and other electromagnetic waves, carry both energy and momentum.

Question 66:

(i) Arrange the following electromagnetic waves in the descending order of their wavelengths: (a) Microwaves (b) Infrared rays (c) Ultraviolet radiation (d) X-rays
(ii) Write one use each of any two of them.

Detailed Solution:

(i) Descending order of wavelengths:

- **Microwaves** have the longest wavelengths.
- **Infrared rays** come next with shorter wavelengths.
- **Ultraviolet radiation** has even shorter wavelengths.
- **X-rays** have the shortest wavelengths among these.

Order: Microwaves > Infrared rays > Ultraviolet radiation > X-rays.

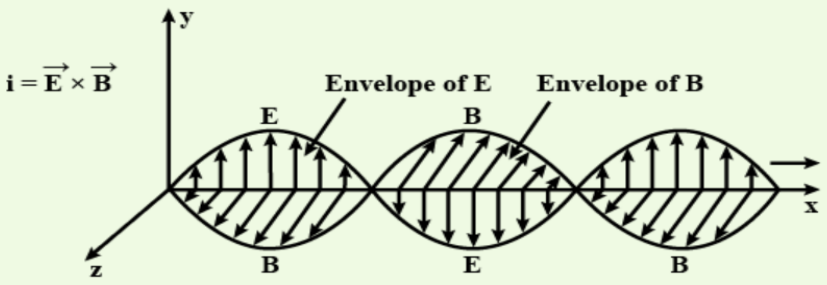
(ii) Uses:

- **Microwaves:** Used in microwave ovens for heating food.
- **X-rays:** Used in medical imaging to view internal structures like bones.

Question 67:

(i) An electromagnetic wave is traveling in a medium, with a velocity v = i. Draw a sketch showing the propagation of the electromagnetic wave, indicating the direction of the oscillating electric and magnetic fields.
(ii) How are the magnitudes of the electric and magnetic fields related to velocity of the electromagnetic wave?

$\vec{E} \times \vec{B}$ represent the direction of propogation of wave.
Refer image,
Graph showing B along $\hat{k}$ and E along $\hat{j}$
(b) Speed of electromagnetic wave is $V = \frac{E_o}{B_o}$
Where E_o =Magnititude of electric field
B_o =Magnititude of magnetic field



Question 68:

A capacitor of capacitance C is being charged by connecting it across a DC source along with an ammeter. Will the ammeter show a momentary deflection during the process of charging? If so, how would you explain this momentary deflection and the resulting continuity of current in the circuit? Write the expression for the current inside the capacitor.

Detailed Solution:

- **Ammeter Deflection:**
  - Yes, the ammeter will show a momentary deflection during the charging process. This deflection is due to the current flowing into the capacitor as it charges.
- **Explanation:**
  - As the capacitor charges, electrons accumulate on one plate, creating a potential difference across the plates. This movement of charge creates a conduction current in the circuit, which causes the ammeter to deflect.
  - Inside the capacitor, there is no actual movement of charge across the dielectric; instead, there is a displacement current, which maintains the continuity of current in the circuit.
- **Expression for Current:**
  - The displacement current I_d is given by:

$$I_d = \epsilon_0 \frac{dE}{dt} A = \epsilon_0 \frac{dV}{dt} \cdot \frac{A}{d}$$

  - This is equal to the conduction current outside the capacitor during charging.

Question 69:

When an ideal capacitor is charged by a DC battery, no current flows. However, when an AC source is used, the current flows continuously. How does one explain this, based on the concept of displacement current?

Detailed Solution:

- **DC Case:**
  - When a DC battery is connected, the capacitor initially charges, and a current flows. Once fully charged, the current stops because there is no change in the electric field, and hence no displacement current.
- **AC Case:**
  - When an AC source is used, the voltage across the capacitor continually changes direction and magnitude, causing a continuously changing electric field. This results in a continuous displacement current within the capacitor, which allows the current to flow continuously in the external circuit.

Question 70:

Explain briefly how electromagnetic waves are produced by an oscillating charge? How is the frequency of the electromagnetic waves produced related to that of the oscillating charge?

Detailed Solution:

- **Production of Electromagnetic Waves:**
  - An oscillating charge generates a time-varying electric field. This changing electric field induces a magnetic field, which in turn induces an electric field. This process continues, and the disturbance propagates as an electromagnetic wave.
- **Frequency Relationship:**
  - The frequency of the electromagnetic wave is exactly the same as the frequency of the oscillating charge. If the charge oscillates with a frequency f, the electromagnetic wave produced also has a frequency f.

Question 71:

Name the constituent radiation of the electromagnetic spectrum, which is used for (i) aircraft navigation (ii) studying the crystal structure. Write the frequency range for each.

Detailed Solution:

(i) Aircraft Navigation:

- **Microwaves** are used in RADAR systems for aircraft navigation.
- **Frequency Range:** Typically 1 GHz to 100 GHz.

(ii) Studying Crystal Structure:

- **X-rays** are used to study crystal structures through X-ray diffraction techniques.
- **Frequency Range:** Typically 10^{16} Hz to 10^{19} Hz.

Question 73:

Arrange the following electromagnetic radiations in ascending order of their frequencies:

(a) Microwaves
(b) Infrared rays
(c) Ultraviolet radiation
(d) X-rays

Detailed Solution:

- **Microwaves** have the lowest frequencies.
- **Infrared rays** have higher frequencies than microwaves.
- **Ultraviolet radiation** has higher frequencies than infrared rays.
- **X-rays** have the highest frequencies among these.

Question 74:

How are X-rays produced? Write their two important uses.

Detailed Solution:

- **Production of X-rays:**
  - X-rays are produced when high-energy electrons are suddenly decelerated upon striking a metal target, such as tungsten, in an X-ray tube. This deceleration causes the release of energy in the form of X-rays.
- **Two Important Uses:**
  1. **Medical Imaging:** X-rays are used extensively in medical diagnostics to create images of the inside of the body, particularly bones.
  2. **Security Scanning:** X-rays are used in security scanners at airports to inspect the contents of luggage and other items.

Question 75:

How are infrared rays produced? Write their two important uses.

Detailed Solution:

- **Production of Infrared Rays:**
  - Infrared rays are produced by the thermal motion of atoms and molecules. Any object with a temperature above absolute zero emits infrared radiation.
- **Two Important Uses:**
  1. **Thermal Imaging:** Infrared rays are used in thermal cameras to detect heat emitted by objects, useful in night vision devices.
  2. **Remote Controls:** Infrared rays are widely used in remote control devices for televisions, air conditioners, and other electronic gadgets.

Question 76:

How are microwaves produced? Write their two important uses.

Detailed Solution:

- **Production of Microwaves:**
  - Microwaves are produced by devices such as magnetrons and klystrons, which generate microwaves by accelerating electrons in a vacuum tube.
- **Two Important Uses:**
  1. **Cooking:** Microwaves are used in microwave ovens to heat and cook food by causing water molecules in the food to vibrate, generating heat.
  2. **Communication:** Microwaves are used in satellite and cellular communications due to their ability to penetrate the atmosphere and travel long distances.

Question 77:

Electromagnetic waves with wavelength:

(i) λ_1 is suitable for RADAR systems used in aircraft navigation.

(ii) λ_2 is used to kill germs in water purifiers.

(iii) λ_3 is used to improve visibility in runways during fog and mist conditions.

Identify and name the part of the electromagnetic spectrum to which these radiations belong. Also, arrange these wavelengths in ascending order of their magnitude.

Detailed Solution:

- (i) λ_1 - RADAR Systems:
  - **Part of Spectrum:** Microwaves.
- (ii) λ_2 - Water Purifiers:
  - **Part of Spectrum:** Ultraviolet (UV) radiation.
- (iii) λ_3 - Visibility in Fog:
  - **Part of Spectrum:** Infrared rays.
- Ascending Order of Wavelengths:
  - **UV (λ_2)** has the shortest wavelength.
  - **Infrared (λ_3)** has a longer wavelength than UV.
  - **Microwaves (λ_1)** have the longest wavelength.

Question 78:

(i) Depict a plane electromagnetic wave propagating along the X-axis. Write the expressions for its oscillating electric and magnetic fields.
(ii) Write three characteristics of electromagnetic waves.

Detailed Solution:

(i) Plane Electromagnetic Wave:

- **Expression for Electric Field E:**
  - $E = E_0 \sin(kx - \omega t)\hat{j}$, where E_0 is the amplitude, k is the wave number, ω is the angular frequency, x is the position, and t is time. $\hat{j}$ indicates the direction of the electric field along the Y-axis.
- **Expression for Magnetic Field B:**
  - $B = B_0 \sin(kx - \omega t)\hat{k}$, where B_0 is the amplitude, and $\hat{k}$ indicates the direction of the magnetic field along the Z-axis.

(ii) Three Characteristics of Electromagnetic Waves:

1. **Transverse Nature:** The electric and magnetic fields oscillate perpendicular to each other and to the direction of wave propagation.
2. **Speed:** In a vacuum, electromagnetic waves travel at the speed of light, $c = 3 \times 10^8$ m/s.
3. **No Medium Required:** Electromagnetic waves can propagate through a vacuum without requiring a medium.

Question 79:

Electromagnetic waves of wavelengths λ_1, λ_2, and λ_3 are used in RADAR systems, in water purifiers, and in remote switches of TV, respectively.
(i) Identify the electromagnetic waves and
(ii) Write one source of each of them.

Detailed Solution:

(i) Identification:

- **λ_1 - RADAR Systems:** Microwaves.
- **λ_2 - Water Purifiers:** Ultraviolet (UV) radiation.
- **λ_3 - Remote Switches of TV:** Infrared rays.

(ii) Sources:

- **Microwaves:** Produced by a magnetron in a microwave oven or RADAR system.
- **Ultraviolet Radiation:** Produced by mercury vapor lamps.
- **Infrared Rays:** Emitted by infrared LEDs in remote controls.

Question 80:

Name the electromagnetic waves which are produced by the following:
(i) Radioactive decays of nucleus
(ii) Welding arcs
(iii) Hot bodies

Write one use of each of these waves.

Detailed Solution:

(i) Radioactive Decays of Nucleus:

- **Electromagnetic Wave:** Gamma rays.
- **Use:** Gamma rays are used in radiotherapy to treat cancer.

(ii) Welding Arcs:

- **Electromagnetic Wave:** Ultraviolet (UV) radiation.
- **Use:** UV radiation is used for sterilization and disinfection.

(iii) Hot Bodies:

- **Electromagnetic Wave:** Infrared rays.
- **Use:** Infrared rays are used in thermal imaging and night vision devices.

Question 81:

Name the electromagnetic waves with their frequency range, produced in the following:
(i) Some radioactive decay
(ii) Sparks during electric welding
(iii) TV remote

Detailed Solution:

(i) Some Radioactive Decay:

- **Electromagnetic Wave:** Gamma rays.
- **Frequency Range:** 10^{19} Hz and above.

(ii) Sparks During Electric Welding:

- **Electromagnetic Wave:** Ultraviolet (UV) radiation.
- **Frequency Range:** 10^{15} Hz to 10^{17} Hz.

(iii) TV Remote:

- **Electromagnetic Wave:** Infrared rays.
- **Frequency Range:** 10^{12} Hz to 10^{14} Hz.

Question 82:

(i) Identify the part of the electromagnetic spectrum used in (a) RADAR and (b) eye surgery. Write their frequency range.

(ii) Prove that the average energy density of the oscillating electric field is equal to that of the oscillating magnetic field.

Detailed Solution:

(i) Identification and Frequency Range:

- (a) RADAR:
  - **Part of Spectrum:** Microwaves.
  - **Frequency Range:** Typically from 1 GHz to 100 GHz.
- (b) Eye Surgery:
  - **Part of Spectrum:** Ultraviolet (UV) rays, particularly UV-A and UV-B.
  - **Frequency Range:** Approximately 10^{15} Hz to 10^{17} Hz.

(ii) Energy Density Proof:

- The energy density u in an electromagnetic wave is given by:

$$u = \frac{1}{2}\epsilon_0 E^2 + \frac{1}{2}\frac{B^2}{\mu_0}$$

  where ϵ_0 is the permittivity of free space, E is the electric field, B is the magnetic field, and μ_0 is the permeability of free space.

- The average energy densities of the electric field and magnetic field are equal:

$$\langle u_E \rangle = \langle u_B \rangle = \frac{1}{2}\epsilon_0 E^2 = \frac{1}{2}\frac{B^2}{\mu_0}$$

  Since $E = cB$ where c is the speed of light, we have:

$$\frac{1}{2}\epsilon_0 E^2 = \frac{1}{2}\epsilon_0 c^2 B^2 = \frac{1}{2}\frac{B^2}{\mu_0}$$

  This shows that the average energy density of the oscillating electric field is equal to that of the oscillating magnetic field.

Question 85:

(i) Identify the part of the electromagnetic spectrum which is:
(a) suitable for RADAR system used in aircraft navigation,
(b) produced by bombarding a metal target by high-speed electrons.

(ii) Why does galvanometer show a momentary deflection at the time of charging and discharging a capacitor? Write the necessary expression to explain this observation.

Detailed Solution:

(i) Identification:

- (a) RADAR System:
  - **Part of Spectrum:** Microwaves.
- (b) Bombarding Metal Target:
  - **Part of Spectrum:** X-rays.

(ii) Galvanometer Deflection:

- A galvanometer shows a momentary deflection during the charging and discharging of a capacitor because of the transient current that flows in the circuit. This current is due to the movement of charges as the capacitor stores or releases energy.
- The displacement current I_d in the capacitor is related to the rate of change of the electric flux:

$$I_d = \epsilon_0 \frac{d\Phi_E}{dt}$$

This transient current causes the galvanometer to deflect momentarily.

Question 86:

(i) Which segment of electromagnetic waves has highest frequency? How are these waves produced? Give one use of these waves.

(ii) Which EM waves lie near the high frequency end of the visible part of EM spectrum? Give its one use. In what way, this component of light has harmful effects on humans?

Detailed Solution:

(i) Highest Frequency Segment:

- **Segment:** Gamma rays.
- **Production:** Produced during nuclear reactions and certain types of radioactive decay.
- **Use:** Gamma rays are used in cancer treatment (radiotherapy).

(ii) High-Frequency Visible EM Waves:

- **Waves:** Ultraviolet (UV) rays, specifically UV-C.
- **Use:** UV-C is used for sterilization and disinfection.
- **Harmful Effects:** Prolonged exposure to UV rays can cause skin cancer and damage to the eyes (cataracts).

Question 87:

Name the parts of the electromagnetic spectrum which is:
(i) suitable for RADAR systems in aircraft navigation.
(ii) used to treat muscular strain.
(iii) used as a diagnostic tool in medicine.

Detailed Solution:

(i) RADAR Systems:

- **Part of Spectrum:** Microwaves.

(ii) Treat Muscular Strain:

- **Part of Spectrum:** Infrared rays. Infrared radiation is used in physiotherapy to provide deep tissue heating and relieve muscular pain.

(iii) Diagnostic Tool in Medicine:

- **Part of Spectrum:** X-rays. X-rays are used in medical imaging to view internal structures like bones.

Question 88:

Answer the following questions:
(i) Name the waves which are produced during radioactive decay of a nucleus. Write their frequency range.
(ii) Welders wear special glass goggles while working. Why? Explain.
(iii) Why are infrared waves often called as heat waves? Give their one application.

Detailed Solution:

(i) Radioactive Decay Waves:

- **Waves:** Gamma rays.
- **Frequency Range:** 10^{19} Hz and above.

(ii) Welders' Goggles:

- Welders wear special glass goggles to protect their eyes from harmful ultraviolet (UV) radiation emitted during welding. UV radiation can cause severe eye damage, including a condition called "welder's flash" or photokeratitis.

(iii) Infrared Waves as Heat Waves:

- Infrared waves are called heat waves because they increase the kinetic energy of molecules, resulting in heat. **Application:** Infrared heaters are used in space heating.

Question 89:

Answer the following questions:

(i) Show, by giving a simple example, how EM waves carry energy and momentum.

(ii) How are microwaves produced? Why is it necessary in microwave ovens to select the frequency of microwaves to match the resonant frequency of water molecules?

(iii) Write two important uses of infrared waves.

- **Energy:** The energy carried by electromagnetic waves is evident from their ability to heat objects (e.g., sunlight warming the Earth) and perform work (e.g., driving a solar cell).

Electromagnetic waves, like light, are made up of tiny particles called photons. Even though photons don't have mass, they carry both energy and momentum. The momentum p of a photon is given by the formula:

$$p = \frac{E}{c}$$

where E is the energy of the photon and c is the speed of light.

This means that when light hits something, it can exert a tiny force because of the momentum it carries. The energy carried by photons is what causes effects like warming when sunlight hits your skin. So, this explains how light, and other electromagnetic waves, carry both energy and momentum.

(ii) Production of Microwaves and Resonant Frequency:

- **Production:** Microwaves are produced by devices like magnetrons.
- **Resonance in Ovens:** The frequency of microwaves in ovens is chosen to match the resonant frequency of water molecules (about 2.45 GHz). This ensures efficient energy absorption by water, leading to faster heating.

(iii) Uses of Infrared Waves:

1. **Thermal Imaging:** Used in night vision and security cameras.
2. **Remote Controls:** Used in controlling electronic devices like TVs.

Question 90:

State clearly how a microwave oven works to heat up a food item containing water molecules. Why are microwaves found useful for the RADAR systems in aircraft navigation?

Detailed Solution:

Microwave Oven Function:

- Microwaves in the oven are tuned to the resonant frequency of water molecules (2.45 GHz). When microwaves pass through the food, they cause water molecules to oscillate rapidly, increasing their kinetic energy and heating the food.

Microwaves in RADAR:

- Microwaves are used in RADAR systems because they can penetrate clouds, rain, and fog, and they can reflect off objects, making them ideal for detecting objects and navigation in all weather conditions.

Question 91:

(i) Describe briefly how electromagnetic waves are produced by oscillating charges?
(ii) Give one use of each of the following:
(a) Microwaves (b) Ultraviolet rays (c) Infrared rays (d) γ-rays

Detailed Solution:

(i) Production of Electromagnetic Waves:

- Oscillating charges produce electromagnetic waves by creating time-varying electric and magnetic fields that propagate through space.

(ii) Uses of Electromagnetic Waves:

- **(a) Microwaves:** Used in microwave ovens for cooking.
- **(b) Ultraviolet rays:** Used for sterilization and disinfection.
- **(c) Infrared rays:** Used in thermal imaging and night vision devices.
- **(d) γ-rays:** Used in cancer treatment through radiotherapy.

CASE STUDY

Question (i):

Electromagnetic waves can be deflected by

- (a) only electric field
- (b) only magnetic field
- (c) Both (a) and (b)
- (d) None of the above

Detailed Solution:

- **Explanation:** Electromagnetic waves consist of both electric and magnetic fields oscillating perpendicular to each other and to the direction of propagation. However, electromagnetic waves as a whole are not deflected by electric or magnetic fields because the wave is a self-propagating entity where the fields constantly regenerate each other.

Correct Answer: (d) None of the above

Question (ii):

Total energy density of electromagnetic waves in vacuum is given by the relation

- (a) $\frac{1}{2}\epsilon_0 E^2 + \frac{B^2}{2\mu_0}$
- (b) $\frac{1}{2}\epsilon_0 E^2 = \frac{1}{2}\mu_0 B^2$
- (c) $\frac{E^2+B^2}{c}$
- (d) $\frac{1}{2}\epsilon_0 E^2 = \frac{B^2}{2\mu_0}$

Detailed Solution:

- **Explanation:** The total energy density u in an electromagnetic wave in a vacuum is the sum of the energy densities of the electric and magnetic fields:

$$u = \frac{1}{2}\epsilon_0 E^2 + \frac{B^2}{2\mu_0}$$

where ϵ_0 is the permittivity of free space, μ_0 is the permeability of free space, E is the electric field strength, and B is the magnetic field strength. This formula accounts for the fact that energy is stored in both the electric and magnetic fields.

Correct Answer: (a) $\frac{1}{2}\epsilon_0 E^2 + \frac{B^2}{2\mu_0}$

Question (iii):

The speed of electromagnetic wave in vacuum depends upon the source of radiation

- (a) increases as we move from γ-rays to radio waves
- (b) decreases as we move from γ-rays to radio waves
- (c) is same for all of them
- (d) None of the above

Detailed Solution:

- **Explanation:** The speed of electromagnetic waves in a vacuum is a fundamental constant and does not depend on the frequency or wavelength of the radiation. Whether it is γ-rays, radio waves, or any other form of electromagnetic radiation, the speed in a vacuum is always $c = 3 \times 10^8$ m/s.

Correct Answer: (c) is same for all of them

Question (iv):

Solar radiation is

- (a) transverse electromagnetic wave
- (b) longitudinal electromagnetic wave
- (c) stationary wave
- (d) None of the above

Detailed Solution:

- **Explanation:** Solar radiation consists of electromagnetic waves that are transverse in nature. In a transverse wave, the electric and magnetic fields oscillate perpendicular to the direction of propagation. This is the case for all electromagnetic radiation, including solar radiation.

Correct Answer: (a) transverse electromagnetic wave

Question (v):

A plane electromagnetic wave of frequency 25 MHz travels in free space along the x-direction. At a particular point in space and time, $E = 6.3\,\mathrm{V/m}$. The corresponding magnetic field at that point will be

- (a) $2.1 \times 10^{-8}\,\mathrm{kT}$
- (b) $2.1 \times 10^{6}\,\mathrm{kT}$
- (c) $3.5 \times 10^{6}\,\mathrm{kT}$
- (d) $3.0 \times 10^{5}\,\mathrm{kT}$

Detailed Solution:

- **Explanation:** The relationship between the electric field E and the magnetic field B in an electromagnetic wave is given by:

$$B = \frac{E}{c}$$

  where c is the speed of light in vacuum, $c = 3 \times 10^{8}\,\mathrm{m/s}$.

- Substituting the given values:

$$B = \frac{6.3\,\mathrm{V/m}}{3 \times 10^{8}\,\mathrm{m/s}} = 2.1 \times 10^{-8}\,\mathrm{T}$$
