Q28.

a) In Young's double slit experiment, derive the condition for (I) constructive interference and (II) destructive interference at a point on the screen.

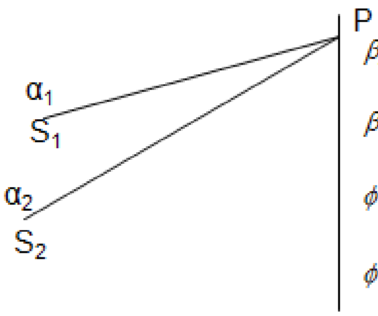
b) A beam of light consisting of two wavelengths, 800 nm and 600 nm is used to obtain the interference fringes in a Young's double slit experiment on a screen placed 1.4 m away. If the two slits are separated by 0.28 mm, calculate the least distance from the central bright maximum where the bright fringes of the two wavelengths coincide.

Answer: (a) Let d = distance of separation between two slits.

D = Perpendicular distance of the screen from the slits

a & R = amplitude of the waves emitted from S_1 and S_2 respectively.

λ = wave length of light ($\omega = 2\pi\nu = 2\pi c/\lambda$)



$$\beta_1 = \alpha_1 + \frac{2\pi}{\lambda}x_1$$

$$\beta_2 = \alpha_2 + \frac{2\pi}{\lambda}x_2$$

$$\phi = \beta_2 - \beta_1 = \alpha_2 + \frac{2\pi}{\lambda}x_2 - \left(\alpha_1 + \frac{2\pi}{\lambda}x_1\right)$$

$$\phi = (\alpha_2 - \alpha_1) + \frac{2\pi}{\lambda}(x_2 - x_1)$$

Let y_1 and y_2 be the displacement at any point P on the screen at an instant of time t of the waves emitted from S_1 and S_2 respectively. Using displacement equation:

$$y_1 = a \sin \omega t \rightarrow (1)$$
$$y_2 = a \sin(\omega t \pm \phi) \rightarrow (2)$$
$$\phi = (\alpha_2 - \alpha_1) + \frac{2\pi}{\lambda}(x_2 - x_1) \rightarrow (3)$$
$$y = y_1 + y_2 = a \sin \omega t + a \sin(\omega t \pm \phi)$$
$$y = a \sin \omega t + b \sin \omega t . \cos \phi \pm b \cos \omega t . \sin \phi$$
$$y = (a + b \cos \phi) \sin \omega t \pm b \cos \omega t . \sin \phi \rightarrow (4)$$

Putting $b \sin \phi = c \sin \delta \rightarrow (5)$

$a + b \cos \phi = c \cos \delta \rightarrow (6)$

Putting equation (5) and (6) in (4)

$$y = c \sin \omega t . \cos \delta \pm c \cos \omega t . \sin \delta$$
$$y = c \sin(\omega t \pm \delta) \rightarrow (7)$$

From equation (7) we find that c is the amplitude of the resultant wave due to the superposition. Squaring and adding equation (5) & (6)

$$c^2 = b^2 \sin^2 \phi + a^2 + b^2 \cos^2 \phi + 2ab \cos \phi$$
$$c^2 = a^2 + b^2 + 2ab \cos \phi \rightarrow (8)$$

I = Resultant intensity at P due to the superposition of the two waves

$$I \propto (amplitude)^2$$
$$I \propto c^2$$
$$I = \text{constant}.c^2$$
$$I = \text{constant}.\left[a^2 + b^2 + 2ab \cos \phi\right] \rightarrow (9)$$

(I)Condition for constructive interference:

From equation (9) we find I is maximum when $\cos\phi$ is maximum.

$$I = \text{constant}\left[a^2 + b^2 + 2ab \cos \phi\right]$$
$$\cos\phi = 1 = \cos 0 = \cos 2\pi = \cos 4\pi = \cos 6\pi = \ldots$$

$\phi = 2n\pi \rightarrow (10)$ where $n = 0, 1, 2, 3, 4, \ldots$

or $\frac{2\pi}{\lambda}\Delta = 2n\pi \rightarrow (11)$

$$\Delta = \frac{2n\pi}{2\pi}\lambda = 2n\frac{\lambda}{2} \rightarrow (12)$$

where $n = 0, 1, 2, 3, \ldots$ an integer

$$\Delta = 0, \lambda, 2\lambda, 3\lambda, 4\lambda \ldots\ldots$$

Path difference should be even multiple of λ/2.

(II) **Condition of minimum intensity (Destructive interference):** From equation (9) intensity is minimum when cosØ is minimum i.e. cosØ= -1=cosπ=cos2π=cos3π,...

i.e. Ø = π, 3π, 5π, 7π, ...

Ø = (2n+1) π → (13)

where n=0,1,2,3,4,..

$$\therefore \frac{2\pi}{\lambda}\Delta = (2n+1)\pi$$

$$\text{or } \Delta = (2n+1)\frac{\lambda}{2} \rightarrow (14)$$

Where n = 0,1,2,3,... .. an integer

$$\text{i.e. } \Delta = 1.\frac{\lambda}{2},\ 3\frac{\lambda}{2},\ 5\frac{\lambda}{2},\ 7\frac{\lambda}{2},\ldots\ldots\ldots$$

Thus for destructive interference path difference should be odd multiple of λ/2.

b) Position of first bright fringe,

Where, $\lambda_A = 800\ \text{nm} = 800 \times 10^{-9}\text{m} = 8 \times 10^{-7}\text{m}$ and $D = 1.4\ \text{m},\ d = 0.28\ \text{mm} = 0.28 \times 10^{-3}\text{m}$

$X_A = n_1\lambda_A\ \frac{D}{d}$

For wavelength, $\lambda_B = 600\ \text{nm} = 600 \times 10^{-9}\text{m} = 6 \times 10^{-7}\text{m}$

Position of first bright fringe is

$X_B = n_2\lambda_B\frac{D}{d}$

Since fringes coincides hence X_A=X_B

Or $n_1\lambda_A\ \frac{D}{d} = n_2\lambda_B\frac{D}{d}, \frac{n_1}{n_2} = \frac{\lambda_B}{\lambda_A} = \frac{600}{800} = \frac{3}{4}$, this is possible if n_1=3 and n_2=4 therefore common distance=

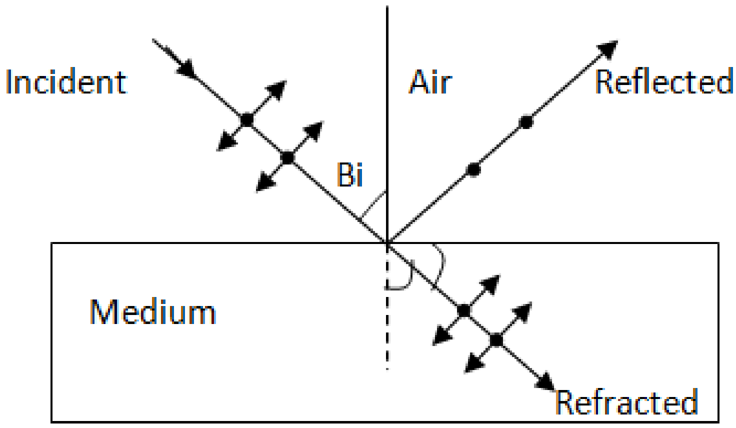
$X_A = n_1\lambda_A\ \frac{D}{d} = 3 \times 8 \times 10^{-7} \times \frac{1.4}{0.28\times10^{-3}} = 120 \times 10^{-4} = 0.012\text{m} = 12\text{mm}$

OR

(a) How does an unpolarized light light incident on a Polaroid get polarized? Describe briefly,with the help of a necessary diagram, the polarization of light by reflection from a transparent medium.

(b) Two Polaroid's 'A' and 'B' are kept in crossed position. How should a third Polaroid 'C' be placed between them so that the intensity of polarized light transmitted by Polaroid B reduces to 1/8th of the intensity of unpolarized light incident on A?

i. **Answer:**



The independent light waves whose planes of vibrations are randomly oriented about the direction of propagation are said to be unpolarized light. When unpolarized light is incident on the boundary between two transparent media, the reflected light is polarized with electric vector perpendicular to the plane of incidence. Whenever unpolarized light is incident from air to a transparent medium at an angle of incidence equal to polarizing angle, the reflected light gets polarized as shown in the diagram above. Thus Light can be polarized by reflecting it from a transparent medium. The extent of polarization depend on the angle of incidence, called Brewster's angle.

Let μ= refractive index of the transparent medium

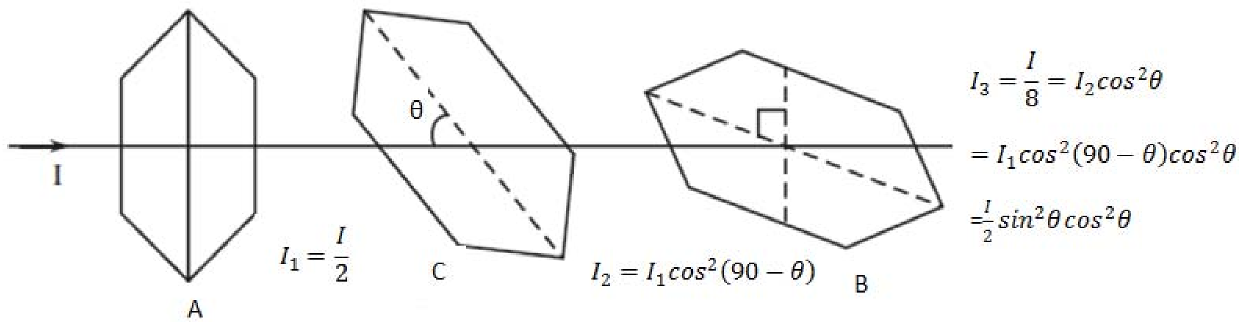
Bi= Brewster angle then

$\mu = tanB_i \ also \ \alpha + \delta = 90^0$

The refracted and reflected rays make a right angle with each other

(b) Given: A and B are kept at crossed position, intensity of light passing through A is half of intensity falling on A. Final output intensity from C is 1/8th of intensity falling on A.

Let θ = angle of inclination of C with the axis of A then if I, I_1,I_2 and I_3 be the intensity of light falling on A, passing though A, passing through B and passing through C respectively then



As output intensity calculated above

$$I_3 = \frac{I}{8} = I_2 cos^2\theta = I_1 cos^2(90-\theta)cos^2\theta = \frac{I}{2} sin^2\theta cos^2\theta$$

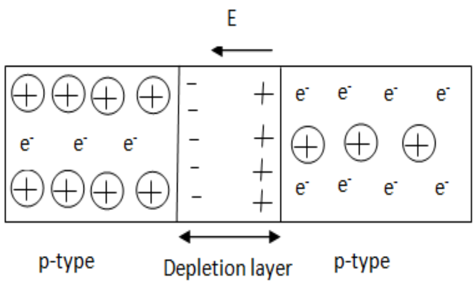
$$\frac{I}{8} = \frac{I}{2} sin^2\theta cos^2\theta \ or \ 1 = 4sin^2\theta cos^2\theta \ \ or \ 1 = sin2\theta \ or \ 2\theta = 90 \ or \ \theta = 45^0$$

Thus Polaroid C should be kept at 45^0 with the direction of axis of A.

Q29 (a) Describe briefly, with the help of a diagram, the role of the two important processes involved in the formation of a p-n junction.

(b) Name the device which is used as a voltage regulator. Draw the necessary circuit diagram and explain its working.

Answer:

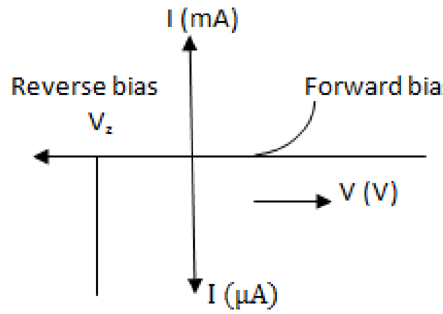


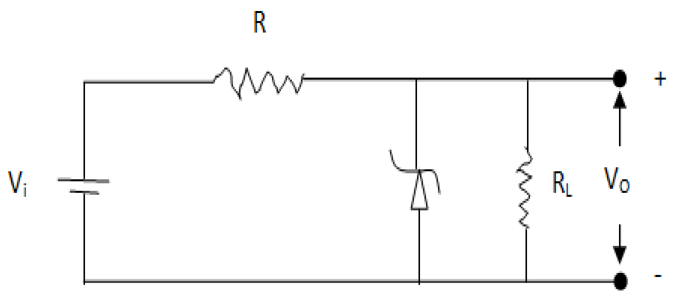
As shown in p side we have higher concentration of holes majority charge carriers and in n side we have higher concentration of electrons. Therefore diffusion of holes that is electrons to the right of the junction may fill up the vacancies to the left of the junction. Similarly because of concentration difference conduction electrons diffuse from right to left. This makes left half positively charged and right half negatively charged. Electric field will be created from right to left, holes will be pushed to the left half and conduction electrons pushed towards right half. This region where no charge carrier remains is depletion region.

Diffusion current: Because of concentration difference holes having higher kinetic energy can cross the depletion region by overcoming the force due to electric field. Similarly diffusion electrons from right to left having higher kinetic energy can cross the junction opposed by field. The electric potential of the n-side is higher than that of the p-side, there is potential barrier at the junction which allows only a small amount of diffusion. This diffusion results electric current from p side to n side called diffusion current.

Drift current: Thermal collision results breaking of covalent bond and electrons jumps to the conduction band, electron hole pair gets created. Also conduction electron fills up vacant bond and electron-hole pair is destroyed. These processes continue in every part of the material. However if an electron-hole pair is created in the depletion region, electron is pushed by electric field towards n-side and holes towards P-side. Thus there is a regular flow of electrons towards n-side and holes towards p-side, this generates current from n-side to p-side called drift current.

(b) Zener diode is used as voltage regulator.



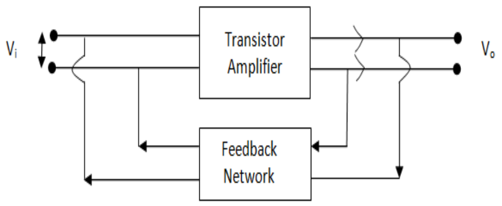


Working: When the reverse-bias voltage across p-n junction diode is increased, at a particular voltage the reverse current suddenly increases to a large value, called breakdown of diode, voltage is called breakdown voltage. In this voltage the rate of creation of hole-electron pairs increases thus current increases.

Zener diode is connected to unregulated DC voltage. Zener diode is operated in reverse bias. The current through R and Zener diode increases as voltage increased. The current through the diode increases by the voltage remains constant in breakdown region. I-V characteristics shown in graph shows voltage V_o across Load R_L is constant. If there is small change in input voltage V_i the current through RL remains same.

OR

(a) Explain briefly the principle on which a transistor amplifier works as an oscillator. Draw the necessary circuit diagram and explain its working.
Answer: Oscillator is a device which converts D.C power to alternating power of desired frequency. It is self-sustained transistor amplifier.

<table>
<tr>
<td>Block Diagram:

</td>
<td>As shown in the block diagram a portion of the output is fed back in phase to the input the process is called feedback.

Amplification is done by (amplifier circuit) Common Emitter (CE) transistor.

Feedback is done by Tank circuit.</td>
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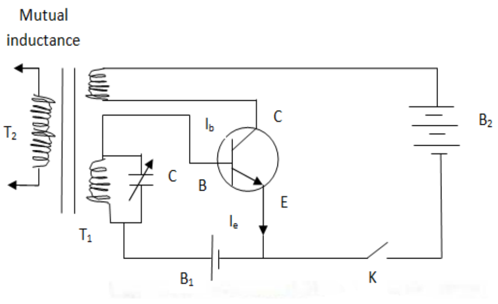
<tr>
<td>Circuit Diagram:

</td>
<td>Working: The basic parts in the circuit are amplifier and LC network. The amplifier section is a transistor in common emitter mode and LC network is simply consists of an inductor and a capacitance. Change is current is due to change in magnetic field in inductor and electric field across capacitor. Batteries are used to bias the transistor. A part of input signal is returned back to the input section after passing through LC network. This signal is amplified is amplified by transistor and a part is again fed back to its input section. Thus it is self sustaining device. The component with the proper frequency ν_0 gets resonantly amplified and the output acts as a source of alternating voltage of that frequency. The frequency can be varied by varying L and C. Phase shift of 180^0 is made by CE amplifier and frequency of oscillation

$$\nu_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$$</td>
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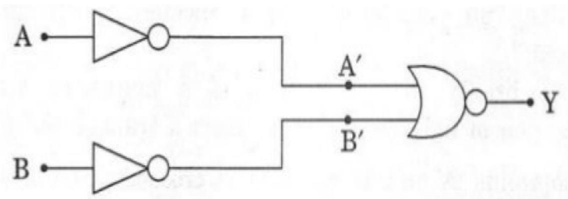
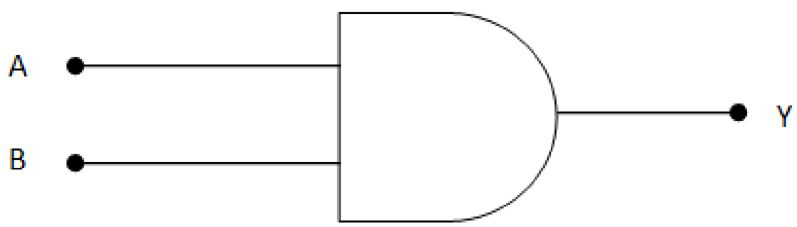
(b) Identify the equivalent gate for the following circuit and write its truth table.



Answer: Truth Table

A	B	A'	B'	Y=$\overline{A' + B'}$
0	0	1	1	0
0	1	1	0	0
1	0	0	1	0
1	1	0	0	1

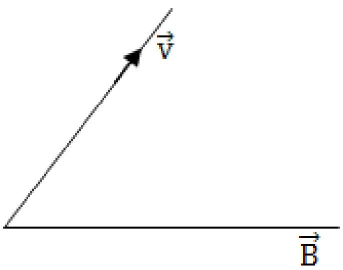
Thus from the truth table we find the input single A, B has output similar to AND operation.



Equivalent gate is AND as shown above.

Q30.(a) Write the expression for the force, $\vec{F}$, acting on a charged particle of charge 'q', moving with a velocity $\vec{v}$ in the presence of both electric field $\vec{E}$ and magnitude field $\vec{B}$. Obtain the condition under which the particle moves without deflection through the fields.

Answer: (a) Based on assumption that the direction of $\vec{E}$, $\vec{v}$ and $\vec{B}$ are such that $\vec{E} \perp \vec{v}$, $\vec{E} \perp \vec{B}$ and $\vec{v}$ is not parallel or anti parallel to $\vec{B}$.



Force due to electric field = $q\vec{E}$

Force due to magnetic field= $q(\vec{v} \times \vec{B})$

Therefore force due to electric and magnetic field

$$\vec{F} = q[\vec{E} + (\vec{v} \times \vec{B})]$$

For null deflection force due to electric field must balance the force due to magnetic field.

$$q\vec{E} = q(\vec{v} \times \vec{B})$$

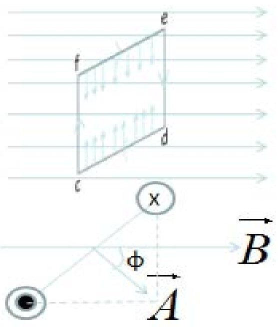
E=vBsin90^0

$$v = \frac{E}{B}$$

Velocity should be the ratio of magnitude of electric and magnetic field.

(b) A rectangular loop of size $l \times b$ carrying a steady current I is placed in a uniform magnetic field $\vec{B}$. Prove that the torque $\vec{\tau}$ acting on the loop is given by $\vec{\tau} = \vec{m} \times \vec{B}$, Where $\vec{m}$ is the magnetic moment of the loop.

Answer:



cdef is the rectangular coil of size $l \times b$

l & b = the length of each vertical & horizontal side of the coil respectively (assuming) the coil to be rectangular

i = the current flowing through the coil.

B = the induction vector of the magnetic field in which the coil is suspended.

We know that the force experienced by the current carrying conductor placed in a magnetic field is

$\vec{F} = i\left(\vec{l} \times \vec{B}\right) \rightarrow (1)$

Force on each wire 'de' and 'fc'

$\left|\vec{F}\right| = ibB\sin(90-\phi) = ibB\sin\phi$

where ϕ = angle between the normal to the plane of the coil and the direction of the magnetic field.

The direction of the force on the wires 'de' & 'fc' are in the plane of the coil along the downward and upward direction respectively and hence cancel out.

Force on each wire 'de' and 'fc'

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The direction of the force on the wires 'de' & 'fc' are in the plane of the coil along the downward and upward direction respectively and hence cancel out.

Moment of the couple $\Gamma = ilB \times OC$

$\Gamma = ilBb\sin\phi = i(lb)B\sin\phi = iAB\sin\phi$

$$\tau = \vec{m} \times \vec{B}$$

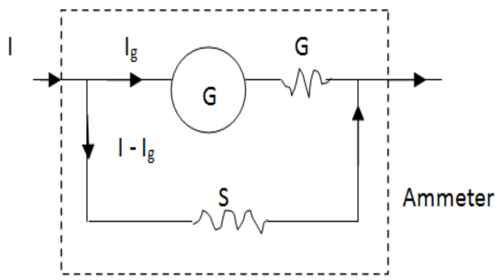
iA=$\vec{m}$ =magnetic moment.

OR

(a)Explain giving reasons, the basic difference in converting a galvanometer into (i) a voltmeter and (ii) an ammeter.

Answer: (i) A voltmeter measures potential drop. Ideally it should not draw any current. To convert a galvanometer to voltmeter a large resistance in series is connected to the Galvanometer.

(ii) An ammeter is used to measure current. The resistance should be zero. A galvanometer can be converted to ammeter by connecting a low resistance in parallel.



Let I_g be the current with which the galvanometer gives full scale deflection. Since galvanometer and shunt are connected in parallel then

P. D. Across galvanometer = P. D. Across shunt

$$Ig\,G = (I - Ig)\,S$$

$$\therefore\ S = \left(\frac{Ig}{I - Ig}\right) G$$

Hence by connecting a shunt of resistance S across the galvanometer, we get an ammeter of desired range.

Expression for the resistance of the ammeter:

Let R be the effective resistance of ammeter then

$$\frac{1}{R} = \frac{1}{G} + \frac{1}{S} = \frac{S+G}{GS}$$

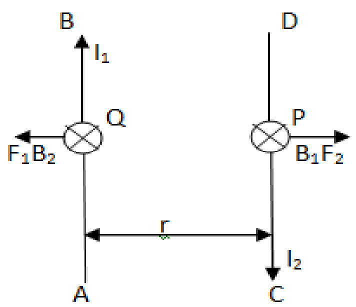
$$\text{Hence } R = \frac{GS}{G+S}$$

(a) Two long straight parallel conductors carrying steady currents I_1 and I_2 are separated by a distance 'd'. Explain briefly with the help of a suitable diagram how the magnetic field due to one conductor acts on the other. Hence deduce the expression for the force acting between the two conductors. Mention the nature of this force.

Answer: Consider two infinitely long thin conductors carrying currents in opposite directions.

Magnetic field B_1 due to I_1 at P on conductor CD is given by

$B_1 = \frac{\mu_0 I_1}{2\pi r}$



The magnetic field B_1 is perpendicular to plane of paper and directed inward. This field will produce a force/length F_2 on conductor given CD by

$F_2 = B_1 I_2 = \frac{\mu_0 I_1 I_2}{2\pi r}$ $\quad [\because F = BIl, Here\ l = 1]$

By *Fleming's left hand rule* direction of F_2 is away from the conductor AB.

Similarly the current I_2 will create a field B_2 at Q directed inward which in turn will create force/length F_1

$\therefore F_1 = B_2 I_1 = \frac{\mu_0 I_1 I_2}{2\pi r}$

By *Fleming's left hand rule*, the direction of F_1 is away from the conductor AB. Hence the conductors repel each other.