SAMPLE CONTENT

Absolute

For all Agricultural, Medical, Pharmacy and Engineering Entrance Examinations held across India.

Physics Vol - II

NEET-UG & JEE (Main)

4332 MCQs with Hints

Aurora Borealis

'Aurora Borealis' (Northern Lights) seen in the northern skies is caused due to the interaction of the Earth's magnetic field with charged particles or ions travelling down the atmosphere.

Target Publications Pvt. Ltd.

For all Agricultural, Medical, Pharmacy and Engineering Entrance Examinations held across India.

Absolute

NEET – UG & JEE (Main)

PHYSICS Vol. II

Salient Features

- Exhaustive coverage of MCQs subtopic wise.
- '4332' MCQs including questions from various competitive exams.
- Includes solved MCQs from NEET-UG, JEE (Main), MHT-CET and various entrance examinations from year 2015 to 2018.
- Various competitive exam questions are exclusively covered.
- Concise theory for every topic.
- Hints provided wherever relevant.
- Topic test at the end of each chapter.
- Important inclusions: Knowledge bank and Googly questions.

Solutions/hints to Topic Test available in downloadable PDF format at ***www.targetpublications.org/tp12871***

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PREFACE

Target's **"Absolute Physics Vol - II"** is compiled according to the notified syllabus for NEET-UG & JEE (Main), which in turn has been framed after reviewing various state syllabi as well as the ones prepared by CBSE, NCERT and COBSE.

The book comprises of a comprehensive coverage of **Theoretical Concepts** & **Multiple Choice Questions**. The flow of content & MCQ's is planned keeping in mind the weightage given to a topic as per the NEET-UG & JEE (Main) exam.

MCQs in each chapter are a mix of questions based on high order thinking, theory, numerical, graphical, multiple concepts. The level of difficulty of the questions is at par with that of various competitive examinations like CPMT, JEE, AIEEE, TS EAMCET (Med. and Engg.), BCECE, Assam CEE, AP EAMCET (Med. and Engg.) and the likes. Also to keep students updated, questions from most recent examinations such as AIPMT/NEET, JEE (Main), MHT-CET, K CET, GUJ CET, WB JEEM, of years 2015, 2016, 2017 and 2018 are covered exclusively.

Unique points are represented in the form of **Notes** at the end of theory section, **Formulae** are collectively placed after notes for quick revision and **Shortcuts** are included to save time of students while dealing with rigorous questions.

An additional feature of **Knowledge Bank** is introduced to give students glimpse of various interesting concepts related to the subtopic.

Googly Questions are specifically prepared to develop thinking skills required to answer any tricky or higher order question in students. These will give students an edge required to score in highly competitive exams.

Topic Test has been provided at the end of each chapter to assess the level of preparation of the student on a competitive level.

We are confident that this book will cater to needs of students of all categories and effectively assist them to achieve their goal. We welcome readers' comments and suggestions which will enable us to refine and enrich this book further.

All the best to all Aspirants!

Yours faithfully,
Authors
Edition: Second

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Note: ** marked section is not for JEE (Main)

07 Electromagnetic Waves

7.1 Need for displacement current and origin of electromagnetic waves

- **Displacement current:**
  i. *The current which comes into play in the region, whenever the electric field and hence the electric flux is changing with time is known as displacement current.*
  ii. Formula:
  a. $I_D = \varepsilon_0 \dfrac{d\phi_E}{dt}$
  where, ε_0 = absolute permittivity of space.
  $\dfrac{d\phi_E}{dt}$ = rate of change of electric flux.
  b. $I_D = \dfrac{CdV}{dt}$,
  where, C is capacitance and $\dfrac{dV}{dt}$ is change in potential with respect to time.
  iii. Unit: ampere in SI system.
  iv. Displacement current was first postulated by Maxwell.
  v. Displacement current is zero for steady electric flux linked in a region.
- **Conduction current:**
  i. *The current in the electric field which arises due to the flow of electrons in the connecting wires of the circuit, in a definite closed path is called conduction current.*
  ii. When a capacitor is connected to the battery, it starts storing charge due to conduction current when the capacitor gets fully charged, the conduction current becomes zero in the circuit.
  iii. Conduction current exists even when the electrons flow at uniform rate.
- **Ampere-Maxwell's circuital law, need for displacement current:**
  i. **Ampere–Maxwell's law:**
  The line integral of magnetic field $\vec{B}$ over a closed path in vacuum is equal to μ_0 times the sum of the conduction current (I) and displacement current (I_D).
  $$\oint \vec{B}.\overline{dl} = \mu_0\left(I + \varepsilon_0 \frac{d\phi_E}{dt}\right)$$
  where, μ_0 = absolute permeability of free space.
  ii. According to Ampere's circuital law, the line integral of current magnetic field $\vec{B}$ around any closed path or circuit is equal to μ_0(absolute permeability of free space) times the total current (I) threading the closed circuit.
  $$\oint \vec{B}\overline{dl} = \mu_0 I$$
  iii. However, when Ampere's circuital law was applied to an electric circuit containing a capacitor as one of the circuit elements, the law appeared to be inconsistent or incomplete.
  iv. To overcome this inconsistency, James Clerk Maxwell introduced the concept of displacement current which he assumed to flow across the gap between the plates of the capacitor.
  v. Thus, through the conducting wires, there is a flow of conduction current I_C and through the gaps across the plates of capacitor, there is flow of displacement current I_D.
  vi. Maxwell modified Ampere's circuital law, by treating the current I as the sum of the conduction current I_C and the displacement current I_D.
  $$\therefore \quad \oint \vec{B}.\overline{dl} = \mu_0(I_C + I_D)$$
  $$\therefore \quad \oint \vec{B}.\overline{dl} = \mu_0\left(I_C + \varepsilon_0 \frac{d\phi_E}{dt}\right) \quad \left[\because I_D = \varepsilon_0 \frac{d\phi_E}{dt}\right]$$
  This equation is known as Ampere–Maxwell's circuital law or modified Ampere's circuital law.
  vii. The conduction and displacement currents are individually discontinuous, but the two currents together possess the property of continuity through any closed electric circuit.

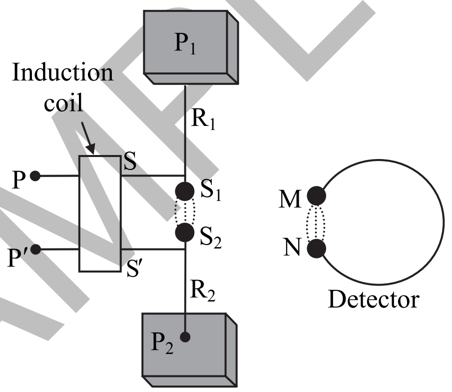
viii. The displacement current is precisely equal to the conduction current, when the two are present in different parts of the circuit.
ix. Like conduction current, the displacement current is also a source of magnetic field.

- **Origin of electromagnetic waves:**

i. In 1865, Maxwell predicted the existence of electromagnetic (em) waves on the basis of mathematical equations, called Maxwell's equation.
ii. According to Maxwell, the time varying magnetic and electric field produced by an accelerated charge are mutually perpendicular and are source of each other. These mutually perpendicular time varying electric and magnetic field constitute electromagnetic waves and propagate in space in a direction perpendicular to both the direction of varying electric and magnetic fields.

Year	Physicist	Significance
1887	Hertz	Production and detection of em waves of wavelength of 6 m
1894	J.C. Bose	Production of em waves of wavelength 5 mm to 25 mm
1896	Marconi	Production of em waves those could cover several kilometres by connecting one spark gap terminal to antenna and another to earthing
1899	Marconi	Established wireless communication across distance 50 km

- **Hertz's experiment:**



Hertz experimental setup

i. In 1887, Hertz experimentally demonstrated the production of electromagnetic waves by using a spark oscillator.
ii. Hertz's experimental setup consists of two metal plates P_1 and P_2 held parallel to each other and connected to two spheres S_1 and S_2 through thick metallic rods R_1 and R_2.
iii. The two rods R_1 and R_2 are connected to an induction coil to apply high voltage across the two metal plates.
iv. The spheres can slide over the rods, so as to adjust the gaps between them.
v. Discharge of the metal plates takes place in the form of a spark in the gap between the spheres S_1 and S_2 which in turns radiates electromagnetic waves.
vi. The waves thus radiated are detected with the help of a detector made of a circular coil and two metal spheres M and N.
vii. The wavelength of electromagnetic waves produced was found to be,

$$\lambda = \frac{c}{\nu} = \frac{3\times10^8}{5\times10^7} = 6 \text{ m.}$$

viii. Hertz also showed that these electromagnetic waves possessed all the properties of light waves, i.e., reflection, refraction, interference etc.

- **Speed of electromagnetic waves:**

i. For an electromagnetic wave propagating in the positive x-direction, the values of electric and magnetic fields at a distance x from the origin are represented by the equation,

$$E(x) = E_0 \sin \omega\left(t - \frac{x}{c}\right)$$

$$B(x) = B_0 \sin \omega\left(t - \frac{x}{c}\right)$$

Where, c = the velocity of the electromagnetic waves.
B_0 and E_0 = amplitude of magnetic and electric field respectively.

ii. The speed of electromagnetic waves in free space is given as,

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

where,
μ_0 = absolute permeability of free space.
ε_0 = absolute permittivity of free space.

iii. For free space,
$\mu_0 = 1.257 \times 10^{-6}$ T m A^{-1} and
$\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}

$$c = \frac{1}{\sqrt{1.257\times10^{-6}\times8.854\times10^{-12}}}$$

$\therefore$ $c = 3 \times 10^8$ m s^{-1}
Thus, speed of electromagnetic waves in free space is equal to the speed of light in vacuum.

iv. The velocity of electromagnetic wave in a material medium is given by,

$$v = \frac{1}{\sqrt{\mu\varepsilon}}$$

v. The amplitudes (peak values) of the electric and magnetic fields in free space are related to the speed of electromagnetic waves in free space as, $c = \frac{E_0}{B_0}$

vi. The velocity of electromagnetic waves does not depend on amplitude of field vectors.

- **Maxwell's equations:**
Maxwell's equations predict that the time and space dependant electric and magnetic fields propagate as transverse waves called electromagnetic waves, which possess velocity equal to that of light. The four Maxwell's equations are as given below:

i. **Gauss' law in electrostatics:**
The total electric flux through any closed surface is always equal to $\frac{1}{\varepsilon_0}$ *times the net charge enclosed by the surface.*
Mathematically,

$$\oint \vec{E}\cdot\vec{ds} = \frac{q}{\varepsilon_0}$$

This equation is known as Maxwell's first equation.
This law:

a. gives total electric flux in terms of charge enclosed by the closed surface.
b. predicts that the electric lines of force start from positive charge and end on negative charge i.e., electric field lines do not form a continuous closed path.
c. predicts that the isolated charge exists.

ii. **Gauss' law in magnetism:**
The net magnetic flux crossing any closed surface is always zero.
Mathematically,

$$\oint \vec{B}\cdot\vec{ds} = 0$$

This equation is known as Maxwell's second equation.
This law:

a. shows number of magnetic field lines entering a closed surface is equal to number of magnetic field lines leaving that closed surface.
b. predicts that magnetic field lines form a continuous closed loop.
c. also predicts that the isolated monopole does not exist.

iii. **Faraday's law of electromagnetic induction:**
The line integral of electric field along a closed path is equal to time rate of change of magnetic flux through the surface bounded by that closed path.
Mathematically,

$$\oint \vec{E}\cdot\vec{dl} = -\frac{d}{dt}\int_s \vec{B}\cdot\vec{ds}$$

This equation is known as Maxwell's third equation.

iv. **Ampere – Maxwell's law:**
The line integral of magnetic field along a closed path is equal to μ_0 times the total current (sum of displacement and conduction current) threading the surface bounded by that closed path.
Mathematically,

$$\oint \vec{B}\cdot\vec{dl} = \mu_0\left(I_C + \varepsilon_0\frac{d\phi_E}{dt}\right)$$

This equation is known as Maxwell's fourth equation.

7.2 Electromagnetic waves and their characteristics

- **Electromagnetic waves:**
Electromagnetic waves are transverse waves in which there are time – varying, sinusoidal variations of electric and magnetic fields mutually perpendicular to each other and propagating in space in a direction perpendicular to the direction of wave propagation.
e.g.: infrared rays, microwaves, radio-waves, X-rays, UV-rays etc.

- **Characteristics of electromagnetic waves:**

i. Electromagnetic waves propagate in the form of time varying electric and magnetic fields, such that the two fields are perpendicular to each other and also to the direction of propagation of the wave. In other words, electromagnetic waves are transverse in nature.
ii. Electromagnetic waves are produced by accelerated electric charges or in a nuclear transition or in the annihilation of an electron and a positron.
iii. Electromagnetic waves do not require any material medium for their propagation. They can travel through vacuum as well as through solids, liquids and gases.
iv. Velocity of em waves in vacuum / free space (c) = frequency (ν)×wavelength (λ)
v. Electromagnetic waves travel with the speed of light in vacuum.
vi. In a given material medium, the velocity (v_m) of electromagnetic waves is given by,

$$v_m = \frac{1}{\sqrt{\mu\varepsilon}}$$

where μ = Permeability of the given medium
ε = Permittivity of the given medium

vii. Electromagnetic waves obey the principle of superposition of waves.

viii. The electromagnetic waves possess properties of light, laws of reflection and refraction. They exhibit phenomena of interference and diffraction.

ix. Electric and magnetic fields in electromagnetic waves vibrate in phase.

x. Electromagnetic waves can be polarized.

xi. The energy of electromagnetic waves is equally distributed among the electric and magnetic field vector. In other words, average electric energy density (u_E) and average magnetic energy density (u_B) of an electromagnetic wave are equal i.e.,$u_E = u_B$

In vacuum, due to static electric (E) and magnetic (B) field, $u_E = \frac{1}{2}\varepsilon_0 E_0^2$ and

$u_B = \frac{1}{2}\frac{B_0^2}{\mu}$

But in em waves, as electric and magnetic fields vary with space and time, therefore,

$u_E = \frac{1}{2}\varepsilon_0\ E_{rms}^2$ and $u_B = \frac{1}{2}\ \frac{B_{rms}^2}{\mu}$

where, $E_{rms} = \frac{E_0}{\sqrt{2}}$ and $B_{rms} = \frac{B_0}{\sqrt{2}}$

The average energy density of electromagnetic waves is therefore, given by $u = u_E + u_B = 2u_E = 2u_B$

xii. The ratio of the amplitudes of electric and magnetic fields is always constant and it is equal to velocity of the electromagnetic waves, $c = \frac{E_0}{B_0}$.

xiii. The low frequency electromagnetic waves are unaffected by external electric and magnetic fields.

xiv. The energy transported by electromagnetic waves per second per unit area is represented by a vector quantity $\vec{S}$ called pointing vector. It is given by,

$\vec{S} = \vec{E} \times \vec{H} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$

xv. The momentum transported by electromagnetic waves is given by,

$p = \frac{U}{c} = \frac{S \times A}{c}$

Where, U is energy transported by electromagnetic waves in a given time, c is speed of electromagnetic waves in free space and A is area of cross-section of surface upon which electromagnetic wave is incident. As a result, when these waves strike a surface, pressure is exerted by them on the surface. This pressure is called as radiation pressure.

xvi. If incident electromagnetic wave is completely reflected then momentum delivered to the surface is $2\frac{U}{c}$ as momentum of electromagnetic wave changes from p to − p.

xvii. The intensity of electromagnetic waves i.e., energy crossing per second per unit area of a surface normally is given by,

$I = \frac{1}{2}\frac{E_0 B_0}{\mu_0} = \frac{1}{2}\frac{B_0^2}{\mu_0}c = \frac{1}{2}\varepsilon_0 E_0^2 c$

7.3 Transverse nature of electromagnetic waves

i. The electromagnetic waves are produced by accelerated electric charges. An accelerated charge produces a magnetic field in the surrounding region which gives rise to an electric field.

ii. The electric and magnetic fields are mutually perpendicular to each other. If the accelerated charge is oscillating, both the electric and magnetic fields vary with time and they travel outwards from the charge in the form of electromagnetic waves.

iii. If $\vec{E}$ is along the Y-axis and $\vec{B}$ is along the Z-axis, the direction of propagation of wave is along $\vec{E} \times \vec{B}$ i.e., along the X-axis as shown in figure (a).

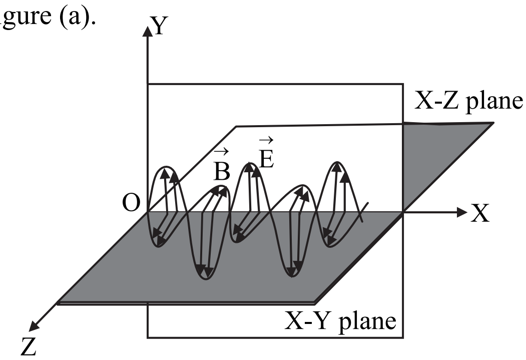


Figure (a) Electromagnetic wave propagating along X axis

iv. A single electromagnetic wave propagating perpendicular to both electric and magnetic field in magnified form is as shown in figure (b).

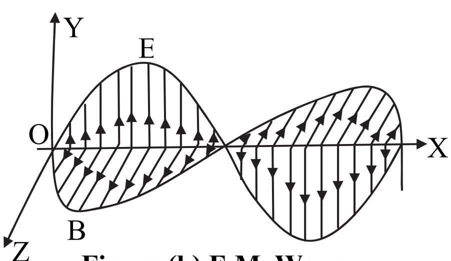


Figure (b) E.M. Wave

v. The electric field and magnetic field vary sinusoidally with X and is given by,
$E_y = E_0 \sin(kx - \omega t)$
$B_z = B_0 \sin(kx - \omega t)$
where, E_0 = amplitude of electric intensity $\vec{E}$.
B_0 = amplitude of magnetic induction $\vec{B}$.
$k = \frac{2\pi}{\lambda}$ = Propagation constant.
λ = wavelength of oscillations
$\omega = 2\pi\nu$ = Angular frequency of oscillations.

vi. Both the electric and magnetic fields attain their maximum and minimum values at the same time and at the same point in space i.e., they oscillate in same phase with same frequency.

vii. Energy is equally distributed between electric vector $\vec{E}$ and $\vec{B}$ vibrating in same phase.

viii. From the figures, it is observed that propagation of electromagnetic field is in the direction of $\vec{E} \times \vec{B}$. As the electric and magnetic fields are mutually perpendicular to each other and in the direction of wave propagation, the electromagnetic waves are transverse in nature.

7.4 Electromagnetic spectrum

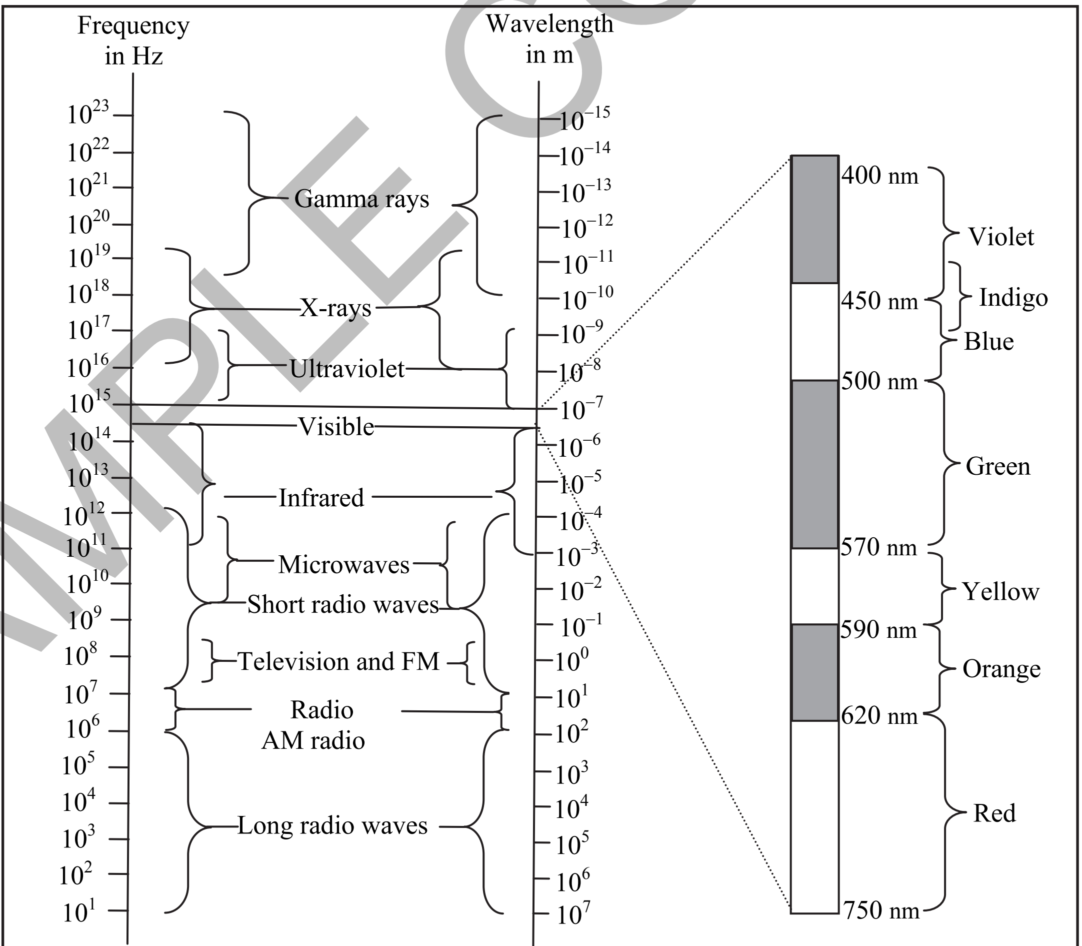
- **Electromagnetic spectrum:**

i. *The orderly distribution* (*i.e., sequential arrangement*) *of electromagnetic waves according to their wavelengths (or frequencies) in the form of distinct groups having different properties is called the electromagnetic spectrum.*

ii. The spectrum of electromagnetic radiations has no upper or lower limits i.e., sharp boundaries. All regions overlap.

iii. The known electromagnetic waves have wavelength ranging from 10^{-15} m to more than 10^4 m.

iv. The main parts of an electromagnetic spectrum in the order of increasing wavelength from 10^{-5} Å or 10^{-15} m to 10^6 m are γ – rays, X – rays, ultraviolet rays, visible light, infrared rays, microwaves and radiowaves. The different parts of the electromagnetic spectrum differ in their methods of production and detection.



Electromagnetic spectrum

- **Gamma rays (γ-rays):**
  i. Gamma rays are electromagnetic waves having wavelength ranging nearly from 10^{-15} m to 10^{-10} m.
  ii. The gamma rays are high energy electromagnetic waves having very high frequency ranging nearly from 3×10^{18} Hz to 5×10^{22} Hz.
  iii. Gamma rays are detected with Geiger counter, photographic plate, fluorescence.
  iv. These gamma rays are emitted from the nuclei of some radioactive elements such as uranium, radium etc.
  v. Gamma rays were discovered by Paul Ulrich Villard.
  vi. γ-rays have high penetrating power. They can penetrate through several centimetres of thick iron and lead blocks.
  vii. They have moderate ionizing power.
  viii. They can produce fluorescence in some substances like willemite, zinc sulphide, barium platinocyanide, etc.
  ix. They can affect a photographic plate.
  x. γ-rays are not deflected by electric and magnetic fields.
  xi. γ-rays knock out electrons from the surface on which they are incident.
  xii. γ-rays produce heating effect in the surface exposed to them.
  xiii. They cause photoelectric effect, Compton scattering and pair production.

- **Applications of Gamma rays:**
  i. In radiotherapy for the treatment of cancer and tumour.
  ii. In food industry to kill micro-organisms.
  iii. To preserve the food items.
  iv. To produce nuclear reactions.
  v. In gamma ray astronomy.

- **X-rays:**
  i. X-rays are electromagnetic waves having very short wavelength ranging nearly from 10^{-11} m to 10^{-8} m.
  ii. The frequency range of X-rays is from 1×10^{16} Hz to 3×10^{19} Hz.
  iii. They are produced, when fast moving electrons (Cathode rays) are suddenly stopped by an obstacle.
  iv. X-rays are produced in the laboratory by using Coolidge X-ray tube.
  v. X-rays were discovered by Wilhelm Conrad Roentgen in 1895.
  vi. X-rays are detected by ionisation chamber, photographic plate, scintillation counters, semi-conductor detector, etc.
  vii. X-rays can travel in vacuum with the speed of light.
  viii. X-rays are not deviated by electric and magnetic fields.
  ix. X-rays affect photographic plates.
  x. X-rays ionize the gas through which they pass.
  xi. They produce fluorescence in many substances like zinc sulphide, barium platinocyanide etc.
  xii. X-rays travel in straight line and cast the shadows of the objects falling in their path.
  xiii. X-rays can undergo reflection, refraction, interference, diffraction and polarization.
  xiv. X-rays can penetrate through materials like paper, thin sheet of metal, wood, flesh, skin, etc., but they cannot penetrate denser objects, such as bones, heavy metals, etc.
  xv. Prolong exposure can have injurious effect on human bodies.
  xvi. They cause photoelectric effect.

- **Applications of X-rays:**
  i. In surgery, X-ray photographs are useful to detect bone fracture or the presence of foreign objects like bullets or hidden metal in a human body.
  ii. For detecting faults, cracks, flaws and gaps in metals.
  iii. To distinguish real diamonds, gems from artificial ones.
  iv. To detect the structure of crystals, constitution and properties of atoms and molecules in complex substance.
  v. To cure skin diseases and to destroy tumours in the body of a patient.
  vi. For detection of explosives, opium etc.

Knowledge Bank

Unlike optical (visible radiation) and radio telescopes (radio waves), X – rays astronomy is not possible on the earth. This is because X –rays due to their small wavelengths are absorbed by atmosphere, while optical and radio waves can penetrate the atmosphere.
Hence, we can work with optical and radio telescope from the surface of the earth but X – ray astronomy is possible only from satellites orbiting the earth.

- **Ultraviolet rays:**
  i. Ultraviolet rays are electromagnetic waves of short wavelengths ranging from 10^{-8} m to 3.9×10^{-7} m.
  ii. Ultraviolet rays were discovered by Johann Wilhelm Ritter in 1801.
  iii. They can be produced by the arcs of mercury and iron. They can also be obtained by passing discharge through hydrogen and xenon.

iv. Their wavelengths are shorter than those of violet light.
v. The sun is the most important natural source of UV-rays.
vi. UV-rays can travel in vacuum with the speed of light.
vii. UV-rays can undergo reflection, refraction, interference and polarization.
viii. UV-rays can cause photoelectric effect.
ix. UV-rays produce fluorescence in certain materials.
x. UV-rays cannot pass through glass but they can pass through quartz, fluorite, rock salts etc.
xi. UV-rays possess the property of synthesizing vitamin D when the skin is exposed to sunlight.

- **Applications of Ultraviolet rays:**

i. In checking the mineral samples.
ii. UV absorption spectra is used to study molecular structure.
iii. To destroy bacteria and hence they are used for sterilizing surgical instrument.
iv. In burglar alarms as they can cause photo electric effect.
v. In high resolving power microscopes.
vi. To distinguish between real and false gems.
vii. In the analysis of chemical compounds.

- **Visible light:**

i. Visible rays are small part of electromagnetic spectrum which is detected by human eyes.
ii. The wavelength range varies between 3.9×10^{-7} m to 7.5×10^{-7} m.
iii. The frequency range of visible light is 4×10^{14} Hz to 8×10^{14} Hz.
iv. Visible radiation is obtained when electrons in atoms move from one energy level to a lower energy level, emitting radiation.
v. Visible light is produced by heating bodies to glow.
e.g.: Electric bulbs, sodium lamp, fluorescent tubes.
vi. Visible radiation can be detected by the eye, photocells and photographic plate.
vii. Visible light consists of different colours ranging from red to violet.
viii. Different wavelengths give rise to different colours. The wavelength range of red colour is the largest while that of violet colour is the smallest. Wavelength range of various parts of visible rays is as follows:

Colour	Wavelength range in m
Violet	4×10^{-7} to 4.5×10^{-7}
Blue	4.5×10^{-7} to 5×10^{-7}
Green	5×10^{-7} to 5.7×10^{-7}
Yellow	5.7×10^{-7} to 5.9×10^{-7}
Orange	5.9×10^{-7} to 6.2×10^{-7}
Red	6.2×10^{-7} to 7.5×10^{-7}

- **Infrared rays:**

i. Infrared rays are electromagnetic waves which are responsible for heat radiation.
ii. Infrared rays can be produced using Nernst lamp, Globar, LASER.
iii. It was discovered by Sir Frederick William Hershell in 1800.
iv. The wavelength ranges nearly from 7×10^{-7} m to 10^{-3} m.
v. The frequency ranges from 3×10^{11} Hz to 4×10^{14} Hz.
vi. All hot bodies are sources of infrared rays.
vii. About 60% of solar radiations are infrared in nature.
viii. Infrared rays obey laws of reflection and refraction.
ix. They can produce interference and polarization.
x. They affect the photographic plates.
xi. When infrared rays are allowed to fall on the material surface, its temperature increases.
xii. I.R. rays are strongly absorbed by glass.
xiii. Thermocouple, thermopile, bolometer etc are used to detect infrared rays.
xiv. They can penetrate through thick columns of fog and mist.

- **Applications of infrared rays:**

i. In taking photographs during conditions of fog, smoke, darkness etc.
ii. In diagnosis of superficial tumours and varicose veins.
iii. To cure infantile paralysis and to treat sprains, dislocations and fractures.
iv. In solar water heaters and solar cookers.
v. In medicine.
vi. Special infrared photographs of the body, called thermograms, can show up diseased parts because they radiate less heat than the healthy parts, which is sensitive to infrared rays.
vii. Infrared rays are reflected by low lying clouds and keep the earth warm hence they show green house effect.
viii. To keep green house warm.
ix. In remote controls of television, V.C.R etc.

- **Microwaves:**
  i. Microwaves are the electromagnetic waves of short wavelength ranging from 1×10^{-3} m to 0.3 m.
  ii. Frequency range of microwaves is 5×10^{9} Hz to 1×10^{12} Hz.
  iii. Microwaves are produced by special vacuum tubes called klystrons, magnetrons and gunn diodes.
  iv. They obey the laws of reflection and refraction.
  v. They travel in vacuum with the speed of light.
  vi. They heat an object on which they are incident.

- **Applications of microwaves:**
  i. In radar system for the location of distant objects like ships, aeroplanes etc.
  ii. In long distance telephone communication system.
  iii. For cooking.
  iv. In the study of atomic and molecular structure.
  v. For the transmission of TV signals.

- **Radio waves:**
  i. Radio waves are electromagnetic waves having very long wavelengths ranging from few centimetres to few hundred kilometres.
  ii. Radio waves are produced by oscillating electric circuits containing an inductor and a capacitor.
  iii. The frequency of the waves produced by the circuit depends upon the magnitudes of the inductance and the capacitance. So by choosing suitable values of the inductance and the capacitance, microwaves or radio waves of any desired frequency can be produced.
  iv. They obey laws of reflection and refraction.
  v. Radio waves get diffracted from obstacles coming in their path. The size of the obstacle should be large as radio waves are having quite larger wavelengths.

- **Applications of radio waves:**
  i. For wireless communication purposes.
  ii. For radio broadcasting and transmission of TV signals.
  iii. Cellular phones use radio waves to transmit voice communication in the ultra high frequency (UHF) band.

Notes

1. *While the conduction current is due to the flow of electrons through the connecting wires in an electric circuit, the displacement current arises due to the time rate of change of electric flux in some part of the electric circuit.*
2. *The conduction and displacement currents are entirely different from each other. However, displacement current produces magnetic field in the same manner, as the conduction current does.*
3. *The displacement current is always equal to the conduction current.*
4. *Maxwell's equations are mathematical formulation of Gauss' law in electrostatics, Gauss' law in magnetism, Faraday's law of electromagnetic induction and Ampere's circuital law.*
5. *The frequency of electromagnetic waves is its inherent characteristic. When an electromagnetic wave travels from one medium to another, its wavelength and velocity change but frequency remains unchanged.*
6. *All the types of electromagnetic waves travel with the same speed in free space.*
7. *The electric vector of an electromagnetic wave is responsible for its optical effect. For this reason, the electric vector is also called light vector.*
8. *The direction of propagation of an electromagnetic wave is given by the cross product of electric field and magnetic field vectors i.e.,* $\vec{E} \times \vec{B}$
9. *During the discharge of a capacitor, the current in the circuit increases.*

Formulae

1. **Displacement current:** $I_D = \varepsilon_0 \frac{d\phi_E}{dt}$
2. **Ampere's circuital law:** $\oint \vec{B} \cdot \vec{dl} = \mu_0 I$
3. **Modified Ampere's circuital law:**
$$\oint \vec{B} \cdot \vec{dl} = \mu_0 \left(I_C + \varepsilon_0 \frac{d\phi E}{dt} \right)$$
4. **Maxwell's equations:**
   i. $\oint \vec{B} \cdot \vec{ds} = \frac{q}{\varepsilon_0}$
   ii. $\oint \vec{B} \cdot \vec{ds} = 0$
   iii. $\oint \vec{B} \cdot \vec{dl} = -\frac{d\phi B}{dt}$
   iv. $\oint \vec{B} \cdot \vec{dl} = \mu_0 \left(I_C + \varepsilon_0 \frac{d\phi B}{dt} \right)$

5. **Electromagnetic wave:**
   i. velocity of electromagnetic waves in free space, $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = \frac{E_0}{B_0}$
   ii. velocity of electromagnetic waves in a material medium, $v_m = \frac{1}{\sqrt{\mu\varepsilon}}$

6. **Refractive index (n) of a material medium:**
$n = \frac{c}{v} = \frac{1}{\sqrt{\mu_0\varepsilon_0}} \times \frac{\sqrt{\mu\varepsilon}}{1} = \sqrt{\frac{\mu\varepsilon}{\mu_0\varepsilon_0}} = \sqrt{\mu_r\varepsilon_r}$
Where $\frac{\mu}{\mu_0} = \mu_r$ relative permeability, $\frac{\varepsilon}{\varepsilon_0} = \varepsilon_r$ relative permittivity of the material medium.

7. **Average electric energy density:** $u_E = \frac{1}{2}\varepsilon_0 E^2$

8. **Average magnetic energy density:** $u_B = \frac{1}{2}\frac{B^2}{\mu_0}$

9. **Energy transported by electromagnetic wave per second per unit area:**
$\vec{S} = \vec{E} \times \vec{H} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$

10. **Momentum transported by electromagnetic wave:**
$p = \frac{U}{c}$, where, U is energy transport by electromagnetic wave.

11. **Intensity of electromagnetic waves:**
$I = \frac{1}{2}\frac{E_0 B_0}{\mu_0} = \frac{1}{2}\frac{B_0^2}{\mu_0}c = \frac{1}{2}\varepsilon_0 E_0^2 c$

12. **Pressure exerted by electromagnetic wave:**
$P = \frac{I}{c}$

Shortcuts

1. E.M. waves transport momentum, energy and information. It does not transport charge.
2. Displacement current between the plates of capacitor,
$$I_D = \varepsilon_0 \frac{d(EA)}{dt} = \varepsilon_0 A \frac{dE}{dt}$$
$$= \varepsilon_0 A \frac{d}{dt}\left(\frac{V}{d}\right) = \frac{\varepsilon_0 A}{d}\frac{dV}{dt}$$
$$= C\frac{dV}{dt}$$
Here E = electric field between the plates of capacitor, V = potential difference, d = separation between the plates, C = capacitance of the capacitor, A = area of plates.
3. If E_0 and B_0 be the peak values of the electric and magnetic fields, then
$$I = \frac{E_0 B_0}{2\mu_0} = \frac{E_0^2}{2\mu_0 c} = \frac{cB_0^2}{2\mu_0}$$
Where, $E_0 = \sqrt{2}\ E_{rms}$ and $B_0 = \sqrt{2}\ B_{rms}$

Multiple Choice Questions

7.1 Need for displacement current and origin of electromagnetic waves

1. Which of the following is the unit of displacement current?
   (A) Cs^{-1} (B) Vs^{-1}
   (C) Vm^{-1} (D) Cm^{-1}

2. **Assertion:** The unit of displacement current is ampere.
   Reason: Displacement current is another name for conduction current.
   (A) Assertion is True, Reason is True; Reason is a correct explanation for Assertion.
   (B) Assertion is True, Reason is True; Reason is not a correct explanation for Assertion.
   (C) Assertion is True, Reason is False.
   (D) Assertion is False, Reason is True.

3. **Assertion:** Displacement current goes through the gap between the plates of a capacitor when the charge of the capacitor does not change.
   Reason: The displacement current arises in the region in which the electric field and hence the electric flux does not change with time.
   [GUJ CET 2009]
   (A) Assertion is True, Reason is True; Reason is a correct explanation for Assertion.
   (B) Assertion is True, Reason is True; Reason is not a correct explanation for Assertion.
   (C) Assertion is True, Reason is False.
   (D) Assertion is False, Reason is False.

4. In electromagnetic wave, according to Maxwell, changing electric field gives ________. **[MH CET 2014]**
   (A) stationary magnetic field.
   (B) conduction current.
   (C) eddy current.
   (D) displacement current.

5. The wavelength of electromagnetic waves from Hertz experiment was found to be
   (A) 6 m (B) 2 m
   (C) 10 m (D) 3 m

6. The unit of expression for $\mu_0\,\varepsilon_0$ is
   (A) $\frac{m}{s}$ (B) $\frac{m^2}{s^2}$
   (C) $\frac{s^2}{m^2}$ (D) $\frac{s}{m}$

7. The amplitude of electric and magnetic fields relate to each other as
(A) $E_0 = B_0$ (B) $E_0 = c B_0$
(C) $E_0 = \frac{B_0}{c}$ (D) $E_0 = \frac{c}{B_0}$

8. The speed of electromagnetic wave in vacuum **[Kerala PMT 2004]**
(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 these.

9. Light is an electromagnetic wave. Its speed in vacuum is given by the expression **[CBSE PMT 1993; MP PMT 1994; R PMT 1999; MP PET 2001; Kerala PET 2001; AIIMS 2002]**
(A) $\sqrt{\mu_0\varepsilon_0}$ (B) $\sqrt{\frac{\mu_0}{\varepsilon_0}}$
(C) $\sqrt{\frac{\varepsilon_0}{\mu_0}}$ (D) $\frac{1}{\sqrt{\mu_0\varepsilon_0}}$

10. Two equations are given below
i. $\oint \vec{E}.d\vec{A} = \frac{Q}{\varepsilon_0}$ ii. $\oint \vec{B}.d\vec{A} = 0$
[TS EAMCET (Engg.) 2016]
(A) i. – Ampere's law
ii. – Gauss' law for electricity
(B) i. – Gauss' law for electric fields
ii. – Gauss' law for magnetic fields
(C) i. – Faraday's law
ii. – Gauss' law for electric fields
(D) Both i. and ii. represent Faraday's law

11. Which of the following law asserts that the electric field lines cannot form closed loops?
(A) Gauss' law.
(B) Faraday's law.
(C) Unmodified Ampere's law.
(D) Modified Ampere's law.

12. Maxwell's equations describe the fundamental laws of **[C PMT 1996]**
(A) Electricity only.
(B) Magnetism only.
(C) Mechanics only.
(D) Both (A) and (B)

13. A parallel plate capacitor with plates of area A and separation between the plates d, is charged by a constant current I. Consider a plane surface of area A/2 parallel to the plates and drawn symmetrically between the plates. The displacement current through this area will be.
(A) I (B) $\frac{I}{2}$ (C) $\frac{I}{4}$ (D) $\frac{I}{6}$

14. The capacity of a parallel plate air capacitor is 2 μF and voltage between the plates is changing at the rate of 3 V/s. The displacement current in the capacitor is **[MH CET 2015]**
(A) 2 μA (B) 3 μA
(C) 5 μA (D) 6 μA

15. If a source is transmitting electromagnetic wave of frequency 8.2×10^6 Hz, then wavelength of the electromagnetic wave transmitted from the source will be **[D PMT 1999]**
(A) 36.6 m (B) 40.5 m
(C) 42.3 m (D) 50.9 m

16. Electromagnetic waves travel in a medium which has relative permeability 1.3 and relative permittivity 2.14. Then the speed of the electromagnetic wave in the medium will be **[MH CET 2003]**
(A) $13.6\times10^6\ \frac{m}{s}$
(B) $1.8\times10^2\ \frac{m}{s}$
(C) $3.6\times10^8\ \frac{m}{s}$
(D) $1.8\times10^8\ \frac{m}{s}$

17. A particle of charge -16×10^{-18} coulomb moving with velocity 10 ms^{-1} along the X-axis enters a region where an electric field of induction E of magnitude $10^4\ \frac{V}{m}$ is along the negative Z-axis.
If the charged particle continues moving along the X-axis, the magnitude of B is **[AIEEE 2003]**
(A) $10^{-3}\ \frac{Wb}{m^2}$ (B) $10^{3}\ \frac{Wb}{m^2}$
(C) $10^{5}\ \frac{Wb}{m^2}$ (D) $10^{16}\ \frac{Wb}{m^2}$

18. The magnetic field in a travelling electromagnetic wave has a peak value of 20 nT. The peak value of electric field strength is **[JEE (Main) 2013]**
(A) 3 V/m (B) 6 V/m
(C) 9 V/m (D) 12 V/m

19. In an electromagnetic wave in free space the root mean square value of the electric field is E_{rms} = 6 V/m. The peak value of the magnetic field is: **[NEET (UG) 2017]**
(A) 1.41×10^{-8} T
(B) 2.83×10^{-8} T
(C) 0.70×10^{-8} T
(D) 4.23×10^{-8} T

20. A plane electromagnetic wave of frequency 20 MHz travels through a space along x direction. If the electric field vector at a certain point in space is 6 V m^{-1}, what is the magnetic field vector at that point? **[K CET 2014]**
(A) 2×10^{-8} T (B) $\frac{1}{2} \times 10^{-8}$ T
(C) 2 T (D) $\frac{1}{2}$ T

7.2 Electromagnetic waves and their characteristics

21. In an electromagnetic wave, the direction of the magnetic induction $\vec{B}$ is
(A) parallel to the electric field $\vec{E}$.
(B) perpendicular to the electric field $\vec{E}$.
(C) antiparallel to the poynting vector $\vec{S}$.
(D) random.

22. **Assertion:** The pairs E_x, B_y and E_y, B_x, components of space and time varying electric field ($\vec{E}$) and magnetic field ($\vec{B}$) can generate a plane electromagnetic wave travelling along the Z-direction.
Reason: Electromagnetic waves propagate in the direction of vector $\vec{E} \times \vec{B}$.
(A) Assertion is True, Reason is True; Reason is a correct explanation for Assertion.
(B) Assertion is True, Reason is True; Reason is not a correct explanation for Assertion.
(C) Assertion is True, Reason is False.
(D) Assertion is False, Reason is False.

23. If $\vec{E}$ and $\vec{B}$ represent electric and magnetic field vectors of the electromagnetic wave, the direction of propagation of electromagnetic wave is along **[K CET 2017; NCERT Exemplar]**
(A) $\vec{E}$ (B) $\vec{B}$
(C) $\vec{B} \times \vec{E}$ (D) $\vec{E} \times \vec{B}$

24. Fundamental particle in an electromagnetic wave is ________. **[DCE 1998]**
(A) photon (B) electron
(C) phonon (D) proton

25. Consider the following statements about electromagnetic radiations; All of them
i. have energy.
ii. exert pressure on an object.
iii. have the same momentum.
Of these statements
(A) (i), (ii) and (iii) are correct.
(B) (i) and (ii) are correct.
(C) (ii) and (iii) are correct.
(D) (i) and (iii) are correct.

26. Which of the following statements about electromagnetic waves is/are true? **[BCECE 2015]**
(1) Electromagnetic waves travel at the same speed in any medium.
(2) All electromagnetic waves can ionize living cells.
(3) All electromagnetic waves are transverse waves.
(A) (3) only
(B) (1) and (3) only
(C) (2) and (3) only
(D) (1), (2) and (3)

27. Which of the following type of radiations are radiated by an oscillating electric charge?
(A) Electric (B) Magnetic
(C) Thermoelectric (D) Electromagnetic

28. For electromagnetic waves, in vacuum,
(A) $c = \frac{\nu}{\lambda}$ (B) $\lambda = \frac{1}{\nu}$
(C) $c = \nu\lambda$ (D) $c = \frac{1}{\lambda}$

29. For an electromagnetic wave,
(A) Average electric density and average magnetic energy density are zero.
(B) Average electric density and average magnetic energy density are equal.
(C) Average electric density and average magnetic energy density have different values.
(D) Average electric density and average magnetic energy density do not exist.

30. Energy transported by electromagnetic waves per second per unit area is given as,
(A) $\frac{\vec{E}}{\mu_0}$ (B) $\frac{\vec{B}}{\mu_0}$
(C) $\frac{\vec{E} \times \vec{B}}{\mu_0}$ (D) $\frac{\mu_0}{\vec{E} \times \vec{B}}$

31. Momentum carried by an electromagnetic wave having energy U is given as,
(A) $\frac{U}{c}$ (B) $U \times c$
(C) $\frac{c}{U}$ (D) $\frac{2U}{c}$

32. A radiation of energy 'E' falls normally on a perfectly reflecting surface. The momentum transferred to the surface is (c = velocity of light) **[AIPMT 2015]**
(A) $\frac{E}{c}$ (B) $\frac{2E}{c}$
(C) $\frac{2E}{c^2}$ (D) $\frac{E}{c^2}$

33. Choose the false statement.
(A) E.M. waves are produced by accelerated charged particles.
(B) For E.M. waves, $\frac{E_0}{B_0} = c$.
(C) E.M. waves cannot be polarised.
(D) The energy in e.m. waves is divided equally between the electric and magnetic field vectors.

34. For E.M. waves which of the following statement is true?
(A) E.M. waves obey the principle of superposition of waves.
(B) E.M. waves are produced by accelerated particles.
(C) For an E.M. wave, $c = \frac{1}{(\mu_0\varepsilon_0)^2}$
(D) E.M. waves always travel with speed of light.

35. Electromagnetic wave consists of periodically oscillating electric and magnetic vectors **[K CET 2010; Similar in CBSE PMT 1994]**
(A) in mutually perpendicular planes but vibrating in phase.
(B) in randomly oriented planes but vibrating in phase.
(C) in mutually perpendicular planes but vibrating with a phase difference of $\frac{\pi}{2}$.
(D) in mutually perpendicular planes but vibrating with a phase difference of π.

36. During the propagation of electromagnetic waves in a medium **[JEE (Main) 2014]**
(A) electric energy density is double of the magnetic energy density.
(B) electric energy density is half of the magnetic energy density.
(C) electric energy density is equal to the magnetic energy density.
(D) both electric and magnetic energy densities are zero.

37. The ratio of contributions made by the electric field and magnetic field components to the intensity of an EM wave is **[NCERT Exemplar]**
(A) c:1 (B) c^2:1
(C) 1:1 (D) $\sqrt{c}:1$

38. Out of the following options which one can be used to produce a propagating electromagnetic wave
[NEET P-I 2016; Similar in D PMT 2007]
(A) A chargeless particle
(B) An accelerating charge
(C) A charge moving at constant velocity
(D) A stationary charge

39. When the sun shines on your hands, your hands get warm because
(A) e.m. waves transfer large amount of radiation pressure.
(B) e.m. waves transfer large amount of momentum.
(C) e.m. waves transfer energy.
(D) all of the above.

40. Choose an incorrect statement:
i. The velocity of light depends on electric and magnetic properties of the medium.
ii. The velocity of e.m. wave in vacuum is a fundamental constant.
iii. The velocity of e.m. wave depends on the refractive index of material medium.
iv. The velocity of e.m. waves is its inherent characteristic.
(A) i and ii (B) ii and iii
(C) iii (D) iv

41. In a plane electromagnetic wave of frequency 3×10^{14} Hz, the amplitude of electric field oscillations is 64 N/C. What is the wavelength of magnetic field oscillations?
(A) 1 mm (B) 1 μm
(C) 1 nm (D) 1 pm

42. The dielectric constant of air is 1.006. The speed of electromagnetic wave travelling in air is $a \times 10^8\ ms^{-1}$, where a is? **[Kerala PET 2007]**
(A) 3 (B) 3.88
(C) 2.5 (D) 3.2

43. A radiowave has a maximum magnetic field induction of 10^{-4} T on arrival at a receiving antenna. The maximum electric field intensity of such a wave is
(A) zero (B) $3\times10^4\frac{V}{m}$
(C) $5.8\times10^{-9}\frac{V}{m}$ (D) $3.3\times10^{-13}\frac{V}{m}$

44. For an e.m. wave propagating along X-axis, $E_{max} = 30\frac{V}{m}$. The maximum value of magnetic field is, **[DCE 2007]**
(A) 10^{-7} T (B) 10^{-8} T
(C) 10^{-9} T (D) 10^{-6} T

45. What is the energy density at a distance of 5 m from a point source of em waves, if the electric field strength at that point is $100\frac{V}{m}$?
(A) $44\times10^{-9}\frac{J}{m^3}$ (B) $22\times10^{-9}\frac{J}{m^3}$
(C) $11\times10^{-9}\frac{J}{m^3}$ (D) $88\times10^{-9}\frac{J}{m^3}$

46. In an electromagnetic wave, the amplitude of electric field is $1\ \frac{V}{m}$. The frequency of wave is 5×10^{14} Hz and is moving along Z-axis. What is the average energy density of electric field?
(A) 4.4×10^{-12} J/m^3
(B) 6.6×10^{-12} J/m^3
(C) 2.2×10^{-12} J/m^3
(D) 8.8×10^{-12} J/m^3

47. The rms value of the electric field of the light coming from the sun is 720 N/C. The average total density of the electromagnetic wave is **[BCECE 2014]**
(A) 81.35×10^{-12} J/m^3
(B) 3.3×10^{-3} J/m^3
(C) 4.58×10^{-6} J/m^3
(D) 6.37×10^{-9} J/m^3

7.3 Transverse nature of electromagnetic waves

48. Electromagnetic waves are transverse in nature is evident by **[AIEEE 2002]**
(A) polarisation (B) interference
(C) reflection (D) diffraction

49. Energy stored in electromagnetic oscillations is in the form of **[AFMC 1994; Haryana CET 2000]**
(A) electrical energy.
(B) magnetic energy.
(C) both (A) and (B).
(D) none of these.

50. Which of the following has zero average value in a plane electromagnetic wave?
(A) Kinetic energy.
(B) Magnetic field.
(C) Electric field.
(D) Both (B) and (C).

51. An electromagnetic wave going through vacuum is described by $E = E_0 \sin(kx - \omega t)$. Which of the following is independent of wavelength?
(A) k (B) ω (C) $\frac{k}{\omega}$ (D) $k\omega$

52. Consider the following two statements regarding a linearly polarised plane electromagnetic wave:
i. electric field and the magnetic field have equal average values.
ii. electric energy and the magnetic energy have equal average values.
(A) (i) is true. (B) (ii) is true.
(C) Both are true. (D) Both are false.

53. The electric field for an e.m. wave is
$E = E_0 \sin\left[\pi(12 \times 10^{15} t - 4 \times 10^7 x)\right]$
What is the speed of the e.m. wave?
(A) 12×10^{15} m/s (B) 4×10^7 m/s
(C) 3×10^8 m/s (D) 48×10^8 m/s

54. A plane electromagnetic wave travels in free space along X-axis. At a particular point in space, the electric field along Y-axis is 9.3 Vm^{-1}. The magnetic induction (B) along Z-axis is
(A) 3.1×10^{-8} T (B) 3×10^{-5} T
(C) 3.1×10^{-7} T (D) 9.3×10^{-6} T

55. In a plane e.m. wave, the magnetic field oscillates sinusoidally with a frequency of 3×10^{10} Hz and amplitude 128 nT. Then the wavelength of the wave and the amplitude of the oscillating electric field respectively will be,
(A) 10^{-6} m; 50 V m^{-1}
(B) 10^{-2} m; 28 V m^{-1}
(C) 10^{-2} m; 38.4 V m^{-1}
(D) 10^{-9} m; 49 V m^{-1}

56. The magnetic field in a plane electromagnetic field is given by
$B_y = 2 \times 10^{-7} \sin(0.5 \times 10^3 z + 1.5 \times 10^{11} t)$ T
The expression for the electric field may be given by **[AMU (Med.) 2009]**
(A) $E_y = 2\times10^{-7} \sin(0.5\times10^3 z + 1.5\times10^{11} t)\ \frac{V}{m}$
(B) $E_x = 2\times10^{-7} \sin(0.5\times10^3 z + 1.5\times10^{11} t)\ \frac{V}{m}$
(C) $E_y = 60 \sin(0.5 \times 10^3 z + 1.5\times10^{11} t)\ \frac{V}{m}$
(D) $E_x = 60 \sin(0.5 \times 10^3 z + 1.5\times10^{11} t)\ \frac{V}{m}$

57. The oscillating magnetic field in a plane electromagnetic wave is given by,
$B_y = 8 \times 10^{-6} \sin[2 \times 10^{11} t + 300\ \pi x]$ (in T)
then wavelength of the wave
(A) 6.67×10^{-3} m (B) 4.67×10^{-3} m
(C) 2.67×10^{-3} m (D) 5.67×10^{-3} m

7.4 Electromagnetic spectrum

58. Which rays are not the portion of electromagnetic spectrum? **[Haryana CET 2000]**
(A) X-rays (B) Microwaves
(C) α-rays (D) Radiowaves

59. All components of the electromagnetic spectrum in vacuum have the same **[K CET 2007]**
(A) energy (B) velocity
(C) wavelength (D) frequency

60. Which of the following is of shortest wavelength?
(A) X-rays (B) γ-rays
(C) microwaves (D) radiowaves

61. The wavelength of X-rays is of the order of **[Manipur (Med.) 2009]**
(A) 1 cm (B) 1 micron
(C) 1 Å (D) 1 m

62. The range of wavelength of the visible light is **[MP PMT 2000; MP PET 2002]**
(A) 10 Å to 100 Å
(B) 4,000 Å to 8,000 Å
(C) 8,000 Å to 10,000 Å
(D) 10,000 Å to 15,000 Å

63. The wavelength 21 cm emitted by atomic hydrogen in interstellar space belongs to _______.
(A) radio waves (B) infrared waves
(C) microwaves (D) γ-rays

64. Infrared radiation was discovered in 1800 by **[K CET 2005]**
(A) William Wollaston.
(B) William Hershell.
(C) Wilhelm Roentgen.
(D) Thomas Young.

65. Gamma rays have wavelength in the range,
(A) 10^{-12} to 10^{-14} m
(B) 10^{-18} to 10^{-10} m
(C) 10^{-4} to 10^{-2} m
(D) 10^{-8} to 10^{-4} m

66. Radiowaves do not penetrate in the band of _______.
(A) ionosphere (B) mesosphere
(C) troposphere (D) stratosphere

67. A radar sends the waves towards a distant object and receives the signal reflected by object. These waves are _______.
(A) sound waves (B) light waves
(C) radiowaves (D) microwaves

68. The wavelength of ultraviolet rays is of the order of _______.
(A) 10^{-3} m (B) 10^{-1} m
(C) 10^{-8} m (D) 10^{-14} m

69. The radiation pressure (in N/m^2) of the visible light is of the order of **[D PMT 2009]**
(A) 10^{-2} (B) 10^{-4}
(C) 10^{-6} (D) 10^{-8}

70. The penetrating power of X-ray increases with the increase in its _______.
(A) velocity (B) intensity
(C) frequency (D) wavelength

71. Radio waves diffract around building although light waves do not. The reason is that radio waves **[AMU 2000]**
(A) travel with speed greater than c.
(B) have much greater wavelength than light.
(C) have wavelength equal to light.
(D) are not electromagnetic waves.

72. Which of the following is used to make thermograms?
(A) X-rays (B) Gamma rays
(C) Infrared rays (D) Microwaves

73. The energy of the e.m. waves is of the order of 15 keV. To which part of the spectrum does it belong? **[AIPMT Re-Test 2015]**
(A) γ-rays (B) X-rays
(C) Infra-red rays (D) Ultraviolet

74. In which one of the following regions of the electromagnetic spectrum will the vibrational motion of molecules give rise to absorption? **[SCRA 1994]**
(A) Ultraviolet (B) Microwaves
(C) Infrared (D) Radio waves

75. Which of the following is used for wireless communication and transmission of T.V signals?
(A) Gamma rays (B) Infrared rays
(C) Radio waves (D) Microwaves

76. Gamma rays is used in
(A) detecting flaws, gaps, cracks in metals.
(B) burglar alarms.
(C) radio therapy for treatment of cancer and tumour.
(D) sterilizing surgical instruments.

77. Nuclei of radioactive elements like uranium, radium emit
(A) X-rays. (B) radio waves.
(C) gamma rays. (D) UV rays.

78. Synthesization of vitamin D when the skin is exposed to light is a property of _______.
(A) γ-rays (B) Microwaves
(C) X-rays (D) UV rays

79. Infrared spectrum lies between **[NCERT 1980]**
(A) radio wave and microwave region.
(B) microwave and visible region.
(C) visible and ultraviolet region.
(D) ultraviolet and X-rays.

80. Radio waves of constant amplitude can be generated with **[CBSE PMT 1993]**
(A) rectifier. (B) filter.
(C) F.E.T. (D) oscillator.

81. Infrared radiations are detected by _______. **[AIEEE 2002]**
(A) spectrometer (B) pyrometer
(C) nanometer (D) photometer

82. Radiowaves with frequencies higher than television signals are
(i) ultrasonic waves (ii) sound waves
(iii) light waves (iv) microwaves
(A) only (i).
(B) Both (ii) and (iv).
(C) Only (iii).
(D) Both (iii) and (iv).

83. Finger prints on a piece of paper may be detected by sprinkling fluorescent powder on the paper and then looking at it in
(A) dark light.
(B) sun-light.
(C) infrared light.
(D) ultraviolet light.

84. Absorption of X-rays is maximum in which of the following material sheets of the same thickness? **[AFMC 2009]**
(A) Cu (B) Au
(C) Be (D) Pb

85. The statement: A washed white shirt glows under sun light
(A) is incorrect because sun light does not produce fluorescence.
(B) is incorrect because such shirt looks pale after absorption of sun light.
(C) is correct because UV radiation from sunlight produces fluorescence due to sun light.
(D) is correct because IR radiation from sunlight produces fluorescence on dyes.

86. Which of the following statements is wrong? **[NCERT 1976]**
(A) Ultraviolet rays have a wavelength longer than infra-red rays.
(B) Infra-red rays travel with the same velocity as visible light.
(C) Infra-red can be focused by a lens and can be reflected by a mirror just as visible light.
(D) Infra-red rays have more heating power than visible light rays.

87. Electromagnetic radiation used to sterilize milk is **[KCET 2016]**
(A) X – ray (B) γ – ray
(C) UV – ray (D) Radiowaves

88. When X – rays are allowed to pass through a body, X – rays are _______ by / through the bones and ______ by / through surrounding body tissues.
(A) reflected, absorbed
(B) refracted, passed
(C) absorbed, passed
(D) absorbed, absorbed

89. Electromagnetic radiation of highest frequency is **[Kerala PMT 2002]**
(A) infrared radiation.
(B) visible radiations.
(C) X-rays.
(D) γ-rays.

90. X-rays are not used for radar purposes, because they are not
(A) reflected by target.
(B) partly absorbed by target.
(C) electromagnetic waves.
(D) completely absorbed by target.

91. Which of the following shows green house effect? **[CBSE PMT 2002]**
(A) Ultraviolet rays (B) Infrared rays
(C) X-rays (D) Gamma rays

92. Which of the following will deflect in electric field? **[AIIMS 1996]**
(A) X-rays
(B) gamma rays
(C) cathode rays
(D) ultraviolet rays

93. In medicine, to destroy cancer cells _______ rays are used. **[GUJ CET 2017]**
(A) Ultraviolet (B) Visible
(C) Gamma (D) Infrared

94. Which one of the following are not transverse waves? **[AFMC 1999]**
(A) Sound waves
(B) Visible light waves
(C) Gamma rays
(D) X-rays

95. Arcs of iron and mercury can produce _______.
(A) X-rays (B) UV rays
(C) infrared rays (D) microwaves

96. Klystrons, magnetrons, gunndiode vacuum-tubes are used to produce _______.
(A) microwave (B) radio wave
(C) infrared rays (D) X-rays

97. The ratio of speed of infrared rays and UV rays in vacuum is,
(A) 1 (B) 1.43
(C) 2 (D) 2.43

98. Which of the following represents an infrared wavelength? **[C PMT 1975; MP PET/PMT 1988]**
(A) 10^{-4} cm (B) 10^{-5} cm
(C) 10^{-6} cm (D) 10^{-7} cm

99. Which of the following e.m. waves are used in telecommunication?
(A) X-rays (B) Infra red
(C) Microwaves (D) Ultra violet

100. Which of the following statement is wrong? **[NCERT 1976]**
(A) Infrared photon has more energy than the photon of visible light.
(B) Photographic plates are sensitive to ultraviolet rays.
(C) Photographic plates can be made sensitive to infrared rays.
(D) Infrared rays are invisible but can cast shadows like visible light rays.

101. In electromagnetic spectrum, the frequencies of γ-rays, X-rays and ultraviolet rays are denoted by n_1, n_2 and n_3 respectively then **[MH CET 2014]**
(A) $n_1 > n_2 > n_3$ (B) $n_1 < n_2 < n_3$
(C) $n_1 > n_2 < n_3$ (D) $n_1 < n_2 > n_3$

102. The wavelength of the short radio waves, microwaves, ultraviolet waves are λ_1, λ_2 and λ_3 respectively. Arrange them in decreasing order. **[GUJ CET 2014]**
(A) $\lambda_1, \lambda_3, \lambda_2$ (B) $\lambda_1, \lambda_2, \lambda_3$
(C) $\lambda_3, \lambda_1, \lambda_1$ (D) $\lambda_2, \lambda_1, \lambda_3$

103. Which one of the following have minimum wavelength? **[Pb PET 2001]**
(A) Ultraviolet rays (B) Cosmic rays
(C) X-rays (D) γ-rays

104. If λ_v, λ_x and λ_m represent the wavelength of visible light, X-rays and microwaves respectively, then **[CBSE PMT 2005]**
(A) $\lambda_m > \lambda_x > \lambda_v$ (B) $\lambda_v > \lambda_m > \lambda_x$
(C) $\lambda_m > \lambda_v > \lambda_x$ (D) $\lambda_v > \lambda_x > \lambda_m$

105. If v_s, v_x and v_m are the speeds of gamma rays, X-rays and microwaves respectively in vacuum, then **[C PMT 1993]**
(A) $v_s > v_x > v_m$ (B) $v_s < v_x < v_m$
(C) $v_s > v_x < v_m$ (D) $v_s = v_x = v_m$

106. The frequencies of X rays, γ rays and ultra violet rays are respectively p, q and r then **[GUJ CET 2015]**
(A) p < q, q > r (B) p > q, q > r
(C) p < q, q < r (D) p > q, q < r

107. Frequencies of various radiations are given as:
$f_v \rightarrow$ Visible light
$f_r \rightarrow$ Radio waves
$f_{uv} \rightarrow$ Ultra Violet waves
Then, which of following is true? **[GUJ CET 2018]**
(A) $f_{uv} < f_v < f_r$ (B) $f_r < f_v < f_{uv}$
(C) $f_v < f_r < f_{uv}$ (D) $f_{uv} < f_r < f_v$

108. Red light differs from blue light in its
(A) speed.
(B) frequency.
(C) intensity.
(D) amplitude.

109. Pick out the longest wavelength from the following types of radiations. **[CBSE PMT 1990]**
(A) Blue light
(B) γ-rays
(C) X-rays
(D) Red light

110. The range of wavelength of the different waves of visible light is
(A) $\lambda_{Violet} > \lambda_{Green} > \lambda_{Orange} > \lambda_{Red}$
(B) $\lambda_{Red} > \lambda_{Orange} > \lambda_{Green} > \lambda_{Violet}$
(C) $\lambda_{Violet} > \lambda_{Red} > \lambda_{Green} > \lambda_{Orange}$
(D) $\lambda_{Violet} > \lambda_{Orange} > \lambda_{Red} > \lambda_{Green}$

111. Choose the correct sequence of the radiation sources in increasing order of the wavelength of electromagnetic waves produced by them. **[AP EAMCET (Engg.) 2016]**
(A) X-ray tube, Magnetron valve, Radioactive source, Sodium lamp.
(B) Radioactive source, X-ray tube, Sodium lamp, Magnetron valve.
(C) X-ray tube, Magnetron valve, Sodium lamp, Radioactive source
(D) Magnetron valve, Sodium lamp, X-ray tube, Radioactive source

112. The frequency of visible light is of the order of _______.
(A) 10^{14} Hz (B) 10^{10} Hz
(C) 10^6 Hz (D) 10^4 Hz

113. Frequency of a wave is 6×10^{15} Hz. The wave is **[Orissa PMT 2004]**
(A) Radiowave
(B) Microwave
(C) X-ray
(D) None of these

114. Earth's atmosphere is richest in _______. **[DCE 1997, 1999]**
(A) ultraviolet
(B) infrared
(C) X-rays
(D) microwaves

115. There are three wavelengths 10^7 m, 10^{-11} m, 10^{-7} m. Find their corresponding names respectively.
(A) Radiowaves, X-rays, Visible rays.
(B) X-rays, Visible rays, Radio waves.
(C) X-rays, γ-rays, Visible rays.
(D) Visible rays, γ-rays, X-rays.

116. Match **List-I** (Electromagnetic wave type) with **List-II** (Its association/application) and select the correct option from the choices given below the lists:

List-I		List-II	
(a)	Infrared waves	(i)	To treat muscular strain
(b)	Radio waves	(ii)	For broadcasting
(c)	X-rays	(iii)	To detect fracture of bones
(d)	Ultraviolet rays	(iv)	Absorbed by the ozone layer of the atmosphere

[JEE (Main) 2014]

	(a)	**(b)**	**(c)**	**(d)**
(A)	(iv)	(iii)	(ii)	(i)
(B)	(i)	(ii)	(iv)	(iii)
(C)	(iii)	(ii)	(i)	(iv)
(D)	(i)	(ii)	(iii)	(iv)

117. a. The wavelength of microwaves is greater than that of UV-rays.
b. The wavelength of infrared rays in lesser than that of UV-rays.
c. The wavelength of microwaves is lesser than that of IR rays.
d. Gamma ray has shortest wavelength in the electromagnetic spectrum.
[Kerala PET 2007]
(A) a and b are true.
(B) b and c are true.
(C) c and d are true
(D) a and d are true.

Miscellaneous

118. The displacement current flows in the dielectric of a capacitor when the potential difference between its plates
(A) is changing with time.
(B) is changing with distance.
(C) has assumed a constant value.
(D) becomes zero.

119. According to Maxwell's hypothesis, a changing electric field gives rise to
[AIIMS 1998]
(A) an e.m.f.
(B) electric current.
(C) magnetic field.
(D) pressure radiant.

120. If c is the speed of electromagnetic waves in vacuum, its speed in a medium of dielectric constant K and relative permeability μ, is
[Kerala PET 2005]
(A) $v = \frac{1}{\sqrt{\mu_r K}}$
(B) $v = c\sqrt{\mu_r K}$
(C) $v = \frac{c}{\sqrt{\mu_r K}}$
(D) $v = \frac{K}{\sqrt{\mu_r c}}$

121. The wavelength of electromagnetic wave is same for _______.
(A) odd frequencies
(B) even frequencies
(C) all frequencies
(D) all intensities

122. In an electromagnetic wave, the average energy density associated with magnetic field is given by
(A) $\frac{1}{2}\frac{B^2}{\mu_0}$
(B) $\frac{1}{2}\mu_0 B^2$
(C) $\frac{1}{2}\frac{B^2}{\varepsilon_0}$
(D) $\frac{1}{2}\varepsilon_0 B^2$

123. An EM wave radiates outwards from a dipole antenna, with E_0 as the amplitude of its electric field vector. The electric field E_0 which transports significant energy from the source falls off as **[NCERT Exemplar]**
(A) $\frac{1}{r^3}$
(B) $\frac{1}{r^2}$
(C) $\frac{1}{r}$
(D) remains constant

124. In an electromagnetic wave, the average energy density associated with the electric field is given by
(A) $\frac{1}{2}\frac{B^2}{\varepsilon_0}$
(B) $\frac{1}{2}\varepsilon_0 E^2$
(C) $\frac{1}{2}\frac{E^2}{\mu_0}$
(D) $\frac{1}{2}\mu_0 B^2$

125. **Assertion:** The displacement current is always equal to the conduction current.
Reason: The displacement current is given by

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

It leads to

$$I_D = \frac{dq}{dt}\left(\because \phi_E = E \times A = \frac{q}{\varepsilon_0 A} \times A = \frac{q}{\varepsilon_0}\right)$$

$\Rightarrow$ $I_D = I_C$
(A) Assertion is True, Reason is True; Reason is a correct explanation for Assertion.
(B) Assertion is True, Reason is True; Reason is not a correct explanation for Assertion.
(C) Assertion is True, Reason is False.
(D) Assertion is False, Reason is False.

126. A linearly polarised electromagnetic wave given as $E = E_0 \hat{i} \cos(kz - \omega t)$ is incident normally on a perfectly reflecting infinite wall at z = a. Assuming that the material of the wall is optically inactive, the reflected wave will be given as **[BCECE 2015; Similar in NCERT Exemplar]**
(A) $\vec{E}_r = E_0 \hat{i} \sin(kz - \omega t)$
(B) $\vec{E}_r = E_0 \hat{i} \cos(kz - \omega t)$
(C) $\vec{E}_r = -E_0 \hat{i} \cos(kz + \omega t)$
(D) $\vec{E}_r = E_0 \hat{i} \cos(kz + \omega t)$

127. An em wave is propagating in a medium with a velocity $\vec{v} = v\hat{i}$. The instantaneous oscillating electric field of this em wave is along + y axis. Then the direction of oscillating magnetic field of the em wave will be along **[NEET (UG) 2018]**
(A) – z direction (B) + z direction
(C) – y direction (D) – x direction

128. A parallel plate capacitor consists of circular plates each of radius 10 cm separated by a distance of 2 mm. If the charging current is 0.2 A, what is the rate of variation of potential?
(A) $1.44 \times 10^9 \frac{V}{s}$ (B) $2.88 \times 10^9 \frac{V}{s}$
(C) $0.72 \times 10^9 \frac{V}{s}$ (D) $0.36 \times 10^9 \frac{V}{s}$

129. **Assertion:** The displacement current like conduction current is a source of magnetic field.
Reason: Ampere's law is logically consistent for every circuit.
(A) Assertion is True, Reason is True; Reason is a correct explanation for Assertion.
(B) Assertion is True, Reason is True; Reason is not a correct explanation for Assertion.
(C) Assertion is True, Reason is False.
(D) Assertion is False, Reason is True.

130. A small metallic ball is charged positively and negatively in a sinusoidal manner at a frequency of 10^6 cps. The maximum charge on the ball is 10^{-6} C. what is the displacement current due to this alternating current? **[DCE 2005]**
(A) 6.28 A (B) 3.8 A
(C) 3.75×10^{-4} A (D) 122.56 A

131. A 100 Ω resistance and a capacitor of 100 Ω reactance are connected in series across a 220V source. When the capacitor is 50% charged, the peak value of the displacement current is **[NEET P-II 2016]**
(A) $11\sqrt{2}$A (B) 2.2 A
(C) 11 A (D) 4.4 A

132. A plane electromagnetic wave is incident on a material surface. If the wave delivers momentum p and energy E, then
(A) p = 0, E = 0
(B) $p \neq 0, E \neq 0$
(C) $p \neq 0, E = 0$
(D) $p = 0, E \neq 0$

133. The pressure exerted by an electromagnetic wave of intensity I (watts/m^2) on a non-reflecting surface is [c is the velocity of light] **[AFMC 2005]**
(A) Ic (B) Ic^2
(C) $\frac{I}{c}$ (D) $\frac{I}{c^2}$

134. The electric field intensity produced by the radiation coming from 100 W bulb at a 3 m distance is E. The electric field intensity produced by the radiations coming from 50 W bulb at the same distance is **[NCERT Exemplar]**
(A) $\frac{E}{2}$ (B) 2E
(C) $\frac{E}{\sqrt{2}}$ (D) $\sqrt{2}$ E

135. Radiations of intensity $0.5 \frac{W}{m^2}$ are striking a metal plate. The pressure on the plate is **[DCE 2004]**
(A) $0.166 \times 10^{-8} \frac{N}{m^2}$
(B) $0.332 \times 10^{-8} \frac{N}{m^2}$
(C) $0.111 \times 10^{-8} \frac{N}{m^2}$
(D) $0.083 \times 10^{-8} \frac{N}{m^2}$

136. Electromagnetic waves travel in a medium with a speed of 2×10^8 ms^{-1}. The relative permeability of the medium is 1. Find the relative permittivity.
(A) 1.85 (B) 3.82
(C) 2.25 (D) 6.42

137. Relative permeability and relative permittivity of a medium are respectively 4 and 9. If the magnetic induction field of the electromagnetic wave travelling in the medium is 4.2×10^{-8} T, then the magnitude of its electric field is **[AP EAMCET (Med.) 2016]**
(A) 4.2 Vm^{-1}
(B) 2.1×10^{-8} Vm^{-1}
(C) 4.2×10^{-8} Vm^{-1}
(D) 2.1 Vm^{-1}

138. An EM wave from air enters a medium. The electric fields are $\vec{E}_1 = E_{01}\hat{x}\cos\left[2\pi\nu\left(\frac{z}{c}-t\right)\right]$ in air and $\vec{E}_2 = E_{02}\hat{x}\cos[k(2z - ct)]$ in medium, where the wave number k and frequency ν refer to their values in air. The medium is non–magnetic. If ε_{r_1} and ε_{r_2} refer to relative permittivities of air and medium respectively, which of the following options is correct? **[JEE (Main) 2018]**
(A) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}}=\frac{1}{4}$ (B) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}}=\frac{1}{2}$
(C) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}}=4$ (D) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}}=2$

139. Find the wavelength of electromagnetic waves of frequencies 4×10^{17} Hz in free space. **[CBSE 2004]**
(A) 8.9×10^{-10} m (B) 6.3×10^{-10} m
(C) 7.5×10^{-10} m (D) 7.8×10^{-10} m

140. The electric field in a plane electromagnetic wave is given by,
$E_y = 72 \sin[1.5 \times 10^3 x + 5 \times 10^{11} t]$ (in V m^{-1})
What are the amplitudes of the electric and magnetic fields associated with the wave?
(A) 72 V m^{-1}; 2.4×10^{-7} T
(B) 42 V m^{-1}; 9.8 T
(C) 1.5 V m^{-1}; 2.4×10^{-6} T
(D) 5 V m^{-1}; 9.8×10^{-7} T

141. In a plane e.m. wave, the amplitude of electric field oscillations of frequency 10^{16} Hz is $48\ \frac{V}{m}$. What is the amplitude of magnetic field oscillation?
(A) $48\ \frac{Wb}{m^2}$ (B) $16\ \frac{Wb}{m^2}$
(C) $48\times10^{-8}\ \frac{Wb}{m^2}$ (D) $16\times10^{-8}\ \frac{Wb}{m^2}$

142. In an electromagnetic field, the amplitude of magnetic field is 3×10^{-10} T. If the frequency of the waves is 10^{12} Hz, then the amplitude of the associated electrical field will be **[UPSEAT 2002]**
(A) $9\times10^{-2}\ \frac{V}{m}$ (B) $3\times10^{-2}\ \frac{V}{m}$
(C) $3\times10^{-10}\ \frac{V}{m}$ (D) $9\ \frac{V}{m}$

143. The average energy density of an e.m wave with its electric field component
$E = \left(50\frac{N}{C}\right)\sin(\omega t - kx)$ will be nearly
(A) $10^{-8}\ \frac{J}{m^3}$ (B) $10^{-7}\ \frac{J}{m^3}$
(C) $10^{-6}\ \frac{J}{m^3}$ (D) $10^{-5}\ \frac{J}{m^3}$

144. Light with an energy flux of 25×10^4 Wm^{-2} falls on a perfectly reflecting surface at normal incidence. If the surface area is 15 cm^2, the average force exerted on the surface is **[AIPMT 2014]**
(A) 1.25×10^{-6} N (B) 2.50×10^{-6} N
(C) 1.20×10^{-6} N (D) 3.0×10^{-6} N

145. Radio waves and visible light in vacuum have **[K CET 2000]**
(A) same velocity but different wavelength.
(B) continuous emission spectrum.
(C) band absorption spectrum.
(D) line emission spectrum.

146. **Assertion:** A portable AM radio set must be kept horizontal to receive the signals properly.
Reason: Radio waves are polarised electromagnetic waves. **[AIIMS 2007]**
(A) Assertion is True, Reason is True; Reason is a correct explanation for Assertion.
(B) Assertion is True, Reason is True; Reason is not a correct explanation for Assertion.
(C) Assertion is True, Reason is False.
(D) Assertion is False, Reason is False.

147. A red LED emits light at 0.1 watt uniformly around it. The amplitude of the electric field of the light at a distance of 1 m from the diode is **[JEE (Main) 2015]**
(A) 1.73 V/m (B) 2.45 V/m
(C) 5.48 V/m (D) 7.75 V/m

148. X-rays and γ-rays of same energies are distinguished by their _______.
(A) frequencies
(B) charges
(C) ionising power
(D) method of production

149. Wave which cannot travel in vacuum is **[MP PMT 1994]**
(A) X-rays (B) infrasonic
(C) ultraviolet (D) radio waves

150. **Assertion:** Sound waves are electromagnetic waves.
Reason: Sound wave can pass through the vacuum.
(A) Assertion is True, Reason is True; Reason is a correct explanation for Assertion.
(B) Assertion is True, Reason is True; Reason is not a correct explanation for Assertion.
(C) Assertion is True, Reason is False.
(D) Assertion is False, Reason is False.

151. The shortest wavelength of X-rays emitted from an X-ray tube depends upon
(A) nature of the gas in the tube.
(B) nature of target of the tube.
(C) voltage applied to tube.
(D) all of the above.

152. One requires 11 eV of energy to dissociate a carbon monoxide molecule into carbon and oxygen atoms. The minimum frequency of the appropriate electromagnetic radiation to achieve the dissociation lies in **[NCERT Exemplar]**
(A) visible region.
(B) infrared region.
(C) ultraviolet region.
(D) microwave region.

153. The energy of gamma (γ) ray photon is E_γ and that of an X-ray photon is E_X. If the visible light photon has an energy of E_v, then we can say that **[WB JEEM 2014]**
(A) $E_x > E_\gamma > E_v$
(B) $E_\gamma > E_v > E_x$
(C) $E_\gamma > E_x > E_v$
(D) $E_x > E_v > E_\gamma$

154. The energy of X-ray photon is 3.3×10^{-16} J. Its frequency is
(A) 2×10^{19} Hz
(B) 5×10^{18} Hz
(C) 5×10^{17} Hz
(D) 5×10^{16} Hz

155. Arrange the following electromagnetic radiations per quantum in the order of increasing energy: **[JEE (Main) 2016]**
A : Blue light B : Yellow light
C : X – ray D : Radiowave
(A) A, B, D, C (B) C, A, B, D
(C) B, A, D, C (D) D, B, A, C

156. **Assertion:** The electrical conductivity of earth's atmosphere increases with altitude.
Reason: The high energy particles (i.e., γ-rays and cosmic rays) coming from outer space and entering our earth's atmosphere cause ionisation of the atoms of the gases present there.
(A) Assertion is True, Reason is True; Reason is a correct explanation for Assertion.
(B) Assertion is True, Reason is True; Reason is not a correct explanation for Assertion.
(C) Assertion is True, Reason is False.
(D) Assertion is False, Reason is False.

157. Light with an energy flux of 20 W/cm^2 falls on a non-reflecting surface at normal incidence. If the surface has an area of 30 cm^2, the total momentum delivered (for complete absorption) during 30 min is **[NCERT Exemplar]**
(A) 36×10^{-5} kg-m/s
(B) 36×10^{-4} kg-m/s
(C) 108×10^{4} kg-m/s
(D) 1.08×10^{7} kg-m/s

Answers to MCQ's

1. (A)	2. (C)	3. (D)	4. (D)	5. (A)	6. (C)	7. (B)	8. (C)	9. (D)	10. (B)
11. (A)	12. (D)	13. (B)	14. (D)	15. (A)	16. (D)	17. (B)	18. (B)	19. (B)	20. (A)
21. (B)	22. (A)	23. (D)	24. (A)	25. (B)	26. (A)	27. (D)	28. (C)	29. (B)	30. (C)
31. (A)	32. (B)	33. (C)	34. (A)	35. (A)	36. (C)	37. (C)	38. (B)	39. (C)	40. (D)
41. (B)	42. (A)	43. (B)	44. (A)	45. (A)	46. (C)	47. (C)	48. (A)	49. (C)	50. (D)
51. (C)	52. (C)	53. (C)	54. (A)	55. (C)	56. (D)	57. (A)	58. (C)	59. (B)	60. (B)
61. (C)	62. (B)	63. (A)	64. (B)	65. (A)	66. (A)	67. (D)	68. (C)	69. (C)	70. (C)
71. (B)	72. (C)	73. (B)	74. (B)	75. (C)	76. (C)	77. (C)	78. (D)	79. (B)	80. (D)
81. (B)	82. (D)	83. (D)	84. (D)	85. (C)	86. (A)	87. (C)	88. (C)	89. (D)	90. (A)
91. (B)	92. (C)	93. (C)	94. (A)	95. (B)	96. (A)	97. (A)	98. (A)	99. (C)	100. (A)
101. (A)	102. (B)	103. (B)	104. (C)	105. (D)	106. (A)	107. (B)	108. (B)	109. (D)	110. (A)
111. (B)	112. (A)	113. (D)	114. (B)	115. (A)	116. (D)	117. (D)	118. (A)	119. (C)	120. (C)
121. (D)	122. (A)	123. (C)	124. (B)	125. (A)	126. (D)	127. (B)	128. (A)	129. (C)	130. (A)
131. (B)	132. (B)	133. (C)	134. (C)	135. (A)	136. (C)	137. (D)	138. (A)	139. (C)	140. (A)
141. (D)	142. (A)	143. (A)	144. (B)	145. (A)	146. (B)	147. (B)	148. (D)	149. (B)	150. (D)
151. (C)	152. (C)	153. (C)	154. (C)	155. (D)	156. (A)	157. (B)			

Hints to MCQ's

2. Conduction current is the current due to flow of charges in a conductor and displacement current is the current due to the changing electric field between the plates of the capacitor.

3. Displacement current arises due to induced charge on other plate of the capacitor. This results into magnetic field due to the time varying electric field.

4. In electromagnetic wave, change in electric field gives displacement current, $I_D = \varepsilon_0 \frac{d\phi_E}{dt}$

8. Speed of EM waves in vacuum is given as, $\frac{1}{\sqrt{\mu_0\varepsilon_0}}$ = constant

13. Suppose the charge on the capacitor at time t is Q, the electric field between the plates of the capacitor is $E = \frac{Q}{\varepsilon_0 A}$. The flux through the area considered is $\phi_E = \frac{Q}{\varepsilon_0 A}.\frac{A}{2} = \frac{Q}{2\varepsilon_0}$

∴ The displacement current,

$I_D = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0\left(\frac{1}{2\varepsilon_0}\right)\frac{dQ}{dt} = \frac{I}{2}$.

14. $I_D = \frac{CdV}{dt} = 2 \times 10^{-6} \times 3 = 6 \times 10^{-6}\ A = 6\ \mu A$

15. $\lambda = \frac{c}{\nu} = \frac{3\times10^8}{8.2\times10^6} = 36.59$ m

16. $v = \frac{c}{\sqrt{\mu_r\varepsilon_r}} = \frac{3\times10^8}{\sqrt{1.3\times2.14}} = 1.8 \times 10^8$ m/s

17. $v = \frac{E}{B} \Rightarrow B = \frac{10^4}{10} = 10^3$ Wb/m^2

18. $E = Bc = 20 \times 10^{-9} \times 3 \times 10^8 = 6$ V/m.

19. $E_{rms} = \frac{E_0}{\sqrt{2}}$

But $E_0 = cB_0$

∴ $B_0 = \frac{\sqrt{2}E_{rms}}{c} = \frac{\sqrt{2}\times6}{3\times10^8} = 2.83 \times 10^{-8}$ T

20. $B = \frac{E}{c} = \frac{6}{3\times10^8} = 2 \times 10^{-8}$ T

25. Electromagnetic radiations have energy and exert pressure but different e.m. radiations have different momenta.

36. Energy is equally divided between electric and magnetic field.

38. Electromagnetic waves are produced by accelerated charged particles.

39. Your hand gets warm due to absorption of energy from e.m. waves only. Due to large value of 'c', amount of momentum transfer and radiation pressure transfer is extremely small.

40. The frequency of e.m. wave is its inherent characteristic.

41. $\lambda = \frac{c}{\nu} = \frac{3\times10^8}{3\times10^{14}} = 10^{-6}$ m $= 1\ \mu$m

42. $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = 3 \times 10^8$ m/s

Air acts as free space or vacuum

∴ a = 3

43. $E_0 = cB_0 = 3 \times 10^8 \times 10^{-4} = 3 \times 10^4$ V/m

44. $B_0 = \frac{E_0}{c} = \frac{30}{3\times10^8} = 10^{-7}$ T

45. $u_E = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\times8.85\times10^{-12} \times (100)^2$

∴ $u_E \approx 44 \times 10^{-9}$ J/m^3

46. The average energy density,

$u_E = \frac{1}{2}\varepsilon_0 E^2$

$= \frac{1}{2}\varepsilon_0\left(\frac{E_0}{\sqrt{2}}\right)^2$

$= \frac{1}{4}\varepsilon_0 E_0^2 = \frac{1}{4}\times8.85\times10^{-12}\times(1)^2$

∴ $u_E = 2.2 \times 10^{-12}$ J/m^3

47. Average energy density due to electric field

$u_E = \frac{1}{2}\varepsilon_0 E^2$ where, E is rms value

∴ $u_E = \frac{1}{2}\times 8.85 \times 10^{-12} \times (720)^2$

$= 2.29 \times 10^{-6}$ J/m^3

Total average density

$U = 2u_E = 2 \times 2.29 \times 10^{-6} = 4.58 \times 10^{-6}$ J/m^3

48. Polarisation is shown by only transverse waves.

50. In electromagnetic wave, the average value of electric field or magnetic field is zero.

53. $c = \frac{\omega}{k} = \frac{12\times10^{15}}{4\times10^7} = 3 \times 10^8$ m/s

54. $B_0 = \frac{E_0}{c} = \frac{9.3}{3\times10^8} = 3.1 \times 10^{-8}$ T

55. $\lambda = \frac{c}{\nu} = \frac{30\times10^8}{3\times10^{10}} = 10^{-2}$ m

$E_0 = cB_0 = 3 \times 10^8 \times 128 \times 10^{-9} = 38.4$ V m^{-1}

56. Given:

$B_y = 2\times10^{-7}\sin(0.5\times10^3\ z + 1.5\times10^{11}t)$ T

Here, electric field vector $\vec{E}$ is along X-axis.

$\therefore$ $E_0 = B_0c = 2 \times 10^{-7} \times 3 \times 10^8 = 60$ Vm^{-1}

$\therefore$ $E_x = 60 \sin(0.5 \times 10^3\ z + 1.5 \times 10^{11}\ t)$ Vm^{-1}

57. Here, $B_y = 8 \times 10^{-6} \sin[2 \times 10^{11}\ t + 300\ \pi x]$

The Y-component of the magnetic field is given by,

$B_y = B_0 \sin 2\pi\left(\frac{x}{\lambda} + \frac{t}{T}\right)$

Comparing the given equation with the above equation,

$\frac{2\pi}{\lambda} = 300\ \pi$

$\therefore$ $\lambda = \frac{2}{300} = 6.67 \times 10^{-3}$ m

59. All components of the electromagnetic spectrum travel in vacuum with velocity 3×10^8 m / s .

62. Wavelength of visible spectrum is 3900 Å – 7500 Å.

66. Radiowaves are reflected by ionosphere.

68. The wavelength of ultraviolet rays lies between 100 Å to 3800 Å.

69. The radiation pressure of visible light is of the order of 7×10^{-6} Nm^{-2}.

70. The penetrating power of X-rays depends upon its energy which in turn depends upon frequency and energy $\propto$ frequency.

73. $\lambda = \frac{hc}{E} = \frac{6.6\times10^{-34}\times3\times10^8}{15\times10^3\times1.6\times10^{-19}} = 0.825$ Å

$\therefore$ $\lambda \approx 1$Å

This wavelength value belongs to X-ray region of the spectrum.

74. Molecular spectra due to vibrational motion lie in the microwave region of EM-spectrum. Due to Kirchhoff's law in spectroscopy, the same will be absorbed.

81. Infrared rays produce heat, when they fall on matter and hence they can be detected by a pyrometer.

82. The frequency of television signal is smaller than that of microwave and visible waves.

85. Washing powders contain fluorescent dyes which absorb UV radiations and upon exposure emit light.

88. Different parts of the body absorb the X – rays in varying degrees. Soft tissues such as muscles allow more of the X – rays to pass through them, while bones being dense absorbs much of the radiation.

As a result bones appear white and soft tissues show up in shades of grey while air appears black on the X – ray photographic plate.

90. X-rays being of high energy radiations, penetrate the target and hence are not reflected back.

91. Infrared radiations are reflected by low lying clouds and keep the earth warm.

106. The order of frequency of given rays:

UV-ray < X-ray < γ-ray

$\therefore$ r < p < q

107. The order of wavelengths of given radiations is

$\lambda_{uv} < \lambda_v < \lambda_r$

The radiation with minimum wavelength has maximum frequency.

$\therefore$ The order of frequencies of given radiations is

$f_{uv} > f_v > f_r$

109. $\lambda_{Red} > \lambda_{Blue} > \lambda_{X\text{-ray}} > \lambda_{\gamma\text{-ray}}$

111. X-ray tube, magnetron valve, radioactive source, sodium lamp produce X-rays, microwaves, γ - rays and visible light respectively.

$\lambda_{\gamma\text{-rays}} < \lambda_{X\text{-rays}} < \lambda_{visible} < \lambda_{microwave}$

112. The wavelength of visible light is 3900 Å to 7500 Å. Mean wavelength, λ = 6000 Å.

$\therefore$ Frequency, $\nu = \frac{c}{\lambda}$

$\therefore$ $\nu = \frac{3\times10^8}{60000\times10^{-10}} = 5 \times 10^{14}$ Hz

117. The wavelength of microwaves is greater than that of UV rays. Gamma ray has shortest wavelength in the e.m. spectrum.

118. The displacement current I_D is given by,

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

Where, ϕ is the electric flux. For a parallel plate capacitor,

ϕ = EA

Where A is the area of the plate and E is the electric field between the plates. Now, E = V/d where d is the distance between the plates.

Hence,

$$I_D = \varepsilon_0 \frac{d}{dt}(AE) = \varepsilon_0 A \frac{dE}{dt} = \frac{\varepsilon_0 A}{d}\frac{dV}{dt}$$

Thus, I_D exists along as the potential difference V is changing with time t.

119. According to the Maxwell's EM theory, the propagation of EM waves contains electric and magnetic field vibrating in mutually perpendicular direction. Thus, the changing of electric field gives rise to a magnetic field.

120. Speed of light in vacuum $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ and in another medium $v = \frac{1}{\sqrt{\mu\varepsilon}}$

$\therefore \quad \frac{c}{v} = \sqrt{\frac{\mu\varepsilon}{\mu_0\varepsilon_0}} = \sqrt{\mu_r K} \Rightarrow v = \frac{c}{\sqrt{\mu_r K}}$

123. A dipole antenna radiates EM waves outwards. The amplitude of electric field vector is inversely proportional to distance from antenna (r) i.e., $E_o \propto \frac{1}{r}$

126. A wave gets reflected from denser medium without any change in its form but with phase change of 180° or π^c

Incident wave is moving along $+\hat{i}$ hence reflected wave will move along $-\hat{i}$ with additional phase difference of π^c.

$\therefore$ Equation of reflected wave

$$\vec{E}_r = E_0\left(-\hat{i}\right)\cos\left[k(-z) - \omega t + \pi\right]$$

$$= E_0\left(-\hat{i}\right)\cos\left[\pi - (kz + \omega t)\right]$$

$$= E_0\left(-\hat{i}\right)\left[-\cos(kz + \omega t)\right]$$

$\qquad\qquad \ldots[\because \cos(\pi - \theta) = -\cos\theta]$

$\therefore \quad \vec{E}_r = E_0\,\hat{i}\cos(kz + \omega t)$

127. Direction of propagation of an em wave is along, $\vec{E}\times\vec{B}$.

Given: Wave velocity $\left(v\hat{i}\right)$ i.e., $\vec{E}\times\vec{B}$ is along +x-axis, electric field is along +y-axis. This implies according to vector product rules, $\vec{B}$ is along +z-axis.

128. $I_D = I_C = c\frac{dV}{dt} = \frac{\varepsilon_0 A}{d}\frac{dV}{dt}$

$$= \frac{\varepsilon_0}{d}A\frac{dV}{dt}$$

Here $A = \pi \times (0.1)^2\ m^2$ and $d = 2 \times 10^{-3}$ m

$$\frac{dV}{dt} = \frac{2\times10^{-3}\times0.2}{8.85\times10^{-12}\times3.14\times10^{-2}} = 1.44 \times 10^9\ \frac{V}{s}$$

129. Ampere's law is logically inconsistent when applied to an electrical circuit containing a capacitor. For such circuits modified Ampere's circuital law is applied.

130. Charge oscillating sinusoidally is given by

$Q = q_0 \sin \omega t$

Displacement current,

$I_D = \frac{dq}{dt} = q_0\,\omega\cos\omega t$

$(I_D)_{max} = q_0\,\omega = q_0 \times 2\pi\nu$

$= 10^{-6} \times 2 \times 3.14 \times 10^6$

$= 6.28$ A

131. For R-C series circuit,

$Z = \sqrt{R^2 + X_C^2}$

$= \sqrt{(100)^2 + (100)^2}$

$= 100\sqrt{2}\ \Omega$

Peak value of displacement current,

$i_0 = \frac{V_0}{Z} = \frac{V_{rms}\sqrt{2}}{Z} = \frac{220\sqrt{2}}{100\sqrt{2}} = 2.2$ A

132. EM waves carry momentum and hence can exert pressure on surfaces. They also transfer energy to the surface so, $p \neq 0$ and $E \neq 0$.

134. Intensity of EM waves is,

$I = \frac{U}{At} = \frac{Power}{A}$

$\therefore \quad I \propto$ Power (P) $\qquad \ldots$(i)

Also, intensity I is given as,

$\therefore \quad I = \frac{1}{2}\varepsilon_0 E_0^2 c$

$\therefore \quad I \propto E_0^2 \qquad \ldots$(ii)

From equations (i) and (ii),

$E_0^2 \propto P \Rightarrow E_0 \propto \sqrt{P}$

$\therefore \quad \frac{E_2}{E_1} = \sqrt{\frac{P_2}{P_1}} = \sqrt{\frac{50}{100}} = \frac{1}{\sqrt{2}}$

$\therefore \quad E_2 = \frac{E}{\sqrt{2}}$

135. The pressure exerted

Pressure $(P) = \frac{I}{c} = \frac{0.5}{3\times10^8} = 0.166\times10^{-8}\ \frac{N}{m^2}$

136. The speed of electromagnetic waves in a medium is given by,

$v = \frac{1}{\sqrt{\mu\,\varepsilon}}, \qquad \ldots$(i)

Where μ and ε are absolute permeability and absolute permittivity of the medium.

Now, $\mu = \mu_0\mu_r$ and $\varepsilon = \varepsilon_0\,\varepsilon_r$

Therefore, the equation (i) becomes

$$v = \frac{1}{\sqrt{\mu_0\mu_r \times \varepsilon_0\varepsilon_r}} = \frac{1}{\sqrt{\mu_0\varepsilon_0}} \times \frac{1}{\sqrt{\mu_r\varepsilon_r}} = \frac{c}{\sqrt{\mu_r\varepsilon_r}}$$

$$\therefore \quad \varepsilon_r = \frac{c^2}{v^2\,\mu_r} = \frac{\left(3\times10^8\right)^2}{\left(2\times10^8\right)^2 \times 1} = 2.25$$

137. $E = Bv$ but $v = \dfrac{c}{\sqrt{\mu_r\,\varepsilon_r}}$

$$\therefore \quad E = \frac{Bc}{\sqrt{\mu_r\,\varepsilon_r}} = \frac{4.2\times10^{-8} \times 3\times10^8}{\sqrt{4\times9}} = 2.1 \text{ V/m}$$

138. $E_1 = E_{01}\,\hat{x}\,\cos\left[2\pi\nu\left(\dfrac{z}{c} - t\right)\right]$

$$E_2 = E_{02}\,\hat{x}\,\cos\,[k(2z - ct)]$$

$$= E_{02}\,\hat{x}\,\cos\left[\frac{2\pi}{\lambda}\times c\left(\frac{2z}{c} - t\right)\right] \quad \ldots\left(\because k = \frac{2\pi}{\lambda}\right)$$

$$= E_{02}\,\hat{x}\cos\,2\pi\nu\left(\frac{2z}{c} - t\right) \quad \ldots\left(\because \frac{c}{\lambda} = \nu\right)$$

From above equation, we can say,
The velocity of EM waves in new medium is,

$$v = \frac{c}{2}$$

$$\therefore \quad \frac{1}{\sqrt{\mu_0\,\varepsilon_2}} = \frac{1}{2}\times\frac{1}{\sqrt{\mu_0\,\varepsilon_1}}$$

$$\therefore \quad \sqrt{\frac{\varepsilon_1}{\varepsilon_2}} = \frac{1}{2}$$

$$\therefore \quad \frac{\varepsilon_1}{\varepsilon_2} = \frac{1}{4}$$

Relative permittivity, $\varepsilon_r = \dfrac{\varepsilon}{\varepsilon_0}$

$$\therefore \quad \frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = \frac{1}{4}$$

139. $\lambda = \dfrac{c}{\nu} = \dfrac{3\times10^8}{4\times10^{17}} = 7.5 \times 10^{-10}$ m

140. From given equation, it follows that
$E_0 = 72$ V m^{-1}
Also, $B_0 = \dfrac{E_0}{c} = \dfrac{72}{3\times10^8} = 2.4 \times 10^{-7}$ T

141. $B_0 = \dfrac{E_0}{c} = \dfrac{48}{3\times10^8} = 16 \times 10^{-8}$ Wb/m^2

142. Velocity of electromagnetic (c) $= \dfrac{E_0}{B_0}$
where, E_0 = amplitude of electric field
and B_0 = amplitude of magnetic field
$\therefore \quad E_0 = cB_0 = 3 \times 10^8 \times 3 \times 10^{-10}$
$\therefore \quad E_0 = 9 \times 10^{-2}$ V/m

143. Average energy density of e.m wave,

$$U_{av} = \frac{1}{2}\varepsilon_0 E_0^2$$

$$= \frac{1}{2}\times\left(8.85\times10^{-12}\right)\times\left(50\right)^2 = 1.1 \times 10^{-8}$$

$$\approx 10^{-8} \text{ J/m}^3$$

144. Since wave is totally reflected, momentum delivered to the surface is 2U/c.

$$F_{av} = \frac{2U/c}{t}$$

For unit time,

$$F_{av} = \frac{2(S\times A)}{c} = \frac{2\times25\times10^4\times15\times10^{-4}}{3\times10^8}$$

$$= 250 \times 10^{-8} = 2.5 \times 10^{-6} \text{ N}$$

145. In vacuum, velocities of all EM waves are same but their wavelengths are different.

146. The radio waves are polarised electromagnetic waves. The antenna of portable AM radio is sensitive to only magnetic components of electromagnetic waves. Hence the set should be put horizontal and in proper situation so that the signals are received properly from radio station.

147. Intensity $I = \dfrac{\text{Power}}{\text{Area}} = \dfrac{P}{4\pi r^2}$

Also, $I = U_{av}c$

$$\therefore \quad \frac{P}{4\pi r^2} = \frac{1}{2}\varepsilon_0\,E_0^2 \times c$$

$$\therefore \quad E_0 = \sqrt{\frac{2P}{4\pi\varepsilon_0 r^2 c}}$$

$$= \sqrt{\frac{2 \times 0.1 \times 9 \times 10^9}{1^2 \times 3\times10^8}} \quad \ldots\left(\because \frac{1}{4\pi\varepsilon_0} = 9\times10^9 \text{ S.I. units}\right)$$

$$= \sqrt{6} = 2.45 \text{ V/m}$$

149. Infrasonic waves are mechanical waves.

150. Sound waves are not electromagnetic waves and require a material medium for propagation.

151. $eV = \dfrac{hc}{\lambda} \Rightarrow \lambda = \dfrac{hc}{eV}$ i.e., $\lambda \propto \dfrac{1}{V}$

152. $E = h\nu$, $E = 11\text{eV} = 11 \times 1.6 \times 10^{-19}$ J

$$\therefore \quad \nu = \frac{E}{h} = \frac{11\times1.6\times10^{-19}}{6.62\times10^{-34}} = 2.65 \times 10^{15} \text{ Hz}$$

This frequency value belongs to UV region.

153. $E \propto \nu$
$\nu_\gamma > \nu_x > \nu_v$
$\therefore \quad E_\gamma > E_x > E_v$

154. $\nu = \frac{E}{h} = \frac{3.3\times10^{-16}}{6.6\times10^{-34}} = 5\times10^{17}$ Hz

155. Energy $\propto \nu$

$\nu_{Radio} < \nu_{yellow} < \nu_{blue} < \nu_{X\text{-rays}}$

$\therefore$ $E_{Radio} < E_{yellow} < E_{blue} < E_{X\text{-rays}}$

Hence, correct increasing order is D, B, A, C.

157. Total energy falling on surface U = ϕ At

Where, energy flux ϕ = 20 W/cm^2, area A = 30 cm^2, time t = 30 × 60 s

Momentum of incident light

$p_i = \frac{U}{c} = \frac{20\times30\times30\times60}{3\times10^8} = 36\times10^{-4}$ kg

The surface is a non reflective surface

$\therefore$ Momentum of reflected light $p_f = 0$

$\therefore$ Momentum delivered to surface

$= p_i - p_f$

$= 36\times10^{-4}$ kg m/s

Topic Test

1. What is the energy density at a distance of 8 m from a point source of em waves, if the electric field strength at that point is $170\ \frac{V}{m}$?

(A) $3.9\times10^{-9}\ \frac{J}{m^3}$ (B) $22\times10^{-7}\ \frac{J}{m^3}$

(C) $1.1\times10^{-9}\ \frac{J}{m^3}$ (D) $1.28\times10^{-7}\ \frac{J}{m^3}$

2. According to Maxwell's equation, the velocity of light in any medium is expressed as

(A) $\frac{1}{\sqrt{\mu_0\varepsilon_0}}$ (B) $\frac{1}{\sqrt{\mu\varepsilon}}$

(C) $\sqrt{\frac{\mu}{\varepsilon}}$ (D) $\sqrt{\frac{\mu_0}{\varepsilon}}$

3. The oscillating magnetic field in a plane electromagnetic wave is given by,

$B_y = 10^{-6}\sin[7\times10^{11}\ t + 400\ \pi x]$ (in T) then wavelength of the wave

(A) 6.67×10^{-3} m (B) 4.67×10^{-3} m

(C) 5.0×10^{-3} m (D) 5.67×10^{-3} m

4. If a source is transmitting electromagnetic wave of frequency 3.4×10^6 Hz, then wavelength of the electromagnetic wave transmitted from the source will be

(A) 36.6 m (B) 88.24 m

(C) 42.3 m (D) 150.9 m

5. **Assertion:** Finger prints on a piece of paper may be detected by sprinkling flourescent powder on the paper and then looking it into ultraviolet light.

Reason: The ultraviolet light can cause fluorescence.

(A) Assertion is True, Reason is True; Reason is a correct explanation for Assertion.

(B) Assertion is True, Reason is True; Reason is not a correct explanation for Assertion.

(C) Assertion is True, Reason is False.

(D) Assertion is False, Reason is False.

6. Which radiation in sunlight causes heating effect?

(A) Ultraviolet

(B) Infrared

(C) Visible light

(D) All of these

7. Which of the following electromagnetic waves have the longest wavelength?

(A) Heat waves

(B) Light waves

(C) Radiowaves

(D) Microwaves

8. Radiations of intensity $1.2\ \frac{W}{m^2}$ are striking a metal plate. The pressure on the plate is

(A) $0.4\times10^{-8}\ \frac{N}{m^2}$

(B) $0.332\times10^{-8}\ \frac{N}{m^2}$

(C) $0.268\times10^{-8}\ \frac{N}{m^2}$

(D) $0.8\times10^{-8}\ \frac{N}{m^2}$

9. RADAR is operated in the _______.

(A) infrared region

(B) X-ray region

(C) microwave region

(D) radio wave region

10. A parallel plate capacitor with plates of area A and separation between the plates d, is charged by a constant current I. Consider a plane surface of area 4A parallel to the plates and drawn symmetrically between the plates. The displacement current through this area will be

(A) 2I (B) $\frac{I}{2}$

(C) $\frac{I}{4}$ (D) 4I

11. For an e.m. wave propagating along X-axis, $E_{max} = 90 \frac{V}{m}$. The maximum value of magnetic field is,
(A) 3×10^{-7} T
(B) 3×10^{-8} T
(C) 2×10^{-9} T
(D) 3×10^{-6} T

12. A small metallic ball is charged positively and negatively in a sinusoidal manner at a frequency of 8×10^5 cps. The maximum charge on the ball is 2 μC what is the displacement current due to this alternating current?
(A) 6.28 A
(B) 10 A
(C) 3.75×10^{-4} A
(D) 122.56 A

13. In general, the wavelength of microwaves is
(A) more than that of radiowaves.
(B) less than that of ultraviolet waves.
(C) more than that of infrared waves
(D) less than that of infrared waves.

14. The magnetic field in a travelling electromagnetic wave has a peak value of 40 μT. The peak value of electric field strength is
(A) 3 mV/m (B) 6 kV/m
(C) 9 V/m (D) 12 kV/m

15. Electromagnetic waves travel in a medium which has relative permeability 1.42 and relative permittivity 2.31. Then the speed of the electromagnetic wave in the medium will be
(A) $165 \times 10^6 \frac{m}{s}$
(B) $1.8 \times 10^2 \frac{m}{s}$
(C) $2.6 \times 10^8 \frac{m}{s}$
(D) $2.9 \times 10^8 \frac{m}{s}$

16. The wavelength of light visible to eye is of the order of
(A) 10^{-2} m (B) 10^{-10} m
(C) 1 m (D) 6×10^{-7} m

Answers to Topic Test

1.	(D)	2.	(B)	3.	(C)	4.	(B)
5.	(A)	6.	(B)	7.	(C)	8.	(A)
9.	(C)	10.	(D)	11.	(A)	12.	(B)
13.	(C)	14.	(D)	15.	(A)	16.	(D)