Class- XII

Physics

TIME ALLOWED: 3 hours **MAX MARKS:70**

General Instructions:

(i) All questions are compulsory. There are 26 questions in all

(ii) The question paper has five sections. Section A, Section B, Section C, Section D and Section E.

(iii) Section A contains five questions of one mark each, Section B contains five questions of two marks each, Section C contains twelve questions of three marks each, Section D contains one value based question of four marks and Section E contains three questions of five marks each.

(iv) There is no overall choice. However, an internal choice has been provided for one question of two marks, one question of three marks and all the three questions of five marks weightage. You have to attempt only one of the choices in such questions.

(v) You may use the following values of physical constants wherever necessary.

$c = 3\times10^{8}\,\text{m s}^{-1}$

$h = 6.63\times10^{-34}\ \text{J s}$

$e = 1.6\times10^{-19}\,\text{C}$

$\mu_0 = 4\pi\times10^{-7}\,\text{T m A}^{-1}$

$\varepsilon_0 = 8.854\times10^{-12}\,\text{C}^2\text{N}^{-1}\text{m}^{-2}$

$\dfrac{1}{4\pi\varepsilon_0} = 9\times10^{9}\,\text{Nm}^2\text{C}^{-2}$

$m_e = 9.1\times10^{-31}\,\text{kg}$

mass of neutron = 1.675×10^{-27}kg

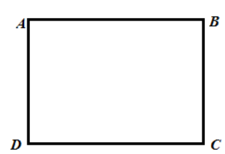
mass of proton = 1.673×10^{-27}kg

Avogadro number = 6.023×10^{23} per gram mole

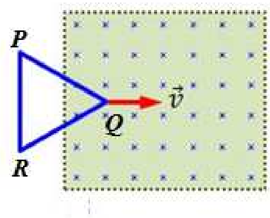
Boltzmann constant = $1.38\times10^{-23}\text{JK}^{-1}$

SECTION A

1. A thin, flat, metal plate ABCD of uniform thickness is given a charge Q. How will the charge be distributed on the surface of the metal?



2. A wire is bent in the form of a triangle and is moved into a uniform magnetic field B directed inwards and perpendicular to the plane of the paper. What is the direction of induced current in the frame?



3. A proton and an α particle have equal kinetic energies. Which of the two particles will have a higher de Broglie wavelength? Justify.

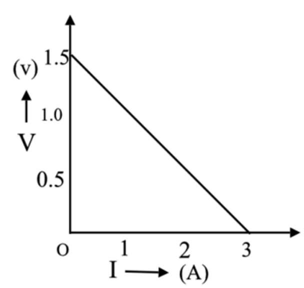
4. A small quantity of antimony is added to a germanium crystal in motel state and the resultant crystal is allowed to crystallize. What kind of semiconductor is formed? What is the ratio of the number of holes to the number of electrons in the semiconductor which is formed?

5. Identify *X* and *Y* in the following block diagram of a simple receiver.

$\boxed{Antenna} \rightarrow \boxed{Amplifier} \rightarrow \boxed{X} \rightarrow \boxed{Y} \rightarrow \boxed{Amplifier} \rightarrow \boxed{Output}$

SECTION B

6. Define internal resistance of a cell. The graph given below shows a plot of potential difference in volts in a given circuit to the current in amperes flowing in the circuit. Using the graph, determine the value of the e m f ε of the cell and its internal resistance *r*.



OR

A 4 wire potentiometer and a 10 wire potentiometer are connected across a battery of emf 5 V. Which of these potentiometers would have greater sensitivity? Why?
Suggest a method by which the sensitivity of the 4 wire potentiometer may be increased.

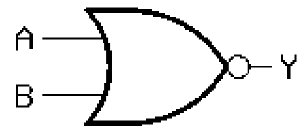
7. What is angle of Dip? Where, on the Earth's surface will it have (i) a maximum value(ii) minimum value?

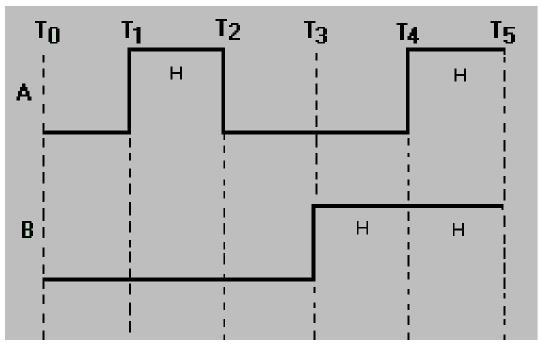
If the horizontal component of the earth's magnetic field at a place is $\frac{1}{\sqrt{3}}$ times the vertical component at the place, what is the angle of Dip?

8. (a) What is the angle between the directions of electric and magnetic field vectors?

(b) Write the value of the phase difference between the electric and magnetic fields in an electromagnetic wave?
(c) How are the amplitudes of the electric field and magnetic fields related?
(d) Give the expression for the speed of an electromagnetic wave in vacuum.

9. The circuit symbol of a logic gate and two input waveforms A and B are shown below.



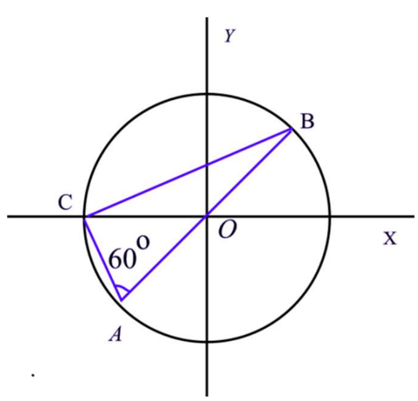


(i) Name the gate.
(ii) Write the truth table of the inputs given.
(iii) Sketch the output waveform.

10. What is an electrical transducer? What is the use of repeater in a communication system?

SECTION C

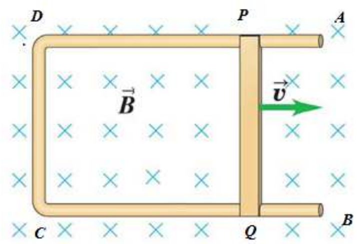
11. A system of charges $\frac{q}{3}, -\frac{q}{3}$ and $\frac{2q}{3}$ are placed at points *A*, *B* and *C* of a circle of radius *R*. The centre of the circle is *O* and $\angle BAC = 60°$. Find (i)the electric field at point *O*. (ii) Potential at point *O*



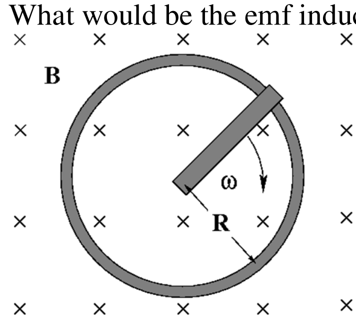
12. A long solenoid of length *l*, having *n* turns per unit length carries a current *I*. Using Ampere's circuital law, determine an expression for the magnetic field inside the solenoid.

Graphically represent the variation of the magnetic field of the solenoid with distance from its centre along its axis.

13. A conductor PQ of length *l* moves with a constant speed *v* in a uniform magnetic field $\vec{B}$ on a rectangular wire frame ABCD, of negligible resistance. Deduce an expression for the induced e m f in the rod.



The wire frame is now removed and the rod is allowed to rotate with uniform angular speed ω in the same magnetic field with one end hinged at the centre and the other end resting on a metallic ring. What would be the emf induced in the rod in this case?



14. State the condition under which resonance occurs in a series LCR circuit. Draw graphs to show the variation of (i) current and (ii) impedance with frequency of the ac supply.

15. The process of charging of a capacitor cannot be explained using Ampere's circuital law. Explain the contradiction involved. How is this contradiction removed by the introduction of *displacement current*?

16. A biconvex lens of equal radii of curvature *R* is placed on a plane mirror. An optical needle with its tip on the principal axis is moved along the axis till the real, inverted image is formed above the tip of the needle. The distance between the lens and thee needle is measured as f_1.A few drops of water are poured on the surface of the plane mirror and the lens is placed over it. The experiment is repeated and the distance between the lens and the needle is measured as *f*. Find the refractive index of the liquid.

OR

Explain with suitable diagrams, the formation of (i) primary rainbow (ii) secondary rainbow. Explain the differences between them. What are the conditions necessary for observing a rainbow?

17. (a) Explain what happens to the Young's double slit pattern when
(i) the screen is moved away from the source
(ii) The whole apparatus is immersed in water.
In both cases write expressions for the new fringe width.
(b) The plane of two polaroids is kept perpendicular to the direction of incident light, with their transmission axes making an angle of 45° with each other. Find the fraction of the incident unpolarised light transmitted through the system.

18. Write Einstein's photoelectric equation. Draw a plot of photoelectric current versus anode potential for three frequencies $\nu_1 > \nu_2 > \nu_3$. How does the saturation current for a particular intensity vary for different frequencies? What would happen to the saturation current if the intensity of light corresponding to the frequency ν_2 is doubled?

19. An electron in hydrogen atom makes a transition from the fourth excited state to the ground state. Find the maximum number of photons emitted in the process. Find the value of the wavelengths of the photon with (i) maximum energy (ii) minimum energy.

20. (a) What are the properties of nuclear forces?
(b) Find the binding energy and binding energy per nucleon of ${}^{16}_{8}O$ nucleus, given the mass of ${}^{16}_{8}O$ = 15.994914u, mass of a proton =1.007825u and mass of a neutron = 1.008665 u.

21. What is a zener diode? Explain how a zener diode is used as a voltage regulator.

22. (a) What kind of waves can be used for line of sight communication? Write their range of frequencies.
(b) For an amplitude modulated wave, the maximum amplitude is found to be 8V, while the minimum was found to be 2V. Determine the modulation index.
(c) What is the function of a square law device in amplitude modulation?

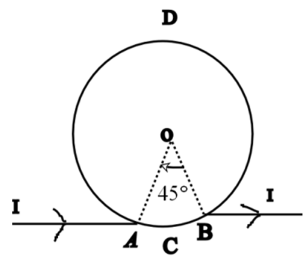
SECTION D

23. Shreya was travelling to her hometown by bus when a heavy downpour started. There was distant rolling of thunder and flashes of lightning in the sky. One of the passengers in the bus, on seeing the lightning, panicked and asked the driver to stop so that they could take shelter under a large near the road side. Shreya calmed her down and advised the driver and the passengers that they were safer inside the bus than under the tree.
(a) What was the principle on the basis of which Shreya came to this conclusion?
(b) Tall buildings are more prone to lightning strikes. What are the measures that should be taken to protect the building from damage?
(c) What values displayed by Shreya are worth emulating?

SECTION E

24. (a) Two cells of e m f ε_1 and ε_2 with internal resistances r_1 and r_2 are connected in parallel. Derive an expression for (i) the equivalent e m f and (ii) equivalent internal resistance of the combination.

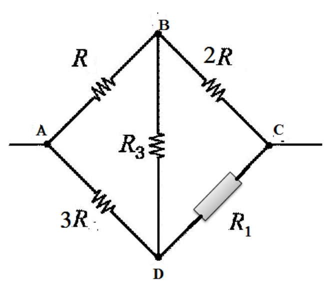
(b) A wire of resistance 24Ω is bent in the form of a circle of radius *R*. A current *I* enters the ring through *A* and leaves the ring through *B*. If $\angle AOB = 45°$, where *O* is the center of the ring, calculate the equivalent resistance of the ring . If the battery connected between A and B has an e m f of 12 V, calculate the current through the circuit.



OR

(a) Derive the condition for bridge balance in a Wheatstone's network.

(b) In a Wheatstone's bridge shown, the balance point is achieved when a carbon resistor with a colour code *brown, red, orange* is connected across the arm CD. Find the value of *R*. The resistors in the arms AD and CD are now exchanged and the resistor across AB is replaced with a carbon resistor to obtain bridge balance condition. Find the colour code of the resistor connected across AB, when the bridge is in balanced condition.



25. Alternating source of e mf $v = v_m \sin \omega t$ is applid across a series combination of an inductor of inductance *L*, a capacitor of capacitance *C* and a resistor of resistance *R*. Derive analytically an expression for (i) current flowing in the circuit (ii) phase angle between the current and the voltage in the circuit.

OR

Derive an expression for the Q factor of a series RLC circuit. Explain how the sharpness of resonance may be increased.

26. (a) State Huygens's principle. A plane wave front propagates from a denser medium to a rarer medium. Using Huygens's principle, construct the refracted wave front and hence verify the Snell's law of refraction.

(b) Draw the shape of wave front in each of the following cases.

(i) light emerging from a convex lens when a point source is placed at its focus.

(ii) Parallel beam of light after refraction through a prism.

OR

Describe using Huygens's principle how a diffraction pattern is obtained on a screen due to a single narrow slit.

Obtain the condition for angular width of secondary maxima and secondary minima.

Draw a plot of intensity distribution for the single slit diffraction pattern.

(Solution)
Class- XII Physics

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Section A

1. The charge concentrates at the sharp edges A, B, C and D of the plate.

2. In the anticlockwise direction , PRQP

3. If the proton and the α particle have the same kinetic energy *K,*

$$\lambda_p = \frac{h}{\sqrt{2m_p K}} ; \lambda_\alpha = \frac{h}{\sqrt{2m_\alpha K}}$$

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha}{m_p}}$$

$$\because m_\alpha = 4m_p$$

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{4} = 2$$

$$\boxed{\lambda_p = 2\lambda_\alpha}$$

4. Antimony is a pentavalent impurity; hence on doping a germanium crystal with it would produce an *n* type semiconductor.

$n_{\text{electrons}} > n_{\text{holes}}$

5. *X* – Intermediate frequency stage (IF stage); *Y*- Detector

Section B

6. The resistance offered by the electrolyte of a cell to the passage of current is called the internal resistance of the cell.

The relation between the e m f ε, potential difference *V* , current *I* and the internal resistance *r* is

$V = \varepsilon - Ir$

From the graph, When $I = 0, V = \varepsilon = 1.5V$.

The emf of the cell is 1.5V.

When $V = 0, \varepsilon = Ir$,

$$r = \frac{\varepsilon}{I} = \frac{1.5}{3} = 0.5\Omega$$

The internal resistance of the cell is 0.5Ω .

OR

The 10 wire potentiometer will have greater sensitivity, since it has a lower value of potential gradient.
If a suitable resistance is connected in series with the driver cell of the 4 wire potentiometer, the potential drop per unit length of the potentiometer wire is reduced, hence its sensitivity increases.

7. Angle of Dip is the angle between the horizontal component of the earth's magnetic field and the direction of the total magnetic field on the earth. It has a maximum value of $I = 90°$ at the poles and a minimum value of $I = 0°$ at the equator.

$$\tan I = \frac{Z_E}{H_E} = \frac{Z_E}{\frac{1}{\sqrt{3}} Z_E} = \sqrt{3}$$

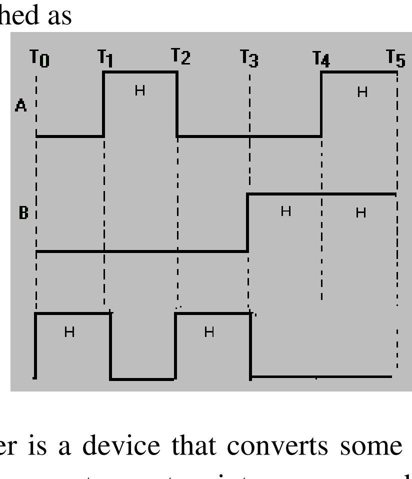
$\boxed{I = 60°}$

8. (a) 90°
(b) 0°
(c) $E_0 = cB_0$
(d) $c = \dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$

9. The gate is NOR gate
The truth table for the wave form is

Time interval	A	B	$Y = \overline{A+B}$
$T_0 - T_1$	0	0	1
$T_1 - T_2$	1	0	0
$T_2 - T_3$	0	0	1
$T_3 - T_4$	0	1	0
$T_4 - T_5$	1	1	0

The waveform is sketched as

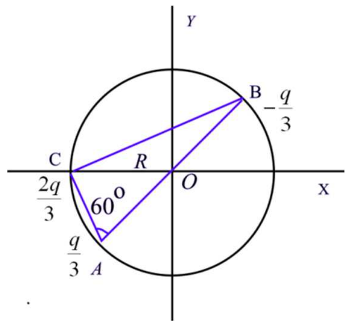


10. An electrical transducer is a device that converts some physical variable like pressure, displacement, force, temperature, etc., into corresponding variations in the electrical signal at its output.

Repeaters are used to increase the range of a communication system.

Section C

11. The charges are placed as shown.



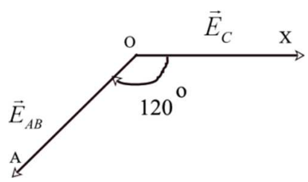
(i) The electric field at O due to $\frac{q}{3}$ at A is $\vec{E}_A = \frac{1}{4\pi\varepsilon_0}\frac{q}{3R^2}O\hat{A}$

The electric field at O due to $-\frac{q}{3}$ at B is $\vec{E}_B = \frac{1}{4\pi\varepsilon_0}\frac{q}{3R^2}O\hat{A}$

The two fields act in the same direction, so they add up. The resultant $\vec{E}_{AB} = \frac{1}{4\pi\varepsilon_0}\frac{2q}{3R^2}O\hat{A}$.

The electric field due to $\frac{2q}{3}$ at C is $\vec{E}_C = \frac{1}{4\pi\varepsilon_0}\frac{2q}{3R^2}O\hat{X}$.

The Electric field at O is the vector sum of the fields $\vec{E}_{AB}$ and $\vec{E}_C$ acting at 120^0.



$$E_O{}^2 = E_{AB}^2 + E_C^2 + 2E_{AB}E_C\cos 120°$$

Since $\left|\vec{E}_{AB}\right| = \left|\vec{E}_C\right| = E$

$$E_O{}^2 = E^2 + E^2 + 2E^2\left(-\frac{1}{2}\right)$$

$$E_O = E = \frac{1}{4\pi\varepsilon_0}\frac{2q}{3R^2}$$

The direction will be along the angular bisector of the angle XOA

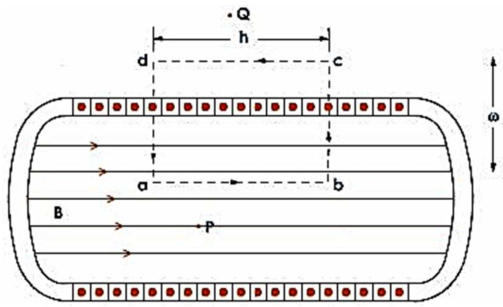
(ii) the potential at O

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{3R} + \frac{1}{4\pi\varepsilon_0}\frac{-q}{3R} + \frac{1}{4\pi\varepsilon_0}\frac{2q}{3R}$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{2q}{3R}$$

12. Consider a solenoid of length l with n turns per unit length. It carries a current I. For a long solenoid, the field at the interior midpoint of the solenoid is uniform and for an external point Q it is vanishingly small. The field outside the solenoid is assumed to be zero.

Consider a rectangular amperian loop *abcd*. Applying Ampere's circuital law to the loop,



The line integral $\oint \vec{B} \cdot d\vec{l}$ is broken into four parts and

$$\oint \vec{B} \cdot d\vec{l} = \int_a^b \vec{B} \cdot d\vec{l} + \int_b^c \vec{B} \cdot d\vec{l} + \int_c^d \vec{B} \cdot d\vec{l} + \int_d^a \vec{B} \cdot d\vec{l}$$

For the integrals $\int_b^c \vec{B} \cdot d\vec{l}$ and $\int_d^a \vec{B} \cdot d\vec{l}$ the directions of their respective $d\vec{l}$ vectors are perpendicular to the direction of $\vec{B}$.

$$\int_b^c \vec{B} \cdot d\vec{l} = \int_d^a \vec{B} \cdot d\vec{l} = 0$$

In the integral $\int_c^d \vec{B} \cdot d\vec{l}$, the value of $|\vec{B}|$ is zero since the part of the loop lies outside the solenoid.

$$\int_c^d \vec{B} \cdot d\vec{l} = 0$$

Therefore, integrating over the length of the solenoid,

$$\oint \vec{B} \cdot d\vec{l} = \int_a^b \vec{B} \cdot d\vec{l} = Bl \qquad \ldots\ldots(1)$$

According to Ampere's circuital law, $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_e$, where $I_e = nIl$, the total current included in the loop.

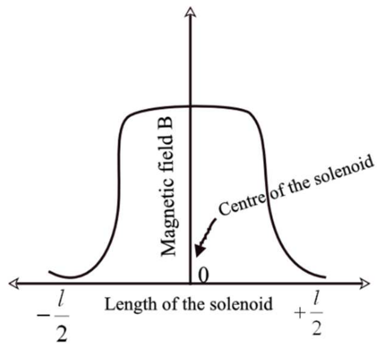
$$\oint \vec{B} \cdot d\vec{l} = \mu_0 nIl \qquad \ldots\ldots(2)$$

From equations (1) and (2)

$$Bl = \mu_0 nIl$$

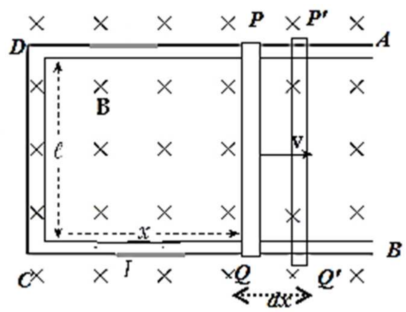
$$\boxed{B = \mu_0 nI}$$

The variation of magnetic field with distance from the centre of the solenoid is given below.



13. The magnetic flux enclosed in the loop is

$\phi_B = BA = Blx$



Let the rod PQ move through a small distance dx to $P'Q'$. The change in the magnetic flux,

$d\phi_B = d\left(Blx\right) = Bldx$

Rate of change of magnetic flux is equal to the induced e m f.

$$\varepsilon = -\frac{d\phi_B}{dt}$$

$$= -\frac{d}{dt}\left(Bldx\right)$$

$$= -Bl\frac{dx}{dt}$$

The negative sign is a consequence of Lenz's law.

Since $v = \frac{dx}{dt}$,

$\boxed{\varepsilon = -Blv}$

If the rod is rotated, the magnitude of e mf generated across a length dl of the rod as it moves at right angles to the field with a angular velocity ω, is

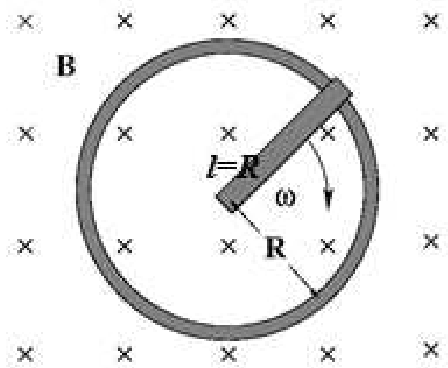
$d\varepsilon = Bvdl$

The e m f induced in the whole rod will be

$\varepsilon = \int d\varepsilon = \int Bvdl$

Since the radius of the circular path $R = l$, the length of the conductor,

$v = l\omega$



$$\varepsilon = \int_0^l B\omega l dl$$
$$= \frac{1}{2} B\omega l^2$$

14. For an RLC circuit with resistance *R,* inductance *L* and capacitance *C* driven under a ac voltage $v = v_m \sin \omega t$, where v_m is the voltage amplitude and ω is the frequency of the applied a c, the current amplitude i_m is given by

$$i_m = \frac{v_m}{Z} = \frac{v_m}{\sqrt{R^2 + (X_C - X_L)^2}},$$

Where, *Z* is the impedance of the circuit, X_C is the capacitive reactance and X_L is the inductive reactance.

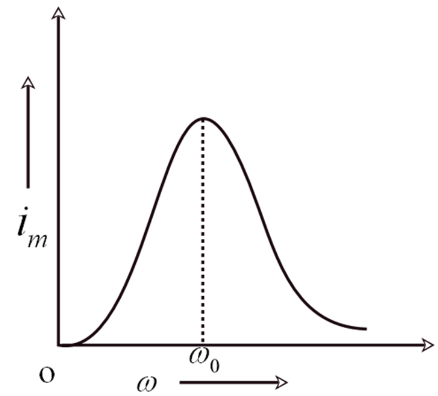
When the frequency ω is varied, at a particular frequency ω_0, the value of impedance is minimum and the current is maximum. This frequency is called resonant frequency.

when $\omega = \omega_0$, $X_C = X_L$ and Z = R.

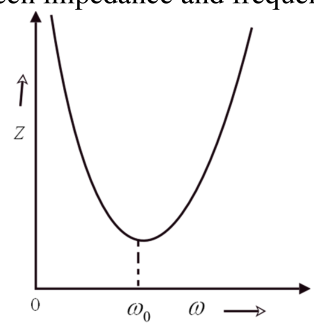
$$\frac{1}{C\omega_0} = L\omega_0$$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

When $\omega = 0, X_C = \infty, Z = \infty, i_m = 0$. As the frequency increases the current amplitude increases. It reaches a maximum value at $\omega = \omega_0$., and with further increase in the frequency, it decreases as the impedance increases. The graphical relationship between current amplitude and frequency is given below.

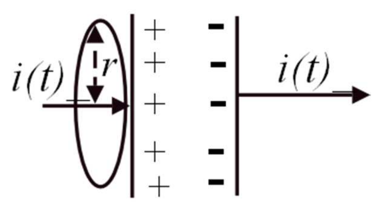


The impedance $Z=\infty$ when $\omega=0$. The impedance decreases and reaches a minimum at $\omega=\omega_0$, where $Z=R$. On further increase in frequency, the impedance increases. The graph between impedance and frequency is given below.



15. Consider a parallel plate capacitor through which a time dependant current *i(t)* flows. Ampere's circuital law is written as

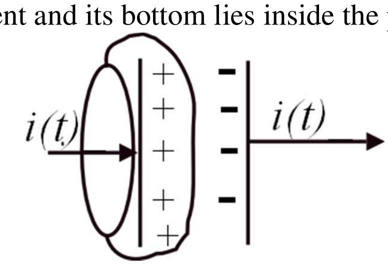
$\oint \vec{B} \cdot d\vec{l} = \mu_0 i(t)$



A plane loop of radius *r* with its plane perpendicular to the direction of the current carrying conductor and centred symmetrically with respect to the wire is considered. Applying Ampere's circuital law to the loop,

$B(2\pi r) = \mu_0 i(t)$

Consider a different surface which has the same boundary but pot like surface. It does not touch the current and its bottom lies inside the plates of the capacitor.



On applying Ampere's circuital law to the surface, the left hand side of the equation remains unchanged while the right hand side of the equation becomes zero. This is because, no current passes through the surface.

When calculated in one way, there is magnetic field at the point on the surface of the loop, while it becomes zero when calculated in another way. This is a a contradiction that is not explained by Ampere's circuital law.

In between the plates, there exists an electric field E due to the charge Q on the plates. This vanishes outside the plates and has a constant magnitude between the plates and acts perpendicular to the plates.

Using Gauss's law, the electric flux between the plates is $\phi_E = \frac{Q}{\varepsilon_0}$. If this flux varies with time,

$$\frac{d\phi_E}{dt} = \frac{1}{\varepsilon_0}\frac{dQ}{dt}$$

But $\frac{dQ}{dt} = i$

Therefore,

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

This is the missing term in Ampere's circuital law, called the displacement current.

The current carried by conductors due to flow of charges is called conduction current i_c and the current due to the changing electric field is called displacement current i_d.

$$\begin{aligned}\oint \vec{B}\bullet d\vec{l} &= \mu_0 i \\ &= \mu_0\left(i_c + i_d\right) \\ &= \mu_0 i_c + \mu_0\varepsilon_0 \frac{d\phi_E}{dt}\end{aligned}$$

This is known as Ampere- Maxwell law.

16. When the convex lens is placed on the mirror, the distance measured is the focal length of the lens. The distance f measured with the liquid is the focal length of the combination of the glass lens and the plano concave liquid lens. If the focal length of the liquid lens is f_2,

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\frac{1}{f_2} = \frac{1}{f} - \frac{1}{f_1} = \frac{f_1 - f}{ff_1} \qquad \ldots\ldots(1)$$

For the plano concave lens,

$$\frac{1}{f_2} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

But, $R_1 = -R; R_2 = \infty$

$$\frac{1}{f_2} = (n-1)\left(-\frac{1}{R} - \frac{1}{\infty}\right)$$

$$= -(n-1)\left(\frac{1}{R}\right) \qquad \ldots\ldots(2)$$

From equations (1) and (2)

$$(n-1)\left(\frac{1}{R}\right) = -\frac{f_1 - f}{ff_1}$$

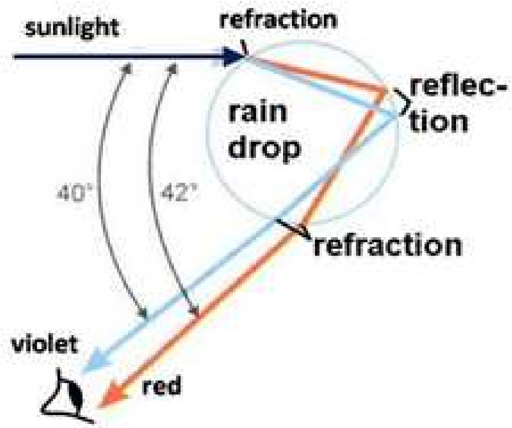
$$\boxed{n = 1 + \frac{R(f - f_1)}{ff}}$$

OR

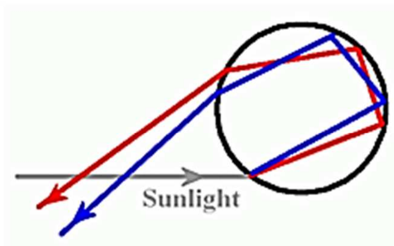
The formation of a rainbow is due to the combined effort of dispersion, refraction and reflection of sunlight by spherical water droplets of rain.

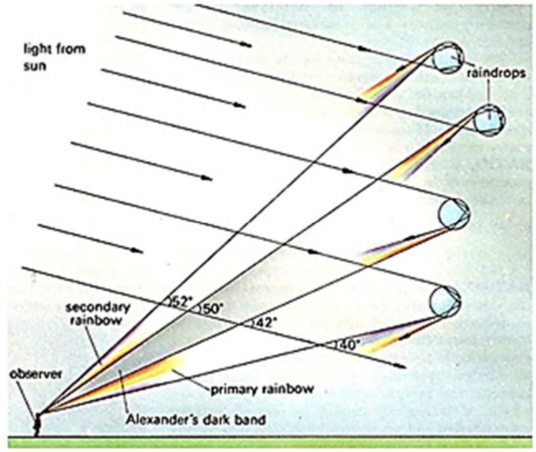
(i) Primary rainbow: Consider sunlight entering a spherical water droplet as shown below.

Sunlight is first refracted as it enters the drop and white light separates into its constituent colours. Red, which has the longer wavelength, is bent less while violet is bent more due to its shorter wavelength. The rays then strike the inner surface of the water droplet and if the angle of incidence is greater than the critical angle for water (48^{o}), it undergoes total internal reflection. The reflected light is refracted again and emerges out of the drop. Violet light emerges at an angle of 40^{o}with respect to the incident sunlight and the red light emerges out at 42^{o}.the observer sees the rainbow with red at the top and violet at the bottom.



Secondary rainbow: If the light ray which enters the drop undergoes two successive reflections before being refracted out from the drop, a secondary rainbow is formed. The red colour emerges out at an angle of 50^{o} with respect to the incident light and the violet at 53^{o}. The order of colours in the secondary rainbow is inverted. The intensity of light is also reduced in the secondary rainbow when compared to the primary rainbow.





The conditions for observing a rainbow:
Sun should shine in one part of the sky while it should rain in the opposite part of the sky.
The observer should stand with his back towards the sun.

17. (a) The fringe width β in Young's double slit experiment is given by

$\beta = \dfrac{\lambda D}{d}$, where, the wavelength of the incident light is λ, the distance between the source and the screen is D and the distance between the two coherent sources is d.

(i) If D is increased, β increases since $\beta \propto D$.

(ii)If the apparatus is immersed in water of refractive index n_w, the wavelength of incident light in water is $\lambda_w = \dfrac{\lambda}{n_w}$.

The new fringe width $\beta_w = \dfrac{\lambda_w D}{d} = \dfrac{\lambda D}{n_w d}$

The fringe width decreases.

(b) Let the intensity of the initial unpolarised light be I_0. After passing through the polariser, the emergent light will have half the original intensity. The light entering the analyser has an intensity $I = \dfrac{I_0}{2}$. If the transmission axes of the analyser is at an angle of 45° to that of the polariser, then

$$I_T = \frac{I_0}{2}\cos^2\theta = \frac{I_0}{2}\left(\frac{1}{\sqrt{2}}\right)^2 = \boxed{\frac{I_0}{4}}$$

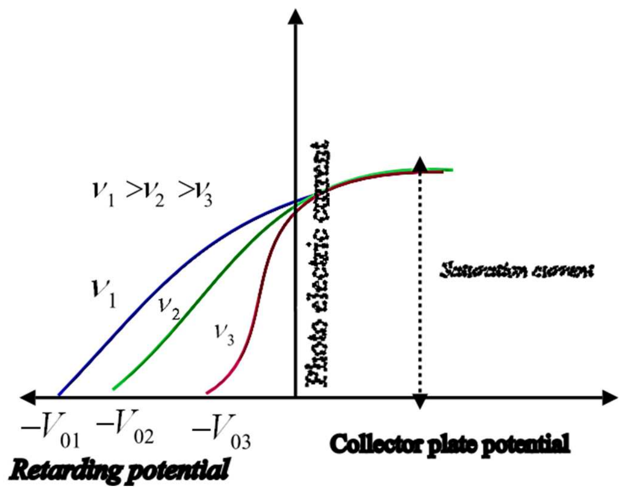
One fourth of the incident light is transmitted through the analyser.

18. Einstein's photoelectric equation is written as,

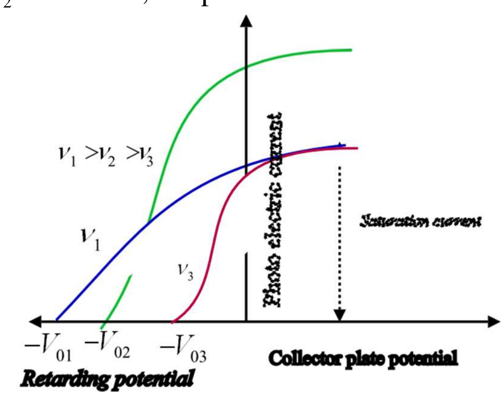
$K_{\max} = h\nu - \phi_0$

Where, the maximum kinetic energy of the photoelectrons is $K_{\max}$, the energy of the incident photon is $h\nu$ and the photoelectric work function of the material is ϕ_0.

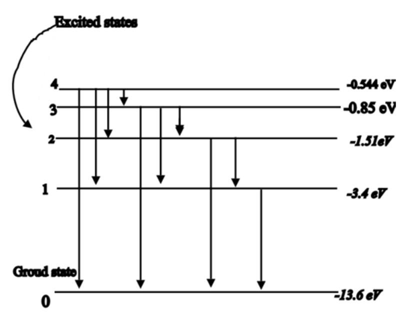
The graph between anode potential and the frequencies for a constant intensity is as below.



The saturation current for a particular intensity is independent of frequency.
Photoelectric current is directly proportional to the intensity of radiation
If the intensity of ν_2 is doubled, the photoelectric current is also doubled.



19. The energy level diagram of hydrogen atom with the transitions from the fourth excited state is given below.



Each transition results in the emission of a photon. As there are10 possible transitions, the maximum number of photons emitted is 10.
(i) The photon with maximum energy corresponds to the transition from the fourth excited state (5th state) to the ground state.

$$h\nu_{\max} = -0.544 - (-13.6) = 13.06 eV$$

$$= 2.09 \times 10^{-18}\text{ J}$$

$$h\nu_{\max} = \frac{hc}{\lambda_{\min}} = 2.09\times10^{-18}\,\text{J}$$

$$\lambda_{\min} = \frac{6.62\times10^{-34}\times3\times10^{8}}{2.09\times10^{-18}} = \boxed{9.502\times10^{-8}\,\text{m}}$$

(ii) The photon with minimum energy corresponds to the transition from fourth excited state to the third excited state.

$$h\nu_{\min} = -0.544-(-0.85) = 0.306eV$$

$$= 4.9\times10^{-20}\,\text{J}$$

$$h\nu_{\min} = \frac{hc}{\lambda_{\max}} = \boxed{4.9\times10^{-20}\,\text{J}}$$

$$\lambda_{\max} = \frac{6.62\times10^{-34}\times3\times10^{8}}{4.9\times10^{-20}\,\text{J}} = 4.053\times10^{-6}\,\text{m}$$

20. (a) (i) Nuclear forces are attractive forces stronger than both Coulomb force and Gravitational force.

(ii) It is a short range force; it falls to zero if the distance between the nucleons is more than a few femtometers and has a property of saturation.

(iii)Nuclear forces are charge independent.

(b) Mass defect

$$\Delta M = \left[Zm_p + (A-Z)m_n\right] - M$$

$$= \left[(8\times1.007825)+(16-8)(1.008665)\right]-15.99053$$

$$= 0.137006u$$

Binding energy is the mass defect converted to energy.

$$B.E = \Delta Mc^2 = (0.137006u)\left(931.5\text{MeV/c}^2\right)$$

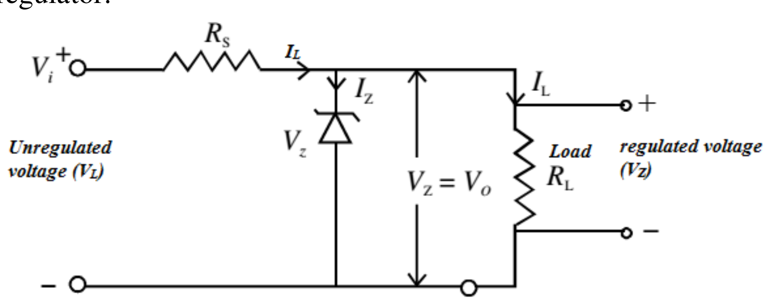
$$= \boxed{127.62\text{MeV}}$$

$$\frac{B.E}{A} = \frac{127.62}{16} = \boxed{7.98\text{MeV}}$$

21. Zener diode is a heavily doped p-n junction diode designed to operate in reverse bias conditions in the breakdown region.

At breakdown voltage, Zener voltage remains constant even when current through it varies.

Voltage regulator:



The unregulated dc voltage (filtered output of a rectifier) is connected to a reverse biased zener diode through a series resistance R_s. If the input voltage increases, the current through R_s and the zener diode increases. This increases the voltage drop across R_s without any change in the voltage across the zener diode. This is because, in the breakdown region, zener voltage remains constant even when the current through it increases.

If the input voltage decreases, the currents through R_s and the zener diode decreases. This decreases the voltage drop across R_s without any change in the voltage across the zener diode. Thus any increase or decrease in the input voltage has no effect on the zener voltage and the voltage across the load resistance R_L remains constant. The Zener diode acts as a voltage regulator.

22. (a) Space waves are used for line of sight communication. Electromagnetic waves of frequencies greater than 40MHz are used in this method of communication.

(b) $\mu = \frac{A_{\max} - A_{\min}}{A_{\max} + A_{\min}} = \frac{8-2}{8+2} = 0.6$

(c) A square law device is non linear device that adds the modulating signal to the carrier signal to produce an output of the form $y(t) = Bx(t) + Cx^2(t)$, where, B and C are constants.

Section D

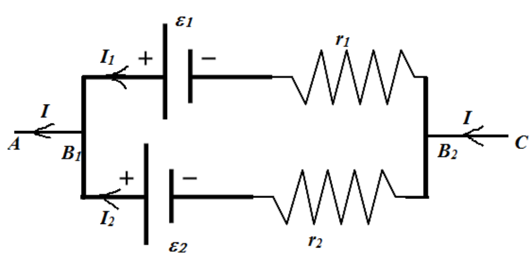
23. (a) Electrostatic shielding- field inside a hollow metallic conductor is zero.

(b) Lightning arrestors can be mounted on the buildings. The sharp and pointed ends of the lightning arrestor attract the charge and conduct it to the ground without causing damage to the building.

(c) Scientific thinking, care for co passengers

Section E

24. Consider two cells of e mf s ε_1 and ε_2 with internal resistances r_1 and r_2 connected in parallel as shown.



The currents I_1 and I_2 leave the positive electrodes and at B_1,

$I = I_1 + I_2$

For the first cell, the potential difference between points B_1 and B_2 is

$V_1 = \varepsilon_1 - I_1 r_1$

For the second cell, the potential difference between points B_1 and B_2 is

$V_2 = \varepsilon_2 - I_2 r_2$

Since the cells are in parallel, $V_1 = V_2 = V$, therefore,

$$I_1 = \frac{\varepsilon_1 - V}{r_1} \text{ and } I_2 = \frac{\varepsilon_2 - V}{r_2}.$$

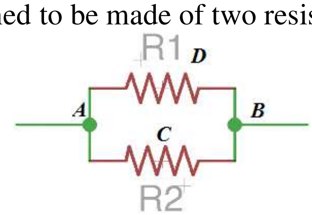
$$I = \frac{\varepsilon_1 - V}{r_1} + \frac{\varepsilon_2 - V}{r_2} = \left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

$$V = \left(\frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}\right) - I\left(\frac{r_1 r_2}{r_1 + r_2}\right)$$

If the cells are replaced by a single cell of emf ε, internal resistance r

$$\varepsilon = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}; r = \frac{r_1 r_2}{r_1 + r_2}$$

(b) The ring may be imagined to be made of two resistors in parallel.



The arc ACB subtends an angle of 45°at the centre. Its length is $\frac{1}{8}$th of the whole wire and its resistance is also $\frac{1}{8}$th of the whole wire.

$$R_{ACB} = R_2 = \frac{24}{8} = 3\Omega$$

$$R_{ADB} = R_1 = 24 - 3 = 21\Omega$$

The equivalent resistance

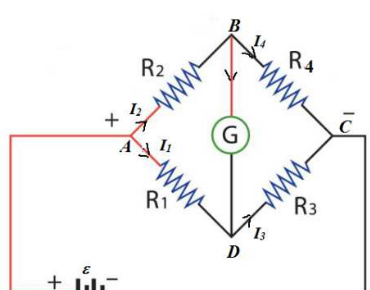
$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2} = \frac{21 \times 3}{21 + 3} = 2.625\Omega$$

The current in the circuit

$$I = \frac{V}{R_{eq}} = \frac{12}{2.625} = 4.57A$$

OR

(a) A Wheatstone's bridge has four resistors R_1, R_2, R_3 and R_4 connected in the form of a network as shown.



A battery of emf ε is connected across points A and C. A galvanometer is connected across Band D. The resistors on the arms are adjusted so that no current flows through the galvanometer.

Applying Kirchhoff's junction rule to B and D,

$I_1 = I_3; I_2 = I_4$

Applying Kirchhoff's loop rule to the loop ADBA,

$-I_1R_1 + 0 + I_2R_2 = 0;$

$I_1R_1 = I_2R_2$

Applying Kirchhoff's loop rule to the loop CDBC and $I_1 = I_3; I_2 = I_4$

$I_2R_4 + 0 - I_1R_3 = 0;$

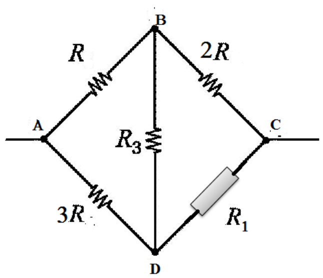
$I_2R_4 = I_1R_3$

From the above equations,

$$\frac{I_1}{I_2} = \frac{R_2}{R_1} = \frac{R_4}{R_3}$$

The condition for balance is $\boxed{\frac{R_2}{R_1} = \frac{R_4}{R_3}}$

(b) The value of R_1:



Brown-1

Red-2

Orange-3

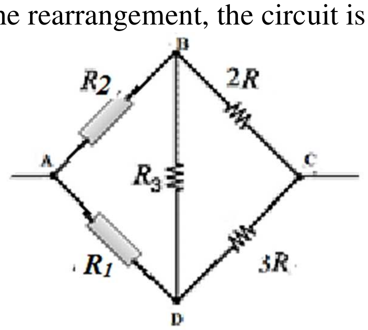
$R_1 = 12 \times 10^3 \Omega$.

For the balance condition,

$$\frac{R}{3R} = \frac{2R}{R_1}; R_1 = 6R$$

$$R = \frac{R_1}{6} = \frac{12\times10^3}{6} = 2\times10^3\Omega$$

After the rearrangement, the circuit is redrawn as follows.



The bridge balance condition in this case is

$$\frac{R_2}{R_1} = \frac{2R}{3R}; R_2 = \frac{2}{3} \times 12 \times 10^3 = 8 \times 10^3 \Omega$$

The colour code for R_2 is *Black(0), Gray(8) Orange (3)*

25. The voltage equation for the circuit is

$$L\frac{di}{dt} + Ri + \frac{q}{C} = v = v_m \sin \omega t$$

Since $i = \frac{dq}{dt}; \frac{di}{dt} = \frac{d^2q}{dt^2}$, therefore,

$$L\frac{d^2q}{dt^2} + R\frac{dq}{dt} + \frac{q}{C} = v_m \sin \omega t. \qquad \ldots\ldots(1)$$

Assuming a solution $q = q_m \sin(\omega t + \theta)$,

$$\frac{dq}{dt} = q_m \omega \cos(\omega t + \theta); \frac{d^2q}{dt^2} = -q_m \omega^2 \sin(\omega t + \theta)$$

Equation (1) is written as,

$$-Lq_m \omega^2 \sin(\omega t + \theta) + Rq_m \omega \cos(\omega t + \theta) + \frac{1}{C} q_m \sin(\omega t + \theta) = v_m \sin \omega t$$

$$q_m \omega \left[-L\omega \sin(\omega t + \theta) + R\cos(\omega t + \theta) + \frac{1}{C\omega} \sin(\omega t + \theta) \right] = v_m \sin \omega t$$

Since $X_L = L\omega; X_C = \frac{1}{C\omega}$,

$$q_m \omega \left[R\cos(\omega t + \theta) + (X_C - X_L) \sin(\omega t + \theta) \right] = v_m \sin \omega t$$

Multiplying and dividing the left hand side by $Z = \sqrt{R^2 + (X_C - X_L)^2}$,

$$q_m \omega Z \left[\frac{R}{Z} \cos(\omega t + \theta) + \frac{(X_C - X_L)}{Z} \sin(\omega t + \theta) \right] = v_m \sin \omega t \quad \ldots\ldots(2)$$

Let $\frac{R}{Z} = \cos\phi; \frac{(X_C - X_L)}{Z} = \sin\phi;$ where $\tan\phi = \frac{X_C - X_L}{R}$

Equation (2) reduces to

$$q_m \omega Z \cos(\omega t + \theta - \phi) = v_m \sin \omega t$$

Comparing the terms on the left hand side and the right hand side of the equation,

$$v_m = q_m \omega Z = i_m Z$$

$$i_m = q_m \omega$$

$$\theta - \phi = -\frac{\pi}{2}; \theta = \phi - \frac{\pi}{2}$$

Writing equation (2) as

$$i = q_m \omega \cos(\omega t + \theta) = i_m \cos\left(\omega t + \phi - \frac{\pi}{2}\right)$$

$$= i_m \sin(\omega t + \phi)$$

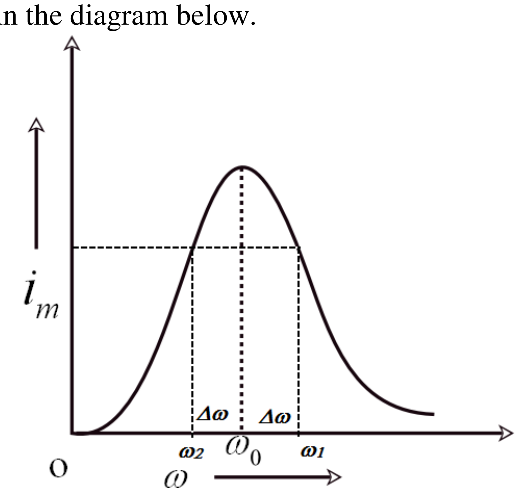
Where $\boxed{i_m = \frac{v_m}{Z} = \frac{v_m}{\sqrt{R^2 + \left(X_C - X_L\right)^2}}}$ and $\boxed{\phi = \tan^{-1}\frac{X_C - X_L}{R}}$

OR

The amplitude of current in an LCR circuit is given by

$$i_m = \frac{v_m}{\sqrt{R^2 + \left(\omega L - \frac{1}{C\omega}\right)^2}}$$

The current attains a maximum value at a frequency $\omega = \omega_0$, where $\omega_0 L = \frac{1}{C_0\omega}$ and the resonant frequency has a value, $\omega_0 = \frac{1}{\sqrt{LC}}$.Choosing a value for ω for which the amplitude is $\frac{1}{\sqrt{2}}$ times the maximum value, where the power dissipated becomes half, there are two values of ω; $\omega_1 = \omega_0 + \Delta\omega$ and $\omega_2 = \omega_0 - \Delta\omega$ for the same value of current, as shown in the diagram below.



These values are symmetrical about ω_0 and the difference between them is called the bandwidth of the circuit. $\omega_1 - \omega_2 = 2\Delta\omega$. Smaller the value of $\Delta\omega$, sharper is the resonance.

Therefore, at ω_1,

$$i_m = \frac{v_m}{\sqrt{R^2 + \left(\omega_1 L - \frac{1}{C_1\omega}\right)^2}} = \frac{i_m^{\max}}{\sqrt{2}} = \frac{v_m}{R\sqrt{2}}$$

Equating the denominators and simplifying,

$$\sqrt{R^2 + \left(\omega_1 L - \frac{1}{C_1\omega}\right)^2} = R\sqrt{2}$$

$$R^2 + \left(\omega_1 L - \frac{1}{C_1\omega}\right)^2 = 2R^2$$

$$\omega_1 L - \frac{1}{C_1\omega} = R$$

Using $\omega_1 = \omega_0 + \Delta\omega$ in the equation,

$$(\omega_0 + \Delta\omega)L - \frac{1}{(\omega_0 + \Delta\omega)C} = R$$

$$\omega_0 L\left(1 + \frac{\Delta\omega}{\omega_0}\right) - \frac{1}{\omega_0 C\left(1 + \frac{\Delta\omega}{\omega_0}\right)} = R$$

Using $\omega_0^2 = \frac{1}{LC}$ in the second term,

$$\omega_0 L\left(1 + \frac{\Delta\omega}{\omega_0}\right) - \frac{\omega_0 L}{\left(1 + \frac{\Delta\omega}{\omega_0}\right)} = R$$

If $\frac{\Delta\omega}{\omega_0} << 1,$ the term $\left(1 + \frac{\Delta\omega}{\omega_0}\right)^{-1} = 1 - \frac{\Delta\omega}{\omega_0}$

Substituting in the equation,

$$\omega_0 L\left(1 + \frac{\Delta\omega}{\omega_0}\right) - \omega_0 L\left(1 - \frac{\Delta\omega}{\omega_0}\right) = R$$

$$\Delta\omega = \frac{R}{2L}$$

The sharpness of resonance is given by

$$\frac{\omega_0}{2\Delta\omega} = \frac{\omega_0 L}{R}$$

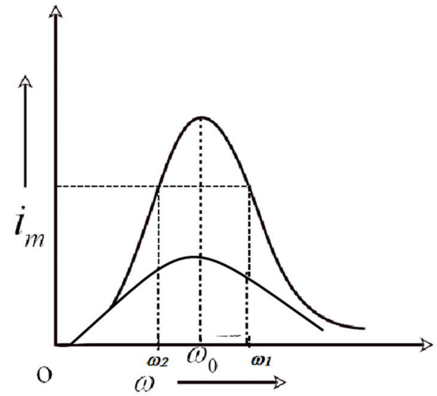
The ratio $\frac{\omega_0 L}{R}$ is also called *Quality factor Q*.

$$\boxed{Q = \frac{\omega_0 L}{R}}$$

$$2\Delta\omega = \frac{Q}{\omega_0}$$

Smaller the bandwidth, sharper is the resonance and larger the value of Q sharper is the resonance.

Using $\omega_0^2 = \frac{1}{LC}$, $Q = \frac{1}{\omega_0 CR}$.



When the value of maximum current is less, the range of $\Delta\omega$ increases and the resonance is less sharp. The selectivity and the sensitivity of such a circuit is low. The tuning is also poor.

To increase the sharpness of resonance,

(i) The quality factor Q must be large.

(ii) The value of R must be low.

(iii) The value of L must be large.

26. (a) Huygens's principle:

(i) A source of light is the center of disturbance which sends waves in all directions.

(ii) The locus of all particles equidistant from the source at any instant is called the wave front.

(iii) Every point on the wave front is a source of secondary wavelets, which travel with the speed of light in the medium.

(iv) The forward envelope of the secondary wavelets at any instant gives the new position of wave front.

Consider a plane wave front AB propagating in a denser medium with a speed v_1. It is incident on the boundary of separation of the mediums 1 and 2, where medium 2 is the rarer medium, at an angle i. Light travels with a speed v_2 in medium 2 such that $v_1 < v_2$.

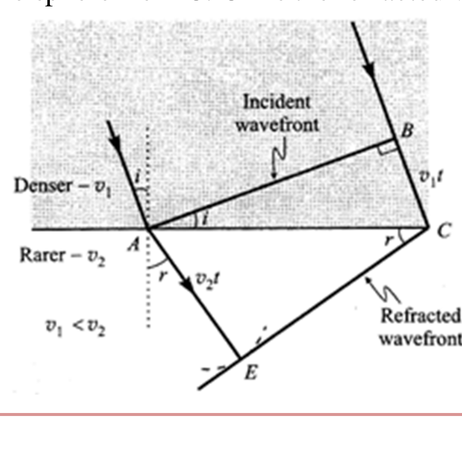
Let the wave front take a time τ to travel a distance BC in the denser medium.

$BC = v_1\tau$

In the same time, the secondary wavelets originating at A, travels a distance AE in the rarer medium.

$AE = v_2\tau$.

Taking AE as radius, a sphere is constructed with A at the centre of the sphere. A tangent is drawn to the sphere from C. CE is the refracted wave front.



In triangles ABC and AEC,

$$\sin i = \frac{BC}{AC}; \sin r = \frac{AE}{AC}$$

$$\frac{\sin i}{\sin r} = \frac{BC}{AE} = \frac{v_1}{v_2}$$

If c is the speed of light in vacuum, and n_1` and n_2 the refractive indices of mediums 1 and 2 respectively, then,

$$n_1 = \frac{c}{v_1}; n_2 = \frac{c}{v_2}$$

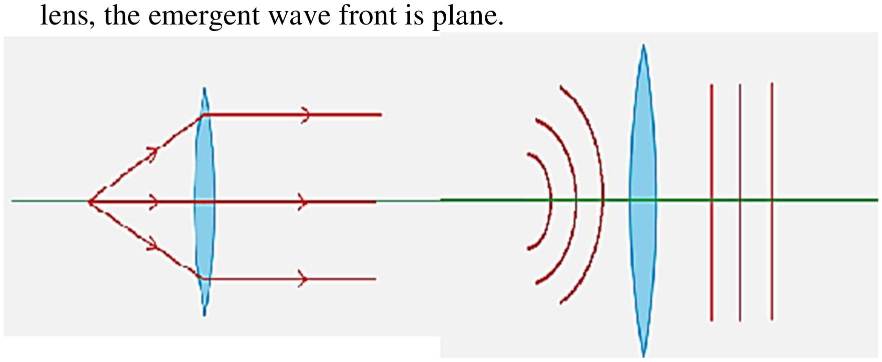
$$\frac{v_1}{v_2} = \frac{n_2}{n_1}$$

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

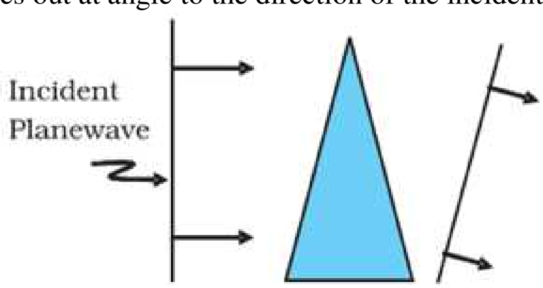
$$n_1 \sin i = n_2 \sin r$$

This is Snell's law of refraction.

(b) (i) When a point source is placed at the focus of a convex lens, the rays are rendered parallel. A point source gives spherical wavefront. After refraction through the lens, the emergent wave front is plane.



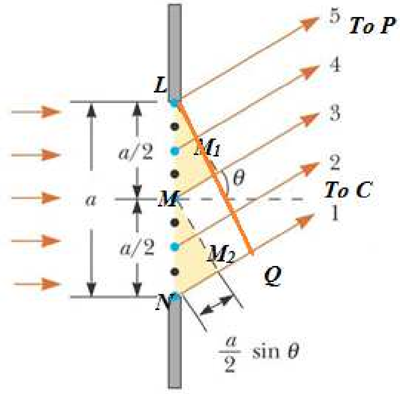
(ii) The incident plane wave front after refraction through a prism remains a plane wave front but comes out at angle to the direction of the incident wave front.



OR

(a) When a narrow slit is illuminated by a monochromatic source, a broad pattern with a central bright fringe and alternate bright and dark regions on either side of the central bright fringe is observed. These fringes reduce in intensity as the distance from the central fringe increases.

Consider a parallel beam of light falling normally on a slit LN.A straight line through M meets the screen at C. The straight lines joining P to different points on the slit are parallel, making an angle θ with the normal NC.



The slit is divided into smaller parts and the phase difference between the parts contributes to the brightness or darkness at a particular point. All the secondary wavelets which reach C have the same path difference and their phase difference is zero. Maximum intensity is observed at C.

At point P, the secondary wavelets diffracted at an angle θ meet. The path difference between the waves starting from L and that from N is given by

$$NP - LP = NQ = a\sin\theta \approx a\theta$$

If the path difference between two waves is λ,

$$a\theta = \lambda$$

Position of minima:

The slit is divided into two halves LM and MN each of size $\frac{a}{2}$. For every point M_1 in LM, there is a corresponding point M_2 in MN such that $M_1M_2 = \frac{a}{2}$.

The path difference between M_1 and M_2 at P is

$$M_1P - M_2P = \frac{a}{2}\theta = \frac{\lambda}{2}$$

The contributions are out of phase by 180° and they cancel each other in the direction $\theta = \frac{\lambda}{a}$.

The intensity is zero when $\theta = \frac{n\lambda}{a}$. Where $n = 1, 2, 3...$ and $n \neq 0$.

The angular width of the secondary minima $\theta_n = \frac{n\lambda}{2}$.

Position of maxima:

Let the point P be located such that the path difference is $\frac{3\lambda}{2}$. The slit is divided into three equal parts. The path difference between two corresponding points of the first two parts will be $\frac{\lambda}{2}$ and they cancel each other. The wavelets from the third part would contribute to some intensity forming a secondary maximum. The intensity of the secondary maximum is much less than that of the central maximum.

The condition for the first secondary maximum is

$$a\theta_1' = \frac{3\lambda}{2}$$

The directions of the secondary maxima are given by

$$\theta_n' = \frac{(2n+1)\lambda}{2a} = \left(n + \frac{1}{2}\right)\frac{\lambda}{a}$$

The intensity distribution for the single slit pattern is given below.