PHYSICS

Class XII

Chapter 8 - Electromagnetic Waves

1 Mark Questions

1. The charging current for a capacitor is 0.25A. What is the displacement current across its plates?
Ans. Displacement current remains the same as charging current and is equal to 0.25A.

2. Write the following radiations in a descending order of frequencies: red light, x – rays, microwaves, radio waves
Ans. X – rays, Red light, Microwaves and Radio waves.

3. How does the frequency of a beam of ultraviolet light change, when it goes from air into glass?
Ans. There is no effect on the frequency of ultraviolet light.

4. What is the ratio of speed of gamma rays and radio waves in vacuum?
Ans. One.

5. It is necessary to use satellites for long distance TV transmission. Why?
Ans. Television signals are not reflected back by the layer of atmosphere called ionosphere thus TV signals from air earth station are reflected back to the earth
by means of an artificial satellite

6. What is the role of ozone layer in the atmosphere?
Ans. It absorbs all the harmful ultraviolet radiations thus protecting us from reaching the dangerous effects of uv radiations.

7. What is the nature of waves used in radar?
Ans. Microwaves are used in Radar.

8. What physical quantity is the same for X-rays of wavelength 10-10 m, red light of wavelength 6800 $\overset{\circ}{A}$ and radio waves of wavelength 500 m?
Ans. The speed of light (3×10^8 m/s) in a vacuum is the same for all wavelengths. It is independent of the wavelength in the vacuum.

2 Mark Questions

1. Write the application of Infra-red radiations?
Ans. (1) infra-red radiations are used to take photographs under foggy conditions.
(2) Infra-red radiations are used in revealing the secret writings on the ancient walls.

2. Which constituent radiation of the electromagnetic spectrum is used?
(1) To photograph internal parts of human body.
(2) For air aircraft navigation
Ans. (1) X -Rays
(2) Microwaves

3. Electric field in a plane electromagnetic wave is given by

$E_z = 60\ sin\left(\frac{10^3 x}{2} + (10^{11})\frac{3t}{2}\right) V/m.$

(a) Write an expression for the magnetic field

(b) What is the magnitude of wavelength and frequency of the wave?

Ans. **(a)** $C = \frac{E_O}{B_O}$

$B_O = \frac{E_O}{C} = \frac{60}{3\times10^8}$

$B_O = 2\times10^{-7} T$

Since magnetic field and electric field are $\perp$ to each other

$By = 2\times10^{-7} T\ sin\left(\frac{10^3}{2}x + (10^{11})\frac{3t}{2}\right)$ —-(1)

Compare e.g. (1) with standard equation

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

$\lambda = 4\pi\times10^{-3} m$

$Also\ 2\pi\frac{1}{T} = (10)^{11}\frac{3}{2}$

$\frac{1}{T} = \upsilon = \frac{3\times10^{11}}{2\times2\pi}$

$\upsilon = \frac{3}{4\pi}\times10^{11} Hz$

4. IF the earth did not have atmosphere would its average surface temperature be higher or lower than what it is now?

Ans. The infra-red radiations get trapped inside the earth's atmosphere due to green house effect which makes the earth warm. Therefore average temperature of the earth would have been low.

5. Sky waves are not used in transmitting TV signals, Why? Suggest two methods by which range of TV transmission can be increased?

Ans. Sky waves are not used in transmitting TV signals as they are not reflected by the ionosphere.

Methods of increasing range of TV transmission

(1) Tall antenna

(2) Geostationary satellites

6. "Greater the height of a TV transmitting antenna, greater is its coverage." Explain.

Ans. Since d = $\sqrt{2hR}$

If height is increased distance upto which TV coverage can be done will increases.

7. A plane electromagnetic wave travels in vacuum along z-direction. What can you say about the directions of its electric and magnetic field vectors? If the frequency of the wave is 30 MHz, what is its wavelength?

Ans. The electromagnetic wave travels in a vacuum along the z-direction. The electric field (*E*) and the magnetic field (*H*) are in the *x*–*y* plane. They are mutually perpendicular.

Frequency of the wave, ν = 30 MHz = $30 \times 10^6\ s^{-1}$

Speed of light in a vacuum, *c* = 3×10^8 m/s

Wavelength of a wave is given as:

$$\lambda = \frac{c}{\nu}$$

$$= \frac{3\times10^8}{30\times10^6} = 10\,m$$

8. A radio can tune in to any station in the 7.5 MHz to 12 MHz band. What is the corresponding wavelength band?

Ans. A radio can tune to minimum frequency, ν_1 = 7.5 MHz= $7.5 \times 10^6\ Hz$

Maximum frequency, ν_2 = 12 MHz = $12 \times 10^6\ Hz$

Speed of light, *c* = 3×10^8 m/s

Corresponding wavelength for ν_1 can be calculated as:

$$\lambda_1 = \frac{c}{\nu_1}$$

$$= \frac{3\times10^8}{7.5\times10^6} = 40\,m$$

Corresponding wavelength for v_2 can be calculated as:

$$\lambda_2 = \frac{c}{\nu_2}$$

$$= \frac{3\times10^8}{12\times10^6} = 25\,m$$

Thus, the wavelength band of the radio is 40 m to 25 m.

9. A charged particle oscillates about its mean equilibrium position with a frequency of 10^9 Hz. What is the frequency of the electromagnetic waves produced by the oscillator?

Ans. The frequency of an electromagnetic wave produced by the oscillator is the same as that of a charged particle oscillating about its mean position i.e., 10^9 Hz.

10. The amplitude of the magnetic field part of a harmonic electromagnetic wave in vacuum is B_0 = 510 nT. What is the amplitude of the electric field part of the wave?
Ans. Amplitude of magnetic field of an electromagnetic wave in a vacuum,
*B*0 = 510 nT = $510 \times 10^{-9}\ T$
Speed of light in a vacuum, *c* = $3 \times 10^{8}\ m/s$
Amplitude of electric field of the electromagnetic wave is given by the relation,
$E = c B_0$
= $3 \times 108 \times 510 \times 10^{-9}$ = 153 N/C
Therefore, the electric field part of the wave is 153 N/C.

4 Mark Questions

1. Given below are some famous numbers associated with electromagnetic radiations in different contexts in physics. State the part of the electromagnetic spectrum to which each belongs.
(a) 21 cm (wavelength emitted by atomic hydrogen in interstellar space).
(b) 1057 MHz (frequency of radiation arising from two close energy levels in hydrogen; known as Lamb shift).
(c)2.7K

(d) 5890 $\overset{0}{\mathrm{A}}$ – 5896

(e) 14.4 keV [energy of a particular transition in 57Fe nucleus associated with a famous high resolution spectroscopic method
(Mossbauer spectroscopy)].
Ans. (a) Radio waves; it belongs to the short wavelength end of the electromagnetic spectrum.
(b) Radio waves; it belongs to the short wavelength end.
(c) Temperature, $T = 2.7\ °K$
λ_m is given by Planck's law as:
$$\lambda_m = \frac{0.29}{2.7} = 0.11 cm$$
This wavelength corresponds to microwaves.
(d) This is the yellow light of the visible spectrum.
(e) Transition energy is given by the relation,
E = $h\nu$
Where,
h = Planck's constant = $6.6 \times 10^{-34}\ Js$
ν = Frequency of radiation
Energy, *E* = 14.4 K eV
$$\therefore \nu = \frac{E}{h}$$
$$= \frac{14.4 \times 10^{3} \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34}}$$

$= 3.4 \times 10^{18} Hz$
This corresponds to X-rays.

2. Answer the following questions:
(a) Long distance radio broadcasts use short-wave bands. Why?
(b) It is necessary to use satellites for long distance TV transmission. Why?
(c) Optical and radio telescopes are built on the ground but X-ray astronomy is possible only from satellites orbiting the earth. Why?
(d) The small ozone layer on top of the stratosphere is crucial for human survival. Why?
(e) If the earth did not have an atmosphere, would its average surface temperature be higher or lower than what it is now?
(f) Some scientists have predicted that a global nuclear war on the earth would be followed by a severe 'nuclear winter' with a devastating effect on life on earth. What might be the basis of this prediction?
Ans. (a) Long distance radio broadcasts use shortwave bands because only these bands can be refracted by the ionosphere.
(b) It is necessary to use satellites for long distance TV transmissions because television signals are of high frequencies and high energies. Thus, these signals are not reflected by the ionosphere. Hence, satellites are helpful in reflecting TV signals. Also, they help in long distance TV transmissions.
(c) With reference to X-ray astronomy, X-rays are absorbed by the atmosphere. However, visible and radio waves can penetrate it. Hence, optical and radio telescopes are built on the ground, while X-ray astronomy is possible only with the help of satellites orbiting the Earth.
(d) The small ozone layer on the top of the atmosphere is crucial for human survival because it absorbs harmful ultraviolet radiations present in sunlight and prevents it from reaching the Earth's surface.
(e) In the absence of an atmosphere, there would be no greenhouse effect on the surface of the Earth. As a result, the temperature of the Earth would decrease rapidly, making it chilly and difficult for human survival.
(f) A global nuclear war on the surface of the Earth would have disastrous consequences. Post-nuclear war, the Earth will experience severe winter as the war will produce clouds of smoke that would cover maximum parts of the sky, thereby preventing solar light form reaching the atmosphere. Also, it will lead to the depletion of the ozone layer.

7 Marks Questions

1. Suppose that the electric field part of an electromagnetic wave in vacuum is E = {(3.1 N/C) cos [(1.8 rad/m) *y* + (5.4×10^6 rad/s)*t*]}$\hat{i}$.
(a) What is the direction of propagation?
(b) What is the wavelength λ ?
(c) What is the frequency ν ?
(d) What is the amplitude of the magnetic field part of the wave?
(e) Write an expression for the magnetic field part of the wave.
Ans. (a) From the given electric field vector, it can be inferred that the electric field is directed along the negative *x* direction. Hence, the direction of motion is along the negative *y* direction i.e., $-\hat{j}$.
(b) It is given that,
$\vec{E} = 3.1 N/C \cos\left[\left(1.8 rad/m\right)y + \left(5.4\times10^8 rad/s\right)t\right]\hat{i}$ …(i)

The general equation for the electric field vector in the positive *x* direction can be written as:

$\vec{E} = E_0 \sin\left(kx - (i)t\right) - \hat{j}$ …(2)

On comparing equations (1) and (2), we get

Electric field amplitude, E_0 = 3.1 N/C

Angular frequency, $\omega = 5.4 \times 10^8\ rad/s$

Wave number, k = 1.8 rad/m

Wavelength, $\lambda = \frac{2\pi}{1.8}$ = 3.490 m

(c) Frequency of wave is given as:

$$\lambda = \frac{2\pi}{1.8}$$

$$= \frac{5.4 \times 10^8}{2\pi} = 8.6 \times 10^7\ Hz$$

(d) Magnetic field strength is given as:

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

Where,

c = Speed of light = $3 \times 10^8\ m/s$

$$\therefore B_0 = \frac{3.1}{3 \times 10^8} = 1.03 \times 10^{-7}\ T$$

(e) On observing the given vector field, it can be observed that the magnetic field vector is directed along the negative z direction. Hence, the general equation for the magnetic field vector is written as:

$$\vec{B} = B_0 \cos\left(ky + (i)t\right)\hat{k}$$

$$= \left\{\left(1.03 \times 10^{-7} T\right)\cos\left[\left(1.8 rad/m\right)y + \left(5.4Kt10^6 rad/s\right)t\right]\right\}\hat{k}$$

2. In a plane electromagnetic wave, the electric field oscillates sinusoid ally at a frequency of 2.0×10^{10} Hz and amplitude 48 V m^{-1} .

(a) What is the wavelength of the wave?

(b) What is the amplitude of the oscillating magnetic field?

(c) Show that the average energy density of the E field equals the average energy density of the B field. [$c = 3 \times 10^8$ m s^{-1}.]

Ans. Frequency of the electromagnetic wave, $\nu = 2.0 \times 10^{10}\ Hz$

Electric field amplitude, $E_0 = 48\ V\ m^{-1}$

Speed of light, $c = 3 \times 10^8\ m/s$

(a) Wavelength of a wave is given as:

$$\lambda = \frac{c}{\nu}$$

$$= \frac{3\times10^8}{2\times10^{10}} = 0.015m$$

(b) Magnetic field strength is given as:

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

$$= \frac{48}{3\times10^8} = 1.6\times10^{-7}T$$

(c) Energy density of the electric field is given as:

$$U_E = \frac{1}{2}\in_0 E^2$$

And, energy density of the magnetic field is given as:

$$U_B = \frac{1}{2\mu_0}B^2$$

Where,

$\in_0$ = Permittivity of free space

μ_0 = Permeability of free space

We have the relation connecting *E* and *B* as:

E = *cB* … (1)

Where,

$$c = \frac{1}{\sqrt{\in_0 \mu_0}} \quad \dots (2)$$

Putting equation (2) in equation (1), we get

$$E = \frac{1}{\sqrt{\in_0 \mu_0}}B$$

Squaring both sides, we get

$$E^2 = \frac{1}{\sqrt{\in_0 \mu_0}}B^2$$

$$\in_0 E^2 = \frac{B^2}{\mu_0}$$

$$\frac{1}{2}\in_0 E^2 = \frac{1}{2}\frac{B^2}{\mu_0}$$

$$\Rightarrow U_E = U_B$$

3. Suppose that the electric field amplitude of an electromagnetic wave is E_0 = 120 N/C and that its frequency is ν = 50.0 MHz. (a) Determine, B_0 , $\omega, k,$ and $\lambda.$ (b) Find expressions for E and B.

Ans. Electric field amplitude, E_0 = 120 N/C

Frequency of source, ν = 50.0 MHz = 50×10^6 Hz

Speed of light, c = 3×10^8 m/s

(a) Magnitude of magnetic field strength is given as:

$$B_0 \frac{E_0}{c}$$

$$= \frac{120}{3 \times 10^8}$$

$$= 4 \times 10^{-7} T = 400\,nT$$

Angular frequency of source is given as:

$$\omega = 2\pi\nu = 2\pi \times 50 \times 10^6$$

$$= 3.14 \times 108\ rad/s$$

Propagation constant is given as:

$$k = \frac{(i)}{c}$$

$$= \frac{3.14 \times 10^8}{3 \times 10^8} = 1.05\,rad/m$$

Wavelength of wave is given as:

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

$$= \frac{3 \times 10^8}{50 \times 10^6} = 6.0\,m$$

(b) Suppose the wave is propagating in the positive *x* direction. Then, the electric field vector will be in the positive *y* direction and the magnetic field vector will be in the positive *z* direction. This is because all three vectors are mutually perpendicular.

Equation of electric field vector is given as:

$$\overline{E} = E_0 \sin\left(kx - (i)t\right) j$$

$$= 120 \sin\left[1.05x - 3.14 \times 10^8 t\right] j$$

And, magnetic field vector is given as:

$$\vec{B} = B_0 \sin\left(kx - (t)t\right) \hat{k}$$

$$\vec{B} = \left(4 \times 10^{-7}\right) \sin\left[1.05x - 3.14 \times 10^8 t\right] \hat{k}$$

4. A parallel plate capacitor (Fig. 8.7) made of circular plates each of radius *R* = 6.0 cm has a capacitance *C* = 100 pF. The capacitor is connected to a 230 V ac supply with a (angular) frequency of 300 rad s^{-1}.

(a) What is the rms value of the conduction current?
(b) Is the conduction current equal to the displacement current?
(c) Determine the amplitude of B at a point 3.0 cm from the axis between the plates.

Ans. Radius of each circular plate,
R = 6.0 cm = 0.06 m
Capacitance of a parallel plate capacitor,
C = 100 pF = $100 \times 10^{-12}\ F$
Supply voltage, *V* = 230 V
Angular frequency, ω = 300 rad s^{-1}

(a) Rms value of conduction current, $I = \frac{V}{X_c}$
Where,
XC = Capacitive reactance

$= \frac{1}{\omega C}$

$\therefore I = V \times \omega C$

$= 230 \times 300 \times 100 \times 10^{-12}$

$= 6.9 \times 10^{-6}\ A$

= 6.9 μA

Hence, the rms value of conduction current is 6.9 μA.
(b) Yes, conduction current is equal to displacement current.
(c) Magnetic field is given as:

$B = \frac{\mu_o r}{2\pi R^2} I_o$

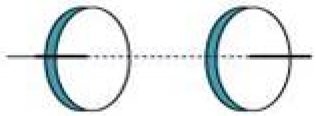
Where,
μ_0 = Free space permeability $= 4\pi \times 10^{-7}\ N A^{-2}$

*I*0 = Maximum value of current = $\sqrt{2}\, I$
r = Distance between the plates from the axis = 3.0 cm = 0.03 m

$$\therefore B = \frac{4\pi \times 10^{-7} \times 0.03 \times \sqrt{2} \times 6.9 \times 10^{-6}}{2\pi > 0(06)^2}$$

$= 1.63 \times 10^{-11}\ T$ Hence, the magnetic field at that point is $1.63 \times 10^{-11}\ T$.

5. Figure 8.6 shows a capacitor made of two circular plates each of radius 12 cm, and separated by 5.0 cm. The capacitor is being charged by an external source (not shown in the figure). The charging current is constant and equal to 0.15 A.



(a) Calculate the capacitance and the rate of charge of potential difference between the plates.
(b) Obtain the displacement current across the plates.
(c) Is Kirchhoff's first rule (junction rule) valid at each plate of the capacitor? Explain.

Ans. Radius of each circular plate,
r = 12 cm = 0.12 m
Distance between the plates,
d = 5 cm = 0.05 m
Charging current,
I = 0.15 A
Permittivity of free space,
$\varepsilon_0 = 8.85 \times 10^{-12}\ C2\ N^{-1}\ m^{-2}$

(a) Capacitance between the two plates is given by the relation,

$$C = \frac{\varepsilon_0 A}{d}\ \lambda = \frac{c}{v} = \frac{3\times10^8}{30\times10^6} = 10m$$

Where,
A = Area of each plate $= \pi r^2$

$$C = \frac{\varepsilon_0 \pi r^2}{d}$$

$$= \frac{8.85\times10\pi^{-12}\times0.k2(\quad)^2}{0.05}$$

$$-8.0032\times10^{-12}F = 80.032pF$$

Charge on each plate, $q = CV$
Where,
V = Potential difference across the plates
Differentiation on both sides with respect to time (t) gives:

$$\frac{dq}{dt} = C\frac{dV}{dt}$$

$$But, \frac{dq}{dt} = current\ (I)$$

$$\therefore \frac{dV}{dt} = \frac{1}{C}$$

$$\Rightarrow \frac{0.15}{80.032\times10^{-12}} = 1.87\times10^9 V/s$$

Therefore, the change in potential difference between the plates is 1.87×10^9 V/s.
(b) The displacement current across the plates is the same as the conduction current. Hence, the displacement current, *id* is 0.15 A.
(c) Yes

Kirchhoff's first rule is valid at each plate of the capacitor provided that we take the sum of conduction and displacement for current.

Fill in the Blanks

1. What is the phase difference between electric and magnetic fields in an electromagnetic wave is------------ **(π)**

2.----------------- have a maximum frequency? **(gamma rays)**

3. According to Maxwell's Hypothesis, a changing electric field gives rise to**-------(Magnetic Field)**

4. Which of the following proves that electromagnetic waves are transverse------------

(Polarisation)

5. Which of the following is used to investigate the structure of solids**--------- (X-Rays)**

Multiple choice questions

1. Which of the following radiations are used to treat muscle ache?

a. Microwaves
b. Infrared Rays
c. Ultraviolet Rays
d. X-Rays

Answer: (b) Infrared Rays

Explanation: Infrared rays are used to treat muscle aches.

2. When is the conduction current the same as the displacement current?

a. When the source is ac
b. When the source is dc
c. When the source is either an ac or a dc
d. When the source is neither dc nor ac

Answer: (a) When the source is ac

Explanation: The conduction current is the same as the displacement current when the source is ac.

3. An electromagnetic wave can be produced when the charge is

a. moving in a circular orbit
b. moving with a constant velocity
c. falling in an electric field
d. Both (a) and (c)

Answer: (d) Both (a) and (c)

Explanation: An accelerated charge is the source of electromagnetic waves (EMWs). When the charge is in a circular motion, the direction of its velocity continuously changes and thus it is in accelerated motion and produces EMWs. A charge falling in an electric field is accelerated by the electric force and thus produces EMWs.

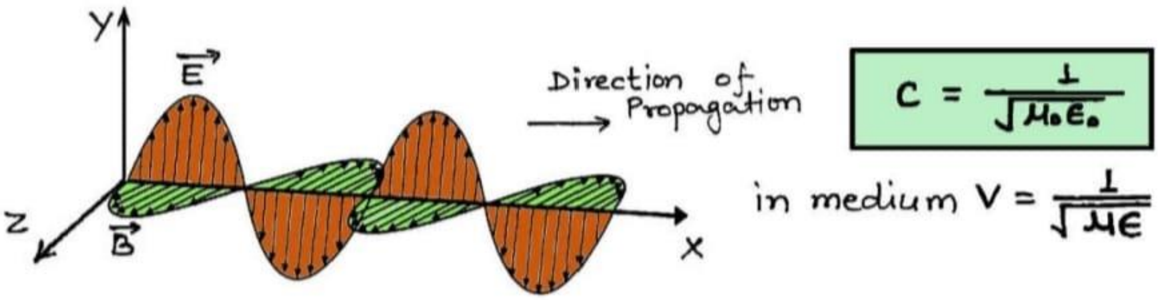
4. Which waves are used by artificial satellites for communication?

a. Infrared rays
b. Microwaves
c. Radiowaves
d. X-Rays

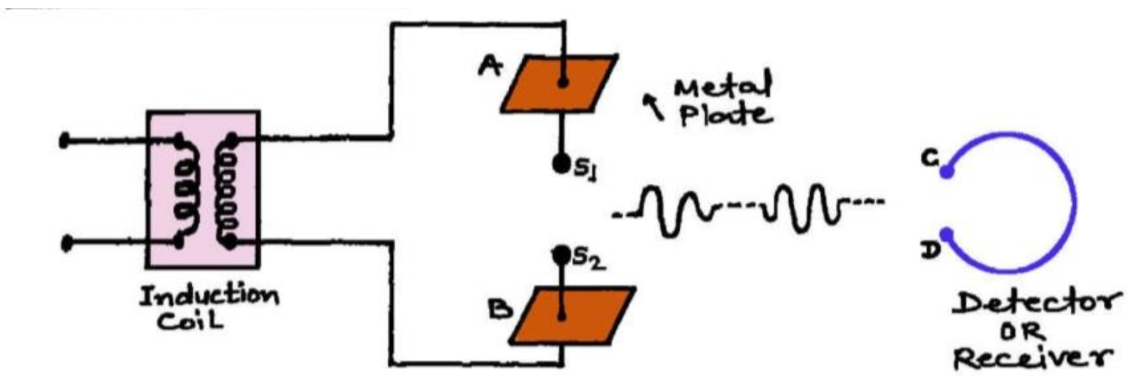
Answer: (b) Microwaves

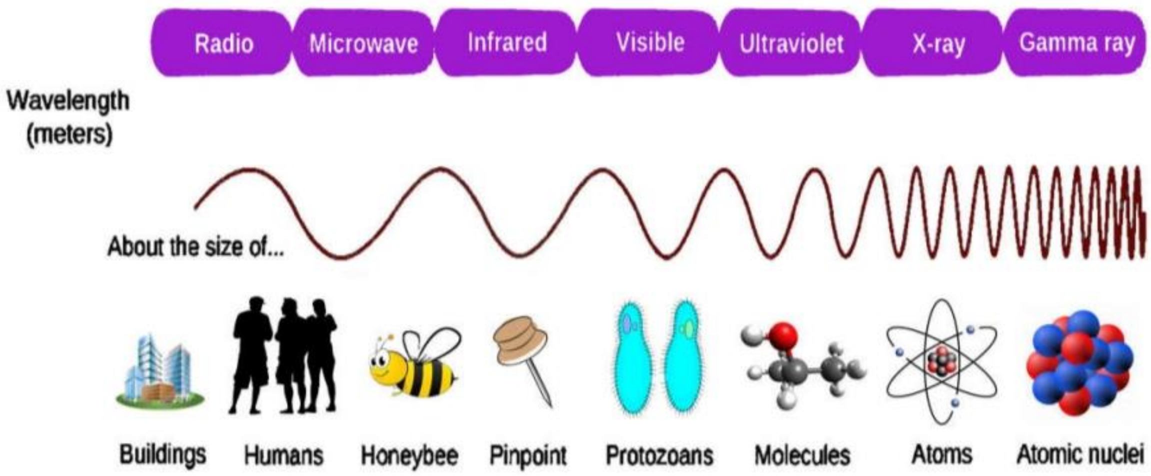
Explanation: Microwaves are used by artificial satellites for communication.

Diagrams



Herte Experiment





SUMMARY

- **Displacement Current:**
  It is due to time-varying electric field is,
  $$i_d = \varepsilon_0 \frac{d\phi_E}{dt}$$
  Displacement current acts as a source of magnetic field in exactly the same way as conduction current.
- **Electromagnetic Waves:**
  a) Electromagnetic waves are produced only by charges that are accelerating, since acceleration is absolute, and not a relative phenomenon.
  b) An electric charge oscillating harmonically with frequency υ , produces electromagnetic waves of the same frequency υ .
  c) An electric dipole is a basic source of electromagnetic waves.
  d) Electromagnetic waves with wavelength of the order of a few metres were first produced and detected in the laboratory by Hertz in 1887. He thus verified a basic prediction of Maxwell's equations.
- **Oscillation of Electric and Magnetic Fields:**
  These oscillate sinusoidally in space and time in an electromagnetic wave. The oscillating electric and magnetic fields, E and B are perpendicular to each other and to the direction of propagation of the electromagnetic wave.
- For a wave of frequency υ , wavelength λ , propagating along *z*-direction,
  $$E = E_X(t) = E_0 \sin(kz - \omega t)$$
  $$= E_0 \sin\left[2\pi\left(\frac{z}{\lambda} - vt\right)\right] = E_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \frac{t}{T}\right)\right]$$
  $$B = B_Y(t) = B_0 \sin(kz - \omega t)$$
  $$= B_0 \sin\left[2\pi\left(\frac{z}{\lambda} - vt\right)\right] = B_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \frac{t}{T}\right)\right]$$
  They are related by $\frac{E_o}{B_o} = c$
- **Relation between μ_0 and ε_0 :**
  The speed *c* of electromagnetic wave in vacuum is related to μ_0 and ε_0 (the free space permeability and permittivity constants) as
  $$C = 1/\sqrt{\mu_0\varepsilon_0}$$
- The value of *c* equals the speed of light obtained from optical measurements. Light is an electromagnetic wave; c is, therefore, also the speed of light. Electromagnetic waves other than light also have the same velocity c in free space.

- **Speed of Light:**
  The speed of light, or of electromagnetic waves in a material medium is
  $$v = 1/\sqrt{\mu\varepsilon}$$
  Where μ is the permeability of the medium and ε its permittivity
- Electromagnetic waves carry energy as they travel through space and this energy is shared equally by the electric and magnetic fields.
- **Energy Per Unit Volume:**
  If in a region of space in which there exist electric and magnetic fields $\vec{E}$ and $\vec{B}$, there exists Energy Density (Energy per unit volume) associated with these fields is,
  $$U = \frac{\varepsilon_0}{2}\vec{E}^2 + \frac{1}{2\mu_0}\vec{B}^2$$
  where we are assuming that the concerned space consists of vacuum only.
- Electromagnetic waves transport momentum as well. When these waves strike a surface, a pressure is exerted on the surface.
- If total energy transferred to a surface in time t is U, total momentum delivered to this surface is $p = U/c$.
- **Electromagnetic Spectrum:**
  The spectrum of electromagnetic waves stretches, in principle, over an infinite range of wavelengths.
  The classification of electromagnetic waves according to frequency is the electromagnetic spectrum.
  There is no sharp division between one kind of wave and the next.
- The classification has more to do with the way these waves are produced and detected.
- **Different Regions of Spectrum:**
  Different regions are known by different names; γ -rays, X-rays, ultraviolet rays, visible rays, infrared rays, microwaves and radio waves in order of increasing wavelength from 10^{-2} Å or 10^{-12} m to 10^{6} m.
  (a) Radio Waves:
  - ✓ These are produced by accelerated motion of charges in wires.
  - ✓ These are used in radio and television communication systems.
  - ✓ These are generally in the frequency range from 500 kHz to about 1000 MHz.

  (b)Microwaves:
  - ✓ These are short wavelength radio waves with frequencies in the gigahertz range.
  - ✓ Due to their short wavelengths, they are suitable for radar systems used in aircraft navigation.
  - ✓ Microwave ovens use them for cooking.

  (c) Infrared Waves:
  - ✓ These are produced by hot bodies and molecules.
  - ✓ They lie in the low frequency or long wavelength end of the visible spectrum.

(d)Visible Light

- ✓ The spectrum runs from about 4×10^{14} Hz to about 7×10^{14} Hz.
- ✓ Our eyes are sensitive to this range of wavelengths.

(e)Ultraviolet light:

- ✓ It covers wavelengths ranging from 400 nm to 0.6 nm.
- ✓ The sun is an important source of UV rays.

(f) X-rays:

- ✓ These cover the range 10 nm to about 10^{-4} nm.

(g)Gamma Rays:

- ✓ These lie in the upper frequency range of the spectrum, and have wavelengths in the range 10^{-10} m to 10^{-14} m.