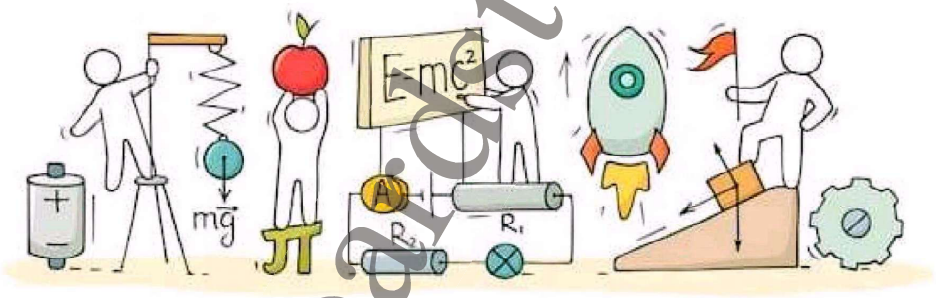
PHYSICS



ELECTROMAGNETIC WAVES

Displacement Current:

The current which comes into play m the region in which the electric field and the electric flux is changing with time. It is given by

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$$

Ampere-Maxwell Law:

$$\oint B\,0 =. dl = \mu_0(I + I_D)$$

Where, μ_0 = Permeability

$$= 4\pi \times 10^{-7} V/Am$$

Maxwell's Equations:

Maxwell's equations relate electric field E and magnetic field B and their sources which are electric charges and current. In free space Maxwell's equations are as follows.

1. $\oint \vec{E} . \overrightarrow{ds} = \frac{q}{\varepsilon_0}$

   This equation represents Gauss's law in electrostatics.

2. $\oint \vec{B} . \overrightarrow{ds} = 0$

   This equation is considered as Gauss's law in magnetism. It states that net magnetic flux passing through a closed surface is zero.

3. $\oint \vec{E} . \overrightarrow{dl} = \frac{d\phi}{dt}$

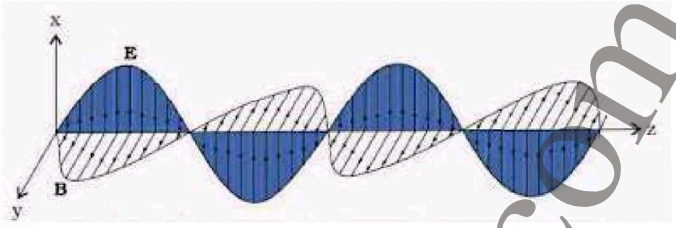
   This equation is Faraday's law of electromagnetic induction. This law relates electric field with changing magnetic flux.

4. $\oint \vec{B} . \overrightarrow{dl} = \mu_0(I_c + I_d)$

   This equation represents Ampere-Maxwell's law or generalized from of Ampere's law.

Electromagnetic Waves:

An electromagnetic wave is a wave radiated by an accelerated or oscillatory charge in which varying magnetic field is the source of electric field and varying electric field is the source of magnetic field. Thus, two fields become source of each other, and the wave propagates in a direction perpendicular to both the fields.



Electromagnetic waves are transverse in nature, i.e., electric and magnetic fields are perpendicular to each other and to the direction of wave propagation. Electromagne-tic waves are not. deflected by electric and magnetic fields.

Sources of electromagnetic waves:

1. An electric charge at rest produces only electrostatic field around it.
2. A charge moving with uniform velocity produces both electric and magnetic field, here magnetic field does not change with time hence it does not produce time varying electric field.
3. An accelerating charge produces both electric field and magnetic field which varies with space and time which forms electromagnetic wave.
4. An accelerating charge emits electromagnetic wave of same frequency as frequency of accelerating charge.
5. An electron orbiting around its nucleus in a stationary orbit does not emit electromagnetic wave. It will emit only during transition from higher energy orbit to lower energy orbit.
6. Electromagnetic wave (X-ray) is produced when high speed electron enters into target of high atomic weight.
7. Electromagnetic wave (γ-rays) is produced during de-excitation of nucleus in radioactivity.

Electromagnetic Spectrum:

The orderly distribution of electromagnetic radiations according to their frequency (or wavelength) is called electromagnetic spectrum. Maxwell predicted the existence of electromagnetic wave. Electromagnetic wave experimentally discovered by Hertz.

At the end of nineteenth century, visible light, ultraviolet, infrared, X-rays and γ-rays had also been discovered.

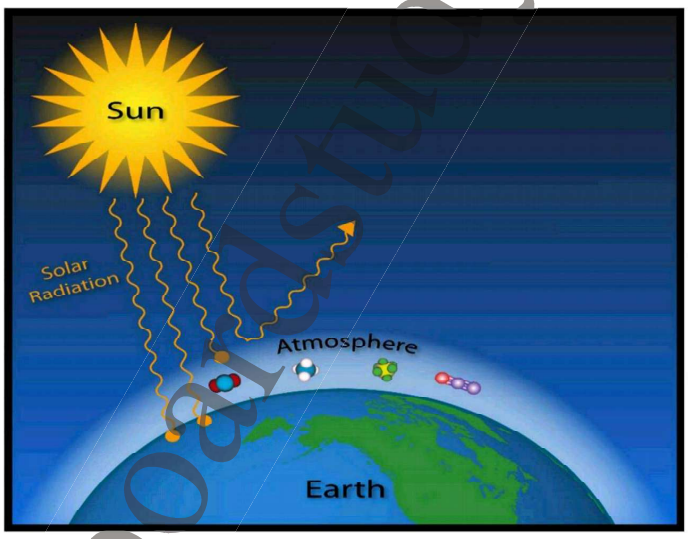
We now know that electromagnetic waves include:

- γ-rays

- X-ray
- Ultraviolet rays
- Visible light
- Infrared
- Microwaves
- Radio waves.

Greenhouse Effect:

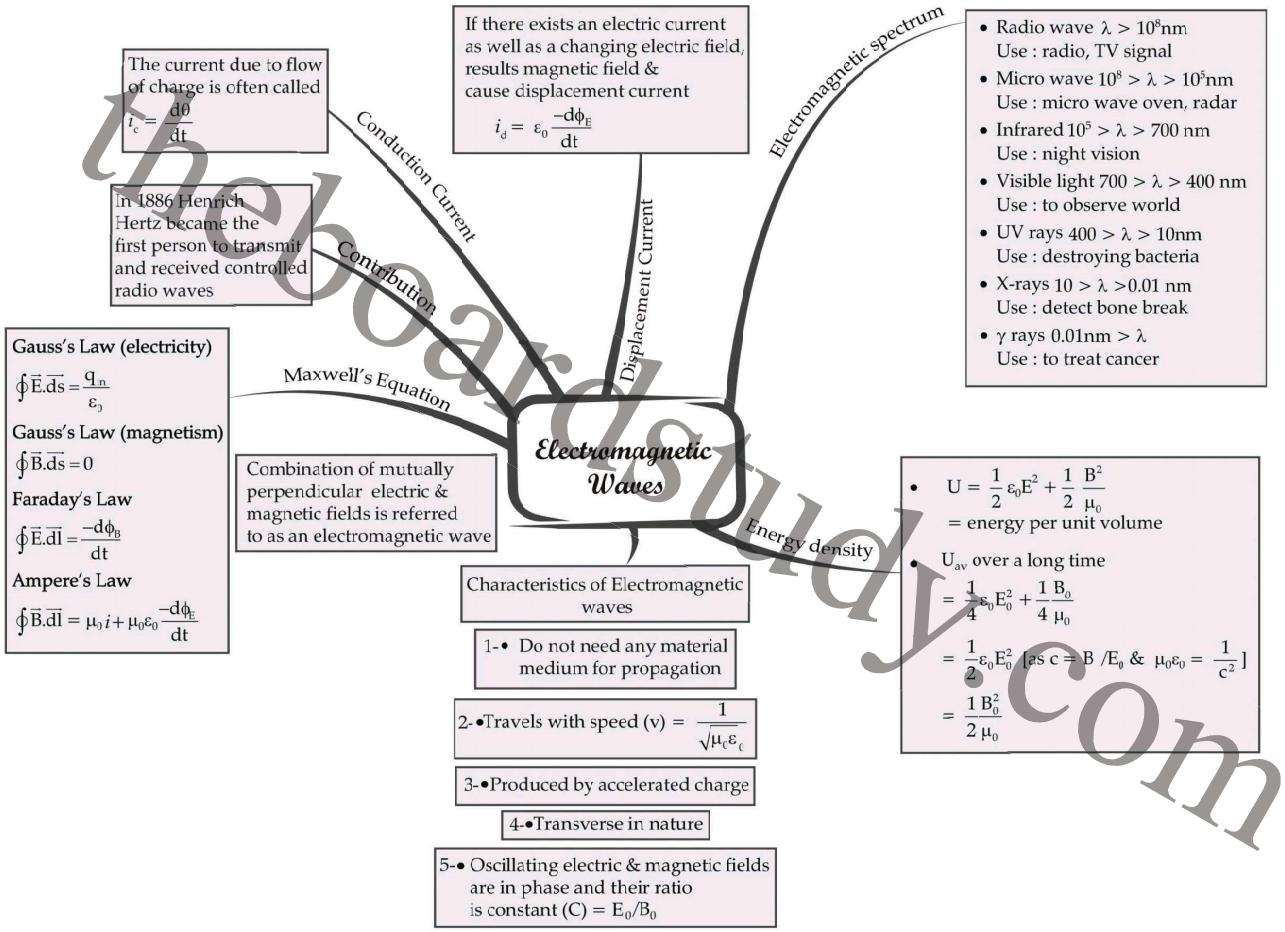
The greenhouse effect is a natural process that warms the Earth's surface. When the Sun's energy reaches the Earth's atmosphere, some of it is reflected to space and the rest is absorbed and re-radiated by greenhouse gases. Greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, ozone, and some artificial chemicals such as chlorofluorocarbons (CFCs).



Maxwell's Experiments:

- Maxwell claimed that time-varying electric fields can generate magnetic fields.
- On the other hand, Faraday-Lenz law claims that a time varying magnetic field generates an electric field.
- According to Faraday-Lenz law, an EMF is induced in a circuit whenever the amount of magnetic flux linked with that circuit changes.
- As a result, electric current gets generated in the circuit which has an electric field associated with it.
- Now, when Maxwell came across this, he claimed that the vice-versa must also be true, i.e., a time varying electric field must also be able to generate a magnetic field.

MIND MAP : LEARNING MADE SIMPLE CHAPTER - 8



Important Questions

Multiple Choice questions-

1. Maxwell in his famous equations of electromagnetism introduced the concept of

(a) ac current

(b) displacement current

(c) impedance

(d) reactance

2. The conduction current is same as displacement current when source is

(a) ac only

(b) dc only

(c) either ac or dc

(d) neither dc nor ac

3. If a variable frequency ac source is connected to a capacitor, then with decrease in frequency the displacement current will

(a) increase

(b) decrease

(c) remains constant

(d) first decrease then increase

4. An electromagnetic wave can be produced, when charge is

(a) moving with a constant velocity

(b) moving in a circular orbit

(c) falling in an electric field

(d) both (b) and (c)

5. Which of the following statement is false for the properties of electromagnetic waves?

(a) Both electric and magnetic field vectors attain the maxima and minima at the same place and same time.

(b) The energy in electromagnetic waves is divided equally between electric and magnetic field vectors.

(c) Both electric and magnetic field vectors are parallel to each other and perpendicular to the direction of propagation of wave.

(d) These waves do not require any material medium for propagation.

6. Which of the following has/have zero average value in a plane electromagnetic wave?

(a) Both magnetic and electric fields

(b) Electric field only

(c) Magnetic field only

(d) None of these

7. A charged particle oscillates about its mean equilibrium position with a frequency of 109 Hz. The frequency of electromagnetic waves produced by the oscillator is

(a) 10^6 Hz

(b) 10^7 Hz

(c) 10^8 Hz

(d) 10^9 Hz

8. If E and B denote electric and magnetic fields respectively, which of the following is dimensionless?

(a) $\sqrt{\mu_0\varepsilon_0}\ \frac{E}{B}$ (b) $\mu_0\varepsilon_0\ \frac{E}{B}$

(c) $\mu_0\varepsilon_0\left(\frac{B}{E}\right)^2$ (d) $\frac{E}{\varepsilon_0}\frac{\mu_0}{B}$

9. The ultra-high frequency band of radio waves in electromagnetic wave is used as in

(a) television waves

(b) cellular phone communication

(c) commercial FM radio

(d) both (a) and (c)

10. The waves used by artificial satellites for communication is

(a) microwaves

(b) infrared waves

(c) radio waves

(d) X-rays

Very Short:

1. Name the part of the electromagnetic spectrum which has the longest wavelength and write its one use. (CBSE 2019C)

2. The small ozone layer on the top of the stratosphere is crucial for human survival. Why?

3. Name the part of the electromagnetic spectrum which is used in the "greenhouse" to keep plants warm.

4. How are radio waves produced? (CBSE AI 2011)

5. How are X-rays produced? (CBSE AI 2011)

6. How are microwaves produced? (CBSE AI 2011)

7. A plane electromagnetic wave travels in a vacuum along the z-direction. What can you say about the direction of electric and magnetic field vectors? (CBSE Delhi 2011)

8. What is the frequency of electromagnetic waves produced by the oscillating charge of frequency v? (CBSE Delhi 2011C)

9. What are the directions of electric and magnetic field vectors relative to each other and relative to the direction of propagation of electromagnetic waves? (CBSE AI 2012)

10. 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 frequency. (CBSE AI 2013)

Short Questions:

1. Radio waves and gamma rays both are transverse in nature and electromagnetic in character and have the same speed in a vacuum. In what respect are they different?

2. Show that the average energy density of the electric field equals the average density of the magnetic field.

3. State four properties of electromagnetic waves.

4. Electromagnetic radiations with wavelength

(a) λ_1 are used to kill germs in water purifiers.

(b) λ_2 are used in TV communication systems.

(c) λ_3 plays an important role in maintaining the earth's warmth.

Name the part of the electromagnetic spectrum to which these radiations belong. Arrange these wavelengths in decreasing order of their magnitude.

5. Name the constituent radiation of the electromagnetic spectrum which

(a) is used in satellite communication.

(b) is used for studying crystal structure.

(c) is similar to the radiations emitted during the decay of a radioactive nucleus.

(d) is absorbed from sunlight by the ozone layer.

(e) produces an intense heating effect.

(f) has its wavelength range between 390 nm and 770 nm.

6. Name the radiations of the electromagnetic spectrum which are used in

(a) warfare to look through the haze.

(b) radar and geostationary satellites

(c) studying the structure and properties of atoms and molecules.

7. Why are microwaves used in RADAR?

8. Electromagnetic waves with wavelength

(a) λ_1 are used to treat muscular strain.

(b) λ_2 are used by an FM radio station for broadcasting.

(c) λ_3 are used to detect fractures in bones.

(d) λ_4 are absorbed by the ozone layer of the atmosphere.

Identify and name the part of the electromagnetic spectrum to which these radiations belong. Arrange

these wavelengths in decreasing order of magnitude.

Long Questions:

1. Answer the following:

(a) Name the em waves which are used for the treatment of certain forms of cancer. Write their frequency

(b) Thin ozone layer on top of the stratosphere is crucial for human survival. Why?

(c) An em wave exerts pressure on the surface on which it is incident. Justify. (CBSE Delhi 2014)

2. Answer the following questions:

(a) Why is the thin ozone layer at the top of the stratosphere crucial for human survival? Identify to which part of the electromagnetic spectrum does this radiation belongs and write one important application of the radiation.

(b) Why are infrared waves referred to as heat rays? How are they produced? What role do they play in maintaining the earth's warmth through the greenhouse effect? (CBSE Delhi 2015C)

Assertion and Reason Questions-

1. Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false and R is also false.

Assertion: Electromagnetic waves exert pressure called radiation pressure.

Reason: Electromagnetic waves carries energy.

2. Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false and R is also false.

Assertion: When a charged particle moves in a circular path. It produces electromagnetic wave.

Reason: Charged particle has acceleration.

Case study Questions-

1. Radio waves are produced by the accelerated motion of charges in conducting wires. Microwaves are produced by special vacuum tubes. Infrared waves are produced by hot bodies and molecules also known as heat waves. UV rays are produced by special lamps and very hot bodies like Sun.

(i) Solar radiation is:

a) Transverse electromagnetic wave.

b) Longitudinal electromagnetic waves.

c) Both longitudinal and transverse electromagnetic waves.

d) None of these.

(ii) What is the cause of greenhouse effect?

a) Infrared rays.

b) Ultraviolet rays

c) X-rays.

d) Radiowaves.

(iii) Biological importance of ozone layer is:

a) It stops ultraviolet rays.

b) It layer reduces greenhouse effect.

c) It reflects radiowaves.

d) None of these.

(iv) Ozone is found in.

a) Stratosphere.

b) Ionosphere.

c) Mesosphere.

d) Troposphere.

(v) Earth's atmosphere is richest in.

a) Ultraviolet.

b) Infrared.

c) X-rays.

d) Microwave.

2. Electrons oscillating in a circuit give rise to radiowaves. A transmitting antenna radiates most effectively the radiowaves of wavelength equal to the size of the antenna. The infrared waves incident on a substance set into oscillation all its electrons, atoms and molecules. This increases the internal energy and hence the temperature of the substance.

(i) If v_g, v_x and v_m are the speeds of gamma rays, X-rays and microwaves respectively in vacuum, the

a) $v_g > v_x > v_m$

b) $v_g < v_x < v_m$

c) $v_g > v_x > v_m$

d) $v_g = v_x = v_m$

(ii) Which of the following wi II deflect in electric field?

a) X-rays.

b) γ−rays.

c) Cathode rays.

d) Ultraviolet rays.

(iii) γ−rays are detected by:

a) Point contact diodes.

b) Thennopiles.

c) Ionization chamber.

d) Photocells.

(iv) The frequency of electromagnetic wave, which best suited to observe a particle ofradius 3×10^{-4}cm is the order of,

a) 10^{15}Hz

b) 10^{14} Hz

c) 10^{13}Hz

d) 10^{12}Hz

(v) We consider the radiation emitted by the human body. Which one of the following statements is true?

a) The radiation emitted is in the infrared region.

b) The radiation is emitted only during the day.

c) The radiation is emitted during the summers and absorbed during the winters.

d) The radiation emitted lies in the ultraviolet region and hence it is not visible.

Answer Key:

Multiple Choice Answers-

1. Answer: b
2. Answer: c
3. Answer: b
4. Answer: d
5. Answer: c
6. Answer: a
7. Answer: d
8. Answer: a
9. Answer: b
10. Answer: a

Very Short Answers:

1. Answer:
   - In the electromagnetic spectrum, long radio waves have the longest wavelength.
   - Radio waves are used in communication systems.
2. Answer: The ozone layer absorbs the ultraviolet rays, emitted by the sun, which are harmful to the living tissues of human beings.
3. Answer: Infrared rays.
4. Answer: They are produced by rapid acceleration and decelerations of electrons in aerials.
5. Answer: By the transition of inner-shell electrons.
6. Answer: By using a magnetron.
7. Answer: The electric and magnetic field vectors will be along the x and y directions.

8. Answer: The frequency of electromagnetic waves produced by the oscillating charge of frequency v is also v.
9. Answer: The three are mutually perpendicular to one other.
10. Answer: UV radiations, 10^{15} to 10^{17} Hz.

Short Questions Answers:

1. Answer: The radio waves have an atomic origin, while gamma rays have a nuclear origin. Further owing to their very small wavelength, gamma rays are highly penetrating in comparison to radio waves.
2. Answer: The average density of the electric field is given by

   $U_e = \frac{1}{2}\varepsilon_0 E^2$ and the average energy density of the magnetic field is given by $U_B = \frac{B^2}{2\mu_0}$.

   But $B = \frac{E}{c}$ and $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$, hence the above equation becomes $U_B = \frac{B^2}{2\mu_0} = \frac{E^2}{2\mu_0 c^2}$

   $U_B = \frac{E^2}{2\mu_0 \times \frac{1}{\mu_0 \varepsilon_0}} = \frac{1}{2}\varepsilon_0 E^2$. Hence the result.
3. Answer:

   (a) They do not require any material medium to travel.

   (b) They are transverse in nature, i.e. electric and magnetic fields are perpendicular to each other and also to the direction of the propagation of the wave.

   (c) The energy of the wave is divided equally amongst the electric and the magnetic field.

   (d) They travel, in free space, with a velocity of 3×10^8 m s^{-1}.
4. Answer:

   (a) λ_1 – Ultraviolet radiations.

   (b) λ_2 – Microwaves

   (c) λ_3 – Infrared rays

   Their order is $\lambda_1 < \lambda_3 < \lambda_2$.
5. Answer:

   (a) Microwaves.

   (b) X-rays

   (c) Gamma rays

   (d) UV rays

   (e) Infrared rays

(f) Visible light.

6. Answer:

   (a) Infrared rays

   (b) Microwaves.

   (c) Gamma rays.

7. Answer: Microwaves are electromagnetic waves of very short wavelength. Such waves are used in RADAR due to the reason that they can travel in a particular direction in the form of a beam without being deflected.

8. Answer:

   (a) Infrared radiations are used to treat muscular strain.

   (b) Radio and microwave radiations are used for FM transmission.

   (c) X-rays are used to detect fractures in bones.

   (d) Ultraviolet radiation is absorbed by the ozone layer of the atmosphere.

   The decreasing order of their wavelength is

   $\lambda_2 > \lambda_1 > \lambda_4 > \lambda_3$.

Long Questions Answers:

1. Answer:

   (a) Gamma rays.

   Frequency range > 3×10^{20} Hz

   (b) The thin ozone layer on top of the stratosphere is crucial for human survival because it absorbs most of the ultraviolet rays coming from the sun. If the ozone layer had not been there, then ultraviolet rays would have entered the earth and caused danger to the survival of the human race.

   (c) An em wave carries a linear momentum with it. The linear momentum carried by a portion of a wave having energy U is given by p = U/c.

   Thus, if the wave incident on a material surface is completely absorbed, it delivers energy U and momentum p = U/c to the surface. If the wave is totally reflected, the momentum delivered is p = 2U/c because the momentum of the wave changes from p to – p. Therefore, it follows that an em wave incident on a surface exerts a force and hence a pressure on the surface.

2. Answer:

   (a) The thin ozone layer on top of the stratosphere is crucial for human survival because it absorbs most of the ultraviolet rays coming from the sun. If the ozone layer had not been

there, then ultraviolet rays would have entered the earth and caused danger to the survival of the human race. This radiation is UV radiation. It is used in sterilization.

(b) Infrared radiations heat up the material on which they fall, hence they are also called heat rays. They are produced by the vibration of atoms and molecules. After falling on the earth, they are reflected back into the earth's atmosphere. The earth's atmosphere does not allow these radiations to pass through as such they heat up the earth's atmosphere.

Assertion and Reason Answers-

1. (b) Both A and R are true but R is not the correct explanation of A.

Explanation:

Electromagnetic waves transport linear momentum as well as energy. When electromagnetic waves strike a surface, a pressure is exerted on the surface. If the intensity of wave is I, the radiation pressure P (force per unit area) exerted on the perfectly absorbing surface is $p = \frac{I}{c}$.

2. (a) Both A and R are true and R is the correct explanation of A.

Explanation:

Accelerated charges radiate electromagnetic waves.

Case Study Answers-

1. Answer :

(i) (a) Transverse electromagnetic wave.

(ii) (a) Infrared rays.

Explanation:

Greenhouse effect is due to infrared rays.

(iii) (a) It stops ultraviolet rays.

Explanation:

Ozone layer absorbs the harmful ultraviolet radiations coming from the sun.

(iv) (a) Stratosphere.

Explanation:

Ozone layer lies in stratosphere.

(v) (b) Infrared.

Explanation:

Heatmosphere of earth is richest in infrared radiation.

2. Answer :

(i) (d) $v_g = v_x = v_m$

Explanation:

All electromagnetic waves travel in vacuum with the same speed.

(ii) (c) Cathode rays.

Explanation:

Cathode rays (beamofelectrons) get deflected in an electric field.

(iii) (c) Ionization chamber.

Explanation:

γ−rays are detected by ionization chamber.

(iv) (b) 10^{14}Hz

Explanation:

$$\text{Size of particle} = \lambda = \frac{c}{v}$$

$$v = \frac{c}{\lambda} = \frac{3\times10^{10}\text{cm s}^{-1}}{3\times10^{-4}\text{cm}} = 3 \times 10^{14}\text{Hz}$$

(v) (a) The radiation emitted is in the infrared region.

Explanation:

Every body at a temperature T > 0 K emits radiation in the infrared region.