



## PHYSICS

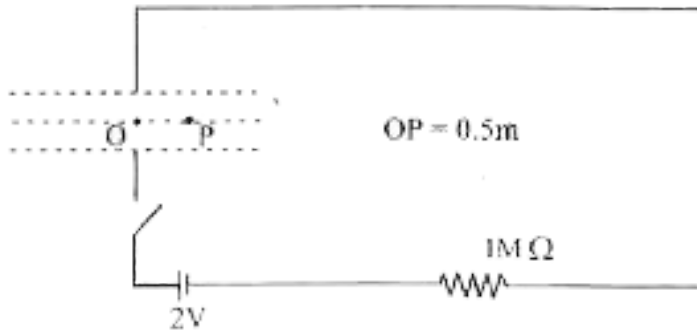
### BOOKS - NEW JYOTHI PHYSICS (TAMIL ENGLISH)

### ELECTROMAGNETIC WAVES

#### Solved Problems

1. A parallel plate capacitor with circular plates of radius 1m has a capacitance of 1nF. At  $t = 0$ , it is connected for charging in series with a resistor  $R = 1M\Omega$  across a 2V battery (Figure). Calculate the magnetic field at a point P,

halfway between the centre and the periphery of the plates, after  $t = 10^{-3} s$ . (The charge on the capacitor at time  $t$  is  $q(t) = CV \left[ 1 - \exp\left(\frac{-t}{\tau}\right) \right]$ , where the time constant  $\tau$  is equal to  $CR$ ).



[▶ Watch Video Solution](#)

2. A plane electromagnetic wave of frequency 25 MHz travels in free space along the  $x$  - direction. At a particular

point in space and time,  $E = 6.3\hat{j}$  V/m. What is B at this point ?



[Watch Video Solution](#)

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

$$B_y = 2 \times 10^{-7} \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t) T.$$

- What is the wavelength and frequency of the wave ?
- Write an expression for the electric field.



[Watch Video Solution](#)

4. Light with an energy flux of  $18W/cm^2$  falls on a non-reflecting surface at normal incidence. If the surface has

an area of  $20\text{cm}^2$ , find the average force exerted on the surface during a 30 minute time span.



[Watch Video Solution](#)

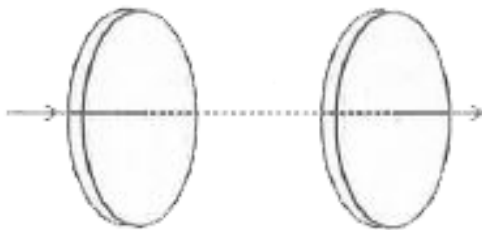
5. Calculate the electric and magnetic fields produced by the radiation coming from a 100 W bulb at a distance of 3m. Assume that the efficiency of the bulb is 2.5% and it is a point source.



[Watch Video Solution](#)

**Solutions To Exercises From Ncert Text**

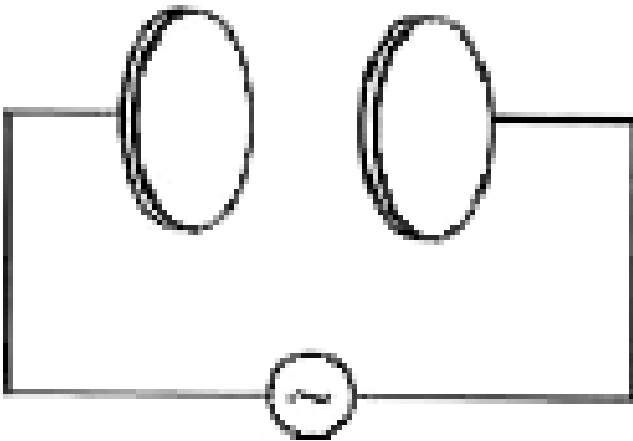
1. Figure shows a capacitor made of two circular plates each of radius 12 cm and separated by 5.0 cm. The capacitor is being charged by an external source (not shown in the figure). The charging current is constant and equal to 0.15 A.



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

 [Watch Video Solution](#)

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



- What is the rms value of the conduction current ?
- Is the conduction current equal to the displacement current ?
- Determine the amplitude of  $B$  at a point  $3.0 \text{ cm}$  from the axis between the plates.



[Watch Video Solution](#)

3. What is the physical quantity same for X - rays of wavelength  $10^{-10}$  m, red light of wavelength  $6800\text{\AA}$  and radiowaves of wavelength 500 m ?



[Watch Video Solution](#)

4. 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 ?



[Watch Video Solution](#)

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



[Watch Video Solution](#)

6. 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 ?



[Watch Video Solution](#)

7. 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 ?





Watch Video Solution

8. Suppose that the electric field amplitude of an electromagnetic wave is  $E_0 = 120 \text{ N/C}$  and that its frequency is  $\nu = 50.0 \text{ MHz}$ .

a. Determine,  $B_0$ ,  $\omega$ ,  $k$ , and  $\lambda$ .

b. Find the expressions for E and B.



Watch Video Solution

9. The terminology of different parts of the electromagnetic spectrum is given in the text. Use the formula  $E = h\nu$  (for energy of a quantum of radiation : photon) and obtain the photon energy in units of eV for

different parts of the electromagnetic spectrum. In what way are the different scales of photon energies that you obtain related to the sources of electromagnetic radiation ?



**Watch Video Solution**

**10.** In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of  $2.0 \times 10^{10}$  Hz and amplitude  $48 \text{ V m}^{-1}$ .

- 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.

$$[c = 3 \times 10^8 \text{ m s}^{-1}].$$

 [Watch Video Solution](#)

11. Suppose that the electric field part of an electromagnetic wave in vacuum is

$$E = \{ (3.1 \text{ N/C}) \cos [ (1.8 \text{ rad/m})y + (5.4 \times 10^6 \text{ rad/s})t ] \} \hat{i}$$

- What is the direction of propagation ?
- What is the wavelength  $\lambda$  ?
- What is the frequency  $\nu$  ?
- What is the amplitude of the magnetic field part of the wave ?
- Write an expression for the magnetic field part of the wave.

 [Watch Video Solution](#)

**12.** About 5% of the power of a 100 W light bulb is converted to visible radiation. What is the average intensity of visible radiation

a. at a distance of 1m from the bulb

b. at a distance of 10m

Assume that the radiation is emitted isotropically and neglect reflection.



**Watch Video Solution**

**13.** Use the formula  $\lambda_m T = 0.29 \text{ cm K}$  to obtain the characteristic temperature ranges for different parts of the electromagnetic spectrum. What do the numbers that you obtain tell you ?



**14.** 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. 2.7 K [temperature associated with the isotropic radiation filling all space - thought to be a relic of the 'big-bang' origin of the universe].
- d.  $5890\text{\AA} - 5896\text{\AA}$  [double lines of sodium]
- e. 14.4 keV [energy of particular transition in  $^{57}\text{Fe}$  nucleus]

associated with a famous high resolution spectroscopic method (Moss bauer spectroscopy)].

 [Watch Video Solution](#)

## Solutions To Exercises From Ncert Text Answer The Following Questions

1. Long distance radio broadcasts use short - wave bands.

Why ?

 [Watch Video Solution](#)

2. It is necessary to use satellites for long distance TV transmission. Why ?



[Watch Video Solution](#)

3. Optical and radiotelescopes are built on the ground, but X - ray astronomy is possible only from satellites orbiting the earth. Why ?



[Watch Video Solution](#)

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



[Watch Video Solution](#)

5. If the earth did not have an atmosphere, would its average surface temperature be higher or lower than what it is now ?

 [Watch Video Solution](#)

6. 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 ?

 [Watch Video Solution](#)



1. A parallel plate capacitor has circular plates, each of radius 5.0 cm. It is being charge so that electric field in the gap between its plates rises steadily at the rate of  $10^{12} \text{Vm}^{-1}\text{s}^{-1}$ . What is the displacement current ?

 [Watch Video Solution](#)

2. In a plane electromagnetic wave of frequency  $1.0 \times 10^{12}$  Hz, the amplitude of the magnetic field is  $5.0 \times 10^{-6} \text{T}$ .

- Calculate the amplitude of the electric field.
- What is the total average energy density ?

 [Watch Video Solution](#)

3. The voltage between the plates of a parallel plate capacitor of capacitance  $1.0\mu F$  is changing at the rate of  $5V s^{-1}$ . What is the displacement current in the capacitance ?

 [Watch Video Solution](#)

4. Electromagnetic waves travel in a medium at a speed of  $2.0 \times 10^8 m s^{-1}$ . The relative permeability of the medium is 1.0. Find the relative permittivity.

 [Watch Video Solution](#)

5. What should be the height of a transmitting antenna if the TV telecast is to cover a radius of 128 km ?

 [Watch Video Solution](#)

6. Light with an energy flux of  $18W/cm^2$  falls on a non-reflecting surface at normal incidence. If the surface has an area of  $20cm^2$ , find the average force exerted on the surface during a 30 minute time span.

 [Watch Video Solution](#)

7. Calculate the electric and magnetic fields produced by the radiation coming from a 100 W bulb at a distance of

3m. Assume that the efficiency of the bulb is 2.5% and it is a point source.

 [Watch Video Solution](#)

## Evaluation Questions And Answers

1. What is an electromagnetic wave ?

 [Watch Video Solution](#)

2. What are the contributions of Faraday and Maxwell in Electromagnetism?

 [Watch Video Solution](#)

### 3. Match the following

<i>A</i>	<i>B</i>	<i>C</i>
i. $\gamma$ ray	Sun burn	Photon emission by fast moving electrons
ii. X-ray	Remote sensing	Electronic de-excitation
iii. UV ray	Diagnosis	Oscillating current
iv. Microwave	Radioactivity	Nucleus



**Watch Video Solution**

4. a. If the fundamental source wave is a vibrating object, what is the fundamental source of an electromagnetic wave ?

b. Give the expression for velocity of E.M waves in vacuum.

c. On what factors does its velocity in vacuum depend ?



**Watch Video Solution**

5. Maxwell noticed that Ampere's circuital law is inconsistent where the electric current changes with time. He showed that consistency required an additional source of magnetic field.

a. What is the current called and which is responsible for the magnetic field ?

b. Given the expression for this type of current.

c. How it differs from conduction current ?



[Watch Video Solution](#)

6. a. What is an electromagnetic spectrum ?

b. How the electromagnetic waves are arranged ?

c. Mention some of the properties of E.M waves.



[Watch Video Solution](#)

7. The electric field vector of an electromagnetic wave is

$$E = E_0 \sin \left[ 2\pi \left( \frac{x}{\lambda} - \frac{t}{T} \right) \right] \hat{j}$$

a. Write the magnetic field vector of this wave.

b. What is the direction of propagation ?

c. With what velocity the wave propagates ?



**Watch Video Solution**

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

b. Where is the position of UV radiation in the electromagnetic spectrum ?

c. Can you convert UV to visible radiation ? Explain.

d. Which radiation is adjacent to UV to the higher frequency side of the electromagnetic spectrum ?

 [Watch Video Solution](#)

9. Both radiowaves and gamma rays are transverse in nature and moving with same speed in free space. Then in what aspect are they different ?

 [Watch Video Solution](#)

10. Proj.j. Prakash asked Vijit whether the average energy density of the electric field and magnetic field are equal or not ? Viji said "yes". Justify the answer.

 [Watch Video Solution](#)



Watch Video Solution

11. What is greenhouse effect ? Explain.



Watch Video Solution

12. Radio waves diffract around the building, while light waves eventhough electromagnetic do not. Why ?



Watch Video Solution

13. Long distance radio broadcasts use short - wave bands.  
Why ?



Watch Video Solution

**14.** Why are microwaves used in RADAR ?



**Watch Video Solution**

**15.** It is necessary to use satellites for long distance TV transmission. Why ?



**Watch Video Solution**

**16.** How are electromagnetic waves emitted ?



**Watch Video Solution**

## Continuous Evaluation Assignment

1. Give the history of electromagnetic waves.



[Watch Video Solution](#)

2. Discuss electromagnetic spectrum.



[Watch Video Solution](#)

3. Explain the various regions of earth's atmosphere.



[Watch Video Solution](#)

4. Which part of the electromagnetic spectrum includes EM waves of wavelength

- a. 100 m
- b. 0.01 m
- c. 100 nm

 [Watch Video Solution](#)

5. What properties of microwaves make them suitable for

- a. Heating food rapidly
- b. Carrying digital signals to and from a satellite ?

 [Watch Video Solution](#)

## Previous Year Questions

1. a. When a low flying aircraft passes over head, we sometimes notice a slight shaking of the picture on our TV screen. Identify the reason behind it.



[Watch Video Solution](#)

2. A. The electric field of a plane electromagnetic wave travelling in the  $+ve$   $Z$  - direction is described by

a.  $E_x = E_0 \sin(kz + \omega t)$

b.  $E_x = E_0 \sin(kz - \omega t)$

c.  $E_x = E_0 \sin(2kz)$

d.  $E_x = E_0 \sin(kz)$

B. We feel excessive sweating on a cloudy day. Why ?



Watch Video Solution

## Competitive Exam Corner

1. If the total electromagnetic energy falling on a surface is  $U$ , then the total momentum delivered (for complete absorption) is

A. a.  $\frac{U}{c}$

B. b.  $cU$

C. c.  $\frac{U}{c^2}$

D. d.  $c^2U$

**Answer: A**

2. Which one of the following is the property of a monochromatic, plane electromagnetic wave in free space ?

A. a. Electric and magnetic fields have a phase

difference of  $\frac{\pi}{2}$

B. b. The energy contribution of both electric and magnetic fields are equal

C. c. The direction of propagation is in the direction of

$$B \times E$$

D. d. The pressure exerted by the wave is the product of its speed and energy density

**Answer: B**

 [Watch Video Solution](#)

3. The electric field of an electromagnetic wave travelling through vacuum is given by the equation  $E = E_0 \sin(kx - \omega t)$ . The quantity that is independent of wavelength is

A. a.  $\frac{k}{\omega}$

B. b.  $k\omega$

C. c.  $\omega$



D. d. k

**Answer: A**



**Watch Video Solution**

4. The electric field of a plane electromagnetic wave varies with time of amplitude  $2Vm^{-1}$  propagating along  $z$  - axis. The average energy density of the magnetic field is (in  $Jm^{-3}$ )

A. a.  $13.29 \times 10^{-12}$

B. b.  $8.86 \times 10^{-12}$

C. c.  $17.72 \times 10^{-12}$

D. d.  $4.43 \times 10^{-12}$

**Answer: B**



**Watch Video Solution**

5. The electromagnetic wave having the shortest wavelength is

A. a. X-rays

B. b. gamma` - rays

C. c. infrared rays

D. d. microwaves

**Answer: B**



**Watch Video Solution**

6. Light travels in two media A and B with speeds  $1.8 \times 10^8 \text{ m s}^{-1}$  and  $2.4 \times 10^8 \text{ m s}^{-1}$  respectively. Then the angle between them is

A. a.  $\sin^{-1}\left(\frac{2}{3}\right)$

B. b.  $\tan^{-1}\left(\frac{3}{4}\right)$

C. c.  $\tan^{-1}\left(\frac{2}{3}\right)$

D. d.  $\sin^{-1}\left(\frac{3}{4}\right)$

**Answer: D**



**Watch Video Solution**

7. The speed of an electromagnetic wave in a material medium of permeability  $\mu$  and permittivity  $\epsilon$  is

A. a.  $\frac{1}{\mu\epsilon}$

B. b.  $\frac{1}{2\mu\epsilon}$

C. c.  $\frac{1}{\sqrt{\mu\epsilon}}$

D. d.  $\frac{1}{\sqrt{2\mu\epsilon}}$

**Answer: C**



**Watch Video Solution**

8. The energy of infrared waves is greater than that of

A. a. visible light

B. b. ultraviolet waves

C. c. X-rays

D. d. micro waves

**Answer: D**



**Watch Video Solution**

9. A plane electromagnetic wave travels in free space along X - direction. If the value of  $\vec{B}$  (in tesla) at a particular point in space and time is  $1.2 \times 10^{-8} \hat{k}$ . The value of  $\vec{E}$  (in  $V m^{-1}$ ) at that point is

A.  $1.2 \hat{j}$

B.  $3.6\hat{k}$

C.  $1.2\hat{k}$

D.  $3.6\hat{j}$

**Answer: D**



**Watch Video Solution**

**10.** If the magnetic field of an electromagnetic wave is given as  $B_y = 2 \times 10^{-7} \sin(10^3x + 1.5 \times 10^{12}t)$  tesla, the wavelength of the electromagnetic wave is

A. 0.314 mm

B. 0.628 mm

C. 6.28 mm

D. 1.26 mm

**Answer: C**



**Watch Video Solution**

**11.** The electromagnetic waves travel with

A. the same speed in all media

B. the speed of sound in free space

C. the speed of light  $c = 3 \times 10^8 \text{ms}^{-1}$  in solid medium

D. the speed of light  $c = 3 \times 10^8 \text{ms}^{-1}$  in free space

**Answer: D**



**Watch Video Solution**

**12.** In a plane electromagnetic wave, the electric field of amplitude  $1 \text{ V m}^{-1}$  varies with time in free space. The average energy density of magnetic field is (in  $\text{Jm}^{-2}$ )

A. a.  $8.86 \times 10^{-12}$

B. b.  $4.43 \times 10^{-12}$

C. c.  $17.72 \times 10^{-12}$

D. d.  $2.21 \times 10^{-12}$

**Answer: D**



**Watch Video Solution**



13. Which one of the following is the property of a monochromatic, plane electromagnetic wave in free space ?

A. Electric and magnetic fields have a phase difference

of  $\frac{\pi}{2}$

B. The energy contribution of both electric and magnetic fields are equal

C. The direction of propagation is in the direction of E

D. The pressure exerted by the wave is the product of energy density and the speed of the wave

**Answer: B**



**Watch Video Solution**

14. The electromagnetic waves detected using a thermopile and used in physical therapy are

- A. a. gamma radiations
- B. b. X-rays
- C. c. ultra-violet radiations
- D. d. infra - red radiations

**Answer: D**



**Watch Video Solution**

15. The amplitudes  $E_0$  and  $B_0$  of electric and the magnetic component of an electromagnetic wave respectively are related to the velocity  $c$  in vacuum as

A. a.  $E_0 B_0 = \frac{1}{c}$

B. b.  $E_0 = \frac{1}{B_0}$

C. c.  $B_0 = cE_0$

D. d.  $E_0 = cB_0$

**Answer: D**



**Watch Video Solution**

16. Identify the mismatched pair

A. a) Microwaves - Aircraft navigation

B. b) Radio waves - Cellular phone

C. c) Infrared waves - Remote switches

D. d)  $\gamma$  - rays - Klystron

**Answer: D**



**Watch Video Solution**