

hapter ontents.

IMPORTANT TOPICS FOR JEE MAIN (2)

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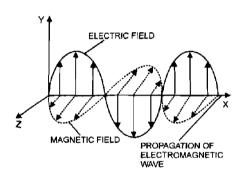
WAVE OPTICS

THEORY

ELECTROMAGNETIC WAVES:

In electromagnetic waves, both the field vectors (\vec{E} and \vec{B}) vary with time and space and have the same frequency and same phase. In figure, the electric field vector (\vec{E}) and magnetic field vector

 (\vec{B}) are vibrating along Y and Z directions and propagation of electromagnetic wave is shown in X-direction.



According to Maxwell the electromagnetic waves are of transverse in nature and they can pass through vacuum with the speed of light (= $3 \times 10^8 \text{ ms}^{-1}$).

The velocity of eletromagnetic wave in a medium is given by

$$v = \frac{1}{\sqrt{\mu_0 \mu_r \in_0 \in_r}}$$

where, μ_0 , μ_r = absolute permeability of space and relative permeability of medium,

 \in_{0} , \in_{r} = absolute permittivity of space and relative permittivity of medium

The velocity of electromagnetic waves of different frequency in vacuum is same but in a medium is different. It is more for red light and less for violet light.

The energy is shared equally between electric field vector and magnetic field vector.

$$U_{av} = \frac{1}{2} \in_{0} E_{0}^{2} = \frac{1}{2} \frac{B_{0}^{2}}{\mu_{0}}$$

It has been found that the velocity (c) of electromagnetic wave in free space is equal to the ratio of amplitude of electric field vector (E_0) and magnetic field vector (E_0) i.e $c = E_0/B_0$.

It was found that the accelerated charge or oscillating charge is a source of electromagnetic waves.

If the plane of electric field is oriented horizontally in respect to the earth, the electromagnetic wave is said to be horizontally polarised. On the other hand, if the plane of electric field vector is oriented vertically the electromagnetic wave is said to be vertically polarised.

The polarisation of electromagnetic wave is mainly the function of the antenna orientation.

Light may be polarized by passing it through a sheet of commercial material called Polaroid

Malus' Law

Suppose we have a second piece of Polaroid whose transmission axis makes an angle θ with that of the first one

If $I_0 \cong E^2$ is the intensity between the two Polaroids, the intensity transmitted by both of them would be: $I(\theta) = I_0 \cos^2 \theta$.

Brewster's law

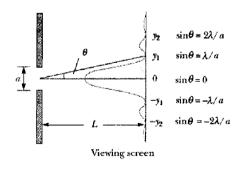
$$\tan \theta_{\rm p} = \frac{\rm n_2}{\rm n_1}$$
: **Brewster's law**

 θ_p is the angle of incidence of unpolarized light which makes the reflected light completely polarized in the perpendicular direction to the plane of incidence (Sir David Brewster, 1812). When the angle of incidence of the initially unpolarized light is θ_p , the reflected and refracted rays are perpendicular to each other.

DIFFRACTION

When light passes through a narrow slit of width comparable to the wavelength of light, the light flares out of the slit; this bending or spreading of waves is called diffraction.

Properties of dark & bright fringes:



- (a) It results from superposition of secondary wavelets originating from various parts of single coherent source.
- (b) Diffraction fringes are never of equal width.
- (c) Intensity of all the bright fringes is not the same.
- (d) Dark fringes are not perfectly dark.



FRAUNHOFER DIFFRACTION BY A CIRCULAR APERTURE

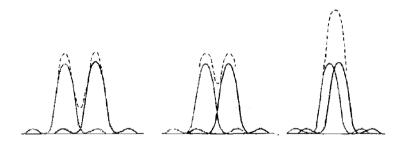
The mathematical analysis shows that the first dark ring is formed by the light diffracted from the hole at an angle θ with the axis $\sin\theta = \frac{1.22\lambda}{b}$.



The radius of the diffraction disc is given by $R = \frac{1.22\lambda D}{b}$,

LIMIT OF RESOLUTION

The fact that a lens forms a disc image of a point source, puts a limit on resolving two neighboring points imaged by a lens.



well resolved

just resolved

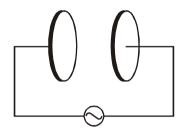
unresolved.

For two objects to be barely resolved, the angular separation between them should be at least:

$$\theta_{R} = \sin^{-1} \left(\frac{1.22\lambda}{b} \right)$$

SUBJECTIVE

- 1. A parallel plate capacitor (fig.) made of circular plates each of radius R = 6.0 cm has a capacitance $C = 100 \mu F$. 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.



- 2. 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?
- 3. In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of $2.0 \times 10^{10} Hz$ 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. [$c = 3 \times 10^8 \text{ m s}^{-1}$]
- **4.** Suppose that the electric field part of an electromagnetic wave in vaccum is

$$E = \{(3.1 \text{ N/C}) \cos [(1.8 \text{ rad/m}) \text{ y} + (5.4 \times 10^8 \text{ rad/s})t] \hat{i}$$

- (a) What is the direction of propagation?
- (b) What is the wavelength λ ?
- (c) What is the frequency v?
- (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.
- A plane electromagnetic wave traveling in the positive direction of x axis in vaccum has components $E_x = E_y = 0$ and $E_z = (2.0 \text{ V/m}) \cos [(\pi \times 10^{15} \text{ S}^{-1}) (t \text{x/c})]$. (a) What is the amplitude of the magnetic field component? (b) Parallel to which axis does the magnetic field oscillate? (c) When the electric field component is in the positive direction of the z axis at a certain point P, what is the direction of the magnetic field component there?

- 6. An open circuit consists of a 12 μF parallel plate capacitor charged to 200V and a 10Ω resistor. At the instant when a switch closes the circuit (with no battery in it) the displacement current between the, plates of the capacitor is
- 7. Two coherent waves are described by the following expressions.

$$E_1 = E_0 \sin \left(\frac{2\pi x_1}{\lambda} - 2\pi ft + \frac{\pi}{6}\right); E_2 = E_0 \sin \left(\frac{2\pi x_2}{\lambda} - 2\pi ft + \frac{\pi}{8}\right)$$

Determine the relationship between x_1 and x_2 that produces constructive interference when the two waves are superposed.

8. A nickel crystal is used as a diffraction grating for x-rays. Then the same crystal is used to diffract electrons. If the two diffraction patterns are identical, and the energy of each x-ray photon is E = 20.0 keY. What is the kinetic energy of each electron?

OBJECTIVE (O)

1.	The velocity of electromagnetic waves in a dielectric medium ($\in_r = 4$) is :-			
	(A) 3×10^8 metre/second	(B) 1.5×10^8 metre/second		
	(C) 6×10^8 metre/second	(D) 7.5×10^7 metre/second		

Which of these statements correctly describes the orientation of the electric field (\vec{E}) , the magnetic 2. field (\vec{B}) , and and velocity of propagation (\vec{v}) of an electromagnetic wave?

(A) \vec{E} is perpendicular to \vec{B} ; \vec{v} may have any orientation relative to \vec{E} .

(B) \vec{E} is perpendicular to \vec{B} ; \vec{v} may have any orientation perpendicular to \vec{E}

(C) \vec{E} is parallel to \vec{B} : \vec{v} is perpendicular to both \vec{E} and \vec{E} .

(D) Each of the three vectors is perpendicular to the other two.

The amplitude of electric field in a parallel light beam of intensity 4Wm⁻² is: **3.**

(A) 35.5 NC⁻¹ (B) 45.5 NC⁻¹ $(C) 49.5 NC^{-1}$ (D) 54.8 NC^{-1}

Instantaneous displacement current of 1.0A in the space between the parallel plates of 1µF capacitor 4. can be established by changing potential difference of:

(C) 10^{-8} V/s

(D) 10^8 V/s

(A) 10^{-6} V/s (B) 10^6 V/s A plane electromagnetic wave,

5.

 $E_z = 100 \cos (6 \times 10^8 t + 4x) \text{ V/m}$

propagates in a medium of dielectric constant:

(A) 1.5 (B) 2.0(C) 2.4(D) 4.0

A large parallel plane capacitor, whose plates have an area of 1 m² and are separated from each other 6. by 1 mm, is being charged at a rate of 25.8 V/s. If the dielectric between the plates has the dielectric constant 10, then the displacement current at this instant is:-

(A) $251 \mu A$ (B) $11 \mu A$ (C) $2.2 \mu A$ (D) $1.1 \, \mu A$

7. The rms value of the electric field of the light coming from the sun is 720 N/c. The average total energy density of the electromagnetic wave is:

(A) $4.58 \times 10^{-6} \text{ J/m}^3$ (B) $6.37 \times 10^{-9} \text{ J/m}^3$

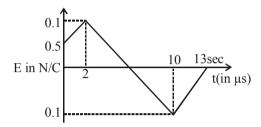
(C) $81.35 \times 10^{-12} \text{ J/m}^3$ (D) $3.3 \times 10^{-3} \text{ J/m}^3$

A beam of light travelling along x-axis is described by the electric field, $E_v = (600 \text{ Vm}^{-1}) \sin \omega (t - x/c)$ 8. then maximum magnetic force on a charge q = 2e, moving along y-axis with a speed of $3.0 \times 10^7 \text{ ms}^{-1} \text{ is } (e = 1.6 \times 10^{-19} \text{ C})$:

(A) $19.2 \times 10^{-17} \text{ N}$ (B) $1.92 \times 10^{-17} \text{ N}$

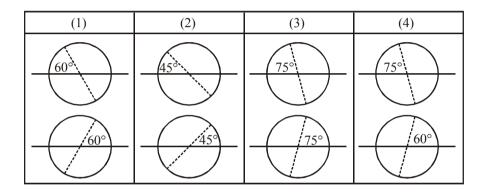
(C) 0.192 N (D) None of these

- **9.** A plane electromagnertic 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 is:
 - (A) $3.1 \times 10^{-8} \,\mathrm{T}$
- (B) $3 \times 10^{-5} \,\mathrm{T}$
- (C) 3.1×10^{-6} T
- (D) 9.3×10^{-6} T
- **10.** The electric field through an area of 2m² varies with time as shown in the graph. The greatest displacement current through the area is at :-

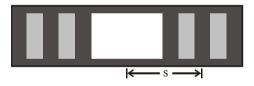


- (A) t = 1 sec.
- (B) t = 4 sec.
- (C) t = 8 sec.
- (D) t = 12 sec.
- 11. A plane electromagnetic wave travelling along the X-direction has a wavelength of 3mm. The variation in the electric field occurs in the Y-direction with an amplitude 66Vm⁻¹. The equation for the electric and magnetic fields as a function of x and t are respectively.
 - (A) $E_y = 33 \cos \pi \times 10^{11} \left(t \frac{x}{c} \right)$; $B_z = 1.1 \times 10^{-7} \cos \pi \times 10^{11} \left(t \frac{x}{c} \right)$
 - (B) $E_y = 11 \cos 2\pi \times 10^{11} \left(t \frac{x}{c} \right)$; $B_y = 1.1 \times 10^{-7} \cos 2\pi \times 10^{11} \left(t \frac{x}{c} \right)$
 - (C) $E_x = 33 \cos \pi \times 10^{11} \left(t \frac{x}{c} \right)$; $B_x = 1.1 \times 10^{-7} \cos \pi \times 10^{11} \left(t \frac{x}{c} \right)$
 - (D) $E_y = 66 \cos 2\pi \times 10^{11} \left(t \frac{x}{c} \right)$; $B_z = 2.2 \times 10^{-7} \cos 2\pi \times 10^{11} \left(t \frac{x}{c} \right)$
- 12. In a stack of three polarizing sheets the first and third are crossed while the middle one has its axis at 45° to the axes of the other two. The fraction of the intensity of an incident unpolarized beam of light that is transmitted by the stack is:
 - (A) 1/2
- (B) 1/3
- (C) 1/4
- (D) 1/8
- 13. A beam of light strikes a piece of glass at an angle of incidence of 60° and the reflected beam is completely plane polarised. The refractive index of the glass is:-
 - (A) 1.5
- (B) $\sqrt{3}$
- (C) $\sqrt{2}$
- (D)(3/2)

- **14.** The Sun is directly overhead and you are facing toward the north. Light coming to your eyes from the sky just above the horizon is:-
 - (A) Partially polarized north-south
- (B) Partially polarized east, west
- (C) Partially polarized up-down
- (D) Randomly polarized
- 15. The diagrams show four pairs of polarizing sheets, with the polarizing directions indicated by dashed lines. The two 'sheets of each pair are placed one behind the other and the front sheet is illuminated by unpolarized light. The incident intensity is the same for all pairs of sheets. Rank the pairs according to the intensity of the transmitted light, least to greatest.

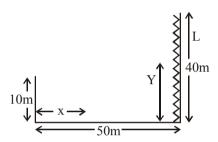


- (A) 1,2, 3, 4
- (B) 4, 2, 1, 3
- (C) 2, 4, 3, 1
- (D) 2, 1,4, 3
- 16. Light of wavelength 600 nm is incident upon a single slit with width 4×10^{-4} m. The figure shows the pattern observed on a screen positioned 2 m from the slits. Determine the distance s.



- (A) 0.002 m
- (B) 0.003 m
- (C) 0.004 m
- (D) 0.006 m
- 17. The image of a star (effectively a point source) is made by a convergent lens of focal length 1m and diameter of aperture 5.0 cm. If the lens is ideal and the effective wavelength in image formation is taken as 5×10^{-5} cm, the diameter of the image formed will be nearest to:
 - (A) zero
- (B) 10⁻⁶ cm
- (C) 10^{-5} cm
- (D) 10^{-3} cm
- 18. In a single slit diffraction pattern, as the width of the slit is increased,
 - (A) the peak intensity of central maxima increases and its width also increases
 - (B) the peak intensity of central maxima increases and its width decreases.
 - (C) the peak intensity of central maxima decreases and its width increases
 - (D) the peak intensity of central maxima decreases and its width also decreases.

- A beam of electrons with de-broglie wavelength of 10⁻⁴ m pass through a slit 10⁻³ m wide. Calculate 19. the angular spread introduced because of diffraction by slit.
 - (A) $\frac{9^{\circ}}{-}$
- (B) $\frac{18^{\circ}}{\pi}$ (C) $\frac{36^{\circ}}{\pi}$
- (D) $\frac{4.5^{\circ}}{\pi}$
- A person lives in a high-rise building on the bank of a river 50m wide. Across the river is a well lit 20. tower of height 40 m. When the person, who is at a height of 10m, looks through a polarizer at an appropriate angle at light of the tower reflecting from the river surface, he notes that intensity of light coming from distance X from his building is the least and this corresponds to the light coming from light bulbs at height 'Y' on the tower. The values of X and Y are respectively close to (refractive index of water $\approx 4/3$)



- (A) 13 m, 27 m
- (B) 22 m, 13 m
- (C) 25 m, 10 m
- (D) 17 m, 29 m
- If a source of power 4kW produces 10²⁰ photons/second, the radiation belongs to a part of the spectrum 21. called [AIEEE 2010]
 - (A) microwaves
- (B) y-rays
- (C) X-rays
- (D) ultraviolet rays
- 22. **Statement-1:** On viewing the clear blue portion of the sky through a Calcite Crystal, the intensity of transmitted light varies as the crystal is rotated.

Statement-1: The light coming from the sky is polarized due to scattering of sun light by particles in the atmosphere. The scattering is largest for blue light. [AIEEE-2011]

- (A) Statement-1 is false, statement-2 is true
- (B) Statement-1 is true, statement-2 is false
- (C) Statement-1 is true, statement-2 true; statement-2 is the correct explanation of statement-1
- (D) Statement-1 is true, statement-2 is true; statement -2 is not correct explanation of statement-1.
- An electromagnetic wave in vacuum has the electric and magnetic fields \vec{E} and \vec{B} , which are always 23. perpendicular to each other. The direction of polarization is given by \vec{X} and that of wave propagation by \vec{k} . Then [AIEEE-2012]

(A) $\vec{X} \parallel \vec{B}$ and $\vec{k} \parallel \vec{E} \times \vec{B}$

(B) $\vec{X} \parallel \vec{E}$ and $\vec{k} \parallel \vec{B} \times \vec{E}$

(C) $\vec{X} \parallel \vec{B}$ and $\vec{k} \parallel \vec{B} \times \vec{E}$

(D) $\vec{X} \parallel \vec{E}$ and $\vec{k} \parallel \vec{E} \times \vec{B}$

24. This question has Statement-1 and statement-2. Of the four choices given after the Statements, choose the one that best describes the two statements. [AIEEE - 2012]

Statement-1: Davisson - Germer experiment established the wave nature of electrons.

Statement-2: If electrons have wave nature, they can interfere and show diffraction.

- (A) Statement-1 is true, Statement-2 is true and Statement-2 is the correct explanation for Statement-1.
- (B) Statement-1 is true, Statement-2 is true and Statement-2 is not the correct explanation of Statement-I
- (C) Statement-1 is false, Statement-2 is true.
- (D) Statement-1 is true, Statement-2 is false
- A beam of unpolarised light of intensity I_0 is passed through a polaroid A and then through another 25. polaroid B which is oriented so that its principal plane makes an angle of 45° relative to that of A. The [JEE-Main 2013] intensity of the emergent light is:-

 $(A) I_0$

(B) $I_0/2$

(C) $I_0/4$

(D) $I_0/8$

Match List-I (Electromagnetic wave type) with List-II (Its association/application) and select the **26.** correct option from the choices given below the lists: [JEE-Main 2014]

	List-I	List-II		
(a)	Infrared waves	(i)	(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	

- (a)
- (b)
- (c)

(i)

(iii)

(A) (iii)

(B) (i)

- (ii) (ii)
- (C) (iv)
 - (iii)
- (D) (i) (ii)
- (ii)
- (iii) (iv)
- During the propagation of electromagnetic waves in a medium: 27.

[JEE-Main 2014]

(A) Electric energy density is equal to the magnetic energy density

(d)

(iv)

(iv)

(i)

- (B) Both electric magnetic energy densities are zero
- (C) Electric energy density is double of the magnetic energy density
- (D) Electric energy density is half of the magnetic energy density.

, Al	LLEN		Important	Topics for JEE-Mains-2 11
28.	seen through a po	plaroid. From the position	when the beam A has	ndicular planes of polarization are maximum intensity (and beam B yo beams appear equally bright. If
	the initial intensit	ites of the two beams are	I_A and I_B respectively, the	ten $\frac{\mathrm{I_A}}{\mathrm{I_B}}$ equals : [JEE-Main 2014]
	(A) 1	(B) $\frac{1}{3}$	(C) 3	(D) $\frac{3}{2}$
29.	A red LED emits	light at 0.1 watt uniforml	y around it. The amplitu	nde of the electric field of the light
	at a distance of 1	m from the diode is:-		[JEE-Main 2015]
	(A) 5.48 V/m	(B) 7.75 V/m	(C) 1.73 V/m	(D) 2.45 V/m
30.	_			ble viewing distance of 25cm, the blve at 500 nm wavelength is:-
				[JEE-Main 2015]
	(A) 100 μm	$(B) 300 \mu m$	(C) 1 µm	(D) $30 \mu m$
31.	illuminated by a p wall of the camer	parallel beam of light of war ra) is the sum of its geom	etrical spread and the spread of	t is assumed that when the hole is f the spot (obtained on the opposite pread due to diffraction. The spot

would then have its minimum size (say b_{min}) when :-

(A)
$$a = \frac{\lambda^2}{L}$$
 and $b_{min} = \sqrt{4\lambda L}$ (B) $a = \frac{\lambda^2}{L}$ and $b_{min} = \left(\frac{2\lambda^2}{L}\right)$

(C)
$$a = \sqrt{\lambda L}$$
 and $b_{min} = \left(\frac{2\lambda^2}{L}\right)$ (D) $a = \sqrt{\lambda L}$ and $b_{min} = \sqrt{4\lambda L}$

- **32.** An observer is moving with half the speed of light towards a stationary microwave source emitting waves at frequency 10 GHz. What is the frequency of the microwave measured by the observer? (speed of light = $3 \times 10^8 \,\mathrm{ms}^{-1}$) [JEE Main - 2017]
 - (A) 17.3 GHz (C) 10.1 GHz (D) 12.1 GHz (B) 15.3 GHz
- The angular width of the central maximum in a single slit diffraction pattern is 60°. The width of the **33.** slit is 1 µm. The slit is illuminated by monochromatic plane waves. If another slit of same width is made near it, Young's fringes can be observed on a screen placed at a distance 50 cm from the slits. If the observed fringe width is 1 cm, what is slit separation distance? (i.e. distance between the centres of each slit.) [JEE-Main 2018]
 - (A) 50 μ m
- (B) $75 \mu m$
- (C) $100 \, \mu m$
- (D) $25 \mu m$

12

An EM wave from air enters a medium. The electric fields are $\vec{E}_1 = E_{01}\hat{x}\cos\left|2\pi v\left(\frac{z}{c}-t\right)\right|$ in air and 34.

 $\vec{E}_2 = E_{02}\hat{x}\cos[k(2z-ct)]$ in medium, where the wave number k and frequency v refer to their values in air. The medium is non-magnetic. If \in_{r_i} and \in_{r_j} refer to relative permittivity of air and medium respectively, which of the following options is correct? [JEE-Main 2018]

- $(A) \frac{\epsilon_{r_1}}{\epsilon} = 2$
- (B) $\frac{\epsilon_{r_i}}{\epsilon_{r_i}} = \frac{1}{4}$ (C) $\frac{\epsilon_{r_i}}{\epsilon_{r_i}} = \frac{1}{2}$ (D) $\frac{\epsilon_{r_i}}{\epsilon_{r_i}} = 4$

- The energy associated with electric field is $(U_{\scriptscriptstyle E})$ and with magnetic field is $(U_{\scriptscriptstyle R})$ for an electromagnetic 35. wave in free space. Then: [JEE Main-2019_Jan]
 - (A) $U_{E} = \frac{U_{B}}{2}$
- $(B) U_E < U_B$
- (C) $U_F = U_R$
- (D) $U_E > U_B$
- A plane electromagnetic wave of frequency 50 MHz travels in free space along the positive x-direction. 36. At a particular point in space and time, $\vec{E} = 6.3 \hat{i} V/m$. The corresponding magnetic field \vec{B} , at that point will be: [JEE Main-2019 Jan]
 - (A) $18.9 \times 10^{-8} \hat{k}T$
- (B) $6.3 \times 10^{-8} \hat{k}T$
- (C) $2.1 \times 10^{-8} \hat{k}T$
- (D) $18.9 \times 10^8 \text{ kT}$
- A conducting circular loop made of a thin wire, has area 3.5×10^{-3} m² and resistance 10Ω . **37.** It is placed perpendicular to a time dependent magnetic field B(t) = $(0.4T)\sin(50\pi t)$. The field is uniform in space. Then the net charge flowing through the loop during t = 0 s and t = 10 ms is close [JEE Main-2019 Jan] to:
 - (A) 14mC
- (B) 21 mC
- (C) 6 mC
- (D) 7 mC
- 38. The electric field of a plane polarized electromagnetic wave in free space at time t = 0 is given by an expression

$$\vec{E}(x,y) = 10\hat{j} \cos[(6x + 8z)]$$

The magnetic field \vec{B} (x, z, t) is given by : (c is the velocity of light)

[JEE Main-2019_Jan]

(A)
$$\frac{1}{c} \left(6\hat{k} + 8\hat{i} \right) \cos \left[\left(6x - 8z + 10ct \right) \right]$$

(B)
$$\frac{1}{c} \left(6\hat{k} - 8\hat{i} \right) \cos \left[\left(6x + 8z - 10ct \right) \right]$$

(C)
$$\frac{1}{c} \left(6\hat{k} + 8\hat{i} \right) \cos \left[\left(6x + 8z - 10ct \right) \right]$$

(D)
$$\frac{1}{c} \left(6\hat{k} - 8\hat{i} \right) \cos \left[\left(6x + 8z + 10ct \right) \right]$$

39. If the magnetic field of a plane electromagnetic wave is given by (The speed of light = 3×10^8 /m/s)

 $B = 100 \times 10^{-6} \sin \left[2\pi \times 2 \times 10^{15} \left(t - \frac{x}{c} \right) \right]$ then the maximum electric field associated with it is:

[JEE Main-2019_Jan]

(A)
$$4 \times 10^4$$
 N/C

(B)
$$4.5 \times 10^4 \text{ N/C}$$

(C)
$$6 \times 10^4 \text{ N/C}$$

(D)
$$3 \times 10^4 \text{ N/C}$$

- 40. A 27 mW laser beam has a cross-sectional area of 10 mm². The magnitude of the maximum electric field in this electromagnetic wave is given by [Given permittivity of space $\epsilon_0 = 9 \times 10^{-12}$ SI units, Speed of light $c = 3 \times 10^8 \text{ m/s}$: [JEE Main-2019 Jan]
 - (A) 1 kV/m
- (B) 2 kV/m
- (C) 1.4 kV/m
- (D) 0.7 kV/m
- An electromagnetic wave of intensity 50 Wm⁻² enters in a medium of refractive index 'n' without any 41. loss. The ratio of the magnitudes of electrric fields, and the ratio of the magnitudes of magnetic fields of the wave before and after entering into the medium are respectively, given by:

[JEE Main-2019 Jan]

- (A) $\left(\frac{1}{\sqrt{n}}, \frac{1}{\sqrt{n}}\right)$ (B) $\left(\sqrt{n}, \frac{1}{\sqrt{n}}\right)$ (C) $\left(\sqrt{n}, \sqrt{n}\right)$

- (D) $\left(\frac{1}{\sqrt{n}}, \sqrt{n}\right)$
- The mean intensity of radiation on the surface of the Sun is about 108 W/m². The rms value of the 42. corresponding magnetic field is closest to: [JEE Main-2019 Jan]
 - (A) 10^{2} T
- (B) 10^{-4} T
- (C) 1T
- (D) 10^{-2} T
- A light wave is incident normally on a glass slab of refractive index 1.5. If 4% of light gets reflected 43. and the amplitude of the electric field of the incident light is 30V/m, then the amplitude of the electric field for the wave propogating in the glass medium will be: [JEE Main-2019 Jan]
 - (A) 10 V/m
- (B) 24 V/m
- (C) 30 V/m
- (D) 6 V/m
- The magnetic field of an electromagnetic wave is given by:-44.

$$\vec{B} = 1.6 \times 10^{-6} \cos(2 \times 10^{7} z + 6 \times 10^{15} t) (2\hat{i} + \hat{j}) \frac{Wb}{m^{2}}$$

The associated electric field will be:-

[JEE Main-2019_April]

(A)
$$\vec{E} = 4.8 \times 10^{2} \cos(2 \times 10^{7} z + 6 \times 10^{15} t) (\hat{i} - 2\hat{j}) \frac{V}{m}$$

(B)
$$\vec{E} = 4.8 \times 10^2 \cos(2 \times 10^7 z - 6 \times 10^{15} t) (2\hat{i} + \hat{j}) \frac{V}{m}$$

(C)
$$\vec{E} = 4.8 \times 10^2 \cos(2 \times 10^7 z - 6 \times 10^{15} t) (-2\hat{j} + \hat{i}) \frac{V}{m}$$

(D)
$$\vec{E} = 4.8 \times 10^2 \cos(2 \times 10^7 z + 6 \times 10^{15} t) (-\hat{i} + 2\hat{j}) \frac{V}{m}$$

- A plane electromagnetic wave travels in free space along the x-direction. The electric field component **45.** of the wave at a particular point of space and time is $E = 6 \text{ V m}^{-1}$ along y-direction. Its corresponding magnetic field component, B would be: [JEE Main-2019_April]
 - (A) 6×10^{-8} T along z-direction
- (B) 6×10^{-8} T along x-direction
- (C) 2×10^{-8} T along z-direction
- (D) 2×10^{-8} T along y-direction

46. The magnetic field of a plane electromagnetic wave is given by:

 $\vec{B} = B_0 \hat{i} [\cos(kz - \omega t)] + B_1 \hat{j} \cos(kz + \omega t)$ where $B_0 = 3 \times 10^{-5}$ T and $B_1 = 2 \times 10^{-6}$ T. The rms value of the force experienced by a stationary charge $Q = 10^{-4}$ C at z = 0 is closest to :

[JEE Main-2019_April]

(C)
$$3 \times 10^{-2} \text{ N}$$

47. The electric field of a plane electromagnetic wave is given by

$$\vec{E} = E_0 \hat{i} \cos(kz) \cos(\omega t)$$

The corresponding magnetic field \vec{B} is then given by:

[JEE Main-2019 April]

(A)
$$\vec{B} = \frac{E_0}{C} \hat{j} \sin(kz) \cos(\omega t)$$

(B)
$$\vec{B} = \frac{E_0}{C} \hat{j} \sin(kz) \sin(\omega t)$$

(C)
$$\vec{B} = \frac{E_0}{C} \hat{k} \sin(kz) \cos(\omega t)$$

(D)
$$\vec{B} = \frac{E_0}{C} \hat{j} \cos(kz) \sin(\omega t)$$

A plane electromagnetic wave having a frequency v = 23.9 GHz propagates along the positive 48. z-direction in free space. The peak value of the electric field is 60 V/m. Which among the following is the acceptable magnetic field component in the electromagnetic wave ?[JEE Main-2019 April]

(A)
$$\vec{B} = 2 \times 10^7 \sin(0.5 \times 10^3 z + 1.5 \times 10^{11} t) \hat{i}$$

(B)
$$\vec{B} = 2 \times 10^{-7} \sin(1.5 \times 10^2 x + 0.5 \times 10^{11} t) \hat{i}$$

(C)
$$\vec{B} = 2 \times 10^{-7} \sin(0.5 \times 10^3 z - 1.5 \times 10^{11} t) \hat{i}$$

(D)
$$\vec{B} = 60 \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t) \hat{k}$$

An electromagnetic wave is represented by the electric field $\vec{E} = E_0 \hat{n} \sin[\omega t + (6y - 8z)]$. Taking unit 49. vectors in x, y and z directions to be $\hat{i}, \hat{j}, \hat{k}$, the direction of propogation \hat{s} , is:

[JEE Main-2019 April]

(A)
$$\hat{s} = \frac{4\hat{j} - 31}{5}$$

(B)
$$\hat{s} = \frac{3\hat{i} - 4\hat{j}}{5}$$

(A)
$$\hat{s} = \frac{4\hat{j} - 3\hat{k}}{5}$$
 (B) $\hat{s} = \frac{3\hat{i} - 4\hat{j}}{5}$ (C) $\hat{s} = \left(\frac{-3\hat{j} + 4\hat{k}}{5}\right)$ (D) $\hat{s} = \frac{-4\hat{k} + 3\hat{j}}{5}$

(D)
$$\hat{s} = \frac{-4\hat{k} + 3}{5}$$

50. A system of three polarizers P_1 , P_2 , P_3 is set up such that the pass axis of P_3 is crossed with respect to that of P₁. The pass axis of P₂ is inclined at 60° to the pass axis of P₃. When a beam of unpolarized light of intensity I₀ is incident on P₁, the intensity of light transmitted by the three polarizers is I. The ratio (I_0/I) equals (nearly): [JEE Main-2019_April]

GEOMETRICAL OPTICS

THEORY

PRISM

DISPERSION OF LIGHT

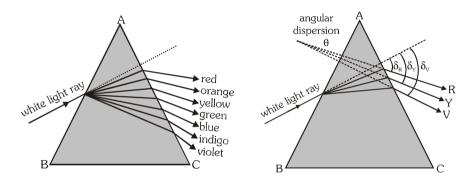
When white light is incident on a prism then it is splitted into seven colours. This phenomenon is known as dispersion. Prism introduces different refractive index with different wavelength

As
$$\delta_{\min} = (\mu - 1) A :: \lambda_R > \lambda_V$$

So
$$\mu_{\rm V} > \mu_{\rm R} \Rightarrow \delta_{\rm m(violet)} > \delta_{\rm m(red)}$$

ANGULAR DISPERSION

It is the difference of angle of deviation for violet colour and red colour Angular dispersion $\theta = \delta_V - \delta_R = (\mu_V - 1)A - (\mu_R - 1)A = (\mu_V - \mu_R)A$ It depends on prism material and on the angle of prism $\theta = (\mu_V - \mu_R)A$



DISPERSIVE POWER (ω)

It is ratio of angular dispersion (θ) to mean colour deviation (δ_{v})

Dispersive power
$$\omega = \frac{\theta}{\delta_y} \Rightarrow \omega = \frac{(\mu_V - \mu_R)A}{(\mu_y - 1)A} = \frac{\mu_V - \mu_R}{\mu_y - 1} \Rightarrow \omega = \frac{\mu_V - \mu_R}{\mu_y - 1}$$

Refractive index of mean colour $\mu_y = \frac{\mu_V + \mu_R}{2}$

Dispersive power depends only on the material of the prism.

COMBINATION OF PRISM

Deviation without dispersion ($\theta = 0^{\circ}$)

Two or more than two thin prism are combined in such a way that deviation occurs i.e. emergent light ray makes angle with incident light ray but dispersion does not occur i.e., light is not splitted into seven colours.

Total dispersion =
$$\theta = \theta_1 + \theta_2 = (\mu_V - \mu_R)A + (\mu'_V - \mu'_R)A'$$

For no dispersion $\theta = 0$; $(\mu_V - \mu_R)A + (\mu'_V - \mu'_R)A' = 0$

Therefore, A' =
$$-\frac{(\mu_V - \mu_R)A}{\mu_V - \mu_R}$$

-ve sign indicates that prism angles are in opposite direction.

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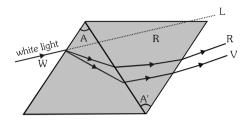
Dispersion without deviation $(\delta = 0^{\circ})$

Two or more than two prisms combine in such a way that dispersion occurs i.e., light is splitted into seven colours but deviation do not occur i.e., emergent light ray becomes parallel to incident light ray.

Total deviation $\delta = \delta_1 + \delta_2$

$$\Rightarrow$$
 δ = 0; (μ -1) A + (μ'-1)A' = 0 \Rightarrow A' = $-\frac{(\mu - 1)A}{\mu' - 1}$

-ve sign indicates that prism angles are in opposite direction.



KEY POINTS

- Dispersive power like refractive index has no units and dimensions and depends on the material of the prism and is always positive.
- As for a given prism dispersive power is constant, i.e., dispersion of different wavelengths will be different and will be maximum for violet and minimum for red (as deviation is maximum for violet and minimum for red).
- As for a given prism $\theta \propto \delta a$ single prism produces both deviation and dispersion simultaneously, i.e., a single prism cannot give deviation without dispersion or dispersion without deviation.
- Ex. White light is passed through a prism of angle 5°. If the refractive indices for red and blue colours are 1.641

and 1.659 respectively, calculate the angle of dispersion between them.

Sol. As for small angle of prism $\delta = (\mu - 1)A$,

$$\delta_{\rm B} = (1.659 - 1) \times 5^{\circ} = 3.295^{\circ} \text{ and } \delta_{\rm R} = (1.641 - 1) \times 5^{\circ} = 3.205^{\circ}$$

so $\theta = \delta_{\rm R} - \delta_{\rm R} = 3.295^{\circ} - 3.205^{\circ} = 0.090^{\circ}$

Ex. Prism angle of a prism is 10°. Their refractive index for red and violet color is 1.51 and 1.52 respectively. Then find the dispersive power.

Sol. Dispersive power of prism
$$\omega = \left(\frac{\mu_{v} - \mu_{r}}{\mu_{y} - 1}\right)$$
 but $\mu_{y} = \frac{\mu_{v} + \mu_{r}}{2} = \frac{1.52 + 1.51}{2} = 1.515$

Therefore
$$\omega = \frac{1.52 - 1.51}{1.515 - 1} = \frac{0.01}{1.515} = 0.019$$

Ex. The refractive indices of flint glass for red and violet colours are 1.644 and 1.664. Calculate its dispersive power.

Sol. Here,
$$\mu_r = 1.644$$
, $\mu_v = 1.664$, $\omega = ?$

Now
$$\mu_y = \frac{\mu_v + \mu_r}{2} = \frac{1.664 + 1.644}{2} = 1.654$$
 $\therefore \omega = \frac{\mu_v - \mu_r}{\mu_v - 1} = \frac{1.664 - 1.644}{1.654 - 1} = 0.0305$

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- Ex. In a certain spectrum produced by a glass prism of dispersive power 0.031, it was found that $\mu_r = 1.645$ and $\mu_v = 1.665$. What is the refractive index for yellow colour?
- **Sol.** Here, $\omega = 0.031$, $\mu_r = 1.645$ $\mu_v = 1.665$, $\mu_v = ?$

$$\therefore \omega = \frac{\mu_v - \mu_r}{\mu_v - 1} \ \therefore \ \mu_v - 1 = \frac{\mu_v - \mu_r}{\omega} = \frac{1.665 - 1.645}{0.031} = \frac{0.020}{0.31} = 0.645 \ \therefore \ \mu_v = 0.645 + 1 = 1.645$$

- Ex. A combination of two prisms, one of flint and other of crown glass produces dispersion without deviation. The angle of flint glass prism is 15°. Calculate the angle of crown glass prism and angular dispersion of red and violet. (μ for crown glass = 1.52, μ for flint glass = 1.65, ω for crown glass 0.20, ω for flint glass = 0.03).
- **Sol.** Here, $A = 15^{\circ}$, A' = ?, $\omega = 0.03$, $\omega' = 0.02$, $\mu = 1.65$, $\mu' = 1.52$, For no deviation, $\delta + \delta' = 0$

$$(\mu - 1)A + (\mu' - 1)A' = 0 \implies (1.65 - 1)15^{\circ} + (1.52 - 1)A' = 0 \implies A' = \frac{-0.65 \times 15}{0.52} = -18.75^{\circ}$$

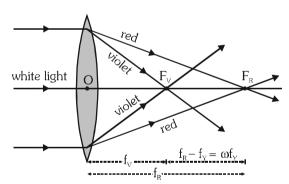
Negative sign indicates that two prisms must be joined in opposition. Net angular dispersion $(\mu_v - \mu_r) A + (\mu'_v - \mu'_r) A' = \omega(\mu - 1) A + \omega'(\mu' - 1) A' = 0.03 \ (1.65 - 1)15^\circ + 0.02 \ (1.52 - 1) \ (-18.75^\circ)$ $= 0.2925 - 0.195 = 0.0975^\circ$

CHROMATIC ABERRATION

The image of a object in white light formed by a lens is usually colored and blurred. This defect of image is called chromatic aberration and arises due to the fact that focal length of a lens is different for different colors.

For a single lens
$$\frac{1}{f} = (\mu - 1) \left[\frac{1}{R_1} - \frac{1}{R_2} \right]$$
 and as μ of lens is

maximum for violet while minimum for red, violet is focused nearest to the lens while red farthest from it. It is defect of lens.



Longitudinal or Axial Chromatic Aberration

When a white object O is situated on the axis of a lens, then images of different colors are formed at different points along the axis. The formation of images of different colors at different positions is called 'axial' or longitudinal chromatic aberration. The axial distance between the red and the violet images $I_R - I_V$ is known as longitudinal aberration. When white light is incident on lens, image is obtained at different point on the axis because focal length of lens depend on wavelength. $f \propto \lambda \Rightarrow f_R > f_V$

$$f_R - f_V = \omega f_V \Rightarrow Axial or longitudinal chromatic aberration$$

If the object is at infinity, then the longitudinal chromatic aberration is equal to the difference in focal-lengths $(f_R f_V)$ for the red and the violet rays.

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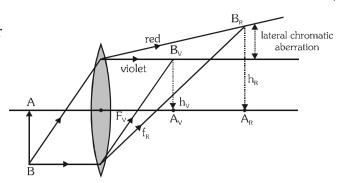
LATERAL CHROMATIC ABERRATION

As the focal-length of the lens varies from color

to color, the magnification $m = \left[\frac{f}{u+f}\right]$

produced by the lens also varies from color to color.

Therefore, for a finite-size white object AB, the images of different colors formed by the lens are of different sizes.



The formation of images of different colors in different sizes is called lateral chromatic aberration.

The difference in the height of the red image $B_R A_R$ and the violet image $B_V A_V$ is known as lateral chromatic aberration. $LCA = h_R - h_V$

ACHROMATISM

If two or more lens combined together in such a way that this combination produce image at a same point then this combination is known as achromatic combination of lenses.

$$\frac{\omega}{f_{_{_{\boldsymbol{y}}}}} + \frac{\omega'}{f_{_{_{\boldsymbol{y}}}}} = 0 \Longrightarrow \frac{\omega_{_{\boldsymbol{1}}}}{f_{_{\boldsymbol{1}}}} + \frac{\omega_{_{\boldsymbol{2}}}}{f_{_{\boldsymbol{2}}}} = 0 \Longrightarrow \frac{\omega_{_{\boldsymbol{1}}}}{\omega_{_{\boldsymbol{2}}}} = -\frac{f_{_{\boldsymbol{1}}}}{f_{_{\boldsymbol{2}}}}$$

For combination of lens. $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$ (Apply sign convention in numerical)

Ex. A flint glass convex lens of focal length 16 cm is placed in contact with crown glass lens. The refractive indices of crown glass for violet and red colour are $\mu_v = 1.525$, $\mu_r = 1.515$ and for flint glass $\mu_{v'} = 1.655$ and $\mu_{r'} = 1.645$.

(a) Find the nature and focal length of the crown glass lens which will form an achromatic combination with the flint glass lens.

(b) What is the focal length of the combination?

Ans. (a) f = -20 cm, (b) + 80 cm, convergent achromatic lens]

Sol. For achromatic combination of lens,

$$\frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0$$

$$\omega = \frac{\mu_{v} - \mu_{r}}{\left(\frac{\mu_{v} + \mu_{r}}{2}\right) - 1}$$

crown glass
$$\omega_1 = \frac{1.525 - 1.515}{\left(\frac{1.525 + 1.515}{2}\right) - 1} = \frac{0.010}{0.520} = \frac{1}{52}$$

flint glass
$$\omega_2 = \frac{1.655 - 1.645}{\left(\frac{1.655 + 1.645}{2}\right) - 1} = \frac{0.010}{0.650} = \frac{1}{65}$$

focal length of combination.

$$\frac{1}{F_{eq}} = \frac{1}{f_1} + \frac{1}{f_2}$$

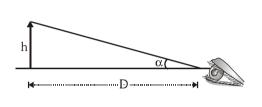
$$=\frac{1}{16}-\frac{1}{20}$$

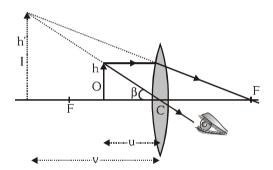
 $F_{eq} = +80$ cm converging.

OPTICAL INSTRUMENTS

Simple microscope

When object is placed between focus and optical centre a virtual, magnified and erect image is formed





Magnifying power (MP) =
$$\frac{\text{visual angle with instrument (}\beta\text{)}}{\text{maximum visual angle for unaided eye (}\alpha\text{)}} \Rightarrow \text{MP} = \frac{\frac{h}{-u}}{\frac{h}{-D}} = \frac{D}{u}$$

(i) When the image is formed at infinity:

by lens equation
$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{-\infty} - \frac{1}{-u} = \frac{1}{f} \Rightarrow u = f$$
 So $MP = \frac{D}{u} = \frac{D}{f}$

(ii) If the image is at minimum distance of clear vision D:

$$\frac{1}{-D} - \frac{1}{-u} = \frac{1}{f} \Rightarrow \frac{1}{u} = \frac{1}{D} + \frac{1}{f} \quad [v = -D \text{ and } u = -ve]$$

Multiplying by D both the sides
$$\frac{D}{u} = 1 + \frac{D}{f} \Rightarrow MP = \frac{D}{u} = 1 + \frac{D}{f}$$

Ex. A man with normal near point 25 cm reads a book with small print using a magnifying glass, a thin convex lens of focal length 5 cm.

(a) What is the closest and farthest distance at which he can read the book when viewing through the magnifying glass?

(b) What is the maximum and minimum MP possible using the above simple microscope?

Sol. (a) As for normal eye far and near point are ∞ and 25 cm respectively, so for magnifier $v_{max} = -\infty$ and

$$v_{min} = -25$$
 cm. However, for a lens as $\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow u = \frac{f}{(f/v) - 1}$

So u will be minimum when v = minimum = -25 cm i.e. $(u)_{min} = \frac{5}{-(5/25)-1} = -\frac{25}{6} = -4.17$ cm

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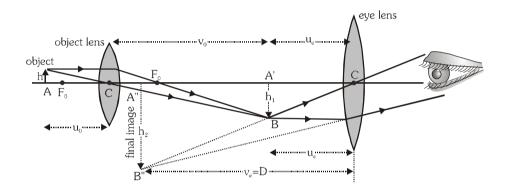
So the closest and farthest distance of the book from the magnifier (or eye) for clear viewing are 4.17 cm and 5 cm respectively.

(b) As in case of simple magnifier MP = (D/u). So MP will be minimum when u = max = 5 cm

$$\Rightarrow$$
 $(MP)_{min} = \frac{-25}{-5} = 5 \left[= \frac{D}{f} \right]$ and MP will be maximum when $u = min = (25/6)$ cm

$$\Rightarrow (MP)_{max} = \frac{-25}{-(25/6)} = 6 \left[= 1 + \frac{D}{f} \right]$$

COMPOUND MICROSCOPE



Compound microscope is used to get more magnified image. Object is placed infront of objective lens and image is seen through eye piece. The aperture of objective lens is less as compare to eye piece because object is very near so collection of more light is not required. Generally object is placed between F-2F due to this a real inverted and magnified image is formed between $2F-\infty$. It is known as intermediate image A'B'. The intermediate image act as a object for eye piece. Now the distance between both the lens are adjusted in such a way that intermediate image falls between the optical centre of eye piece and its focus. In this condition, the final image is virtual, inverted and magnified.

Total magnifying power = Linear magnification × angular magnification MP = $m_0 m_e = \frac{v_0}{11.11}$

(i) When final image is formed at minimum, distance of distinct vision.

$$MP = \frac{v_0}{u_0} \left[1 + \frac{D}{f_e} \right] = \frac{f_0}{f_0 + u_0} \left[1 + \frac{D}{f_e} \right] = \frac{f_0 - v_0}{f_0} \left[1 + \frac{D}{f_e} \right] = \frac{h_2}{h_1} \left(1 + \frac{D}{f_e} \right)$$

Length of the tube = $v_0 + |u_e|$

(ii) When final image is formed at infinity $\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o} \Rightarrow \frac{1}{\infty} + \frac{1}{u_o} = \frac{1}{f} \Rightarrow u_e = f_e$

$$MP = \frac{v_0}{u_0} \left\lceil \frac{D}{f_e} \right\rceil = \frac{f_0}{f_0 + u_0} \left\lceil \frac{D}{f_e} \right\rceil = \frac{f_0 - v_0}{f_0} \left\lceil \frac{D}{f_e} \right\rceil = \frac{h_2}{h_1} \left\lceil \frac{D}{f_e} \right\rceil. \text{ Length of the tube } L = v_0 + f_e$$

Sign convention for solving numerica
$$u = -ve$$
, $v = -ve$, $f = +ve$.

- **Ex.** A thin convex lens of focal length 5 cm is used as a simple microscope by a person with normal near point (25 cm). What is the magnifying power of the microscope?
- **Sol.** Here, f = 5 cm; D = 25 cm, M = ? MP = $1 + \frac{D}{f} = 1 + \frac{25}{5} = 6$
- **Ex.** A compound microscope consists of an objective lens of focal length 2.0 cm and an eye piece of focal length 6.25 cm, separated by a distance of 15 cm. How far from the objective should an object be placed in order to obtain the final image at (a) the least distance of distinct vision (25 cm) (b) infinity?
- **Sol.** Here, $f_0 = 2.0$ cm; $f_e = 6.25$ cm, $u_0 = ?$

(a)
$$v_e = -25 \text{ cm} : \frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e} : \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = \frac{1}{-25} - \frac{1}{6.25} = \frac{-1-4}{25} = \frac{-5}{25} \implies u_e = -5 \text{ cm}$$

As distance between objective and eye piece = 15 cm; $v_0 = 15 - 5 = 10$ cm

$$\because \frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0} \therefore \frac{1}{u_0} = \frac{1}{v_0} - \frac{1}{f_0} = \frac{1}{10} - \frac{1}{2} = \frac{1-5}{10} \Rightarrow u_0 = \frac{-10}{4} = -2.5 \text{ cm}$$

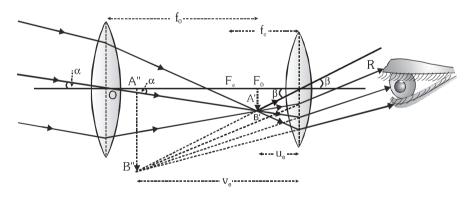
Magnifying power =
$$\frac{v_0}{|u_0|} \left[1 + \frac{D}{f_e} \right] = \frac{10}{2.5} \left[1 + \frac{25}{6.25} \right] = 20$$

(b) :
$$v_e = \infty$$
, $u_e = f_e = 6.25$ cm : $v_0 = 15 - 6.25 = 8.75$ cm.

$$\because \frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0} \Rightarrow \frac{1}{u_0} = \frac{1}{v_0} - \frac{1}{f_0} = \frac{1}{8.75} - \frac{1}{20} = \frac{2 - 8.75}{17.5} \Rightarrow u_0 = \frac{-17.5}{6.75} = -2.59 cm$$

Magnifying power =
$$\frac{v_0}{|u_0|} \times \left[1 + \frac{D}{f_e}\right] = \frac{v_0}{|u_0|} \times \frac{D}{|u_e|} = \frac{8.75}{2.59} \times \frac{25}{6.25} = 13.51$$

ASTRONOMICAL TELESCOPE



A telescope is used to see distant object, objective lens forms the image A'B' at its focus. This image A'B' acts as a object for eyepiece and it forms final image A"B".

$$MP = \frac{\text{visual angle with instrument (\beta)}}{\text{visual angle for unaided eye (\alpha)}} \Rightarrow MP = \frac{\frac{\underline{h'}}{f_0}}{\underline{-u_e}} = -\frac{\underline{f_0}}{\underline{u_e}} [A'B' = h']$$

(i) If the final image is at infinity $v_e^{} = -\infty$, $u_e^{} = -ve$

$$\frac{1}{-\infty} - \frac{1}{-u_e} = \frac{1}{f_e} \Rightarrow u_e = f_e . \text{ So MP} = -\frac{f_0}{f_e} \text{ and length of the tube } L = f_0 + f_e$$

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$$u_e = -ve$$

$$\frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{f_e} \Rightarrow \frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D} = \frac{1}{f_e} \left[1 + \frac{f_e}{D} \right] \text{ So } MP = -\frac{f_0}{u_e} = -\frac{f_0}{f_0} \left[1 + \frac{f_e}{D} \right]$$

Length of the tube is $L = f_0 + u_e$

S. No.	Compound - Microscope	S. No.	Astronomical – Telescope
1.	It is used to increase visual angle of near tiny object.	1.	It is used to increase visual angle of distant large objects.
2.	In it field and eye lens both are convergent, of short focal length and aperture.	2.	In it objective lens is of large focal length and aperture while eye lens of short focal length and aperture and both are convergent.
3.	Final image is inverted, virtual and enlarged and at a distance D to ∞ from the eye.	3.	Final image is inverted, virtual and enlarged at a distance D to ∞ from the eye.
4.	MP does not change appreciably if objective and eye lens are interchanged as [MP \sim (LD $/$ f ₀ f _e)]	4.	MP becomes (1/m²) times of its initial value if objective and eye-lenses are interchanged as MP \sim [f $_0$ / f $_e$]
5.	MP is increased by decreasing the focal length of both the lenses.	5.	MP is increased by increasing the focal length of objective lens and by decreasing the focal length of eyepiece
6.	RP is increased by decreasing the wavelength of light used. $\left(\because RP = \frac{2\mu\sin\theta}{\lambda}\right)$	6.	RP is increased by increasing the aperture of objective. $\left(\because RP = \frac{D}{1.22\lambda}\right)$

- **Ex.** A small telescope has an objective lens of focal length 144 cm and an eyepiece of focal length 6.0 cm. What is the magnifying power of the telescope? What is the separation between the objective and the eyepiece? When final image is formed at infinity.
- **Sol.** Here, $f_0 = 144$ cm; $f_e = 6.0$ cm, MP = ?, L = ?

$$MP = \frac{-f_0}{f_0} = \frac{-144}{6.0} = -24$$
 and $L = f_0 + f_e = 144 + 6.0 = 150.0$ cm

- **Ex.** Diameter of the moon is 3.5×10^3 km and its distance from earth is 3.8×10^5 km. It is seen by a telescope whose objective and eyepiece have focal lengths 4m and 10cm respectively. What will the angular diameter of the image of the moon.
- $\textbf{Sol.} \quad \text{MP} = -\frac{f_0}{f_e} = -\frac{400}{10} = -40 \text{ . Angle subtended by the moon at the objective} = \frac{3.5 \times 10^3}{3.8 \times 10^5} = 0.009 \text{ radian.}$

Thus angular diameter of the image = MP \times visual angle = $40 \times 0.009 = 0.36$ radian = $\frac{0.36 \times 180}{3.14} \approx 21^{\circ}$

Ex. A telescope consisting of an objective of focal length 60 cm and a single-lens eyepiece of focal length 5 cm is focussed at a distant object in such a way that parallel rays emerge from the eye piece. If the object subtends an angle of 2° at the objective, then find the angular width of the image.

Sol.
$$MP = \frac{f_0}{f_0} = \frac{\beta}{\alpha} \Rightarrow \beta = \alpha \frac{f_0}{f_0} = 2^\circ \times \frac{60}{5} = 24^\circ$$

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- **Ex.** The focal lengths of the objective and the eye piece of an astronomical telescope are 60 cm and 5 cm respectively. Calculate the magnifying power and the length of the telescope when the final image is formed at (i) infinity, (ii) least distance of distinct vision (25 cm)
- **Sol.** (i) When the final image is at infinity, then:

$$MP = -\frac{f_0}{f_e} = -\frac{60}{5} = -12$$
 and length of the telescope is $L = f_0 + f_e = 60 + 5 = 65$ cm

(ii) For least distance of distinct vision, the magnifying power is:

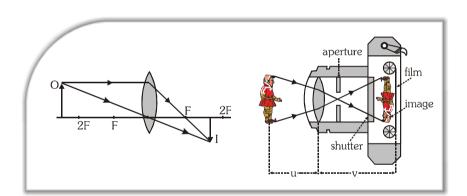
$$MP = -\frac{f_0}{f_e} \bigg(1 + \frac{f_e}{D} \bigg) = -\frac{60}{5} \bigg(1 + \frac{5}{25} \bigg) = -\frac{12 \times 6}{5} = -14.4$$

Now
$$\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e} \Rightarrow \frac{1}{5} = -\frac{1}{25} \frac{1}{u_e} \Rightarrow \frac{-1}{u_e} = \frac{1}{25} + \frac{1}{5} \Rightarrow u_e = -4.17 \text{ cm } \Rightarrow |u_e| = 4.17 \text{ cm}$$

The length of telescope in this position is $L = f_0 + |u_e| = 60 + 4.17 = 64.17$ cm

LENS - CAMERA

There is a convex lens whose aperture and distance from the film can be adjusted. Object is real and placed between ∞ and 2F, so the image is real, inverted diminished and between F and 2F.



If I is the intensity of light, S is the light transmitting area of lens and t is the exposure time, then for proper exposure, $I \times S \times t = constant$

light transmitting area of a lens is proportional to the square of its aperture D; $I \times D^2 \times t = constant$ If aperture is kept fixed, for proper exposure, $I \times t = constant$, i.e., $I_1 t_1 = I_2 t_2$ If intensity is kept fixed, for proper exposure, $D^2 \times t = constant$

Time of exposure
$$\propto \frac{1}{(aperture)^2}$$
 ... (i)

The ratio of focal length to the aperture of lens is called f-number of the camera,

$$f$$
-number = $\frac{focal\ length}{aperture} \Rightarrow Aperture \propto \frac{1}{f-number} ... (ii)$

From equation (i) and (ii) \Rightarrow Time of exposure \propto (f-number)²

24



- Ex. With diaphragm of the camera lens set at $\frac{f}{2}$, the correct exposure time is $\frac{1}{100}$, then with diaphragm set at $\frac{f}{4}$. Calculate the correct exposure time.
- **Sol.** As exposure time $\propto \frac{1}{(\text{aperture})^2} \Rightarrow t_1 \propto \frac{1}{[f/2]^2}$ and $t_2 \propto \frac{1}{[f/4]^2}$

here
$$t_1 = \frac{1}{100}s$$
 then $\frac{t_2}{t_1} = \frac{16}{4} = 4 \Rightarrow t_2 = 4t_1 = \frac{4}{100}s$

- **Ex.** A good photographic print is obtained by an exposure of two seconds at a distance of 20 cm from the lamp. Calculate the time of exposure required to get an equally good result at a distance of 40 cm.
- **Sol.** We know that the intensity of light varies inversely as the (distance)². When distance is doubled, the intensity becomes one–fourth. So, the time of exposure should be four times. Hence, time of exposure $= 2 \times 4 = 8 \text{ s}$
- **Ex.** Photograph of the ground are taken from an aircraft, flying at an altitude of 2000 m, by a camera with a lens of focal length 50 cm. The size of the film in the camera is $18 \text{ cm} \times 18 \text{ cm}$. What area of the ground can be photographed by this camera at any one time.
- **Sol.** As here u = -2000m, f = 0.50m, so from lens formula $\frac{1}{v} \frac{1}{u} = \frac{1}{f}$,

we have
$$\frac{1}{v} - \frac{1}{(-2000)} = \frac{1}{0.5} \Rightarrow \frac{1}{v} = \frac{1}{0.5} - \frac{1}{2000} \approx \frac{1}{0.5} \left[as \frac{1}{0.5} >> \frac{1}{2000} \right] \Rightarrow v = 0.5m = 50 \text{ cm} = f$$

Now as in case of a lens,
$$m = \frac{v}{u} = \frac{0.5}{-2000} = -\frac{1}{4} \times 10^{-3}$$
 So $I_1 = (ma) (mb) = m^2 A [\because A = ab]$

A =
$$\frac{I_1}{m^2}$$
 = $\frac{18 \text{cm} \times 18 \text{cm}}{\left[(1/4) \times 10^{-3} \right]^2}$ = (720 m × 720 m)

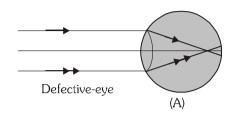
- **Ex.** The proper exposure time for a photographic print is 20 s at a distance of 0.6 m from a 40 candle power lamp. How long will you expose the same print at a distance of 1.2 m from a 20 candle power lamp?
- **Sol.** In case of camera, for proper exposure $I_1D_1^2t_1 = I_2D_2^2t_2$

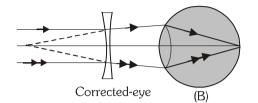
As here D is constant and I = (L/r²);
$$\frac{L_1}{r_1^2} \times t_1 = \frac{L_2}{r_2^2} \times t_2$$

So
$$\frac{40}{(0.6)^2} \times 20 = \frac{20}{(1.2)^2} t \Rightarrow t = 160 \text{ s}$$

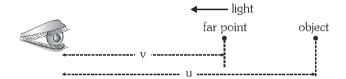
DEFECTS OF EYES

MYOPIA [or Short-sightedness or Near-sightedness]





- (i) Distant object are not clearly visible, but near object are clearly visible because image is formed before the retina.
- (ii) To remove the defect concave lens is used.
- The maximum distance. Which a person can see without help of spectacles is known as far point.

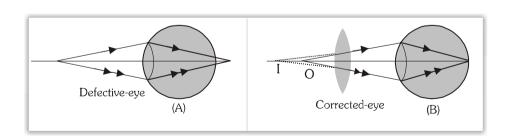


- If the reference of object is not given then it is taken as infinity.
- In this case image of the object is formed at the far point of person.

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} = P \Rightarrow \frac{1}{\text{distance of far point (in m)}} - \frac{1}{\text{distance of object (in m)}} = \frac{1}{f} = P$$

$$\frac{100}{\text{distance of far point (in cm)}} - \frac{100}{\text{distance of object (in cm)}} = P$$

LONG-SIGHTEDNESS OR HYPERMETROPIA



- (i) Near object are not clearly visible but far object are clearly visible.
- (ii) The image of near object is formed behind the retina.
- (iii) To remove this defect convex lens is used.

Near Point:-

The minimum distance which a person can see without help of spectacles.



- In this case image of the object is formed at the near point.
- If reference of object is not given it is taken as 25 cm.

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} = P \Rightarrow \frac{1}{\text{distance of near point (in m)}} - \frac{1}{\text{distance of object (in m)}} = \frac{1}{f} = P$$

distance of near point = -ve, distance of object = -ve, P = +ve

PRESBYOPIA

In this case both near and far object are not clearly visible. To remove this defect two separate spectacles one for myopia and other for hypermetropia are used or bifocal lenses are used.

ASTIGMATISM

In this defect eye can not see object in two orthogonal direction clearly. It can be removed by using cylindrical lens in particular direction.

- **Ex.** A person can not see clearly an object kept at a distance beyond of 100 cm. Find the nature and the power of lens to be used for seeing clearly the object at infinity.
- **Sol.** For lens $u = -\infty$ and and v = -100 cm

$$\therefore \frac{1}{v} - \frac{1}{u} = \frac{1}{f} = \frac{1}{v} = \frac{1}{f} \Rightarrow f = v = -100 cm (concave) \quad \therefore \quad Power \ of \ lens \quad P = \frac{1}{f} = -\frac{1}{1} = -1D$$

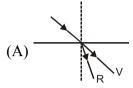
- **Ex.** A far sighted person has a near point of 60 cm. What power lens should be used for eye glasses such that the person can read this book at a distance of 25 cm.
- **Sol.** Here v = -60 cm, u = -25 cm

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = -\frac{1}{60} + \frac{1}{25} \Rightarrow f = \frac{300}{7} cm :: Power = \frac{1}{f(in \ m)} = \frac{1}{(3/7)} = +2.33D$$

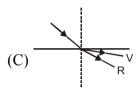
OBJECTIVE (O)

Dispersion:

1. A ray of light is coming from air to water. Which of the following figure shows correct dispersion of light?







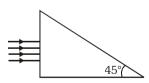


- 2. When white light passes through a glass prism, one gets spectrum on the other side of the prism. In the emergent beam, the ray which is deviating least is or deviation by a prism is lowest for
 - (A) Violet ray

(B) Green ray

(C) Red ray

- (D) Yellow ray
- 3. The angle of prism is 5° and its refractive indices for red and violet colours are 1.5 and 1.6 respectively. The angular dispersion produced by the prism is :-
 - (A) 7.75°
- (B) 5°
- (C) 0.5°
- (D) 0.17°
- 4. A beam of light consisting of red, green and blue and is incident on a right angled prism. The refractive index of the material of the prism for the above red, green and blue wavelengths are 1.39, 1.44 and 1.47 respectively. The prism will



- (A) separate part of the red color from the green and blue colors
- (B) separate part of the blue color from the red and green colors
- (C) separate all the three colors from the other two colors
- $(\ensuremath{\mathrm{D}})$ not separate even partially, any colors from the other two colors
- 5. Two thin prisms of flint glass, with refracting angles of 6° and 8° respectively, possess dispersive powers in the ratio:
 - (A) 4:3
- (B) 3:4
- (C) 1 : 1
- (D) 9: 16

- **6.** Chromatic aberration will be absent if for two thin lenses in contact :-
 - (A) $(\omega_1/F_1) + (\omega_2/F_2) = 0$

(B) $(\omega_1/F_2) + (\omega_2/F_1) = 0$

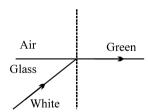
 $(C) (F_1/\omega_2) + (F_2/\omega_1) = 0$

- (D) $(\omega_1/\omega_2) + (F_1 + F_2) = 0$
- 7. The dispersive powers of the materials of the two lenses are in the ratio 4 : 3. If the achromatic combination of these two lenses in contact is a convex lens of focal length 60 cm then the focal lengths of the component lenses are
 - (A) 20 cm and 25 cm

(B) 20 cm and - 25 cm

(C) - 15 cm and 40 cm

- (D) 15 cm and 20 cm
- 8. An achromatic convergent doublet of two lenses in contact has a power of +2D. The convex lens has a power +5D. What is the ratio of the dispersive powers of the convergent and divergent lenses
 - (A) 2:5
- (B) 3:5
- (C) 5:2
- (D) 5:3
- 9. It is desired to make an achromatic combination of two lenses $(L_1 \& L_2)$ made of materials having dispersive powers ω_1 and ω_2 ($<\omega_1$). If the combination of lenses is converging then
 - (A) L₁ is converging
 - (B) L, is converging
 - (C) Power of L_1 is greater than the power of L_2
 - (D) None of these
- 10. White light is incident on the interface of glass and air as shown in the figure. If green light is just totally internally reflected then the emerging ray in air contains [IIT-JEE 2004 (Scr)]



(A) yellow, orange, red

(B) violet, indigo, blue

(C) all colours

- (D) all colours except green
- 11. Myopia can be removed by using a lenses of
 - (A) concave lens

(B) convex lens

(C) cylindrical lens

- (D) by surgical removal
- 12. Loss of the ability of eye to focus on near and far objects with advancing age is called
 - (A) Presbyopia

(B) Astigmatism

(C) Hypermetropia

(D) Myopia

13.	A long sighted person has a minimum distance of distinct vision of 50 cm. He wants to reduce it to				
	25cm. He should use a				
	(A) Concave lens of focal length 50 cm				
	(B) Convex lens of focal length 25 cm				
	(C) Convex lens of focal length 50 cm				
	(D) Concave lens of focal length 25 cm				
14.	4. A person's near point is 50 cm and his far point is 3m. Powers of the lenses he required for				
	reading (ii) for viewing distinct stars				
		B) 2D and - 0.33 D			
	(C) - 2D and 3D (D)	D) 2D and - 3 D			
15.	In a simple microscope, if the final image is locate	ed at infinity then its magnifying power			
	(A) $25/F$ (E)	B) 25/D			
	(C) $F/25$	O) (1+25/F)			
16.	In a compound microscope, the intermediate imag	ge, in normal use is			
	(A) Virtual, erect and magnified				
	(B) Real, erect and magnified				
	(C) Real, inverted and magnified				
	(D) Virtual, inverted and magnified				
17.	If tube length of astronomical telescope is 105 cm	n and magnifying power is 20 for normal setting.			
	Calculate the focal length of objective:-				
	(A) 100 cm (E)	3) 10 cm			
	(C) 20 cm (I	O) 25 cm			
18.	When length of a compound microscope tube increase, its magnifying power				
	(A) decreases				
	(B) increases				
	(C) does not change				
	(D) may increase or decrease				
19.					
	44 cm. The focal length of the objective is :-				
	(A) 4 cm (B) 40 cm (C)	C) 44 cm (D) 440 cm			
20.	When the length of an astronomical telescope tube	e increases its magnifying power			
	(A) Decreases				
	(B) Increases				
	(C) Does not change				
	(D) May increase of decrease				
21.	· · ·	of 120 cm and diameter 5 cm. The focal length of			
	the eye-piece is 2 cm. The magnifying power of te	_			

(C) 60

(D) 300

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(A) 12

(B) 24

- - (A) 18cm, 2cm

(B) 4cm, 16cm

(C) 10cm, 10cm

- (D) 12cm, 8cm
- 24. When monochromatic red light is used instead of blue light in a convex lens, its focal length will:-

[AIEEE- 2011]

- (A) Does not depend on colour of light
- (B) Increase
- (C) Decrease
- (D) Remain same
- **25.** A green light is incident from the water to the air - water interface at the critical angle (θ) . Select the correct statement. [JEE-Main- 2014]
 - (A) The spectrum of visible light whose frequency is more than that of green light will come out to the air medium.
 - (B) The entire spectrum of visible light will come out of the water at various angles to the normal
 - (C) The entire spectrum of visible light will come out of the water at an angle of 90° to the normal.
 - (D) The spectrum of visible light whose frequency is less than that of green light will come out to the air medium.
- 26. An observer looks at a distant tree of height 10 m with a telescope of magnifying power of 20. To the observer the tree appears: [JEE-Main- 2016]
 - (A) 20 times nearer

(B) 10 times taller

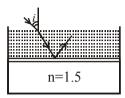
(C) 10 times nearer

(D) 20 times taller

Paragraph for Question 27 to 30

- If an astronomical telescope has objective and eye-pieces of focal lengths 200 cm and 4 cm 27. respectively, then the magnifying power of the telescope for the normal vision is
 - (A) 42
- (B) 50
- (C) 58
- (D) 204
- 28. In the above question the length of the telescope for normal vision, is
 - (A) 204 cm
- (B) 200 cm
- (C) 196 cm
- (D) 203.45 cm
- **29.** In the above question magnifying power of the telescope for distinct vision is
 - (A) 42
- (B) 50
- (C)58
- (D) 204
- In the above question the length of the telescope for distinct vision is 30.
 - (A) 204 cm
- (B) 200 cm
- (C) 196 cm
- (D) 203.45 cm

31. Consider a tank made of glass(reiractive index 1.5) with a thick bottom. It is filled with a liquid of refractive index μ,. A student finds that, irrespective of what the incident angle *i* (see figure) is for a beam of light entering the liquid, the light reflected from the liquid glass interface is never completely polarized. For this to happen, the minimum value of μ is : [JEE Main-2019_Jan]

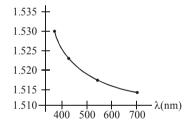


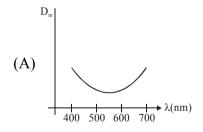
- $(A) \ \frac{3}{\sqrt{5}}$
- (B) $\frac{5}{\sqrt{3}}$
- (C) $\sqrt{\frac{5}{3}}$
- (D) $\frac{4}{3}$
- 32. The eye can be regarded as a single refracting surface. The radius of curvature of this surface is equal to that of cornea (7.8 mm). This surface separates two media of refractive indices 1 and 1.34. Calculate the distance from the refracting surface at which a parallel beam of light will come to focus.

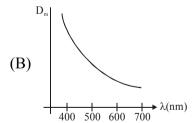
[JEE Main-2019_Jan]

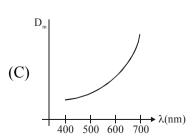
- (A) 2 cm
- (B) 1 cm
- (C) 3.1 cm
- (D) 4.0 cm
- 33. The variation of refractive index of a crown glass thin prism with wavelength of the incident light is shown. Which of the following graphs is the correct one, if D_m is the angle of minimum deviation?

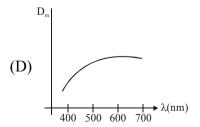
[JEE Main-2019_Jan]











34. Calculate the limit of resolution of a telescope objective having a diameter of 200 cm, if it has to detect light of wavelength 500 nm coming from a star:- [JEE Main-2019 April]

(A) 305×10^{-9} radian

(B) 152.5×10^{-9} radian

(C) 610×10^{-9} radian

- (D) 457.5×10^{-9} radian
- **35.** The wavelength of the carrier waves in a modern optical fiber communication network is close to :

[JEE Main-2019_April]

(A) 600 nm

(B) 900 nm

(C) 2400 nm

- (D) 1500 nm
- **36.** Diameter of the objective lens of a telescope is 250 cm. For light of wavelength 600nm. coming from a distant object, the limit of resolution of the telescope is close to: [JEE Main-2019_April]

(A) 1.5×10^{-7} rad

(B) 2.0×10^{-7} rad

(C) 3.0×10^{-7} rad

- (D) 4.5×10^{-7} rad
- 37. The value of numerical aperature of the objective lens of a microscope is 1.25. If light of wavelength 5000 Å is used, the minimum separation between two points, to be seen as distinct, will be:

[JEE Main-2019_April]

(A) $0.24 \mu m$

(B) $0.48 \mu m$

(C) $0.12 \, \mu m$

(D) 0.38 µm

MODERN PHYSICS

THEORY

ABSORPTION OF X-RAY

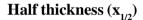
When X-ray passes through x thickness then its intensity $I = I_0 e^{-\mu x}$

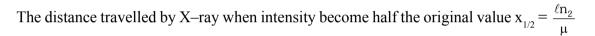
 $I_0 = Intensity of incident X-ray$

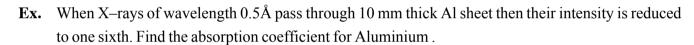
I = Intensity of X-ray after passing through x distance

 μ = absorption coefficient of material

- Intensity of X–ray decrease exponentially.
- Maximum absorption of X-ray \rightarrow Lead (Pb)
- Minimum absorption of X-ray \rightarrow Air







$$\textbf{Sol.} \quad \mu = \frac{2.303}{x} \quad log \bigg(\frac{I_o}{I}\bigg) \ = \frac{2.303}{10} log_{10} \ 6 = \frac{2.303 \times 0.7781}{10} = 0.1752 / mm$$

DIFFRACTION OF X-RAY

Diffraction of X–ray is possible by crystals because the interatomic spacing in a crystal lattice is order of wavelength of X–rays it was first verified by Lauve.

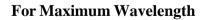
Diffraction of X-ray take place according to Bragg's law $2d \sin\theta = n\lambda$

d = spacing of crystal plane or lattice constant or distance

between adjacent atomic plane

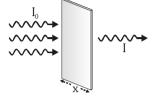
 θ = Bragg's angle or glancing angle

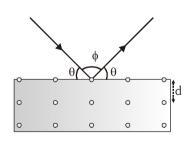
 ϕ = Diffracting angle n = 1, 2, 3



$$\sin \theta = 1, n = 1 \Rightarrow \lambda_{max} = 2d$$

so if $\lambda > 2d$ diffraction is not possible i.e. solution of Bragg's equation is not possible.





OBJECTIVE (O)

- 1. The intensity of gamma radiation from a given source is I. On passing through 36 mm of lead, it is reduced to I/8. The thickness of lead, which will reduce the intensity to I/2 will be-[AIEEE-2005]

 (A) 6 mm
 (B) 9 mm
 (C) 18 mm
 (D) 12 mm
- 2. Match List-I (Fundament Experiment) with List-II (its conclusion) and select the correct option from the choices given below the list: [JEE Main-2015]

	List-I		List-II
(A)	Franck-Hertz Experiment.	(i)	Particle nature of light
(B)	Photo-electric experiment	(iii)	Discrete energy levels of atom
(C)	Davison-Germer Experiment	(iiii)	Wave nature of electroc
		(iv)	Structure of atom

(A) A-ii, B-i, C-iii

(B) A-iv, B-iii, C-ii

(C) A-i, B-iv, C-iii

(D) A-ii, B-iv, C-iii

SEMICONDUCTOR

THEORY

ENERGY BANDS IN SOLIDS

Based on Pauli's exclusion principle

In an isolated atom electrons present in energy level but in solid, atoms are not isolated, there is interaction among each other, due to this energy level splited into different energy levels. Quantity of these different energy levels depends on the quantity of interacting atoms. Splitting of sharp and closely compact energy levels result into energy band. This is discrete in nature. Order of energy levels in a band is 10^{23} and their energy difference = 10^{-23} eV.

Energy Band

Range of energy possessed by electron in a solid is known as energy band.

Valence Band (VB)

Range of energies possessed by valence electron is known as valence band.

- (a) Have bonded electron.
- (b) No flow of current due to such electron.
- (c) Always fulfill by electron.

Conduction Band (CB)

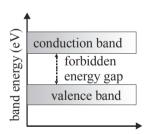
Range of energies possessed by free electron is known as conduction band.

- (a) It has conducting electrons.
- (b) Current flows due to such electrons.
- (c) If conduction band is fully empty then current conduction is not possible.
- (d) Electrons may exist or not in it.

Forbidden Energy gap (FEG) (ΔEg)

$$\Delta E_{g} = (C B)_{min} - (V B)_{max}$$

Energy gap between conduction band and valence band, where no free electron can exist.



- Width of forbidden energy gap depends upon the nature of substance.
- Width is more, then valence electrons are strongly attached with nucleus
- Width of forbidden energy gap is represented in eV.
- As temperature increases forbidden energy gap decreases (very slightly).

CLASSIFICATION OF CONDUCTORS, INSULATORS AND SEMICONDUCTOR: -

On the basis of the relative values of electrical conductivity and energy bands the solids are broadly classified into three categories

- (i) Conductor
- (ii) Semiconductor
- (iii) Insulator

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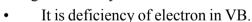
Comparison between conductor, semiconductor and insulator:

Properties	Conductor	Semiconductor	Insulator
Resistivity	$10^{-2} - 10^{-8} \Omega \mathrm{m}$	$10^{-5} - 10^{6} \Omega \mathrm{m}$	$10^{11} - 10^{19} \Omega m$
Conductivity	$10^2 - 10^8 \text{ mho/m}$	$10^5 - 10^{-6} \text{mho/m}$	$10^{-11} - 10^{-19} \text{mho/m}$
Temp. Coefficient	Positive	Negative	Negative
of resistance (α)			
Current	Due to free	Due to electrons	No current
	electrons	and holes	
Energy band diagram	Conduction Band No gap region Valence Band Conductor	Conduction Band / Conduction Band / Conduction Band / Es Valence Band Semi conductor	Conduction Band Conduction Band Established Established Forbidden Established Valence Band Insulator
Forbidden energy gap	≅ 0eV	≅ 1eV	≥ 3eV
Example:	Pt, Al, Cu, Ag	Ge, Si, GaAs,	Wood, plastic,
		GaF_2	Diamond, Mica

CONCEPT OF "HOLES" IN SEMICONDUCTORS

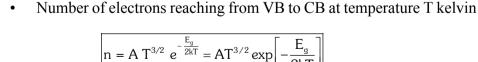
Due to external energy (temp. or radiation) when electron goes from valence band to conduction band (i.e. bonded electrons becomes free) a vacancy of free e⁻ creats in valence band,

which has same charge as electron but positive. This positively charged vaccancy is termed as hole and shown in figure.



- It acts as positive charge carrier.
- It's effective mass is more than electron.
- It's mobility is less than electron.

Note: Hole acts as virtual charge carrier, although it has no physical significance.



where

 $k = Boltzmann constant = 1.38 \times 10^{-23} J/K$

T = absolute temperature

A = constant

 E_{σ} = energy gap between CB and VB

- In silicon at room temperature out of 10^{12} Si atoms only one electron goes from VB to CB.
- In germanium at room temperature out of 109 Ge atoms only one electron goes from VB to CB.

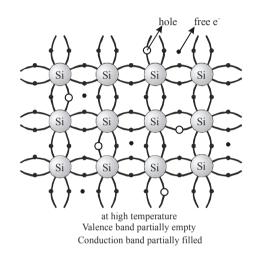
At absolute zero kelvin temperature

At this temperature covalent bonds are very strong and there are no free electrons and semiconductor behaves as perfect insulator.

Si Si

Above absolute temperature

With increase in temperature few valence electrons jump into conduction band and hence it behaves as poor conductor.



EFFECT OF IMPURITY IN SEMICONDUCTOR

Doping is a method of addition of "desirable" impurity atoms to pure semiconductor to increase conductivity of semiconductor.

Doping is a process of deliberate addition of a desirable impurity atoms to a pure semiconductor to modify its properties in controlled manner.

Added impurity atoms are called dopants.

The impurity added may be ≈ 1 part per million (ppm).

- The dopant atom should take the position of semiconductor atom in the lattice.
- The presence of the dopant atom should not distort the crystal lattice.
- The size of the dopant atom should be almost the same as that of the crystal atom.
- The concentration of dopant atoms should not be large (not more than 1% of the crystal atom).

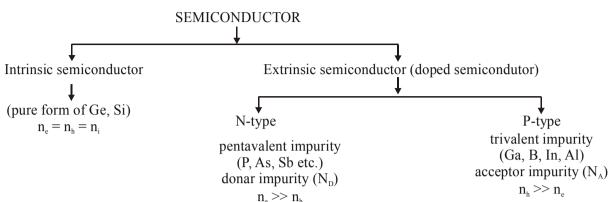
It is to be noted that the doping of a semiconductor increases its electrical conductivity to a great extent.

• The concentration of dopant atoms be very low, doping ratio is vary from

impure : pure :: $1 : 10^6$ to $1 : 10^{10}$ In general it is $1 : 10^8$

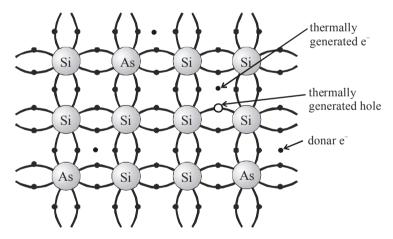
- There are two main method of doping.
 - (i) Alloy method (ii) Diffusion method (The best)
- The size of dopant atom (impurity) should be almost the same as that of crystal atom. So that crystalline structure of solid remain unchanged.

CLASSIFICATION OF SEMICONDUCTOR



N type semiconductor

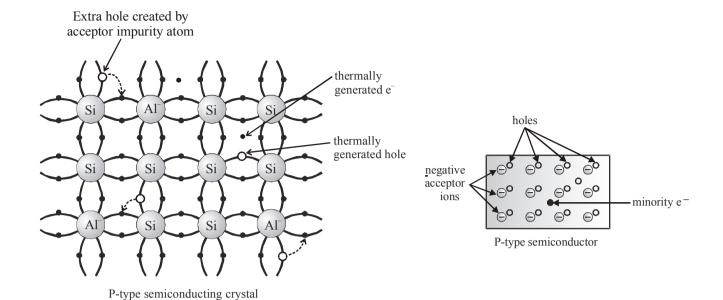
When a pure semiconductor (Si or Ge) is doped by pentavalent impurity (P, As, Sb, Bi) then four electrons out of the five valence electrons of impurity take part, in covalent bonding, with four silicon atoms surrounding it and the fifth electron is set free. These impurity atoms which donate free e⁻ for conduction are called as Donar impurity (N_D). Due to donar impurity free e⁻ increases very much so it is called as "N" type semiconductor. By donating e⁻ impurity atoms get positive charge and hence known as "Immobile Donar positive Ion". In N-type semiconductor free e⁻ are called as "majority" charge carriers and "holes" are called as "minority" charge carriers.



N-type semiconducting crystal

P type semiconductor

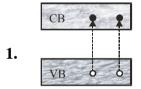
When a pure semiconductor (Si or Ge) is doped by trivalent impurity (B, Al, In, Ga) then outer most three electrons of the valence band of impurity take part, in covalent bonding with four silicon atoms surrounding it and except one electron from semiconductor and make hole in semiconductor. These impurity atoms which accept bonded e^- from valance band are called as Acceptor impurity (N_A). Here holes increases very much so it is called as "P" type semiconductor and impurity ions known as "Immobile Acceptor negative Ion". In P-type semiconductor free e^- are called as minority charge carries and holes are called as majority charge carriers.

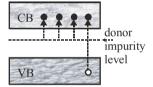


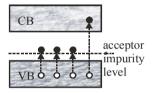
Intrinsic Semiconductor

N-type (Pentavalent impurity)

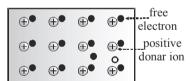
P-type(Trivalent impurity)

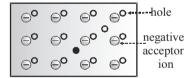












- 3. Current due to electron and ho
- electron and hole 4. n = n = n
- 4. $n_e = n_h = n_i$ 5. $I = I_e + I_h$
- **6.** Entirely neutral
- 7. Quantity of electrons and holes are equal
- Mainly due to electrons

$$\begin{split} & n_{_{h}} << n_{_{e}} \left(N_{_{D}} \ \underline{\sim} \, n_{_{e}}\right) \\ & I \,\underline{\sim} \, I_{_{e}} \end{split}$$

Entirely neutral

Majority - Electrons

Minority - Holes

Mainly due to holes

$$\begin{array}{l} n_{_{h}} >> n_{_{e}} \left(N_{_{A}} \ \underline{\sim} \ n_{_{h}}\right) \\ I \ \underline{\sim} \ I_{_{h}} \end{array}$$

Entirely neutral

Majority - Holes

Minority - Electrons

Mass action Law

In semiconductors due to thermal effect, generation of free e⁻ and hole takes place.

Apart from the process of generation, recombination also occurs simultaneously, in which free efurther recombine with hole.

E

40

At equilibrium rate of generation of charge carries is equal to rate of recombination of charge carrier.

The recombination occurs due to e^- colliding with a hole, larger value of n_e or n_h , higher is the probability of their recombination.

Hence for a given semiconductor rate of recombination $\propto n_{\rm e} \times n_{\rm h}$

so rate of recombination =
$$R n_e \times n_h$$
 $R = recombination coefficient,$

The value of R remains constant for a solid, according to the law of thermodynamics until crystalline lattice structure remains same.

For intrinsic semiconductor $n_e = n_h = n_i$

so rate of recombination = $R n_i^2$

$$R n_e \times n_h = R n_i^2 \implies n_i^2 = n_e \times n_h$$

Under thermal equilibrium, the product of the concentration ' n_e ' of free electrons and the concentration n_b of holes is a constant and it is independent of the amount of doping by acceptor and donor impurities.

Thus from mass action law $n_e \times n_h = n_1^2$

Electron-hole Recombination:

It is necessarly to complete a band that electron is shared from neighbouring atoms or it may also be received from conduction band. In the second case electron recombines with the hole of value band. This process is known as electron-hole recombination.

The breaking of bands or generation of electron-hole pairs, and completion of bands due to recombination is taking place continuously.

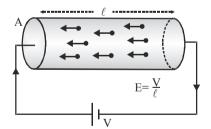
At equilibrium, the rate of generation becomes equal to the rate of recombination, giving a fixed number of free electrons and holes.

RESISTIVITY AND CONDUCTIVITY OF SEMICONDUCTOR

Conduction in conductor

Relation between current (I) and drift velocity (v_d)

$$I = neAv_d$$
 $n = number of electron in unit volume A= cross sectional area$



current density
$$J = \frac{I}{A} \text{ amp/m}^2 = \text{ne } v_d$$

drift velocity of electron
$$v_d = \mu E$$

$$J = ne \mu E$$

$$J = \sigma E$$

Conductivity
$$\sigma = ne\mu = 1/\rho$$

$$\rho = Resistivity$$

Mobility
$$\mu = \frac{v_d}{E}$$

Intrinsic semiconductor
$n_{e} = n_{h}$
$J = ne \left[v_e + v_h \right]$

$$\sigma = \frac{1}{\rho} = \text{en} \left[\mu_e + \mu_h \right]$$

$$\begin{array}{l}
n_h >> n_e \\
J \cong e \ n_h \ v_h
\end{array}$$

$$\sigma = \frac{1}{\rho} \, \cong e \, \, n_{_h} \, \mu_{_h}$$

$$\begin{array}{l} n_{_{e}} >> n_{_{h}} \\ J \stackrel{\cong}{=} e \; n_{_{e}} \, v_{_{e}} \end{array}$$

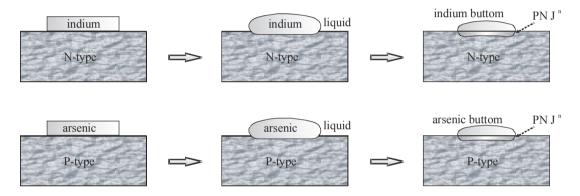
$$\sigma = \frac{1}{\rho} \cong e \, n_e \, \mu_e$$

P - N JUNCTION

Techniques for making P-N junction

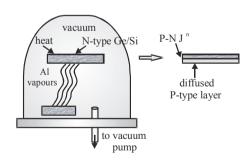
(i) Alloy Method or Alloy Junction

Here a small piece of III group impurity like indium is placed over n—Ge or n—Si and melted as shown in figure ultimetely P - N junction form.



(ii) Diffusion Junction :-

A heated P-type semiconductor is kept in pentavalent impurity vapours which diffuse into P-type semiconductor as shown and make P-N junction.



(iii) Vapour deposited junction or epitaxial junction:

If we want to grow a layer of n–Si or p–Si then p–Si wafer is kept in an atmosphere of Silane (a silicon compound which dissociates into Si at high temperatures) plus phosphorous vapours. On craking of silane at high temperature a fresh layer on n–Si grows on p–Si giving the "P–N junction". Since this junction growth is layer by so it is also referred as layer growth or epitaxial junction formation of P–N junction.

Description of P-N Junction without applied voltage or bias

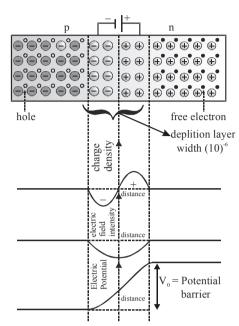
Given diagram shows a P–N junction immediately after it is formed.

P region has mobile majority holes and immobile negatively charged impurity ions.

N region has mobile majority free electrons and immobile positively charged impurity ions.

Due to concentration difference diffusion of holes starts from P to N side and diffusion of e-s starts N to P side.

Due to this a layer of only positive (in N side) and negative (in P-side) started to form which generate an electric field (N to P side) which oppose diffusion process, during diffusion magnitude of electric field increases due to this diffusion it gradually decreased and ultimately stope.



The layer of immobile positive and negative ions, which have no free electrons and holes called as **depletion layer** as shown in diagram.

Width of depletion layer $\cong 10^{-6}$ m

- (a) As doping increases depletion layer decreases
- (b) As temperature is increased depletion layer also increases.
- (c) P-N junction \rightarrow nonohmic, due to nonlinear relation between I and V.

Potential Barrier or contact potential

Ge
$$\longrightarrow$$
 0.3 V

• Electric field, produce due to potential barrier
$$E = \frac{V}{d} = \frac{0.5}{10^{-6}} \implies E \cong 10^5 \text{ V/m}$$

This field prevents the respective majority carrier from crossing barrier region

DIFFUSION AND DRIFT CURRENT

- (1) Diffusion current P to N side
- (2) Drift current N to P side

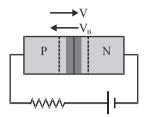
If there is no biasing diffusion current = drift current

So total current is zero

BEHAVIOUR OF P-N JUNCTION WITH AN EXTERNAL VOLTAGE APPLIED OR BIAS

Forward Bias

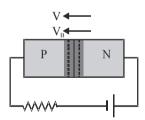
If we apply a voltage "V" such that P-side is positive and N-side is negative as shown in diagram.



The applied voltage is opposite to the junction barrier potential. Due to this effective potential barrier decreases, junction width also decreases, so more majority carriers will be allowed to flow across junction. It means the current flow in principally due to majority charge carriers and it is in the order of mA called as forward Bias.

Reverse Bias

If we apply a voltage "V" such that P-side is negative and N-side is positive as shown in diagram. The applied voltage is in same direction as the junction barrier potential. Due to this effective potential barrier increase junction, width also increases, so no majority carriers will be allowed to flow across junction.



Only minority carriers will drifted. It means the current flow in principally due to minority charge carriers and is very small (in the order of μ A). This bias is called as reversed Bias.

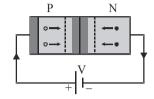
- In reverse bias, the current is very small and nearly constant with bias (termed as reverse saturation current). However interesting behaviour results in some special cases if the reverse bias is increased further beyond a certain limit, above particular high voltage breakdown of depletion layer started.
- Breakdown of a diode is of following two types:
 - (i) Zener breakdown

(ii) Avalanche breakdown

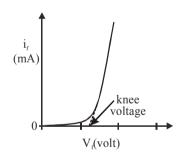
Comparison between Forward Bias and Reverse Bias

Forward Bias

P → positive N → negative



- 1. Potential Barrier reduces
- 2. Width of depletion layer decreases
- 3. P-N jn. provide very small resistance
- 4 Forward current flows in the circuit
- 5. Order of forward current is milli ampere.
- 6. Current flows mainly due to majority carriers.
- 7. Forward characteristic curves.



8. Forward resistance

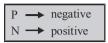
$$R_{\rm f} = \frac{\Delta V_{\rm f}}{\Delta I_{\rm f}} \cong 100\Omega$$

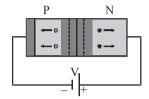
9. Order of knee or cut in voltage

$$\rightarrow$$
 0.7 V

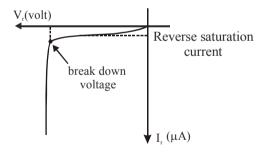
Special point : Generally
$$\frac{R_r}{R_f} = 10^3 : 1 \text{ for Ge}$$

Reverse Bias





- 1. Potential Barrier increases.
- 2. Width of depletion layer increases.
- 3. P-N jn. provide high resistance
- 4. Very small current flows.
- 5. Order of current is micro ampere for Ge or Neno ampere for Si.
- 6. Current flows mainly due to minority carriers.
- 7. Reverse characteristic curve



8. Reverse resistance

$$R_{_{\rm r}} = \frac{\Delta V_{_{\rm r}}}{\Delta I_{_{\rm r}}} \cong 10^6 \, \Omega$$

9. Breakdown voltage

$$\frac{R_{_{r}}}{R_{_{f}}} = 10^4 : 1 \text{ for Si}$$

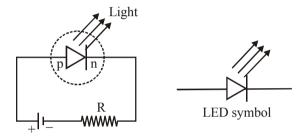
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Light Emitting Diode (LED):

A light emitting diode is simply a forward biased p-n junction which emits spontaneous light radiation. When forward bias is applied, the electron and holes at the junction recombine and energy released is emitted in the form of light. for visible radiation phosphorus doped GaAs is commonly used. The advantages of LEDs are:

- (i) Low operational voltage and less power.
- (ii) Fast action with no warm up time.
- (iii) Emitted light is nearly monochromatic.
- (iv) They have long life.

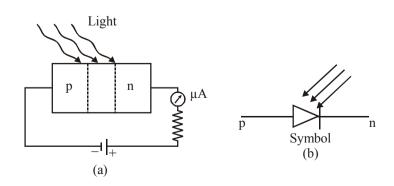
I-V characterisitics of LED are similar to that of Si junction diode but the threshold voltages are much higher and slightly different for each colour. The reverse breakdown voltages of LED's are very low, about 5 V.



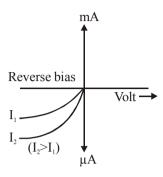
Photodiode:

It is a reversed-biased p-n junction, illuminated by radiation. When p-n junction is reversed biased with no current, a very small reverse saturated current flows across the junction called the dark current. When the junction is illuminated with light, electron-hole pairs are created at the junction, due to which additional current begins to flow across the junction; the current is solely due to minority charge carriers.

- (1) A photodiode is used in reverse bias, although in forward bias current is more than current in reverse bias because in reverse bias it is easier to observe change in current with change in light intensity.
- (2) Photodiode is used to measure light intensity because reverse current increases with increase of intensity of light.

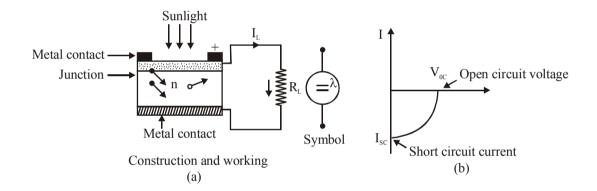


The characteristic curves of a photodiode for two different illuminatios I_1 and I_2 ($I_2 > I_1$) are shown in figure.



Solar Cell

A solar cell is a junction diode which converts tight energy'into electrical energy. A p-n junction solar cell consists of a large junction with no external biasing.



The surface layer of p-region is made very thin so that the incident photons may easily penetrate to reach the junction which is the active region. In an operation in the photovoltaic mode (i.e., generation of voltage due to bombardment of optical photons); the materials suitable for photocells are silicon (Si), gallium arsenide (GaAs), cadmium sulphide (CdS) and cadmium selenide (CdSe).

Working:

When photons of energy greater than band gap energy ($hv > E_g$) are made incident on the junction, electron-hole pairs are created which move in opposite directions due to junction field. These are collected at two sides of junction, thus producing photo-voltage; this gives rise to photocurrent. The characteristic curve of solar cell is shown in fig. Solar cells are used in satellites to recharge their batteries.

11. REVERSE BREAKDOWN

If the reverse bias voltage is made too high, the current through the PN junction increases rapidly at Y_z . The voltage at which this happens is called **breakdown voltage** or **Zener voltage**.

There two mechanism which causes this breakdown. One is called avalanche breakdown and other is called **Zener breakdown**.

E

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Zener breakdown: When reverse bias is increased the electric field at then junction also increases. At some stage the electric field becomes so high that it breaks the covalent bonds creating electron, hole pairs, thus a large number of carriers are generated. This causes a large current to flow. This machanism is know as Zener breakdown.

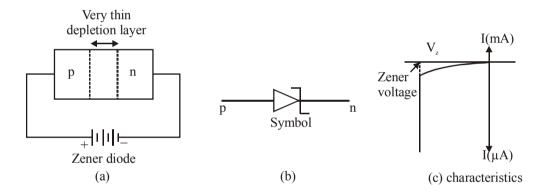
Avalanche breakdown: At high reverse voltage, due to high electric field, the miniority charge carriers, while crossing the junction acquires very high velocities. These by collision breaks down the covalent bonds, generating more carriers. A chain reaction is established, giving rise to high current. This mechanism is called **avalanche breakdown..**

Zener Diode:

A zener diode is a specially designed heavily doped p-n junction, having a very thin depletion layer and having a very sharp breakdown voltage. It is always operated in breakdown region. Its breakdown voltage V_x is less than 6 V.

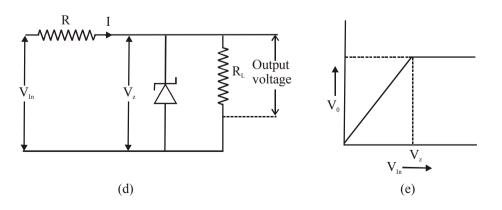
Zener Diode as a Voltage Regulator:

Zener diode may be used as a voltage regulator. The circuit of zener-diode is shown in figure.



In breakdown region the equation: $V_0 = V_z = V_{in} - RI$

Clearly, when the input voltage exceeds zener voltage to keep the voltage regularity, the extra input voltage appears across series resistance R. The voltage regulation curve is shown in figure.



Zener Break down

Where covalent bonds of depletion layer, its self break, due to high electric field of very high Reverse bias voltage.

This phenomena predominant

- (i) At lower voltage after "break down"
- (ii) In P N having "High doping"
- (iii) P N Jn. having thin depletion layer

Here P - N not damage paramanently

"In D.C voltage stablizer zener phenomenan is used".

Avalanche Break down

Here covalent bonds of depletion layers are bro ken by collision of "Minorities" which aquire high kinetic energy from high electric field of very-very high reverse bias voltage.

This phenomena predominant

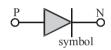
- (i) At high voltage after breakdown
- (ii) In P N having "Low doping"
- (iii) P N Jn. having thick depletion layer

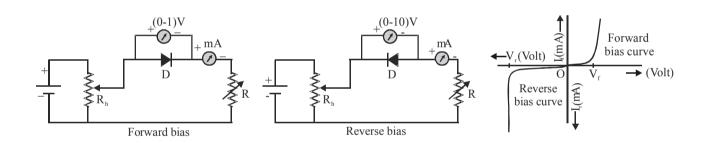
Here P – N damage peramanentaly due to

"Heating effect" due to abruptly increment of minorities during repeatative collisoins.

CHARACTERISTIC CURVE OF P-N JUNCTION DIODE



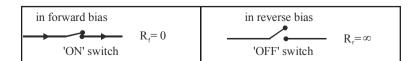




In forward bias when voltage is increased from 0V is steps and corresponding value of current is measured, the curve comes as OB of figure. We may note that current increase very sharply after a certain voltage knee voltage. At this voltage, barrier potential is completely eliminated and diode offers a low resistance.

In reverse bias a microammeter has been used as current is very very small. When reverse voltage is increased from 0V and corresponding values of current measured the plot comes as OCD. We may note that reverse current is almost constant hence called reverse saturation current. It implies that diode resistance is very high. As reverse voltage reaches value $V_{\rm B}$, called breakdown voltage, current increases very sharply.

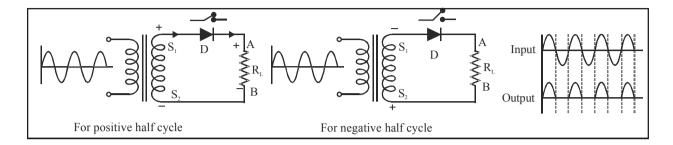
For Ideal Diode



RECTIFIER

It is device which is used for converting alternating current into direct current.

Half wave rectifier



During the first half (positive) of the input signal, let S_1 is at positive and S_2 is at negative potential. So, the PN junction diode D is forward biased. The current flows through the load resistance R₁ and output voltage is obtained.

During the second half (negative) of the input signal, S_1 and S_2 would be negative and positive respectively. The PN junction diode will be reversed biased. In this case, practically no current would flow through the load resistance. So, there will be no output voltage.

Thus, corresponding to an alternating input signal, we get a unidirectional pulsating output as shown.

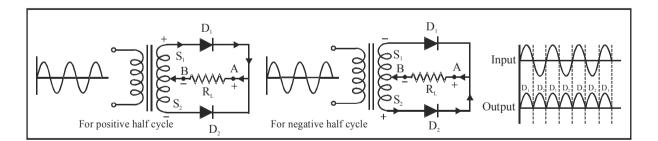
Peak inverse voltage (PIV)

In half wave rectifier PIV = maximum voltage across secondary coil of transformer (V_s)

= Peak value of output (V_m)

Full wave rectifier

When the diode rectifies the whole of the AC wave, it is called full wave rectifier. Figure shows the experiemental arrangement for using diode as full wave rectifier. The alternating signal is fed to the primary a transformer. The output signal appears across the load resistance R_L.



During the positive half of the input signal:

Let S₁ positive and S₂ negative.

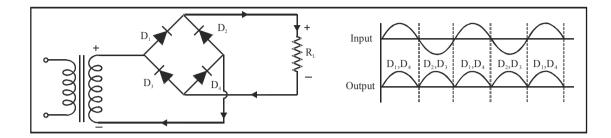
In this case diode D₁ is forward biased and D₂ is reverse biased. So only D₁ conducts and hence the flow of current in the load resistance R_1 is from A to B.

During the negative half of the input signal:

Now S_1 is negative and S_2 is positive. So D_1 is reverse-biased and D_2 is forward biased. So only D_2 conducts and hence the current flows through the load resistance R₁ from A to B.

It is clear that whether the input signal is positive or negative, the current always flows through the load resistance in the same direction and full wave rectification is obtained.

Bridge Rectifier



TRANSISTOR

Inventor William Bradford Shockley, John Bardeen and Walter Houser Brattain.

Transistor is a three terminal device which transfers a signal from low resistance circuit to high resistance circuit.

It is formed when a thin layer of one type of extrinsic semiconductor (P or N type) is sandwitched between two thick layers of other type of extrinsic semiconductor.

Each transistor have three terminals which are :-

- (i) Emitter
- (ii) Base
- (iii) Collector

Emitter

It is the left most part of the transistor. It emits the majority carrier towards base. It is highly doped and medium in size.

Base

It is the middle part of transistor which is sandwitched by emitter (E) and collector (C). It is lightly doped and very thin in size.

Collector

It is right part of the transistor which collect the majority carriers emitted by emitter. It has large size and moderate doping.

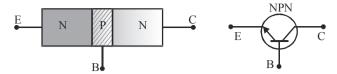
There are two semiconducting PN-junctions in a transistor

- (i) The junction between emitter and base is known as emitter-base junction (J_{FR}).
- (ii) The junction between base and collecter is known as base-collector junction (J_{CR}).

TRANSISTOR ARE OF TWO TYPES

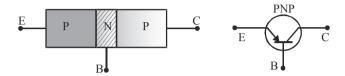
N-P-N Transistor

If a thin layer of P-type semiconductor is sandwitched between two thick layers of N-type semiconductor is known as NPN transistor.

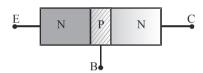


P-N-P Transistor

If a thin layer of N-type of semiconductor is sandwitched between two thick layer of P-type semiconductor is known as PNP transistor.



• Transistor have two P-N Junction J_{EB} and J_{CB} , therefore it can be biased in four following ways as given below:



Emitter-Base	Collector-Base	Region of working
Forward biased	Reverse biased	Active
Reverse biased	Forward biased	Inverse Active
Reverse biased	Reverse biased	Cut off
Forward biased	Forward biased	Saturation

Comparsion between E, B and C

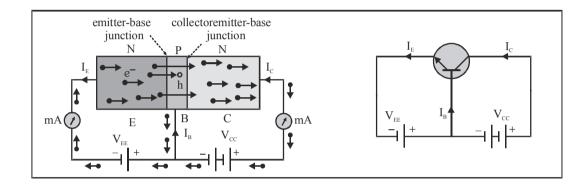
Emitter	Medium size	High dopping
Base	Smallest size	Low dopping
Collector	Largest size	Medium dopping

- The collector region is made physically larger than the emitter. Because collector has to dissipiate much greater power.
- Transistor all mostly work in active region in electronic devices & transistor work as an amplifier in Active region only.
- Transistor i.e. It is a short form of two words "Transfer resistors". Signal is introduced at low resistance circuit and out put is taken at high resistance circuit.

- Base is lightly doped. Otherwise the most of the charge carrier from the emitter recombine in base region and not reaches at collector.
- Transistor is a current operated device i.e. the action of transistor is controlled by the motion of charge carriers. i.e. current.

WORKING OF NPN TRANSISTOR

The emitter Base junction is forward bias and collector base junction is reversed biased of n-p-n transistor in circuit (A) and symbolic representation is shown in Figure.



When emitter base junction is forward bias, electrons (majority carriers) in emitter are repelled toward base.

The barrier of emitter base junction is reduced and the electron enter the base, about 5% of these electron recombine with hole in base region result in small current (I_b) .

The remaining electron ($\approx 95\%$) enter the collector region because they are attracted towards the positive terminal of battery.

For each electron entering the positive terminal of the battery is connected with collector base junction an electron from negative terminal of the battery connected with emitter base junction enters the region.

The emitter current (I_a) is more than the collector (I_a) .

The base current is the difference between I_e and I_c and proportional to the number of electron hole recombination in the base.

$$I_e^{} = I_b^{} + I_c^{}$$

WORKING OF PNP TRANSISTOR

When emitter-base junction is forward biased holes (majority carriers) in the emitter are repelled towards the base and diffuse through the emitter base junction. The barrier potential of emitter-base junction decreases and hole enter the n-region (i.e. base). A small number of holes ($\approx 5\%$) combine with electron of base-region resulting small current (I_b). The remaining hole ($\approx 95\%$) enter into the collector region because they are attracted towards negative terminal of the battery connected with the collector-base junction. These hole constitute the collector current (I_a).

As one hole reaches the collector, it is neutralized by the battery. As soon as one electron and a hole is neutralized in collector a covalent bond is broken in emitter region. The electron hole pair is produced. The released electron enter the positive terminal of battery and hole more towards the collector.

Basic Transistor Circuit Configurations:

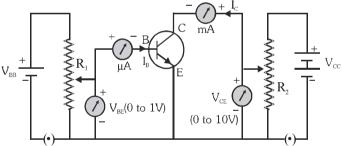
To study about the characteristics of transistor we have to make a circuit [In which four terminals are required]. But the transistor have three terminals, so one of the terminal of transistor is made common in input and output both. Thus, we have three possible configuration of transistor circuit.

- (i) Common base
- (ii) Common emitter
- (iii) Common collector

In these three common emitter is widely used and common collector is rarely used.

Common emitter characterstics of a transistor

Circuit Diagram:

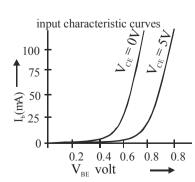


Circuit diagram for characteristic curve of n-p-n transistor in CE mode

Input characterstics

The variation of base current (I_b) (input) with base emitter voltage (V_{EB}) at constant-emitter voltage (V_{CE}) is called input characteristic.

- (i) Keep the collector-emitter voltage (V_{CE}) constant (say $V_{CE} = 1V$)
- (ii) Now change emitter base voltage by R_1 and note the corresponding value of base current (I_b) .
- (iii) Plot the graph between $\boldsymbol{V}_{\scriptscriptstyle EB}$ and $\boldsymbol{I}_{\scriptscriptstyle b}.$
- (iv) A set of such curves can be plotted at different ($V_{CE} = 2V$)

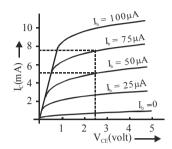


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Output characterstics

The variation of collector current I_c (output) with collector-emitter voltage (V_{CE}) at constant base current (I_b) is called output characteristic.



- (i) Keep the base current (I_b) constant (say $I_b = 10\mu A$)
- (ii) Now change the collector-emitter voltage (V_{CE}) using variable resistance R_2 and note the corresponding values of collector current (I_c) .
- (iii) Plot the graph between $(V_{CE} \text{ versus } I_c)$
- (iv) A set of such curves can be plotted at different fixed values of base current (say 0, 20 μ A, 30 μ A etc.)

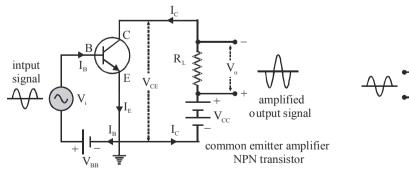
TRANSISTOR AS AN AMPLIFIER

The process of increasing the amplitude of input signal without distorting its wave shape and without changing its frequency is known as amplification.

A device which increases the amplitude of the input signal is called amplifier.

A transistor can be used as an amplifier in active state.

A basic circuit of a common emitter transistor amplifier is shown.





LOGIC GATES

INTRODUCTION:

- A logic gate is a digital circuit which is based on certain logical relationship between the input and the output voltages of the circuit.
- The logic gates are built using the semiconductor diodes and transistors.
- Each logic gate is represented by its characteristic symbol.
- The operation of a logic gate is indicated in a table, known as truth table. This table contains all possible combinations of inputs and the corresponding outputs.
- A logic gate is also represented by a Boolean algebraic expression. Boolean algebra is a method of writing logical equations showing how an output depends upon the combination of inputs. Boolean algebra was invented by George Boole.

BASIC LOGIC GATES

There are three basic logic gates. They are (1) OR gate(2) AND gate, and (3) NOT gate

• The OR gate: The output of an OR gate attains the state 1 if one or more inputs attain the state 1.

Logic symbol of OR gate

$$A \longrightarrow Y = A + B$$

The Boolean expression of OR gate is Y = A + B, read as Y equals A 'OR' B.

Truth table of a two-input OR gate

В	Y
0	0
1	1
0	1
1	1
	0

• The AND gate: The output of an AND gate attains the state 1 if and only if all the inputs are in state 1.

Logic symbol of AND gate

The Boolean expression of AND gate is Y = A.B It is read as Y equals A 'AND' B

Truth table of a two-input AND gate

Α	В	Y
0	0	0
0	1	0
1	0	0
1	1	1

• The NOT gate: The output of a NOT gate attains the state 1 if and only if the input does not attain the state 1.

Logic symbol of NOT gate

$$A \longrightarrow O \longrightarrow Y$$

The Boolean expression is $Y = \overline{A}$, read as Y equals NOT A.

Truth table of NOT gate

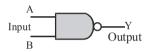
Α	Y
0	1
1	0

COMBINATION OF GATES:

The three basis gates (OR, AND and NOT) when connected in various combinations give us logic gates such as NAND, NOR gates, which are the universal building blocks of digital circuits.

• The NAND gate:

Logic symbol of NAND gate



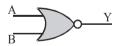
The Boolean expression of NAND gate is $Y = \overline{AB}$

Truth table of a NAND gate

	Α	В	Y
ı	0	0	1
ı	0	1	1
ı	1	0	1
ı	1	1	0

• The NOR gate:

Logic symbol of NOR gate



The Boolean expression of NOR gate is $Y = \overline{A + B}$

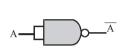
Truth table of a NOR gate

Α	В	Y
0	0	1
0	1	0
1	0	0
1	1	0

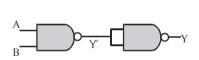
UNIVERSAL GATES:

The NAND or NOR gate is the universal building block of all digital circuits. Repeated use of NAND gates (or NOR gates) gives other gates. Therefore, any digital system can be achieved entirely from NAND or NOR gates. We shall show how the repeated use of NAND (and NOR) gates will gives us different gates.

• The NOT gate from a NAND gate: When all the inputs of a NAND gate are connected together, as shown in the figure, we obtain a NOT gate

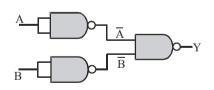


• The AND gate from a NAND gates: If a NAND gate is followed by a NOT gate (i.e., a single input NAND gate), the resulting circuit is an AND gate as shown in figure and truth table given show how an AND gate has been obtained from NAND gates.



Truth table				
Α	В	Y'	Y	
0	0	1	0	
0	1	1	0	
1	0	1	0	
1	1	0	1	

• The OR gate from NAND gates: If we invert the inputs A and B and then apply them to the NAND gate, the resulting circuit is an OR gate.

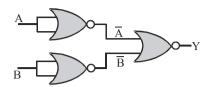


Truth table				
Α	В	Ā	B	Y
0	0	1	1	0
0	1	1	0	1
1	0	0	1	1
1	1	0	0	1

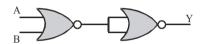
• The NOT gate from NOR gates:- When all the inputs of a NOR gate are connected together as shown in the figure, we obtain a NOT gate



• The AND gate from NOR gates: - If we invert the inputs A and B and then apply them to the NOR gate, the resulting circuit is an AND gate.



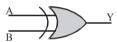
• The OR gate from NOR gate: If a NOR gate is followed by a single input NOR gate (NOT gate), the resulting circuit is an OR gate.



XOR AND XNOR GATES:

• The Exclusive - OR gate (XOR gate):- The output of a two-input XOR gate attains the state 1 if one and only one input attains the state 1.

Logic symbol of XOR gate



The Boolean expression of XOR gate is $Y = A.\overline{B} + \overline{A}.B$ or $Y = A \oplus B$

Truth table of a XOR gate

•	Б	T 7
A	<u>B</u>	<u>Y</u>
0	0	0
0	1	1
1	0	1
1	1	0

• Exclusive - NOR gate (XNOR gate):- The output is in state 1 when its both inputs are the same that is, both 0 or both 1.

Logic symbol of XNOR gate

The Boolean expression of XNOR gate is $Y = A.B + \overline{A}.\overline{B}$ or $Y = \overline{A \oplus B}$ or $A \odot B$ Truth table of a XNOR gate

Α	В	Y
0	0	1
0	1	0
1	0	0
1	1	1

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SUMMARY OF LOGIC GATES

SUMMARY OF LOGIC GATES					
Names	Symbol	Boolean Expression	Truth table	Electrical analogue	Circuit diagram (Practical Realisation)
OR	<u>A</u>	Y = A + B	A B Y 0 0 0 0 1 1 1 0 1 1 1 1	A/ B/	$\begin{array}{c c} A & D_1 \\ \hline \\ B & \hline \\ D_2 & \overline{\overline{\overline{\Psi}}} \end{array}$
AND	<u>A</u> <u>Y</u>	Y = A. B	A B Y 0 0 0 0 1 0 1 0 0 1 1 1	A, B,	$ \begin{array}{c c} A & D \\ \hline B & C_{cc} \end{array} $
NOT or Inverter	<u>A</u> Y	$Y = \bar{A}$	A Y 0 1 1 0	A)
NOR (OR +NOT)	A Y	$Y = \overline{A + B}$	A B Y 0 0 1 0 1 0 1 0 0 1 1 0 1 1 0	TA B)
NAND (AND+NOT)	A Y	$Y = \overline{A.B}$	A B Y 0 0 1 0 1 1 1 0 1 1 1 0	A T ↓ _B	
XOR (Exclusive OR)	A Y	$Y = A \oplus B$ or $Y = \overline{A}.B + A\overline{B}$	A B Y 0 0 0 0 1 1 1 0 1 1 1 0		

 $Y = A \odot B$

 $Y=A.B+\overline{A}.\overline{B}$

 $Y=\overline{A\oplus B}$

or

Α

0

0

1

1

В Ү

1 0

1

0 1

0 0

1

\BOBO-BA\Kata\JEEFAdvanced|\Leader\Physics\Sheet\Important Topics for JEE Mains {2}\E

XNOR

NOR)

(Exclusive

OBJECTIVE (O)

- 1. An electric field is applied to a semi-conductor. Let the number of charge carriers be n and the average drift speed be v. If the temperature is increased
 - (A) Both n and v will increase
 - (B) n will increase but v will decrease
 - (C) v will increase but n will decrease
 - (D) Both n and v will decrease
- 2. The manifestation of band structure in solids is due to -

[AIEEE-2004]

- (A) Bohr's correspondence principle
- (B) Pauli's exclusion principle
- (C) Heisenberg's uncertainty principle
- (D) Boltzmann's law
- **3.** P-type semiconductor is formed when
 - A. As impurity is mixed in Si
- B. Al impurity is mixed in Si

C. B impurity is mixed in Ge

D. P impurity is mixed in Ge

- (A) A and C
- (B) A and D
- (C) B and C
- (D) B and D

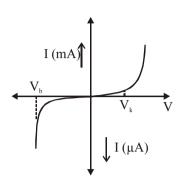
- **4.** In extrinsic semiconductors -
 - (A) The conduction band and valence band overlap
 - (B) The gap between conduction band and valence band is more than 16 eV
 - (C) The gap between conduction band and valence band is near about 1 eV
 - (D) The gap between conduction band and valence band will be 100 eV and more
- 5. A strip of copper and another of germanium are cooled from room temperature to 80 K. The resistance of [AIEEE-2004]
 - (A) copper strip increases and that of germanium decreases
 - (B) copper strip decreases and that of germanium increases
 - (C) each of these increases
 - (D) each of these decreases
- **6.** In a P-N junction diode not connected to any circuit -
 - (A) the potential in the same everywhere
 - (B) the P-type side is at a higher potential then the N-type side
 - (C) there is an electric field at the junction directed from the N-type side to the P-type side
 - (D) there is an electric field at the junction directed from the P-type to the N-type side
- 7. When p-n junction diode is forward biased, then.

[AIEEE-2004]

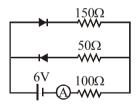
- (A) both the depletion region and barrier height are reduced
- (B) the depletion region is widened and barrier height is reduced
- (C) the depletion region is reduced and barrier height is increased
- (D) both the depletion region and barrier height are increased

8. The V-I characteristic for a p-n junction diode is plotted as shown in the figure. From the plot we can conclude that

 $[V_b \rightarrow breakdown \ voltage, V_k \rightarrow knee \ voltage]$



- (A) the forward bias resistance of diode is very high; almost infinity for small values of V and after a certain value it becomes very low
- (B) the reverse bias resistance of diode is very high in the beginning upto breakdown voltage is not achieved
- (C) both forward and reverse bias resistances are same for all voltages
- (D) both (A) and (B) are correct
- 9. In the below given arrangement determine the ammeter reading, if each diodes have a forward resistance of 50 Ω and infinite backward resistance -



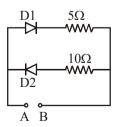
(A) zero

(B) 0.02

(C) 0.03

(D) 0.036

10. A 2V battery is connected across AB as shown in the figure. The value of the current supplied by the battery when in one case battery's positive terminal is connected to A and in other case when positive terminal of battery is connected to B will respectively be:- (JEE-Main Online-2015)



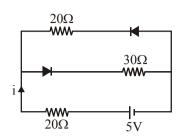
(A) 0.1 A and 0.2 A

(B) 0.4 A and 0.2 A

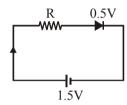
(C) 0.2 A and 0.4 A

(D) 0.2 A and 0.1 A

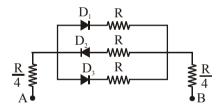
11. Current in the circuit will be -



- (A) $\frac{5}{40}$ A
- (B) $\frac{1}{10}$ A
- (C) $\frac{5}{10}$ A
- (D) $\frac{5}{20}$ A
- 12. The diode used in the circuit shown in the figure has a constant voltage drop of 0.5 V at all currents and a maximum power rating of 100 milliwatts. What should be the value of the resistor R connected in series with the diode for obtaining maximum current -

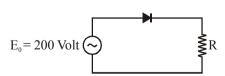


- (A) 1.5Ω
- (B) 5Ω
- (C) 6.67Ω
- (D) 200Ω
- 13. In the following circuits PN-junction diodes D_1 , D_2 and D_3 are ideal for the following potential of A and B, the correct increasing order of resistance between A and B will be -



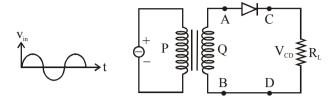
- (i) -10V, -5V,
- (ii) -5V, -10V
- (iii) 4V, -12V

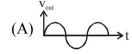
- (A)(i) < (ii) < (iii)
- (B)(iii) < (ii) < (i)
- (C)(ii) = (iii) < (i)
- (D) (i) = (iii) < (ii)
- **14.** A sinusoidal voltage of peak value 200 volt is connected to a diode and resistor R in the circuit shown so that half wave rectification occurs. If the forward resistance of the diode is negligible compared to R then rms voltage (in volt) across R is approximately -

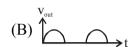


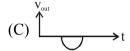
- (A) 200
- (B) 100
- (C) $\frac{200}{\sqrt{2}}$
- (D) 280

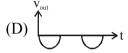
15. In the half-wave rectifier circuit shown. Which one of the following wave forms is true for V_{CD} , if the input is as shown?



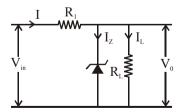








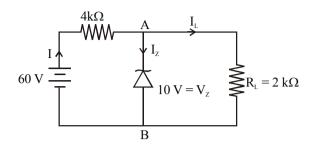
- **16.** Zener diode is a p-n junction which has -
 - (A) p-end heavily doped, n-end lightly doped
 - (B) n-end heavily doped, p-end lightly doped
 - (C) both p and n-ends heavily doped
 - (D) both p and n-ends lightly doped
- 17. Zener diode has both p and n-ends heavily doped so that -
 - (A) it has small thickness of depletion region
 - (B) it has large thickness of depletion region due to large recombination
 - (C) it has large reverse bias voltage
 - (D) it has weak reverse current when reverse biased
- **18.** Most important use of zener diode is to have
 - (A) constant voltage across applied load
 - (B) any desired current at constant voltage
 - (C) a p-n junction working under constant regulated voltage conditions
 - (D) a p-n junction to operate at high voltages
- **19.** In given figure when input voltage increases,



- (A) the current through R_s , R_L and zener increases
- (B) the current through $\boldsymbol{R}_{\scriptscriptstyle S}$ increases, zener increases but through $\boldsymbol{R}_{\scriptscriptstyle L}$ remains constant
- (C) the current through $\boldsymbol{R}_{\mathrm{S}}$ increases, through zener decreases, $\boldsymbol{R}_{\mathrm{L}}$ increases
- (D) the current through $\boldsymbol{R}_{\scriptscriptstyle S}$ increases, through zener remains constant but $\boldsymbol{R}_{\scriptscriptstyle L}$ increases

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20. A Zener diode is connected to a battery and a load as shown below. The currents I, I_Z and I_L are respectively. (JEE-Main Online-2014)



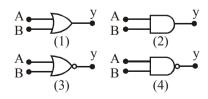
(A) 12.5 mA, 5 mA, 7.5 mA

(B) 15 mA, 7.5 mA, 7.5 mA

(C) 12.5 mA, 7.5 mA, 5 mA

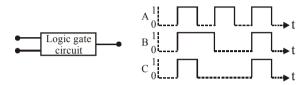
- (D) 15 mA, 5 mA, 10 mA
- **21.** A transistor is used in common emitter mode as an amplifier, then:
 - (1) the base emitter junction is forward biased
 - (2) the base emitter junction is reverse biased
 - (3) the input signal is connected in series with the voltage applied to bias the base emitter junction
 - (4) the Input signal is connected is series with the voltage applied to bias the base collector junction which is correct-
 - (A) 1, 2, 3
- (B) 1, 2, 3, 4
- (C) 1, 3
- (D) 2, 3, 4
- 22. In a n-p-n transistor circuit the collector current is 10 mA. If 90% of the electron emitted reach the collector then -
 - (A) the emitter current will be 9 mA
- (B) the base current will be 9 mA
- (C) the emitter current will be 11 mA
- (D) the base current will be -1 mA
- 23. n-p-n transistors are preferred to p-n-p transistors because -
 - (A) they have low cost

- (B) they have low dissipation energy
- (C) they are capable of handling large power
- (D) electrons have high mobility than holes.
- **24.** When npn transistor is used as an amplifier
- [AIEEE-2004]
- (A) electrons move from collector to base
- (B) holes move from emitter to base.
- (C) electrons move from base to collector
- (D) holes move from base to emitter
- **25.** For a transistor, α is 0.8. The transistor is in CE configuration. The change in the collector current when the base current changes by 6 mA is:-
 - (A) 6 mA
- (B) 4.8mA
- (C) 24mA
- (D) 8mA
- **26.** Given below are four logic gate symbol (figure). Those for OR, NOR and NAND are respectively

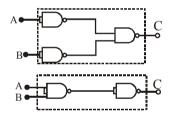


- (A) 1,4,3
- (B) 4,1,2
- (C) 1,3,4
- (D) 4,2,1

- 27. The following truth table corresponds to the logic gate -
 - A 0 0 1 1 B 0 1 0 1 X 0 1 1 1
 - (A) NAND
- (B) OR
- (C) AND
- (D) XOR
- **28.** The following figure shows a logic gate circuit with two input A and B output C. The voltage waveforms of A, B and C are as shown in second figure below. The logic gate is:

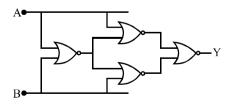


- (A) OR gate
- (C) NAND gate
- (B) AND gate
- (D) NOR gate
- **29.** Which of the following gates will have an output of 1 -
 - (A) $\frac{1}{0}$
- (B) 0
- (C) $\stackrel{0}{\square}$
- (D) 0
- 30. The combination of 'NAND' gates shown here under (figure) are equivalent to -



- (A) An OR gate and an AND gate respectively
- (B) An AND gate and a NOT gate respectively
- (C) An AND gate and an OR gate respectively
- (D) An OR gate and a NOT gate respectively
- 31. A system of four gates is set up as shown. The 'truth table' corresponding to this system is :-

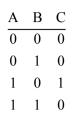
(JEE-Main Online-2013)

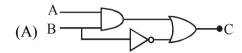


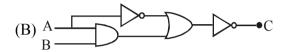
- $(A) \begin{array}{c|cccc} A & B & Y \\ \hline 0 & 0 & 0 \\ \hline 0 & 1 & 0 \\ \hline 1 & 0 & 1 \\ \hline 1 & 1 & 1 \\ \hline \end{array}$
- (B) A B Y 0 0 1 1 1 1 0 0 1 1 1 0
- $(C) \begin{array}{c|cccc} A & B & Y \\ \hline 0 & 0 & 0 \\ \hline 0 & 1 & 1 \\ \hline 1 & 0 & 1 \\ \hline \end{array}$
- $(D) \begin{array}{c|cccc} A & B & Y \\ \hline 0 & 0 & 1 \\ \hline 0 & 1 & 0 \\ \hline 1 & 0 & 0 \\ \hline 1 & 1 & 1 \end{array}$

32. Which of the following circuits correctly represents the following truth table?

(JEE-Main Online-2013)



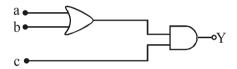






$$(D) \stackrel{A}{\underset{B}{\longrightarrow}} \bigcirc \bigcirc \bigcirc \bigcirc \bigcirc \bigcirc$$

33. To get an output of 1 from the circuit shown in figure the input must be :- (JEE-Main Online-2016)



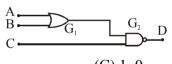
(A)
$$a = 1$$
, $b = 0$, $c = 1$

(B)
$$a = 1$$
, $b = 0$, $c = 0$

(C)
$$a = 0$$
, $b = 1$, $c = 0$

(D)
$$a = 0$$
, $b = 0$, $c = 1$

For the given combination of gates, if the logic states of inputs A, B, C are as follows A = B = C = 034. and A = B = 1, C = 0 then the logic states of output D are -

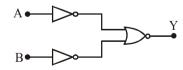


- (A) 0, 0
- (B) 0, 1
- (C) 1, 0
- (D) 1,1

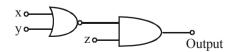
35. This symbol represents



- (A) NOT gate
- (B) OR
- (C) AND gate
- (D) NOR gate
- Which logic gate is represented by the following combination of logic gates -**36.**



- (A) OR
- (B) NAND
- (C) AND
- (D) NOR
- **37.** In which of the following cases, we would obtain an output of one.



(A)
$$x = 1$$
, $y = 1$, $z = 1$

(B)
$$x = 1$$
, $y = 1$, $z = 0$

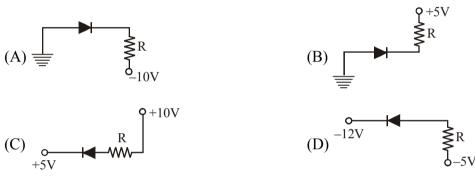
(C)
$$x = 0$$
, $y = 1$, $z = 1$

(D)
$$x = 0$$
, $y = 0$, $z = 1$

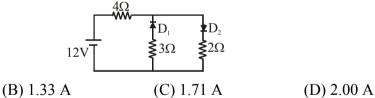
[AIEEE-2005]

[AIEEE-2005]

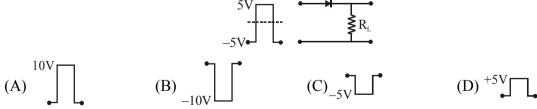
- In a full wave rectifier circuit operating from 50 Hz mains frequency, the fundamental frequency in 38. the ripple would be :-(A) 50 Hz (B) 25Hz (C) 100 Hz (D) 70.7 Hz **39.** The electrical conductivity of a semiconductor increases when electromagnetic radiation of wavelength shorter than 2480 nm is incident on it. The band gap (in eV) for the semiconductor is :-(C) 0.5 eV(D) 0.7 eV(A) 1.1 eV (B) 2.5 eV
- If the ratio of the concentration of electrons to that of holes in a semiconductor is $\frac{7}{5}$ and the ratio of 40. currents is $\frac{7}{4}$ then what is the ratio of their drift velocities -[AIEEE-2006]
- (D) $\frac{4}{5}$ (A) $\frac{5}{4}$ 41. In the following, which one of the diodes is reverse biased; [AIEEE-2006]



42. The circuit has two oppositely connected ideal diodes in parallel. What is the current flowing in the circuit? [AIEEE-2006]



(A) 2.31 AIf in a p-n junction diode, a square input signal of 10V is applied as shown. Then the output signal 43. across R_L will be:-[AIEEE-2007]

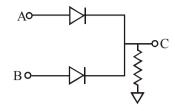


- Carbon, silicon and germanium have four valence electrons each. At room temperature which one of the following statements is most appropriate? [AIEEE-2007]
 - (A) The number of free conduction electrons is significant in C but small in Si and Ge
 - (B) The number of free conduction electrons is negligibly small in all the three
 - (C) The number of free electrons for conduction is significant in all the three
 - (D) The number of free electrons for conduction is significant only in Si and Ge but small in C

E

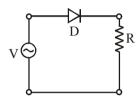
45. In the circuit below, A and B represent two inputs and C represents the output.

[AIEEE-2008]



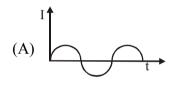
The circuit represents

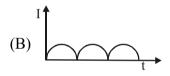
- (A) AND gate
- (B) NAND gate
- (C) OR gate
- (D) NOR gate
- **46.** An p-n junction (D) shown in the figure can act as a rectifier. An alternating current source (V) is connected in the circuit.



The current (I) in the resistor R can be shown by:

[AIEEE-2009]

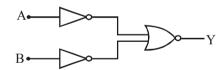


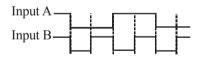




- (D) I
- 47. The logic circuit shown below has the input wave forms 'A' and 'B' as shown. Pick out the correct output waveform.

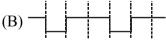
 [AIEEE-2009]





Output is -

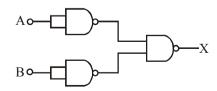






- (D)
- **48.** The combination of gates shown below yields.

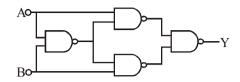
[AIEEE-2010]



- (A) XOR gate
- (B) NAND gate
- (C) OR gate
- (D) NOT gate

Truth table for system of four NAND gates as shown in figure is: 49.

[AIEEE-2012]



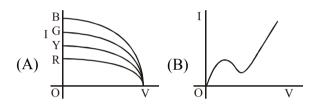
	Α	В	Υ
	0	0	1
(4)	0	1	1
(A)	1	0	0
	1	1	0

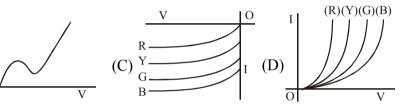
	Α	В	Υ
	0	0	1
(D)	0	1	0
(B)	1	0	0
	1	1	1

	Α	В	Υ
	0	0	0
(C)	0	1	1
(C)	1	0	1
	1	1	0

	Α	В	Υ
	0	0	0
(D)	0	1	0
(D)	1	0	1
	1	1	1

50. The I-V characteristic of an LED is [JEE Main 2013]





51. The forward biased diode connection is:

[JEE Main-2014]

(A)
$$\frac{-3V}{}$$
 WWW $\frac{-3V}{}$

(C)
$$\xrightarrow{-2V}$$
 $\xrightarrow{+2V}$

(B)
$$\stackrel{2V}{\longrightarrow}$$
 $\stackrel{4V}{\longrightarrow}$ (D) $\stackrel{+2V}{\longrightarrow}$ $\stackrel{-2V}{\longrightarrow}$

For a common emitter configuration, if α and β have their usual meanings, the **incorrect** relationship **52.** between α and β is [JEE Main-2016]

(A)
$$\alpha = \frac{\beta^2}{1+\beta^2}$$
 (B) $\frac{1}{\alpha} = \frac{1}{\beta} + 1$ (C) $\alpha = \frac{\beta}{1-\beta}$ (D) $\alpha = \frac{\beta}{1+\beta}$

$$(B) \frac{1}{\alpha} = \frac{1}{\beta} + 1$$

(C)
$$\alpha = \frac{\beta}{1-\beta}$$

(D)
$$\alpha = \frac{\beta}{1+\beta}$$

If a, b, c, d are inputs to a gate and x is its output, then as per the following time graph, the gate is **53.** [JEE Main-2016]

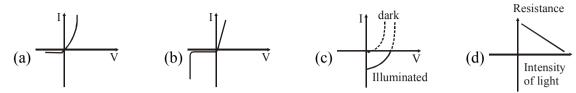


- (c) _____

- (A) NAND
- (B) NOT
- (C) AND
- (D) OR
- The temperature dependence of resistances of Cu and undoped Si in the temperature range 300-**54.** 400K, is best described by :-[JEE Main-2016]
 - (A) Linear decrease for Cu, linear decrease for Si.
 - (B) Linear increase for Cu, linear increase for Si.
 - (C) Linear increase for Cu, exponential increase for Si
 - (D) Linear increase for Cu, exponential decrease for Si

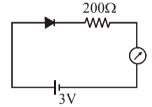
E

55. Identify the semiconductor devices whose characteristics are given below, in the order (a), (b), (c), (d):- [JEE Main-2016]



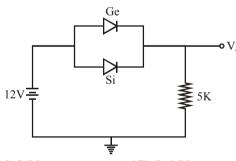
- (A) Zener diode, Solar cell, Simple diode, Light dependent resistance
- (B) Simple diode, Zener diode, Solar cell, Light dependent resistance
- (C) Zener diode, Simple diode, Light dependent resistance, Solar cell
- (D) Solar cell, Light dependent resistance, Zener diode, Simple diode
- 56. In a common emitter amplifier circuit using an n-p-n transistor, the phase difference between the input and the output voltages will be: [JEE Main-2017]
 - (A) 135°
- (B) 180°
- (C) 45°
- (D) 90°
- 57. The reading of the ammeter for a silicon diode in the given circuit is:-

[JEE Main-2018]



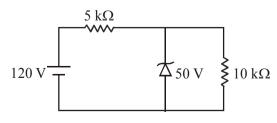
- (A) 15 mA
- (B) 11.5 mA
- (C) 13.5 mA
- (D) 0
- 58. Ge and Si diodes start conducting at 0.3 V and 0.7 V respectively. In the following figure if Ge diode connection are reversed, the value of V_o changes by: (assume that the Ge diode has large breakdown voltage)

 [JEE Main-2019_Jan]



- (A) 0.6 V
- (B) 0.8 V
- (C) 0.4 V
- (D) 0.2 V
- 59. Mobility of electrons in a semiconductor is defined as the ratio of their drift velocity to the applied electric field. If, for an n-type semiconductor, the density of electrons is 10¹⁹m⁻³ and their mobility is 1.6 m²/(V.s) then the resistivity of the semiconductor (since it is an n-type semiconductor contribution of holes is ignored) is close to:

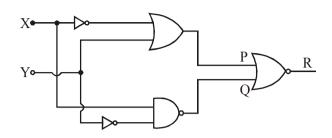
 [JEE Main-2019_Jan]
 - (A) $2\Omega m$
- (B) $0.4\Omega m$
- $(C) 4\Omega m$
- (D) $0.2\Omega m$
- **60.** For the circuit shown below, the current through the Zener diode is :
- [JEE Main-2019_Jan]



- (A) 5 mA
- (B) Zero
- (C) 14 mA
- (D) 9 mA

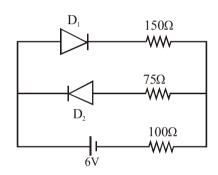
61. To get output '1' at R, for the given logic gate circuit the input values must be:

[JEE Main-2019_Jan]



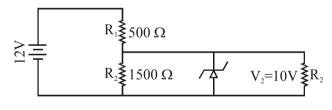
- (A) X = 0, Y = 1
- (B) X = 1, Y = 1
- (C) X = 0, Y = 0
- (D) X = 1, Y = 0
- 62. The circuit shown below contains two ideal diodes, each with a forward resistance of 50Ω . If the battery voltage is 6 V, the current through the 100Ω resistance (in Amperes) is :-

[JEE Main-2019_Jan]

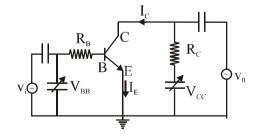


- (A) 0.027
- (B) 0.020
- (C) 0.030
- (D) 0.036
- **63.** In the given circuit the current through Zener Diode is close to :

[JEE Main-2019_Jan]



- (A) 6.0 mA
- (B) 4.0 mA
- (C) 6.7 mA
- (D) $0.0 \, \text{mA}$



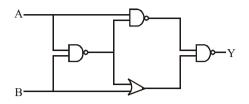
64

In the figure, given that V_{BB} supply can vary from 0 to 5.0 V, $V_{CC} = 5V$, $\beta_{dc} = 200$, $R_B = 100 \, k\Omega$, $R_C = 1 \, k\Omega$ and $V_{BE} = 1.0 \, V$, The minimum base current and the input voltage at which the transistor will go to saturation, will be, respectively: [JEE Main-2019_Jan]

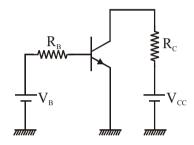
- (A) 20µA and 3.5V
- (B) 25µA and 3.5V
- (C) 25µA and 2.8V
- (D) 20µA and 2.8V

65. The output of the given logic circuit is:

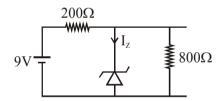
[JEE Main-2019_Jan]



- (A) $\bar{A}B$
- (B) AB
- (C) $AB + \overline{AB}$
- (D) $A\overline{B} + \overline{A}B$
- A common emitter amplifier circuit, built using an npn transistor, is shown in the figure. Its dc current gain is 250, $R_C = 1 k\Omega$ and $V_{CC} = 10 V$. What is the minimum base current for V_{CE} to reach saturation? [JEE Main-2019_April]



- (A) $100 \, \mu A$
- (B) 7 μA
- $(C) 40 \mu A$
- (D) $10 \, \mu A$
- 67. The reverse breakdown voltage of a Zener diode is 5.6 V in the given circuit.

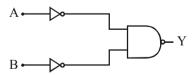


The current I_Z through the Zener is:

[JEE Main-2019_April]

- (A) 7 mA
- (B) 17 mA
- (C) 10 mA
- (D) 15mA
- **68.** The logic gate equivalent to the given logic circuit is:-

[JEE Main-2019_April]

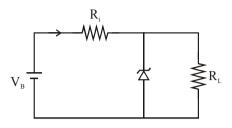


- (A) OR
- (B) AND
- (C) NOR
- (D) NAND
- 69. An NPN transistor is used in common emitter configuration as an amplifier with 1 k Ω load resistance. Signal voltage of 10 mV is applied across the base-emitter. This produces a 3 mA change in the collector current and 15 μ A change in the base current of the amplifier. The input resistance and voltage gain are:

 [JEE Main-2019_April]
 - (A) $0.33 \text{ k}\Omega$, 1.5
- (B) $0.67 \text{ k}\Omega$, 200
- (C) $0.33 \text{ k}\Omega$, 300
- (D) $0.67 \text{ k}\Omega$, 300

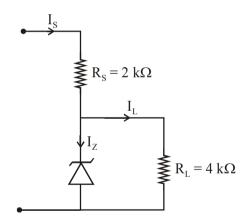
70. The figure represents a voltage regulator circuit using a Zener diode. The breakdown voltage of the Zener diode is 6V and the load resistance is $R_L = 4 \text{ k}\Omega$. The series resistance of the circuit is $R_i = 1 \text{ k}\Omega$. If the battery voltage V_B varies from 8V to 16V, what are the minimum and maximum values of the current through Zener diode?

[JEE Main-2019_April]



- (A) 0.5 mA; 6 mA
- (B) 0.5 mA; 8.5 mA
- (C) 1.5 mA; 8.5 mA
- (D) 1 mA; 8.5 mA
- 71. An npn transistor operates as a common emitter amplifier, with a power gain of 60 dB. The input circuit resistance is 100Ω and the output load resistance is $10 k\Omega$. The common emitter current gain β is : [JEE Main-2019_April]
 - (A) 60
- (B) 10^4
- (C) 6×10^2
- (D) 10^2
- 72. Figure shown a DC voltage regulator circuit, with a Zener diode of breakdown voltage = 6V. If the unregulated input voltage varies between 10 V to 16 V, then what is the maximum Zener current?

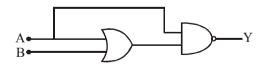
 [JEE Main-2019_April]



- (A) 2.5 mA
- (B) 3.5 mA
- (C) 7.5 mA
- (D) 1.5 mA

73. The truth table for the circuit given in the fig. is:

[JEE Main-2019_April]

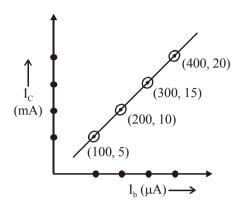


- $\begin{array}{c|cccc}
 A & B & Y \\
 0 & 0 & 1 \\
 0 & 1 & 1 \\
 1 & 0 & 0 \\
 1 & 1 & 0
 \end{array}$
- (B) $\begin{vmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \end{vmatrix}$
- $\begin{array}{c|cccc}
 A & B & Y \\
 0 & 0 & 1 \\
 0 & 1 & 0 \\
 1 & 0 & 0 \\
 1 & 1 & 0
 \end{array}$
- (D) $\begin{vmatrix} A & B & 1 \\ 0 & 0 & 1 \\ 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \end{vmatrix}$

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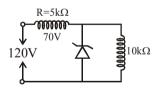
74. The transfer characteristic curve of a transistor, having input and output resistance 100Ω and $100 k\Omega$ respectively, is shown in the figure. The Voltage and Power gain, are respectively:

[JEE Main-2019_April]



- (A) 5×10^4 , 5×10^5
- (C) 5×10^4 , 2.5×10^6

- (B) 5×10^4 , 5×10^6
- (D) 2.5×10^4 , 2.5×10^6
- **75.** Which of the following statements is correct
 - (A) Resistance of semiconductor decreases with increase in temperature
 - (B) In an electric field, displacement of holes is opposite to the displacement of electrons
 - (C) Resistance of a conductor decreases with the increase in temperature
 - (D) n-type semiconductors are neutral
- **76.** Pick out the correct statement the reverse current in p-n junction diode
 - (A) can be minimum and constant
 - (B) remains constant even after the breakdown voltage
 - (C) becomes infinity at breakdown
 - (D) reverse current is controlled by external resistance
- **77.** For the circuit shown in the figure:



- (A) current through zener diode is 4 mA
- (B) current through zener diode is 9 mA
- (C) the output voltage is 50 V
- (D) the output voltage is 40 V
- 78. Which of the following devices are heavily doped p-n junction
 - (A) Photo diode

(B) Light emitting diode

(C) Solar cell

- (D) Zener mode
- **79.** Which of the following statements is correct for proper working of zener diode?
 - (A) Reverse bias voltage should be less than or equal to zener breakdown voltage
 - (B) Reverse bias voltage applied must be greater than zener breakdown voltage.
 - (C) Zener is to be reverse biased for zener action
 - (D) For given zener diode there can be different zener breakdown voltages

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PRINCIPLES OF COMMUNICATION SYSTEM

THEORY

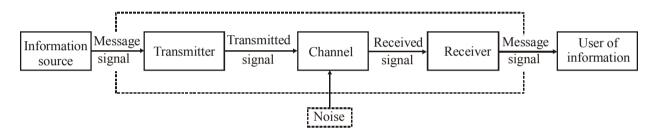
1. INTRODUCTION

Communication means transmission of information. Everyone experiences the need to impart or receive information continuously in the surrounding and for this, we speak, listen, send message by a messenger, use coded signalling methods through smoke or flags or beating of drum etc. and these days we are using telephones, TV, radio, satellite communication etc. The aim of this chapter is to introduce the concepts of communication namely the mode of communication, the need for modulation, production and detection of amplitude modulation.

Elements of a Communication System:

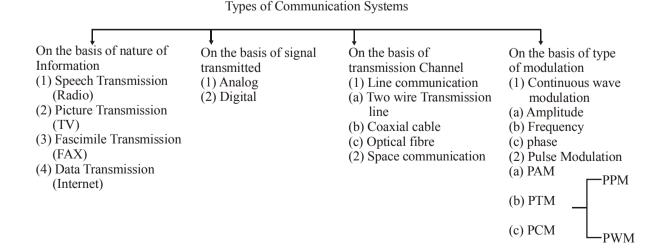
Every communication system has three essential elements-

(i) transmitter (ii) medium/channel (iii) receiver



Transmitter converts the message signal into an electric signal and transmits through channel. The receiver receives the transmitted signal and reconstructs the original message signal to the end user. There are two basic modes of communication: (i) point-to-point and (ii) broadcast.

In point-to-point communication mode, communication takes place over a link between a single transmitter and a receiver as in telephony. In the broadcast mode, there are a large number of receivers corresponding to a single transmitter. Radio and television are most common examples of braoadcast mode of communication. However the communication system can be classified as follows:



Basic terminology Used in Electronic Communication systems:

- (i) **Transducer.** Transducer is the device that converts one form of energy into another. Microphone, photo detectors and piezoelectric sensors are types of transducer. They convert information into electrical signal.
- (ii) Signal Signal is the information converted in electrical form. Signals can be analog or digital. Sound and picture signals in TV are analog.

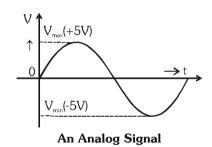
It is defined as a single-valued function of time which has a unique value at every instant of time.

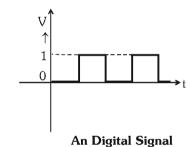
(1) Analog Signal :-

A continuously varying signal (Voltage or Current) is called an analog signal. A decimal number with system base 10 is used to deal with analog signal.

(2) Digital Signal:-

A signal that can have only discrete stepwise values is called a digital signal. A binary number system with base 2 is used to deal with digital signals.

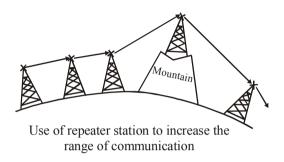




- (iii) Noise: There are unwanted signals that tend to disturb the transmission and processing of message signals. The source of noise can be inside or outside the system.
- (iv) Transmitter: A transmitter processes the incoming message signal to make it suitable for transmission through a channel and subsequent reception.
- (v) Receiver: A receiver extracts the desired message signals from the received signals at the channel output.
- (vi) Attenuation: It is the loss of strength of a signals while propagating through a medium. It is like damping of oscillations.
- (vii) Amplification: It is the process of increasing the amplitude (and therefore the strength) of a signal using an electronic circuit called the amplifier. Amplification is absolutely necessary to compensate for the attenuation of the signal in communication systems.
- (viii) Range: It is the largest distance between the source and the destination upto which the signal gets received with sufficient strength.
- (ix) **Bandwidth**: It is the frequency range over which an equipment operates or the portion of the spectrum occupied by the signal.
- (x) Modulation: The original low frequency message/information signal connot be transmitted to long distances. So, at the transmitter end, information contained in the low frequency message signal is superimposed on a high frequency wave, which acts as a carrier of the information. This process is known as modulation.

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- (xi) **Demodulation :** The process of retrieval of original information from the carrier wave at the receiver end is termed as demodulation. This process is the reverse of modulation.
- (xii) Repeater: A repeater acts as a receiver and a transmitter. A repeater picks up the signal which is coming from the transmitter, amplifies and retransmits it with a change in carrier frequency. Repeaters are necessary to extend the range of a communication system as shown in figure A communication satellite is basically a repeater station in space.



BANDWIDTH

Bandwidth of signals:

Different signals used in a comminication system such as voice, music, picture, computer data etc. all have different ranges of frequency. The difference of maximum and minimum frequency in the range of each signal is called bandwidth of that signal.

Bandwidth can be of message signal as well as of transmission medium.

(i) Bandwidth for analog signals

Bandwdith for some analog sinals are listed below:

Signal	Frequency range	Bandwidth required
Speech	300-3100 Hz	3100-300 =2800 Hz
Music	High frequencies produced by musical instrument Audible range =20 Hz - 20 kHz	20 kHz
Picture TV	Contains both voice and picture	4.2 MHz 6 MHz

(ii) Bandwidth for digital signal

Basically digital signals are rectanglar waves and these can be splitted into a superposition of sinusoidal waves of frequencies v_0 , $2v_0$, $3v_0$, $4v_0$, nv_0 , where n is an integer extending to infinity. This implies that the infinite band width is required to reproduce the rectangular waves. However, for practical purposes, higher harmonics are neglected for limiting the bandwidth

Band width of Transmission Medium

Different types of transmission media offer different band width in which some of are listed below

Frequency Bands						
	Service	Frequency range	Remarks			
1	Wire (most common : Coaxial Cable)	750 MHz (Bandwidth)	Normally operated below 18 GHz			
2	Free space (radio waves)	Few hundred kHz to GHz				
	(i) Standard AM broadcast	540kHz -1600 kHz				
	(ii) FM	88-108 MHz				
	(iii) Television	54-72 MHz 76-88 MHz 174-216 MHz 420-890 MHz	VHF (Very) high frequencies) TV UHF (Ultra hight frequency) TV			
	(iv) Cellular mobile radio	896-901 MHz 840-935 MHz	Mobile to base Station Base station to mobile			
	(v) Satellite Communication	5.925-6.425 GHz 3.7 - 4.2 GHz	Uplinking Downlinking			
3	Optical communication using fibres	1THz-1000 THz (microwaves- ultra violet)	One single optical fibre offers bandwidth > 100 GHz			

Propagation of Electromagnetic Waves:

In case of radio waves communication, an antenna at the transmitter radiates the electromagnetic waves (em waves). The em waves travel through the space and reach the receiving antenna at the other end. As the em wave travels away from the transmitter, their strength keeps on decreasing. Many factors influence the propagation of em waves including the path they follow. The composition of the earth's atmosphere also plays a vital role in the propagation of em waves, as summarised below.

Atmospheric stratum (layer)	Height over earth's surface (approx)	Exists during	Frequencies most likely affected
 Troposphere Ionosphere 	10 km	Day and night	VHF (upto several GHz)
(i) D (part of stratosphere)	65-75 km	Day only	Reflects LF, absorbs MF & HF to some degree
(ii) E (part of stratosphere)	100 km	Day only	Helps surface waves, reflects HF
(iii) F ₁ (Part of Mesosphere)	170-190 km	Daytime, merges with F ₂ at night	Partially absorbs HF waves yet allowing them to reach F ₂
(iv) F ₂ (Thermosphere)	300 km at night, 250-400 km during daytime	Day and night	Efficiently reflects HF waves particularly at night

Ground Wave Propagation:

- (a) The radio waves which travel through atmosphere following the surface of earth are known as ground waves or surface waves and their propagation is called ground wave propagation or surface wave propagation.
- (b) The ground wave transmission becomes weaker with increase in frequency because more absorption of ground waves takes place at higher frequency during propagation through atmosphere.
- (c) The ground wave propagation is suitabel for low and medium frequency i.e. upto 2 or 3 MHz only.
- (d) The ground wave propagation is generally used for local band broadcasting and is commonly called medium wave.
- (e) The maximum range of ground or surface wave propagation depends on two factors:
 - (i) The frequency of the radio waves and
 - (ii) Power of the transmitter

Sky Wave Propagation:

- (a) The sky waves are the radio waves of frequency between 2 MHz to 30 MHz.
- (b) The ionoopheric layer acts as a reflector for a certain range of frequencies (3 to 30 MHz). Electromagnetic waves of frequencies higher than 30 MHz penetrate the ionosphere and escape.
- (c) The highest frequency of radiowaves which when sent straight (i.e. normally) towards the layer of ionosphere gets refelcted from ionosphere and returns to the earth is called critical frequency.. If is given by $f_c = 9 (N_{max})^{1/2}$, where N is the number density of electron/m³.

Space wave propagation:

- (a) The space waves are the radiowaves of very high frequency (i.e. between 30 MHz. to 300 MHz or more).
- (b) the space waves can travel through atmosphere from transmitter antenna to receiver antenna either derectly or after reflection from ground in the earth's troposphere region. That is why the space wave propagation is also called as tropospherical propagation or line of sight propagation.
- (c) The range of communication of space wave propagation can be increased by increasing the heights of transmitting and receiving antenna.

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(d) If the transmitting antenna is at a height h_T , then you can show that the distance to the horizontal d_T is given as $d_T = \sqrt{2Rh_T}$, where R is the radius of the earth (approximately 6400 km). d_T is also called the radio maximum line-of sight distance d_m between the two antennas having heights h_T and h_R above the earth is given by :

$$\boxed{d_{\text{M}} = \sqrt{2Rh_{\text{T}}} + \sqrt{2Rh_{\text{R}}}}$$

where h_{R} is the height of receiving antenna.

Modulation

- * It is a process by which any electrical signal called input / baseband or modulating signal, is mounted onto another signal of high frequency which is known as carrier signal.
- * It is defined as the process by which some characteristic (called parameter) of carrier signal is varied in accordance with the instantaneous value of the baseband signal.
- * The signal which results from this process is known as modulated signal.

Need for Modulation:

(i) To aviod interference:

If many modulating signals travel directly through the same transmission channel, they will interfere with each other and result in distortion.

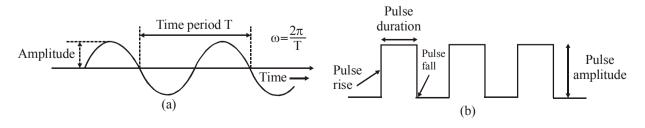
(ii) To design antennas of practicable size :

The minimum height of antenna (not of antenna tower) should be $\lambda/4$ where λ is wavelength of modulating signal. This minimum size becomes impracticable because the frequency of the modulating signal can be upto 5 kHz which corresponds to a wavelength of $3 \times 10^8/5 \times 10^3 = 60$ km. This will require an antenna of the minimum height of $\lambda/4 = 15$ km. This size of an antenna is not practical.

(iii) Effective Power Radiated by an Antenna:

A theoretical study of radiation from a linear antenna (length ℓ) shows that the power radiated is proportional to (frequency)² i.e. $(\ell/\lambda)^2$. For a good transmission, we need high powers and hence this also points out to the need of using high frequency transmission.

The above discussion suggests that there is a need for translating the original low frequency baseband message signal into high frequency wave before transmission. In doing so, we take the help of a high frequency signal, which we already know now, is known as the carrier wave, and a process known as modulation which attaches information to it. The carrier wave may be continuous (sinusoidal) or in the form of pulses, as shown in figure

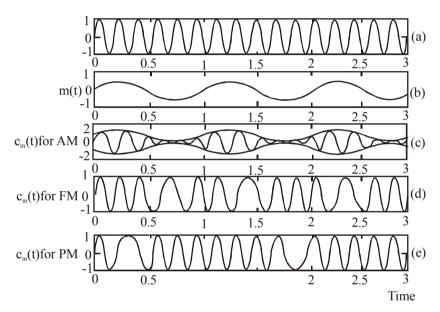


Carrier wave: Sinusoidal

A sinusoidal carrier wave can be represented as

$$c(t) = A_c \sin(\omega_c t + \phi)$$

where c(t) is the signal strength (voltage or current), A_c is the amplitude, ω_c (= $2\pi f_c$) is the angular frequency and ϕ is the initial phase of the carrier wave. Thus, modulation can be affected by varying, any of three parameters, viz A_c , ω_c and ϕ , of the carrier wave can as per the parameter of the message or information signal. This results in three types of modulation : (i) Amplitude modulation (AM) (ii) Frequency modulation (FM) and (iii) Phase modulation (PM), as shown in figure.



Modulation of a carrier wave : (a) a sinusoidal carrier wave (b) a modulating signal : (c) amplitude modulatin :

(d) frequency modulation : and (e) phase modulation

Carrier Wave Pulses:

Similarly, the significant characteristics of a pulse are: Pulse Amplitude, Pulse duration or pulse Width, and pulse Position (denoting the time of rise or fall of the pulse amplitude) Hence, different types of pulse modulation are (a) pulse amplitude modulation (PAM), (b) Pulse duration modulation (PDM) or pulse width modulation (PWM), and (c) Pulse position modulation (PPM).

Ex.1 A separate high freq. wave (i.e. carrier wave) is needed in modulation why?

Ans. This is because we cannot change any of the characteristics (amplitude, frequency or phase) of the audio signal as this would change the message to be communicated. So keeping the audio signal same, the amplitude of freq. or phase of the high freq. carrier wave is modified in accordance with the modulating (i.e. audio signal) signal.

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Amplitude Modulation:

In amplitude modulation the amplitude of the carrier is varied in accordance with the information signals. Let $c(t) = A_c \sin \omega_c t$ represent carrier wave and $m(t) = A_m \sin \omega_m t$ represent the message or the modulating signal where $\omega_m = 2\pi f_m$ is the angular frequency of the message signal. The modulated signal $c_m(t)$ can be written as

$$c_{m}(t) = (A_{c} + A_{m} \sin \omega_{m} t) \sin \omega_{c} t$$

$$= A_{c} \left(1 + \frac{A_{m}}{A_{c}} \sin \omega_{m} t \right) \sin \omega_{c} t \qquad(1)$$

Note that the modulated signal now contains the message signal & it can be written as:

$$c_m(t) = A_c \sin \omega_c t + \mu A_c \sin \omega_m t \sin \omega_c t$$
(2)

Here $\mu = A_m/A_c$ is the modulation index

Often, μ is expressed in percentage and is called the percentage modulation. Importance of modulation index is that it determine the quality of the transmitted signal. When modulation index is small, variation in carrier amplitude will be small. Therefore, audio signal being transmitted will be weak. As the modulation index increases, the audio signal on reception becomes clearer. If the modulation index becomes greater than one, the signal gets lost partially.

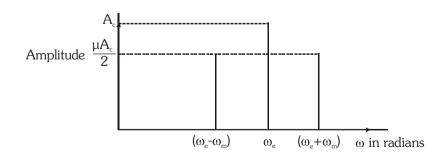
If a carrier wave is modulated by several sine waves the total modulated index m, is given by

$$m_t = \sqrt{m_1^2 + m_2^2 + m_3^2 + \dots}$$

Using the trignomatric relation $\sin A \sin B = \frac{1}{2} (\cos (A - B) - \cos (A + B))$, we can write $c_m(t)$ of eq. (15.4)as

$$c_{m}(t) = A_{c} \sin \omega_{c} t + \frac{\mu A_{c}}{2} \cos(\omega_{c} - \omega_{m}) t - \frac{\mu A_{c}}{2} \cos(\omega_{c} + \omega_{m}) t \qquad(3)$$

Here $\omega_c - \omega_m$ and $\omega_c + \omega_m$ are respectively called the called the lower side and upper side frequencies. The modulated signal now consists of the carrier wave of frequency ω_c plus two sinusoidal waves each with a frequency slightly different from, know as side bands. The frequency spectrum of the amplitude modulated signal is shown in figure :



As long as the broadcast frequencies (carrier waves) are sufficiently spaced out so that sidebands do not overlap, different stations can operate without interfering with each other.

USB

LSB

$$f_{SB} = f_c \pm f_m$$

:. Frequency of lower side band is

$$f_{LSB} = f_c - f_n$$

... (4)

$$\begin{split} \boldsymbol{f}_{LSB} &= \boldsymbol{f}_{c} - \boldsymbol{f}_{m} \\ \text{and frequency of upper side band is} \end{split}$$

$$f_{USB} = f_c + f_m$$

Band width of amplitude modulated wave is

$$= f_{USB} - f_{LSB}$$

$$= (f_f + f_m) - (f_c - f_m) = 2f_m \qquad (5)$$



Phase modulation & frequency modulation are 2 different types of angular modulation.

Power in AM waves: Power dissipated in any circuit $P = \frac{V_{rms}^2}{P}$

Hence:

(i) Carrier power
$$P_c = \frac{\left(\frac{E_c}{\sqrt{2}}\right)^2}{R} = \frac{E_c^2}{2R}$$

(ii) Total power of side bands
$$P_{sb} = \frac{\left(\frac{m_a E_c}{2\sqrt{2}}\right)^2}{R} \times 2 = \frac{m_a^2 E_c^2}{4R}$$

(iii) Total power of AM wave
$$P_{Total} = P_c + P_{ab} = \frac{E_c^2}{2R} \left(1 + \frac{m_a^2}{2} \right)$$

(iv)
$$\frac{P_t}{P_c} = \left(1 + \frac{m_a^2}{2}\right)$$
 and $\frac{P_{ab}}{P_t} = \frac{m_a^2/2}{\left(1 + \frac{m_a^2}{2}\right)}$

(v) Maximum power in the AM (without distortion) will occur when m_a = 1 i.e., $P_t = 1.5 P = 3P_{ab}$

(vi) If I_c = Unmodulated current and I_t = total or modulated current

$$\Longrightarrow \frac{P_{t}}{P_{c}} = \frac{I_{t}^{2}}{I_{c}^{2}} \Longrightarrow \frac{I_{t}}{I_{c}} = \sqrt{\left(1 + \frac{m_{a}^{2}}{2}\right)}$$

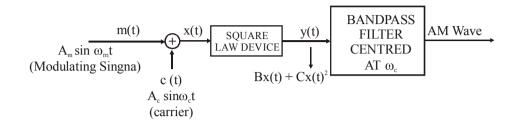
Ex.2 A message signal of frequency 10 kHz and peak voltage of 10 volts is used to modulate a carrier of frequency 1 Mhz and peak voltage of 20 volts. Determine (a) modulation index, (b) the side bands produced.

Sol. (a) Modulation index = 10/20 = 0.5

(b) The side bands are at (1000 + 10 kHz) = 1010 kHz and (1000-10 kHz) = 990 kHz.

Production of Amplitude modulated Wave:

Ampitude modulation can be produced by a veriety of methods. A conceptually simple method is shown in the block diagram of figure.



Here the modulating signal $A_m \sin \omega_m t$ is added to the carrier signal $A_c \sin \omega_c t$ to produce the signal x (t). This signal x (t) = $A_m \sin \omega_m t + A_c \sin \omega_c t$ is passed through a square law device which is a non-linear device which produces an output

$$y(t) = B x (t) + Cx^{2} (t)$$
(4)

where B and C are constants. Thus,

$$y(t) = BA_{m} \sin\omega_{m} t + BA_{c} \sin\omega_{c} t$$

$$+ C \left[A_{m}^{2} \sin^{2}\omega_{m} t + A_{c}^{2} \sin^{2}\omega_{c} t + 2A_{m} A_{c} \sin\omega_{m} t \sin\omega_{c} t\right] \qquad(5)$$

$$= BA_{m} \sin\omega_{m} t + BA_{c} \sin\omega_{c} t$$

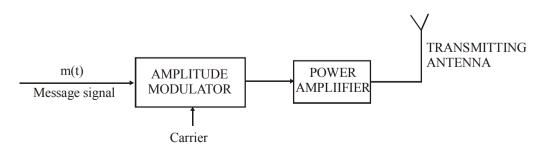
$$\frac{CA_{m}^{2}}{2} + A_{c}^{2} - \frac{CA_{m}^{2}}{2} \cos 2\omega_{m} t - \frac{CA_{c}^{2}}{2} \cos 2\omega_{c} t$$

$$+ CA_{m} A_{c} \cos(\omega_{c} - \omega_{m}) t - CA_{m} A_{c} \cos(\omega_{c} + \omega_{m}) t \qquad(6)$$

where the trigonometric relations $\sin^2 A = (1 - \cos 2A)/2$ and the relation for $\sin A$ sinB mentioned earlier are used.

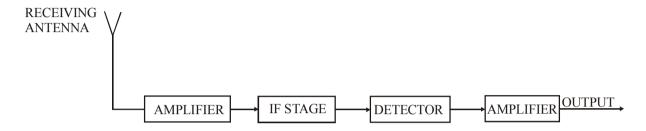
In equation (6), there is a dc term C/2 $(A_m^2 + A_c^2)$ and sinusoids of frequencies ω_m , $2\omega_m$, $\omega_c - \omega_m$ and $\omega_c + \omega_m$. The output of the band pass filter therefore is of the same form as equation (3) and is therefore an AM wave.

It is to be mentioned that the modulated signal connot be transmitted as such. The modulator is to be followed by a power amplifier which provides the necesary power and then the modulated signal is fed to an antenna of appropriate size for radiation as shown in figure.

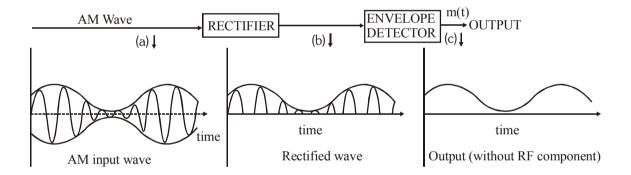


Detection of Amplitude Modulated Wave:

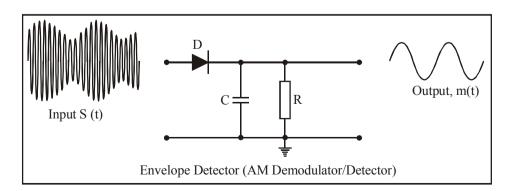
The transmitted message gets attenuated in propagating through the channel. The receiving antenna is therefore to be followed by an amplifier and a detector. In addition, to facilitate further processing, the carrier frequency is usually changed to a lower frequency by what is called an intermediate frequency (IF) stage preceding the detection. The detected signal may not be strong enough to be made use of and hence is required to be amplified. A block diagram of a typical receiver is shown in figure.



Detection is the process of recovering the modulating signal from the modulated carrier wave. We just saw that the modulated carrier wave contains the frequencies ω_c and $\omega_c \pm \omega_m$. In order to obtain the original message signal m(t) of angular frequency ω_m , a simple method is shown in the from of a block diagram in figure.



The modulated signal of the form given in (a) of above figure is passed through a rectifier to produce the output shown in (b). This envelope of signal (b) is the message signal In order to retrieve m(t), the signal is passed through an envelope detector (which may consist of a simple RC circuit).



This is essentially just a half wave rectifier which charges a capacitor to a voltage to the peak voltage of the incoming AM waveform, S(t). When the input wave's amplitude increases, the capacitor voltage in increased via the rectifying diode. When the input's amplitude falls, the capacitor voltage is reduced by being discharged by a 'bleed' resistor, R. The main advantage of this form of AM Demodulator is that it is very simple and cheap!

The circuit relies upon the behaviour of the diode-allowing current through when the input is +ve with respect to the capacitor voltage, hence 'topping up' the capacitor voltage to the peak level, but blocking any current from flowing back out through the diode when the input voltage is below the capacitor voltage.

Consider what happens when we have a carrier frequency, f_o, and use an envelope detector whose

time constant, $\tau = (RC)$. The time between successive peaks of the carrier will be $T = \frac{1}{f}$

Each peak will charge the capacitor to some voltage, V_{peak} , which is proportional to the modulated amplitude of the AM wave. Between each peak and the next the capacitor voltage will therefore be discharged to

$$V'_{peak} = V_{peak} Exp \{-T/\tau\}$$

which, provided that $T \ll \tau$, is approximately the same as

$$V'_{peak} \approx V_{peak} [1-T/\tau]$$

The peak-to-peak size of the ripple, ΔV , will therefore be

$$\Delta V \approx \frac{V_{\text{peak}}T}{\tau} = \frac{V_{\text{peak}}}{f_c\tau}$$

A sudden, large reduction in the amplitude of the input AM wave means that capacitor charge isn't being 'topped up' by each cycle peak. The capacitor voltage therefore falls exponentially until it reaches the new, smaller, peak value. In practice the modulating signal is normally restricted to a specific frequency range. This limits the maximum rate of fall of the AM wave's amplitude. We can therefore hope to avoid negative peak clipping by arranging that the detector's time constant $\tau \ll t_m$ where

$$t_{\rm m} = 1/f_{\rm n}$$

 $t_{_{m}}\!=\!1/f_{_{m}}$ and $f_{_{m}}$ is the highest modulation frequency used in a given situation.

The above implies that we can avoid negative peak clipping by choosing a small value of τ . However, to minimise ripple we want to make τ as large as possible. In practice we should therefore choose a value

$$1/f_{_m} >> \tau >> 1/f_{_c}$$

to minimise the signal distortions caused by these effects. This is clearly only possible if the modulation frequency $f_m \ll f_c$. Envelope detector only work satisfactorily when we ensure this inequality is true. With the modulation index and the resistor the capacitor can be computed by

$$C \le \frac{\sqrt{\left(\frac{1}{m}\right)^2 - 1}}{2\pi R f_m \left(max\right)}$$

1.

OBJECTIVE (O)

If a carrier wave of 1000 kHz is used to carry the signal, the length of transmitting antenna will be

	equal to :-			
	(A) 3 m	(B) 30m	(C) 300 m	(D) 3000 m
2.	The maximum range	of ground or surface w	ave propagation depend	ds on :-
	(A) the frequency of	the radio waves only	(B) power of the tra	nsmitter only
	(C) both of them		(D) none of them	
3.	For television broado	casting, the frequency en	mployed is normally:-	
	(A) $30-300$ MHz	(B) 30-300 GHz	(C) 30-300KHz	(D) 30-3OOHz-
4.	The audio signal :-			
	(A) can be sent direct	tly over the air for large	distance	
	(B) cannot be sent di	rectly over the air for la	rge distance	
	(C) possess very high	h frequency		
	(D) none of the abov	re		
5.	For a carrier frequentransmission-	cy of 100 kHz and a m	odulating frequency of	5 kHz what is the width of AM
	(A) 5 kHz	(B) 10kHz	(C) 20 kHz	(D) 200 KHz
6.	Three waves A, B a	and C of frequencies 1	600 kHz, 5 MHz and 6	60 MHz, respectively are to be
	transmitted from on	e place to another. Wh	nich of the following is	the most appropriate mode of
	communication:			
	(A) A is transmitted	via space wave while B	and C are transmitted v	via sky wave.
	(B) A is transmitted	via ground wave, B via	sky wave and C via sp	ace wave.
	(C) B and C are trans	smitted via ground wav	re while A is transmitted	l via sky wave.
	(D) B is transmitted	via ground wave we wh	nile A and C are transmi	tted via space wave.
7.	A speech signal of 3	kHz is used to modulat	e a carrier signal of free	juency 1 MHz, using amplitude
	modulation. The free	quencies of the side ban	ds will be	
	(A) 1.003 MHz and	0.997 MHz.	(B) 3001 kHz and 2	2997 kHz.
	(C) 1003 kHz and 10	000 kHz.	(D) 1 MHz and 0.9	97 MHz.
8.				frequency ω_{e} to get an amplitude
	mediated wave (AM	The frequency of the .	AM wave will be	
			$\omega_{a} + \omega_{m}$	$\omega_{\circ} - \omega_{\circ}$
	$(A) \omega_{m}$	(B) $\omega_{\rm e}$	(C) $\frac{\omega_{\rm e} + \omega_{\rm m}}{2}$	(D) $\frac{\omega_{\rm e} - \omega_{\rm m}}{2}$
9.	A basic communicati	ion system consists of		
	(A) transmitter	•	rce. (C) user of informat	tion.(D) channel
	(E) receiver.	()	(-)	
	` '	eauence in which these	are arranged in a basic of	communication system :-
	(A) ABCDE	(B) BADEC	(C) BDACE	(D) BEADC
10.	` /	ave can not be observed	()	-
	•			propagation of skywave.
		_		2 is the correct explanation of
	Statement-1		,	1
		-1 and Statement-2 are	true but Statement-2 is	s not the correct explanation of
	Statement- 1.			1

(C) Statement-1 is true but Statement-2 is false.(D) Statement-1 is false but Statement-2 is true.

- **11. Statement 1 :** Ground wave communication is effective only allow frequencies in the range 500kHz to about 1500 kHz.
 - **Statement 2:** The decrease in the intensity of the signal due to absorption by the earth and its atmosphere is higher for higher frequencies.
 - (A) Both Statement-1 and Statement-2 are true, and Statement-2 is the correct explanation of Statement-1.
 - (B) Both Statement-1 and Statement-2 are true but Statement-2 is not the correct explanation of Statement-I.
 - (C) Statement-1 is true but Statement-2 is false.
 - (D) Statement-1 is false but Statement-2 is true.
- **12.** This questions has Statement-1 and Statement-2. Of the four choice given after the statements, choose the one that best describes the two statements.
 - Statement-1: Sky wave signals are used for long distance radio communication. These signals are in general, less stable than ground wave signals.

 [AIEEE-2011]
 - Statement-2: The state of ionosphere varies from hour to hour, day to day and season to season.
 - (A) Statement-1 is true, Statement-2 is true, Statement-2 is the correct explanation of statement-1
 - (B) Statement-1 is true, Statement-2 is true, Statement-2 is not the correct explanation of Statement-1
 - (C) Statement-1 is false, Statement-2 is true
 - (D) Statement-1 is true, Statement-2 is false
- 13. A radar has a power of 1 kW and is operating at a frequency of 10 GHz. It is located on a mountain top of height 500 m. The maximum distance up to which it can detect object located on the surface of the earth (Radius of earth = 6.4×10^6 m) is : [AIEEE-2012]
 - (A) 40 km
- (B) 64
- (C) 80 km
- (D) 16km
- 14. A diode detector is used to detect an amplitude modulated wave of 60% modulation by using a condenser of capacity 250 pico farad in parallel with a load resistance 100 kilo ohm. Find the maximum modulated frequency which could be detected by it. [JEE Main-2013]
 - (A) 10.62kHz

(B) 5.31 MHz

(C) 5.31 kHz

- (D) 10.62MHz
- **15.** A single of 5 kHz frequency is amplitude modulated on a carrier wave of frequency 2 MHz. The frequencies of the resultant signal is/are [JEE Main-2015]
 - (A) 2005 kHz, 2000 kHz and 1995 kHz
- (B) 2000 kHz and 1995 kHz

(C) 2 MHz only

- (D) 2005 kHz and 1995 kHz
- **16.** Choose the correct statement :

[JEE Main-2016]

- (A) In frequency modulation the amplitude of the high frequency carrier wave is made to vary in proportion to the frequency of the audio signal.
- (B) In amplitude modulation the amplitude of the high frequency carrier wave is made to vary in proportion to the amplitude of the audio signal.
- (C) In amplitude modulation the frequency of the high frequency carrier wave is made to vary in proportion to the amplitude of the audio signal.
- (D) In frequency modulation the amplitude of the high frequency carrier wave is made to vary in proportion to the amplitude of the audio signal.

[JEE Main-2017]

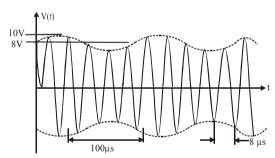
[JEE Main-2018]

- In amplitude modulation, sinusoidal carrier frequency used is denoted by ω and the signal frequency **17.** is denoted by ω_m . The bandwidth $(\Delta \omega_m)$ of the signal is such that $\Delta \omega_m \ll \omega_c$. Which of the following frequencies is not contained in the modulated wave? $(A) \omega_m + \omega_c$ $(D) \omega_{\alpha}$ (B) $\omega_{c} - \omega_{m}$ **18.** A telephonic communication service is working at carrier frequency of 10 GHz. Only 10% of it is utilized for transmission. How many telephonic channels can be transmitted simultaneously if each channel requires a bandwidth of 5 kHz? (A) 2×10^4 (D) 2×10^3 (B) 2×10^5 (C) 2×10^6 **19.** In a communication system operating at wavelength 800 nm, only one percent of source frequency is available as signal bandwidth. The number of channels accommodated for transmitting TV signals of band width 6 MHz are (Take velocity of light $c = 3 \times 10^8 \text{m/s}, h = 6.6 \times 10^{-34} \text{ J-s}$) [JEE Main-2019 Jan] (B) 4.87×10^5 (C) 3.86×10^6 (D) 6.25×10^5 (A) 3.75×10^6
 - 20. The modulation frequency of an AM radio station is 250 kHz, which is 10% of the carrier wave. If another AM station approaches you for license what broadcast frequency will you allot?

[JEE Main-2019 Jan]

- (A) 2750 kHz
- (B) 2000 kHz
- (C) 2250 kHz
- (D) 2900 kHz
- A TV transmission tower has a height of 140 m and the height of the receiving antenna is 40 m. What 21. is the maximum distance upto which signals can be broadcasted from this tower in LOS(Line of Sight) mode ? (Given : radius of earth = 6.4×10^6 m). [JEE Main-2019 Jan]
 - (A) 80 km
- (B) 48 km
- (C) 40 km
- (D) 65 km

22. An amplitude modulated signal is plotted below:



Which one of the following best describes the above signal?

[JEE Main-2019 Jan]

- (A) $(9 + \sin(2.5\pi \times 10^5 \text{ t})) \sin(2\pi \times 10^4 \text{t})V$ (B) $(9 + \sin(4\pi \times 10^4 \text{ t})) \sin(5\pi \times 10^5 \text{t})V$
- (C) $(1 + 9\sin(2\pi \times 10^4 \text{ t})) \sin(2.5\pi \times 10^5 \text{ t})V$ (D) $(9 + \sin(2\pi \times 10^4 \text{ t})) \sin(2.5\pi \times 10^5 \text{ t})V$
- An amplitude modulated signal is given by $V(t) = 10[1 + 0.3\cos(2.2 \times 10^4 t)]\sin(5.5 \times 10^5 t)$. Here t is 23. in seconds. The sideband frequencies (in kHz) are, [Given $\pi = 22/7$] [JEE Main-2019_Jan] (A) 1785 and 1715 (B) 892.5 and 857.5 (C) 89.25 and 85.75 (D) 178.5 and 171.5
- 24. To double the coverging range of a TV transmittion tower, its height should be multiplied by:-

[JEE Main-2019 Jan]

- (A) $\frac{1}{\sqrt{2}}$
- (B)4

- (C) $\sqrt{2}$
- (D)2
- A 100 V carrier wave is made to vary between 160 V and 40 V by a modulating signal. What is the 25. modulation index? [JEE Main-2019_Jan]
 - (A) 0.6
- (B) 0.5
- (C) 0.3
- (D) 0.4

- 26. In a line of sight radio communication, a distance of about 50 km is kept between the transmitting and receiving antennas. If the height of the receiving antenna is 70m, then the minimum height of the transmitting antenna should be: (Radius of the Earth = 6.4 × 10⁶ m). [JEE Main-2019_April]

 (A) 40 m

 (B) 51 m

 (C) 32 m

 (D) 20 m
- 27. The physical sizes of the transmitter and receiver antenna in a communication system are:-

[JEE Main-2019_April]

- (A) proportional to carrier frequency
- (B) inversely proportional to modulation frequency
- (C) inversely proportional to carrier frequency
- (D) independent of both carrier and modulation frequency
- **28.** A signal Acos ω t is transmitted using $v_0 \sin \omega_0 t$ as carrier wave. The correct amplitude modulated (AM) signal is : [JEE Main-2019_April]

(A)
$$v_0 \sin \omega_0 t + A \cos \omega t$$

(B)
$$v_0 \sin \omega_0 t + \frac{A}{2} \sin(\omega_0 - \omega)t + \frac{A}{2} \sin(\omega_0 + \omega)t$$

(C)
$$(v_0 + A)\cos\omega t \sin\omega_0 t$$

(D)
$$v_0 \sin[\omega_0 (1 + 0.01 A \sin \omega t)t]$$

29. A message signal of frequency 100 MHz and peak voltage 100 V is used to execute amplitude modulation on a carrier wave of frequency 300 GHz and peak voltage 400 V. The modulation index and difference between the two side band frequencies are: [JEE Main-2019_April]

(A) 4;
$$1 \times 10^8$$
 Hz

(B)
$$0.25$$
; 1×10^8 Hz

(C) 4;
$$2 \times 10^8$$
 Hz

(D)
$$0.25$$
; 2×10^8 Hz

30. Given below in the left column are different modes of communication using the kinds of waves given the right column. [JEE Main-2019_April]

A.	Optical Fibre	P.	Ultrasound
	communication		
B.	Radar	Q.	Infrared Light
C.	Sonar	R.	Microwaves
D.	Mobile Phones	S.	Radio Waves

(A) A-S, B-Q, C-R, D-P

(B) A-R, B-P, C-S, D-Q

(C) A-Q, B-S, C-R, D-P

- (D) A-Q, B-S, C-P, D-R
- 31. In an amplitude modulator circuit, the carrier wave is given by,
 - $C(t) = 4 \sin{(20000 \pi t)}$ while modulating signal is given by, $m(t) = 2 \sin{(2000 \pi t)}$. The values of modulation index and lower side band frequency are : [JEE Main-2019_April]
 - (A) 0.5 and 9 kHz
- (B) 0.5 and 10 kHz
- (C) 0.3 and 9 kHz
- (D) 0.4 and 10 kHz
- **32.** An audio signal of I5kHz frequency cannot be transmitted over long distances without modulation because
 - (A) the size of the required antenna would be at least 5 km which is not convenient.
 - (B) the audio signal cannot be transmitted through skywaves.
 - (C) the size of the required antenna would be at least 20 km, which is not convenient.
 - (D) effective power transmitted would be very low, if the size of the antenna is less than 5 km.
- **33.** Audio sine waves of 3 kHz frequency are used to amplitude modulate a carrier signal of 1.5 MHz. Which of the following statements are true?
 - (A) The side band frequencies are 1506 kHz and 1494 kHz.
 - (B) The bandwidth required for amplitude modulation is 6kHz.
 - (C) The bandwidth required for amplitude modulation is 3 MHz.
 - (D) The side band frequencies are 1503 kHz and 1497 kHz.

UNIT & DIMENSION

THEORY

Applications of dimensional analysis:

(i) To convert a physical quantity from one system of units to the other:

This is based on a fact that magnitude of a physical quantity remains same whatever system is used for measurement i.e. magnitude = numeric value (n) \times

unit (u) = constant or
$$n_1u_1 = n_2u_2$$

So if a quantity is represented by [MaLbTc]

Then
$$n_2 = n_1 \left[\frac{u_1}{u_2} \right] = n_1 \left[\frac{M_1}{M_2} \right]^a \left[\frac{L_1}{L_2} \right]^b \left[\frac{T_1}{T_2} \right]^c$$

 n_2 = numerical value in II system

 n_1 = numerical value in I system

 M_1 = unit of mass in I system

 M_2 = unit of mass in II system

 $L_1 = \text{unit of length in I system}$

 L_2 = unit of length in II system

 T_1 = unit of time in I system

 T_2 = unit of time in II system

Ex. 1m = 100 cm = 3.28 ft = 39.4 inch(SI) (CGS) (FPS)

Ex. The acceleration due to gravity is 9.8 m s⁻². Give its value in ft s⁻²

Sol. As 1m = 3.2 ft $\therefore 9.8 \text{ m/s}^2 = 9.8 \times 3.28$ ft/s² = 32.14 ft/s² ≈ 32 ft/s²

Ex. Convert 1 newton (SI unit of force) into dyne (CGS unit of force)

Sol. The dimensional equation of force is $[F] = [M^1 L^1 T^{-2}]$ Therefore if n_1 , u_1 , and n_2 , u_3 corresponds to SI & CGS units respectively, then

$$n_2 = n_1 \left[\frac{M_1}{M_2} \right]^1 \left[\frac{L_1}{L_2} \right]^1 \left[\frac{T_1}{T_2} \right]^{-2} = 1 \left[\frac{kg}{g} \right] \left[\frac{m}{cm} \right] \left[\frac{s}{s} \right]^{-2} = 1 \times 1000 \times 100 \times 1 = 10^5$$

 \therefore 1 newton = 10^5 dyne.

Q. The value of Gravitational constant G in MKS system is $6.67 \times 10^{-11} \text{ N-m}^2/\text{kg}^2$. What will be its value in CGS system ?

Ans. $6.67 \times 10^{-8} \text{ cm}^3/\text{g s}^2$

(ii) To check the dimensional correctness of a given physical relation :

If in a given relation, the terms on both the sides have the same dimensions, then the relation is dimensionally correct. This is known as the *principle of homogeneity of dimensions*.

- Ex. Check the accuracy of the relation $T = 2\pi \sqrt{\frac{L}{g}}$ for a simple pendulum using dimensional analysis.
- **Sol.** The dimensions of LHS = the dimension of $T = [M^0 L^0 T^1]$

The dimensions of RHS = $\left(\frac{\text{dimensions of length}}{\text{dimensions of acceleration}}\right)^{1/2}$ (: 2π is a dimensionless constant)

$$= \left(\frac{L}{LT^{-2}}\right)^{1/2} = (T^2)^{1/2} = [T] = [M^0 L^0 T^1]$$

Since the dimensions are same on both the sides, the relation is correct.

(iii) To derive relationship between different physical quantities:

Using the same principle of homogeneity of dimensions new relations among physical quantities can be derived if the dependent quantities are known.

Ex. It is known that the time of revolution T of a satellite around the earth depends on the universal gravitational constant G, the mass of the earth M, and the radius of the circular orbit R. Obtain an expression for T using dimensional analysis.

Sol. We have
$$[T] = [G]^a [M]^b [R]^c$$

$$[M]^0 [L]^0 [T]^1 = [M]^{-a} [L]^{3a} [T]^{-2a} \times [M]^b \times [L]^c = [M]^{b-a} [L]^{c+3a} [T]^{-2a}$$

Comparing the exponents

For [T]:
$$1 = -2a \implies a = -\frac{1}{2}$$

For [M]:
$$0 = b - a \implies b = a = -\frac{1}{2}$$

For [L]:
$$0 = c + 3a \implies c = -3a = \frac{3}{2}$$

Putting the values we get T =
$$G^{-1/2}$$
 $M^{-1/2}$ $R^{3/2} = \sqrt{\frac{R^3}{GM}}$

So the actual expression is
$$T = 2\pi \sqrt{\frac{R^3}{GM}}$$

represented as :-

(A) Avp

(A) 500

(A) m/s

(A) FT^2

be:

1.

2.

3.

4.

5.

(D) A²vρ

(D) 5000

(D) AT²

OBJECTIVE (O)

(B) $Av^2\rho$

(B)5

(B) m/s^2

(B) $F^{-1}A^2T^{-1}$

If area (A), velocity (v), and density (ρ) are base units, then the dimensional formula of force can be

Density of wood is 0.5 g/cc in the CGS system of units. The corresponding value in MKS units is :-

In a book, the answer for a particular question is expressed as $b = \frac{ma}{k} \left[\sqrt{1 + \frac{2k\ell}{ma}} \right]$ here m represents

If force, acceleration and time are taken as fundamental quantities, then the dimensions of length will

An ideal gas enclosed in a vertical cylindrical container supports a freely moving piston of mass M. The piston and the cylinder have equal cross sectional area A. When the piston is in equilibrium, the

mass, a represents acceleration, ℓ represents length. The unit of b should be :-

(C) 0.5

(C) meter

(C) FA^2T

(C) Avo^2

	volume of the gas is V_0 and its pressure is P_0 . The piston is slightly displaced from the equilibrium position and released. Assuming that the system is completely isolated from its surrounding, the					
	piston executes a simp	ele harmonic motion with	n frequency.	[JEE Main-2013]		
	$(A) \; \frac{1}{2\pi} \frac{A\gamma P_0}{V_0 M}$	$(B) \; \frac{1}{2\pi} \frac{V_0 M P_0}{A^2 \gamma}$	(C) $\frac{1}{2\pi} \sqrt{\frac{A^2 \gamma P_0}{M V_0}}$	(D) $\frac{1}{2\pi} \sqrt{\frac{MV_0}{A\gamma P_0}}$		
6.	Expression for time in	terms of G (universal gr	avitational constant), h (Planck constant) and c (speed		
	of light) is proportiona	al to:		[JEE Main-2019_Jan]		
Ren (1)	(A) $\sqrt{\frac{Gh}{c^3}}$	(B) $\sqrt{\frac{hc^5}{G}}$	(C) $\sqrt{\frac{c^3}{Gh}}$	(D) $\sqrt{\frac{Gh}{c^5}}$		
7.	The density of a mater	ial in SI units is 128 kg n	n ⁻³ . In certain units in wh	ich the unit of length is 25 cm		
	and the unit of mass is	50 g, the numerical valu	ue of density of the mate	rial is :		
				[JEE Main-2019_Jan]		
in the second se	(A) 410	(B) 640	(C) 16	(D) 40		
8.	* * * * * * * * * * * * * * * * * * * *	` ′	re considered as fundam	ental units, the dimension of		
	Young's modulus will		4 2	[JEE Main-2019_Jan]		
	(A) $V^{-2} A^2 F^2$	(B) $V^{-4}A^2F$	(C) $V^{-4}A^{-2}F$	(D) $V^{-2}A^2F^{-2}$		

9. The force of interaction between two atoms is given by $F = \alpha \beta \exp\left(-\frac{x^2}{\alpha kt}\right)$; where x is the distance, k

is the Boltzmann constant and T is temperature and α and β are two constants. The dimension of β is:

[JEE Main-2019_Jan]

- (A) $M^2L^2T^{-2}$
- (B) M^2LT^{-4}
- (C) $M^0L^2T^{-4}$
- (D) MLT⁻²
- 10. Let ℓ , r, c and v represent inductance, resistance, capacitance and voltage, respectively. The dimension

of $\frac{\ell}{\text{rev}}$ in SI units will be:

[JEE Main-2019_Jan]

- (A) [LTA]
- (B) [LA⁻²]
- $(C)[A^{-1}]$
- (D) $[LT^2]$
- **11.** If surface tension (S), Moment of inertia (I) and Planck's constant (h), were to be taken as the fundamental units, the dimensional formula for linear momentum would be:-

[JEE Main-2019_April]

- (A) $S^{3/2}I^{1/2}h^0$
- (B) $S^{1/2}I^{1/2}h^0$
- (C) $S^{1/2}I^{1/2}h^{-1}$
- (D) $S^{1/2}I^{3/2}h^{-1}$

12. In SI units, the dimesions of $\sqrt{\frac{\in_0}{\mu_0}}$ is :

[JEE Main-2019_April]

- (A) A^{-1} TML³
- (B) $A^2T^3M^{-1}L^{-2}$
- (C) $AT^2M^{-1}L^{-1}$
- (D) $AT^{-3}ML^{3/2}$
- 13. Which of the following combinations has the dimension of electrical resistance (ε_0 is the permittivity of vacuum and μ_0 is the permeability of vacuum)? [JEE Main-2019_April]
 - $(A) \ \sqrt{\frac{\epsilon_0}{\mu_0}}$
- (B) $\frac{\mu_0}{\epsilon_0}$
- (C) $\sqrt{\frac{\mu_0}{\epsilon_0}}$
- (D) $\frac{\varepsilon_0}{\mu_0}$

VECTOR

THEORY

VECTORS

Precise description of laws of physics and physical phenomena requires expressing them in form of mathematical equations. In doing so we encounter several physical quantities, some of them have only magnitude and other have direction in addition to magnitude. Quantities of the former kind are referred as scalars and the latter as vectors and mathematical operations with vectors are collectively known as vector analysis.

Vectors

A vector has both magnitude and sense of direction, and follows triangle law of vector addition. For example, displacement, velocity, and force are vectors.

Vector quantities are usually denoted by putting an arrow over the corresponding letter, as \vec{A} or \vec{a} . Sometimes in print work (books) vector quantities are usually denoted by boldface letters as \vec{A} or \vec{a} . Magnitude of a vector \vec{A} is a positive scalar and written as $|\vec{A}|$ or \vec{A} .

Geometrical Representation of Vectors.

A vector is represented by a directed straight line, having the magnitude and direction of the quantity represented by it.

e.g. if we want to represent a force of 5 N acting 45° N of E

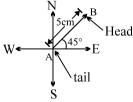
- (i) We choose direction co-ordinates.
- (ii) We choose a convenient scale like 1 cm \equiv 1N
- (iii) We draw a line of length equal in magnitude and in the direction of vector to the chosen quantity.
- (iv) We put arrow in the direction of vector.

$$\overrightarrow{AB}$$

Magnitude of vector:

$$\left| \overrightarrow{AB} \right| = 5N$$

By definition magnitude of a vector quantity is scalar and <u>is always positive</u>.



 $1 \text{ cm} \equiv 1 \text{ N}$

3. TERMINOLOGY OF VECTORS

Parallel vector: If two vectors have same direction, they are <u>parallel</u> to each other. They may be located anywhere in the space.



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Antiparallel vectors: When two vectors are in opposite direction they are said to be antiparallel vectors.

Equality of vectors: When two vectors have equal magnitude and are in same direction and represent the same physical quantity, they are equal.

i.e.
$$\vec{a} = \vec{b}$$



Thus when two parallel vectors have same magnitude they are equal. (Their initial point & terminal point may not be same)

Negative of a vector: When a vector have equal magnitude and is in opposite direction, it is said to be negative vector of the former.

i.e.
$$\vec{a} = -\vec{b}$$
 or $\vec{b} = -\vec{a}$



Thus when two antiparallel vectors have same magnitude they are negative of each other.

Remark: Vector shifting is allowed without change in their direction.

2. **Angle Between two Vectors**

It is the smaller angle formed when the initial points or the terminal points of the two vectors are brought together. It should be noted that $0^{\circ} \le \theta \le 180^{\circ}$.





3. **Addition Of Vectors:**

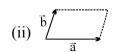
Parallelogram law of addition:

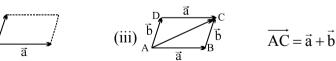
Steps:

- (i) Keep two vectors such that there tails coincide.
- (ii) Draw parallel vectors to both of them considering both of them as sides of a parallelogram.
- (iii) Then the diagonal drawn from the point where tails coincide represents the sum of two vectors, with its tail at point of coincidence of the two vectors.



(i)
$$\vec{b}$$

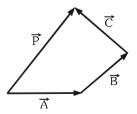




$$\overrightarrow{AC} = \vec{a} + \vec{b}$$

Addition of more than two Vectors

The triangle law can be extended to define addition of more than two vectors. Accordingly, if vectors to be added are drawn in head to tail fashion, resultant is defined by a vector drawn from the tail of the first vector to the head of the last vector. This is also known as the *polygon* rule for vector addition.



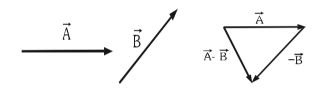
$$\vec{A} + \vec{B} + \vec{C} = \vec{P}$$

Here it is not necessary that three or more vectors and their resultant are coplanar. In fact, the vectors to be added and their resultant may be in different planes. However if all the vectors to be added are coplanar, their resultant must also be in the same plane containing the vectors.

Subtraction of Vectors

A vector opposite in direction but equal in magnitude to another vector \vec{A} is known as negative vector of \vec{A} . It is written as $-\vec{A}$. Addition of a vector and its negative vector results a vector of zero magnitude, which is known as a null vector. A null vector is denoted by arrowed zero $(\vec{0})$.

The idea of negative vector explains operation of subtraction as addition of negative vector. Accordingly to subtract a vector from another consider vectors \vec{A} and \vec{B} shown in the figure. To subtract \vec{B} from \vec{A} , the negative vector $-\vec{B}$ is added to \vec{A} according to the triangle law as shown in figure-II.



If two vectors \vec{a} & \vec{b} are represented by \overrightarrow{OA} & \overrightarrow{OB} then their sum $\vec{a} + \vec{b}$ is a vector represented by \overrightarrow{OC} , where OC is the diagonal of the parallelogram OACB.

•
$$\vec{a} + \vec{b} = \vec{b} + \vec{a}$$
 (commutative)

•
$$(\vec{a} + \vec{b}) + \vec{c} = \vec{a} + (\vec{b} + \vec{c})$$
 (associativity)

$$\bullet \ \vec{a} + \vec{0} = \vec{a} = \vec{0} + \vec{a}$$

•
$$\vec{a} + (-\vec{a}) = \vec{0} = (-\vec{a}) + \vec{a}$$

•
$$|\vec{a} + \vec{b}| \le |\vec{a}| + |\vec{b}|$$

•
$$|\vec{a} - \vec{b}| \ge ||\vec{a}| - |\vec{b}||$$

•
$$|\vec{a} \pm \vec{b}| = \sqrt{|\vec{a}|^2 + |\vec{b}|^2 \pm 2 |\vec{a}| |\vec{b}| \cos \theta}$$
 where θ is the angle between the vectors

Some Important Results:

(1) If
$$\theta = 0^{\circ} \Rightarrow \vec{a} \parallel \vec{b}$$

then, $|\vec{R}| = |\vec{a}| + |\vec{b}| \& |\vec{R}|$ is maximum

(2) If
$$\theta = \pi \Rightarrow \vec{a}$$
 anti $||\vec{b}|$
then, $|\vec{R}| = ||\vec{a}| - |\vec{b}|| \& |\vec{R}|$ is minimum

(3) If
$$\theta = \pi/2 \Rightarrow \vec{a} \perp \vec{b}$$

$$R = \sqrt{a^2 + b^2}$$
& tan $\alpha = b/a$ (α is angle made by \vec{R} with \vec{a})



(4)
$$|\vec{a}| = |\vec{b}| = a$$

$$|\vec{R}| = 2a\cos\theta/2 \& \alpha = \theta/2$$

$$\int_{\frac{\theta}{2}} \vec{b}$$

(5) If
$$|\vec{a}| = |\vec{b}| = a \& \theta = 120^{\circ}$$

then
$$|\vec{R}| = a$$

4. Multiplication Of A Vector By A Scalar:

If \vec{a} is a vector & m is a scalar, then m \vec{a} is a vector parallel to \vec{a} whose modulus is |m| times that of \vec{a} .

This multiplication is called Scalar Multiplication. If \vec{a} and \vec{b} are vectors & m, n are scalars, then:

$$m(\vec{a}) = (\vec{a}) m = m\vec{a}$$

$$m (n\vec{a}) = n(m\vec{a}) = (mn)\vec{a}$$

$$(m+n) \vec{a} = m\vec{a} + n\vec{a}$$

$$m (a + \vec{b}) = m\vec{a} + m\vec{b}$$

Resolution of a Vector into Components

Following laws of vector addition, a vector can be represented as a sum of two (in two-dimensional space) or three (in three-dimensional space) vectors each along predetermined directions. These directions are called axes and parts of the original vector along these axes are called components of the vector.

UNIT VECTOR:

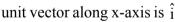
A unit vector is a vector of magnitude of 1, with no units. Its only purpose is to point, i.e. to describe a direction in space.

A unit vector in direction of vector \vec{A} is represented as \hat{A}

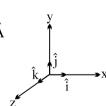
&
$$\hat{A} = \frac{\vec{A}}{|\vec{A}|}$$



Unit Vectors along three coordinates axes:—



unit vector along z-axis is
$$\hat{k}$$



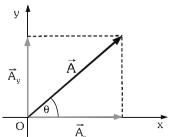
Cartesian components in two dimensions

If a vector is resolved into its components along mutually perpendicular directions, the components are called Cartesian or rectangular components.

In figure is shown, a vector \vec{A} resolved into its Cartesian components

 \vec{A}_x and \vec{A}_y along the x and y-axis. Magnitudes A_x and A_y of these components are given by the following equation.

$$A_x = A\cos\theta$$
 and $A_y = A\sin\theta$
 $\vec{A} = A_y \hat{i} + A_y \hat{j}$



$$A = \sqrt{A_x^2 + A_y^2}$$

Here \hat{i} and \hat{j} are the unit vectors for x and y coordinates respectively.

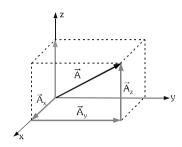
Mathematical operations e.g. addition, subtraction, differentiation and integration can be performed independently on these components. This is why in most of the problems use of Cartesian components becomes desirable.

Cartesian components in three dimensions

A vector \vec{A} resolved into its three Cartesian components one along each of the directions x, y, and z-axis is shown in the figure.

$$\vec{A} = \vec{A}_x + \vec{A}_y + \vec{A}_z = A_x \hat{i} + A_y \hat{j} + A_z \hat{k}$$

$$A = \sqrt{A_x^2 + A_y^2 + A_z^2}$$

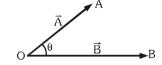


Product of Vectors

In all physical situation, whose description involve product of two vectors, only two categories are observed. One category where product is also a vector involves multiplication of magnitudes of two vectors and sine of the angle between them, while the other category where product is a scalar involves multiplication of magnitudes of two vectors and cosine of the angle between them. Accordingly, we define two kinds of product operation. The former category is known as vector or cross product and the latter category as scalar or dot product.

Scalar or dot product of two vectors

The scalar product of two vectors \vec{A} and \vec{B} equals to the product of their magnitudes and the cosine of the angle θ between them.

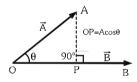


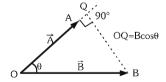
$$\vec{A} \cdot \vec{B} = AB\cos\theta = OA \cdot OB \cdot \cos\theta$$

The above equation can also be written in the following ways.

$$\vec{A} \cdot \vec{B} = (A \cos \theta) B = OP \cdot OB$$

$$\vec{A} \cdot \vec{B} = A (B \cos \theta) = OA \cdot OQ$$





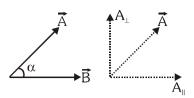
Above two equations and figures, suggest a scalar product as product of magnitude of the one vector and magnitude of the component of another vector in the direction of the former vector.

KEY POINTS

- Dot product of two vectors is commutative: $\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A}$
- If two vectors are perpendicular, their dot product is zero. $\vec{A} \cdot \vec{B} = 0$, if $\vec{A} \perp \vec{B}$
- Dot product of a vector by itself is known as self-product. $\vec{A} \cdot \vec{A} = A^2 \Rightarrow A = \sqrt{\vec{A} \cdot \vec{A}}$
- The angle between the vectors $\theta = \cos^{-1} \left(\frac{\vec{A} \cdot \vec{B}}{AB} \right)$

• (a) Component of \vec{A} in direction of \vec{B}

$$\vec{A}_{||} = \left(|\vec{A}| \cos \theta \right) \hat{B} = |\vec{A}| \left(\frac{\vec{A}.\vec{B}}{|\vec{A}||\vec{B}|} \right) \hat{B} = \left(\frac{\vec{A}.\vec{B}}{|\vec{B}|} \right) \hat{B} = \left(\vec{A}.\hat{B} \right) \hat{B}$$



- (b) Component of \vec{A} perpendicular to \vec{B} : $\vec{A}_{\perp} = \vec{A} \vec{A}_{||}$
- Dot product of Cartesian unit vectors: $\hat{\mathbf{i}} \cdot \hat{\mathbf{i}} = \hat{\mathbf{j}} \cdot \hat{\mathbf{j}} = \hat{\mathbf{k}} \cdot \hat{\mathbf{k}} = 1$ $\hat{\mathbf{i}} \cdot \hat{\mathbf{j}} = \hat{\mathbf{i}} \cdot \hat{\mathbf{k}} = \hat{\mathbf{k}} \cdot \hat{\mathbf{i}} = 0$
- If $\vec{A} = A_x \hat{i} + A_y \hat{j} + A_z \hat{k}$ and $\vec{B} = B_x \hat{i} + B_y \hat{j} + B_z \hat{k}$, their dot product is given by $\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z$

Solved Examples

1. Two displacement vectors of same magnitude are arranged in the following manner









Magnitude of resultant is maximum for

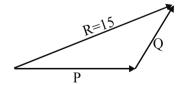
- (A) case I
- (B) case II
- (C) case III
- (D) case IV

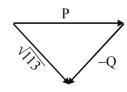
Ans. (B)

- **Sol.** Magnitude of Resultant of \vec{A} and $\vec{B} = \sqrt{A^2 + B^2 + 2AB\cos\theta}$ which is maximum for $\theta = 30^\circ$
- 2. Two vectors \vec{P} and \vec{Q} are added, the magnitude of resultant is 15 units. If \vec{Q} is reversed and added to \vec{P} resultant has a magnitude $\sqrt{113}$ units. The resultant of \vec{P} and a vector perpendicular to \vec{P} and equal in magnitude to \vec{Q} has a magnitude
 - (A) 13 units
- (B) 17 units
- (C) 19 units
- (D) 20 units

Ans. (A)

Sol.
$$P^2 + Q^2 + 2PQ\cos\theta = 225$$
 ...(i)
 $P^2 + Q^2 - 2PQ\cos\theta = 113$...(ii)
By adding (i) & (ii) $2(P^2 + Q^2) = 338$
 $P^2 + Q^2 = 169 \Rightarrow \sqrt{P^2 + Q^2} = 13$





- 3. Three forces are acting on a body to make it in equilibrium, which set can not do it?
 - (A) 3 N, 3 N, 7 N
- (B) 2 N, 3 N, 6 N
- (C) 2 N, 1 N, 1 N
- (D) 8 N, 6 N, 1 N

Ans. (A, B, D)

Sol. They must form a triangle. $(a + b \ge c)$

(A) 150°

P/Q is:-

1.

2.

(D) 120°

OBJECTIVE (O)

two forces. The angle between two forces is :-

(B) 90°

The resultant of two forces, one double the other in magnitude is perpendicular to the smaller of the

If the resultant of two forces of magnitudes P and Q acting at a point at an angle of 60° is $\sqrt{7}$ Q, then

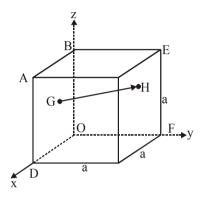
(C) 60°

	(A) 1	(B) $\frac{3}{2}$	(C) 2	(D) 4				
3.	The ratio of maximum The relation between		ides of the resultant of tw	we vectors \vec{A} and \vec{B} is 3:2.				
	(A) A = 5B		(B) 5A = B					
	(C) A = 3B		(D) A = 4B					
4.	If the angle between the	ne unit vectors \hat{a} and \hat{b}	is 60°, then $ \hat{a} - \hat{b} $ is :-					
	(A) 0	(B) 1	(C) 2	(D) 4				
5.	In a methane (CH ₄) m	nolecule each hydrogen	atom is at a corner of a	regular tetrahedron with the				
	•							
	carbon atom at the centre. In coordinates where one of the C–H bonds is in the direction of $\hat{i}+\hat{j}+\hat{k}$,							
	an adjacent C–H bond in the $\hat{i} - \hat{j} - \hat{k}$ direction. Then angle between these two bonds :-							
	(A) $\cos^{-1}\left(-\frac{2}{3}\right)$		(B) $\cos^{-1}\left(\frac{2}{3}\right)$					
	(C) $\cos^{-1}\left(-\frac{1}{3}\right)$		(D) $\cos^{-1}\left(\frac{1}{3}\right)$					
6.	If \vec{a} and \vec{b} are two uni	t vectors such that $\vec{a} + 2\vec{b}$	\vec{b} and $5\vec{a} - 4\vec{b}$ are perpen	dicular to each other then the				
	angle between \vec{a} and		1 1					
	angic between a and	<i>D</i> 15						
	(A) 45°	(B) 60°	(C) $\cos^{-1}\left(\frac{1}{3}\right)$	(D) $\cos^{-1}\left(\frac{2}{7}\right)$				
7.	Two forces P and O or	f magnitude 2F and 3F.	respectively, are at an ar	ngle θ with each other. If the				
	_		ts doubled. Then, the ang					
	-	· ·	•	[JEE Main-2019_Jan]				
	(A) 30°	(B) 60°	(C) 90°	(D) 120°				

Two vectors \vec{A} and \vec{B} have equal magnitudes. The magnitude of $(\vec{A} + \vec{B})$ is 'n' times the magnitude 8. of $(\vec{A} - \vec{B})$. The angle between \vec{A} and \vec{B} is:

[JEE Main-2019_Jan]

- (A) $\sin^{-1} \left[\frac{n^2 1}{n^2 + 1} \right]$ (B) $\cos^{-1} \left[\frac{n 1}{n + 1} \right]$ (C) $\cos^{-1} \left[\frac{n^2 1}{n^2 + 1} \right]$ (D) $\sin^{-1} \left[\frac{n 1}{n + 1} \right]$
- 9. In the cube of side 'a' shown in the figure, the vector from the central point of the face ABOD to the central point of the face BEFO will be: [JEE Main-2019_Jan]



- (A) $\frac{1}{2}a(\hat{i}-\hat{k})$ (B) $\frac{1}{2}a(\hat{j}-\hat{i})$ (C) $\frac{1}{2}a(\hat{k}-\hat{i})$ (D) $\frac{1}{2}a(\hat{j}-\hat{k})$

- **10.** Let $|\vec{A}_1| = 3$, $|\vec{A}_2| = 5$ and $|\vec{A}_1 + \vec{A}_2| = 5$. The value of $(2\vec{A}_1 + 3\vec{A}_2) \cdot (3\vec{A}_1 2\vec{A}_2)$ is :-

[JEE Main-2019_April]

- (A) -112.5
- (B) -106.5
- (C) -118.5
- (D) -99.5

ANSWER KEY

01_WAVE OPTICS

SUBJECTIVE

1. Ans. (a)
$$I_{rms} = V_{rms} \omega C = 6.9 \text{ A}$$
 (b) Yes (c) $B_0 = \frac{\mu_0}{2\pi} \frac{r}{R^2} i_0$, $B_0 = 1.63 \times 10^{-5} \text{ T}$

2. Ans. 153 N/C

3. Ans. (a)
$$\lambda = (c/v) = 1.5 \times 10^{-2} \text{ m}$$
; (b) $B_0 = (E_0/c) = 1.6 \times 10^{-7} \text{ T}$;

(c) Energy density in E field: $u_E = (1/2)\epsilon_0 E^2$

Energy density in B field: $uB = (1/2 \mu) B^2$

Using E = cB, and c =
$$\frac{1}{\sqrt{\mu_0 \epsilon_0}}$$
, $u_E = u_B$

- **4. Ans.** (a) $-\hat{j}$ (b) 3.5 m (b) 86 MHz (c) 10.3 nT (e) {(10.3 nT) cos [(1.8 rad/m) y + (5.4 × 10⁸ rad/s)t]} \hat{k}
- **5. Ans.** (a) 6.7 nT; (b) y; (c) negative direction of y. **6. Ans.** 20A

7. Ans.
$$\left(n - \frac{1}{48}\right)\lambda = x_1 - x_2$$

8. Ans. 391 eV

OBJECTIVE (O)

			` '		
1. Ans. (B)	2. Ans. (D)	3. Ans. (D)	4. Ans. (B)	5. Ans. (D)	6. Ans. (C)
7. Ans. (A)	8. Ans. (B)	9. Ans. (A)	10. Ans. (D)	11. Ans. (D)	12. Ans. (D)
13. Ans. (B)	14. Ans. (B)	15. Ans. (D)	16. Ans. (D)	17. Ans. (D)	18. Ans. (B)
19. Ans. (C)	20. Ans. (A)	21. Ans. (C)	22. Ans. (C)	23. Ans. (D)	24. Ans. (A)
25. Ans. (C)	26. Ans. (B)	27. Ans. (A)	28. Ans. (B)	29. Ans. (D)	30. Ans. (D)
31. Ans. (D)	32. Ans. (A)	33. Ans. (D)	34. Ans. (B)	35. Ans. (C)	36. Ans. (C)
37. Ans. (A)	38. Ans. (B)	39. Ans. (D)	40. Ans. (C)	41. Ans. (B)	42. Ans. (B)
43. Ans. (B)	44. Ans. (D)	45. Ans. (C)	46. Ans. (D)	47. Ans. (B)	48. Ans. (C)
40.4.400	= 0 + (=)				

49. Ans. (C) 50. Ans. (D)

02_GEOMETRICAL OPTICS

OBJECTIVE (O)

1. Ans. (B)	2. Ans. (C)	3. Ans. (C)	4. Ans. (A)	5. Ans. (C)	6. Ans. (A)
7. Ans. (D)	8. Ans. (B)	9. Ans. (B)	10. Ans. (A)	11. Ans. (A)	12. Ans. (A)
13. Ans. (C)	14. Ans. (B)	15. Ans. (A)	16. Ans. (C)	17. Ans. (A)	18. Ans. (A)
19. Ans. (B)	20. Ans. (A)	21. Ans. (C)	22. Ans. (D)	23. Ans. (A)	24. Ans. (B)
25. Ans. (D)	26. Ans. (A)	27. Ans. (B)	28. Ans. (A)	29. Ans. (C)	30. Ans. (D)
31. Ans. (A)	32. Ans. (C)	33. Ans. (B)	34. Ans. (A)	35. Ans. (D)	36. Ans. (C)
3					

37. Ans. (A)

03_MODERN PHYSICS

OBJECTIVE (O)

1. Ans. (D) 2. Ans. (A)

04_SEMICONDUCTOR

OBJECTIVE (O)

1. Ans. (B)	2. Ans. (B)	3. Ans. (C)	4. Ans. (C)	5. Ans. (B)	6. Ans. (C)
7. Ans. (A)	8. Ans. (D)	9. Ans. (B)	10. Ans. (B)	11. Ans. (B)	12. Ans. (B)
13. Ans. (C)	14. Ans. (B)	15. Ans. (B)	16. Ans. (C)	17. Ans. (A)	18. Ans. (A)
19. Ans. (B)	20. Ans. (C)	21. Ans.(C)	22. Ans. (C)	23. Ans. (D)	24. Ans. (C)
25. Ans. (C)	26. Ans. (C)	27. Ans. (B)	28. Ans. (C)	29. Ans. (C)	30. Ans. (A)
31. Ans.(D)	32. Ans. (B)	33. Ans. (A)	34. Ans. (D)	35. Ans. (A)	36. Ans. (C)
37. Ans.(D)	38. Ans. (C)	39. Ans. (C)	40. Ans. (A)	41. Ans. (B)	42. Ans. (D)
43. Ans. (D)	44. Ans. (D)	45. Ans. (C)	46. Ans. (C)	47. Ans. (A)	48. Ans. (C)
49. Ans. (C)	50. Ans. (D)	51. Ans. (D)	52. Ans. (A or C	C)	53. Ans. (D)
54. Ans. (D)	55. Ans. (B)	56. Ans. (B)	57. Ans. (B)	58. Ans. (C)	59. Ans. (B)
60. Ans. (D)	61. Ans. (D)	62. Ans. (B)	63. Ans. (D)	64. Ans. (B)	65. Ans. (B)
66. Ans. (C)	67. Ans. (C)	68. Ans. (A)	69. Ans. (D)	70. Ans. (B)	71. Ans. (D)
72. Ans. (B)	73. Ans. (A)	74. Ans. (C)	75. Ans. (A,B,D	76. Ans	s. (A,C,D)
77 A (D.C)	70 Amg (D.D.)	70 Amg (D.C)			

77. Ans. (B,C) 78. Ans. (B,D) 79. Ans. (B,C)

05_PRINCIPLES OF COMMUNICATION SYSTEM

OBJECTIVE (O)

1. Ans. (C)	2. Ans. (C)	3. Ans. (A)	4. Ans. (B)	5. Ans. (B)	6. Ans. (B)
7. Ans. (A)	8. Ans. (B)	9. Ans. (B)	10. Ans. (A)	11. Ans. (A)	12. Ans. (A)
13. Ans. (C)	14. Ans. (C)	15. Ans. (A)	16. Ans. (B)	17. Ans. (C)	18. Ans. (B)
19. Ans. (D)	20. Ans. (B)	21. Ans. (D)	22. Ans. (D)	23. Ans. (C)	24. Ans. (B)
25. Ans. (A)	26. Ans. (C)	27. Ans. (C)	28. Ans. (B)	29. Ans. (D)	30. Ans. (D)
21 4 (4)	22 4 (4 D	D)	22 4 (D.D.)		

31. Ans. (A) 32. Ans. (A,B,D) 33. Ans. (B,D)

06_UNIT & DIMENSION

OBJECTIVE (O)

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

07_VECTOR

OBJECTIVE (O)

1. Ans. (D)	2. Ans. (C)	3. Ans. (A)	4. Ans. (B)	5. Ans. (C)	6. Ans. (B)
7. Ans. (D)	8. Ans. (C)	9. Ans. (B)	10. Ans. (C)		

Important Notes					