**Series BVM/2**

# PHYSICS

## Paper & Solution

**SET-3**

**Code No. : 55/2/3**

**Time : 3 Hrs.** **Max. Marks : 70**

***General Instruction*** **:**

*(i)* *All questions are compulsory. There are **27** questions in all.*

*(ii)* *This question paper has **four** sections : Section A, Section B, Section C, Section D.*

*(iii)* *Section A contain **five** questions of **one** mark each. Section B contains **seven** questions of **two** marks each, Section C contains **twelve** questions of **three** marks each, Section D contains **three** questions of **five** marks each.*

*(iv)* *There is no overall choice. However, an internal choice(s) has been provided in **two** question of **one** marks, **two** question of **two** marks, **four** questions of **three** 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 :*

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

$h = 6.63 \times 10^{-34}$ Js

$e = 1.6 \times 10^{-19}$ C

$\mu_0 = 4\pi \times 10^{-7}$ T $mA^{-1}$

$\varepsilon_0 = 8.854 \times 10^{-12}$ $C^2N^{-1}m^{-2}$

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N $m^2$ $C^{-2}$

$m_e = 9.1 \times 10^{-31}$ kg

Mass of Neutrons = $1.675 \times 10^{-27}$ kg

Mass of proton = $1.673 \times 10^{-27}$ kg

Avogadro's number = $6.023 \times 10^{23}$ per gram mole

Boltzmann constant = $1.38 \times 10^{-23}$ $JK^{-1}$

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## SECTION A

**Q.1** The magnetic susceptibility of magnesium at 300 K is $1{\cdot}2 \times 10^5$. At what temperature will its magnetic susceptibility become $1{\cdot}44 \times 10^5$ ? **[1]**

**OR**

The magnetic susceptibility $\chi$ of a given material is – 0·5. Identify the magnetic material.

**Sol.** $\chi \propto \frac{1}{T}$

$$\frac{\chi_1}{\chi_2} = \frac{T_2}{T_1} \Rightarrow \frac{1\cdot2\times10}{1\cdot44\times10} = \frac{T_2}{300}$$

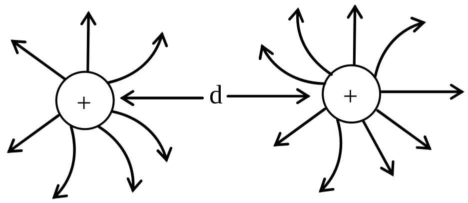
$$T_2 = \frac{3000}{1\cdot2} = \frac{500}{2} = 250 \text{ K}$$

**OR**

Diamagnetic

**Q.2** Draw a pattern of electric field lines due to two positive charges placed a distance d apart. **[1]**

**Sol.**




**Q.3** Which part of the electromagnetic spectrum is used in RADAR? Give its frequency range. **[1]**

**OR**

How are electromagnetic waves produced by accelerating charges?

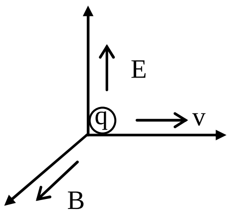
**Sol.** 3KHz – 300 GHz

**OR**

By accelerating charge particle produce changing E & B field.

**Q.4** When a charge q is moving in the presence of electric (E) and magnetic (B) fields which are perpendicular to each other and also perpendicular to the velocity v of the particle, write the relation expressing v in terms of E and B. **[1]**

**Sol.**

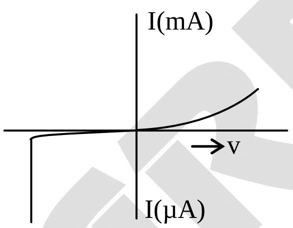



qE = qvB

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

**Q.5** Draw the I-V characteristics of a Zener diode. **[1]**

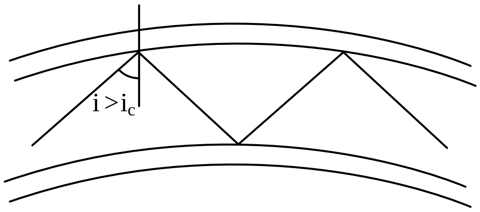
**Sol.**




## SECTION B

**Q.6** State, with the help of a ray diagram, the working principle of optical fibres. Write one important use of optical fibres. **[2]**

**Sol.** Optical fibres use of the phenomenon of total internal reflection.




Use : as light pipe to facilitate visual examination of internal organs.

**Q.7** A photon emitted during the de-excitation of electron from a state n to the first excited state in a hydrogen atom, irradiates a metallic cathode of work function 2 eV, in a photo cell, with a stopping potential of 0·55 V. Obtain the value of the quantum number of the state n. **[2]**

**OR**

A hydrogen atom in the ground state is excited by an electron beam of 12·5 eV energy. Find out the maximum number of lines emitted by the atom from its excited state.

**Sol.** $13.6\,Z^2\left\{\frac{1}{2^2}-\frac{1}{n^2}\right\}\text{eV} = eV_0 + \phi$

$13.6\,(1)^2\left\{\frac{1}{4}-\frac{1}{n^2}\right\}\text{eV} = 0.55\text{eV} + 2\text{ eV}$

$13.6\left\{\frac{1}{4}-\frac{1}{n^2}\right\} = 2.55$

$\frac{1}{4} - \frac{1}{n^2} = \frac{2.55}{13.6}$

$\Rightarrow \frac{1}{n^2} = \frac{1}{4} - \frac{2.55}{13.6}$

$\frac{1}{n^2} = \frac{13.6-10.20}{4\times 13.6} = \frac{1}{n^2} = \frac{34}{4\times 13.6}$

$\Rightarrow \boxed{n = 4}$

**OR**

This beam can excite atom upto n = 3

Thus maximum no. of lines = $\frac{3(3-1)}{2} = 3$

**Q.8** How are electromagnetic waves produced by oscillating charges ? What is the source of the energy associated with the em waves ? **[2]**

**Sol.** Oscillating charges produce changable electric field and magnetic field as they reproduce each other.

The electric and magnetic field vibration is energy in em wave and their source of energy is external force exerting on charge particle in oscillation.

**Q.9** The wavelength of light from the spectral emission line of sodium is 590 nm. Find the kinetic energy at which the electron would have the same de-Broglie wavelength. **[2]**

**Sol.** $\lambda = \frac{h}{\sqrt{2km}}$

$590 \times 10^{-9} = \frac{6.6\times 10^{-34}}{\sqrt{2km}}$

$(590 \times 10^{-9})^2 = \frac{(6.6\times 10^{-34})^2}{2km}$

$k = \frac{(6.6\times 10^{-34})^2}{(590\times 10^{-9})^2 \times 2\times 9.1\times 10^{-31}}$

$k = \frac{43.56\times 10^{-68}}{348100\times 10^{-18}\times 2\times 9.1\times 10^{-31}}$

$k = \frac{43.56\times 10^{-68}\times 10^{18}\times 10^{31}}{348100\times 2\times 9.1}$

$k = 6.8 \times 10^{-6} \times 10^{-19}$

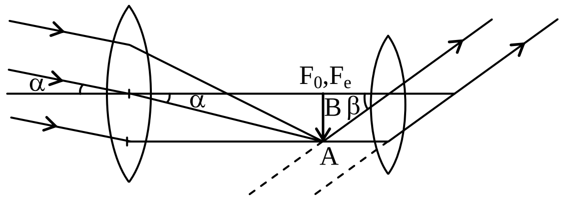
$k = 6.8 \times 10^{-25}$ J

**Q.10** Draw the ray diagram of an astronomical telescope showing image formation in the normal adjustment position. Write the expression for its magnifying power. **[2]**

**OR**

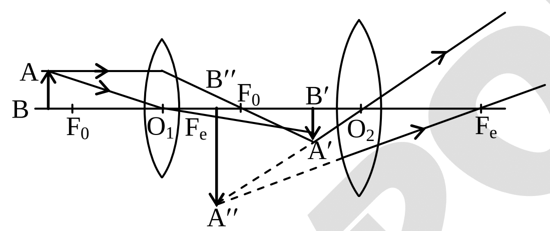
Draw a labelled ray diagram to show image formation by a compound microscope and write the expression for its resolving power.

**Sol.**




$$m = \frac{\beta}{\alpha} = \frac{-AB/F_e}{AB/f_0} = -\frac{f_0}{f_e}$$

**OR**




$$\text{Resolving power} = \frac{2\mu \sin\beta}{1.22\lambda}$$

**Q.11** Explain the following : **[2]**

(a) Sky appears blue.

(b) The Sun appears reddish at (i) sunset, (ii) sunrise.

**Sol.** (a) Sky appears blue due to scattering of light the water droplet size around the wavelength of violet & blue colour.

(b) (i) due to long distance travel by white light red colour reached only

(ii) due to long distance travel by white light red colour reached only

**Q.12** Write the relation between the height of a TV antenna and the maximum range up to which signals transmitted by the antenna can be received. How is this expression modified in the case of line of sight communication by space waves? In which range of frequencies, is this mode of communication used? **[2]**

**Sol.** $d = \sqrt{2RH_T} + \sqrt{2RH_T}$

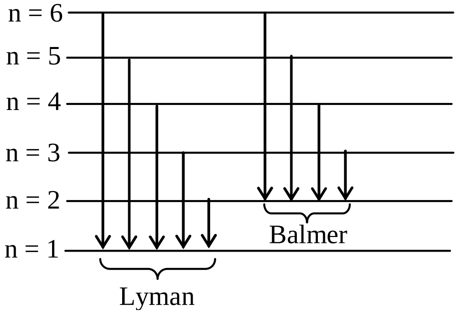
Frequency range should be greater than 40 MHz.

## SECTION C

**Q.13** (a) Draw the energy level diagram for the line spectra representing Lyman series and Balmer series in the spectrum of hydrogen atom.

(b) Using the Rydberg formula for the spectrum of hydrogen atom, calculate the largest and shortest wavelengths of the emission lines of the Balmer series in the spectrum of hydrogen atom. (Use the value of Rydberg constant $R = 1.1 \times 10^7\ m^{-1}$) **[3]**

**Sol.**




$$\frac{1}{\lambda_{\text{largest}}} = 1.1 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\lambda_{\text{largest}} = \frac{36}{1.1 \times 5 \times 10^7} = 6.5 \times 10^{-7}\text{ m}$$

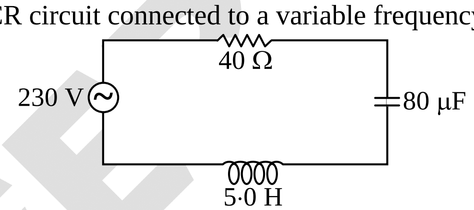
$$\frac{1}{\lambda_{\text{shortest}}} = 1.1 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{\infty^2}\right)$$

$$\lambda_{\text{shortest}} = \frac{4}{1.1 \times 10^7} = 3.6 \times 10^{-7}$$

**Q.14** A capacitor (C) and resistor (R) are connected in series with an ac source of voltage of frequency 50 Hz. The potential difference across C and R are respectively 120 V, 90 V, and the current in the circuit is 3 A. Calculate (i) the impedance of the circuit (ii) the value of the inductance, which when connected in series with C and R will make the power factor of the circuit unity. **[3]**

**OR**

The figure shows a series LCR circuit connected to a variable frequency 230 V source.




(a) Determine the source frequency which drives the circuit in resonance.
(b) Calculate the impedance of the circuit and amplitude of current at resonance.
(c) Show that potential drop across LC combination is zero at resonating frequency.

**Sol.** (a) $X_L = X_C$

$$5\cdot\omega = \frac{1}{W \cdot 80 \times 10^{-6}}$$

$$\omega^2 = \frac{1}{400 \times 10^{-6}}$$

$$\omega^2 = \frac{1}{4 \times 10^{-4}}$$

$$\omega = \frac{1}{2 \times 10^{-2}} = 50\text{ rad/sec}$$

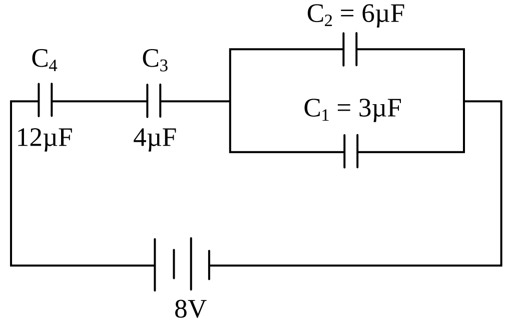
(b) $Z = 40\Omega,\ I_0 = \dfrac{230\sqrt{2}}{40} = \dfrac{23\sqrt{2}}{4}$

(c) $X_L = 50 \times 5 = 250\ \Omega$

$$X_C = \frac{1}{50 \times 80 \times 10^{-6}} = \frac{1}{4 \times 10^{-3}} = 250\ \Omega$$

current is same in series that why voltage drop will same.

**Q.15** In a network, four capacitors $C_1$, $C_2$, $C_3$ and $C_4$ are connected as shown in the figure.




(a) Calculate the net capacitance in the circuit.

(b) If the charge on the capacitor $C_1$ is 6 μC, (i) calculate the charge on the capacitors $C_3$ and $C_4$, and (ii) net energy stored in the capacitors $C_3$ and $C_4$ connected in series. **[3]**

**Sol.** (a) $\frac{1}{9}+\frac{1}{4}+\frac{1}{12} \Rightarrow C_{net} = \frac{9}{4}$

(b) Charge on $C_3$ and $C_4$ will be

$Q = CV$

$Q = \frac{9}{4} \times 8 = 18 \times 10^{-6} C$

Energy store $\frac{Q^2}{2C_3}+\frac{Q^2}{2C_4}$

$\frac{18\times18\times10^{-12}}{2\times4\times10^{-6}}+\frac{18\times18\times10^{-12}}{2\times12\times10^{-6}}$

$E = 54\ \mu J$

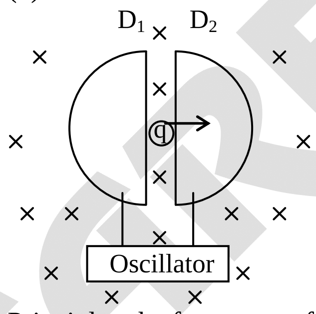
**Q.16** Draw a labelled diagram of cyclotron. Explain its working principle. Show that cyclotron frequency is independent of the speed and radius of the orbit. **[3]**

**OR**

(a) Derive, with the help of a diagram, the expression for the magnetic field inside a very long solenoid having n turns per unit length carrying a current I.

(b) How is a toroid different from a solenoid?

**Sol.**




Principle : the frequency of charge particle moving in magnetic field is independent of its speed.

$qvB = \frac{mv^2}{r}$

$r = \frac{mv}{qB}$

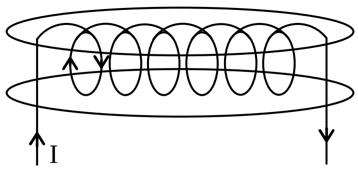
$v = r\omega$

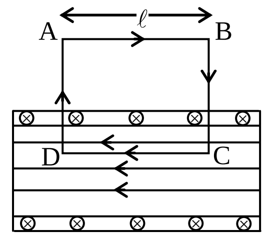
$\omega = \frac{v}{r} = \frac{qB}{m}$

$2\pi f = \frac{qB}{m}$  $\boxed{f = \frac{qB}{2\pi m}}$

**OR**

(a)




From Ampere's law

$\oint \vec{B}\cdot d\vec{\ell} = \mu_0 I_{en}$

$\int_{AB} \vec{B}\cdot d\vec{\ell} + \int_{BC} \vec{B}\cdot d\vec{\ell} + \int_{CD} \vec{B}\cdot d\vec{\ell} + \int_{DA} \vec{B}\cdot d\vec{\ell} = \mu_0 I_{en}$

$0 + 0 + \int B\ell \cos 0 + 0 = \mu_0(N)I$

$= B(\ell) = \mu_0 NI$

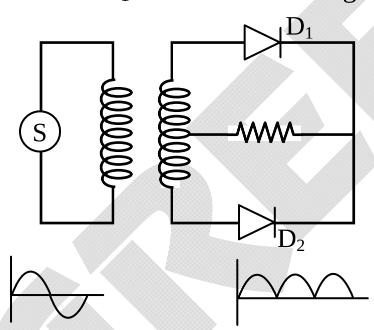
$B = \mu_0 \left(\frac{N}{\ell}\right) I$

$\Rightarrow B = \mu_0 nI$ here $n = \frac{N}{\ell}$

(b) solenoid has N-S poles where as toroid doesn't have separate poles

**Q.17** Draw the circuit diagram of a full wave rectifier. Explain its working principle. Show the input waveforms given to the diodes $D_1$ and $D_2$ and the corresponding output waveforms obtained at the load connected to the circuit. **[3]**

**Sol.** For first input half cycle the $D_1$ behave forward and $D_2$ behave reverse and for second input half cycle $D_2$ as forward and $D_1$ as reverse and we get full wave in DC.




**Q.18** Two large charged plane sheets of charge densities σ and –2σ C/m$^2$ are arranged vertically with a separation of d between them. Deduce expressions for the electric field at points **[3]**

(i) to the left of the first sheet

(ii) to the right of the second sheet, and

(iii) between the two sheets.

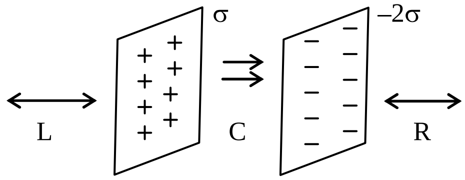
**OR**

A spherical conducting shell of inner radius $r_1$ and outer radius $r_2$ has a charge Q.

(a) A charge q is placed at the centre of the shell. Find out the surface charge density on the inner and outer surfaces of the shell.

(b) Is the electric field inside a cavity (with no charge) zero; independent of the fact whether the shell is spherical or not? Explain.

**Sol.**




Side

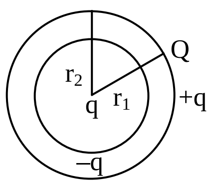
(L) $E_{Net} = \frac{\sigma}{2\in_0} - \frac{2\sigma}{2\in_0} = -\frac{\sigma}{\in_0}$ (toward R)

(C) $E_{Net} = \frac{\sigma}{2\in_0} - \frac{\sigma}{\in_0} = \frac{\sigma + 2\sigma}{2\in_0} = \frac{3\sigma}{2\in_0}$ (toward R)

(R) $E_{Net} = \frac{\sigma}{2\in_0} - \frac{\sigma}{\in_0} = \frac{\sigma - 2\sigma}{2\in_0} = -\frac{\sigma}{\in_0}$ (toward L)

**OR**

(a)



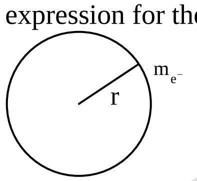

Outer surface $(\sigma_1) = \frac{Q+q}{4\pi r_2^2}$

inner surface $(\sigma_2) = \frac{-q}{4\pi r_1^2}$

(b) inside the cavity without any charge net electric field is always zero according to gauss law.

**Q.19** Prove that the magnetic moment of the electron revolving around a nucleus in an orbit of radius r with orbital speed v is equal to evr/2. Hence using Bohr's postulate of quantization of angular momentum, deduce the expression for the magnetic moment of hydrogen atom in the ground state. **[3]**

**Sol.**




$I = \frac{e}{T}$ $\qquad V = \frac{2\pi r}{T}$

$I = \frac{eV}{2\pi r}$

$\mu = IA$

$\mu = \frac{eV}{2\pi r} \cdot \pi r^2 = \frac{eVr}{2}$

$$\boxed{\mu = \frac{eVr}{2}}$$

$\mu = \frac{eVr \cdot m_e}{2 \cdot m_e}$ $\qquad \left\{ mVr = \frac{nh}{2\pi} \right\}$

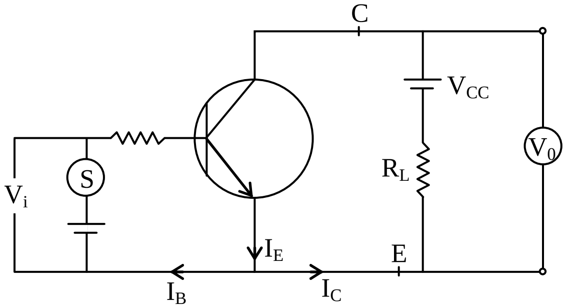
$\mu = \frac{enh}{2m \times 2\pi}$

n = 1 ground state

$\mu = \frac{eh}{4\pi m}$

**Q.20** Prove that in a common-emitter amplifier, the output and input differ in phase by 180º.
In a transistor, the change of base current by 30 mA produces change of 0.02 V in the base-emitter voltage and a change of 4 μA in the collector current. Calculate the current amplification factor and the load resistance used, if the voltage gain of the amplifier is 400. **[3]**

**Sol.**




$V_{CE} = V_{CC} - I_C R_L$

When $i_B$ increase as in first half cycle the $i_C$ will also increase as well as the $V_{CE}$ = –ve this negative sign show the cycle is at phase 180º.

Here $I_B = 30\ \mu A$

$V_i = 0.02$ V

$I_C = 4$ mA

$$\beta = \frac{I_C}{I_B} = \frac{4\times10^{-3}}{30\times10^{-6}} = \frac{4000}{30} = \frac{400}{3}$$

$$R_L = \frac{V_0}{I_C}$$

$$\frac{V_0}{V_i} = 400$$

$V_0 = 400 \times V_i = 400 \times 0.02 = 8V$

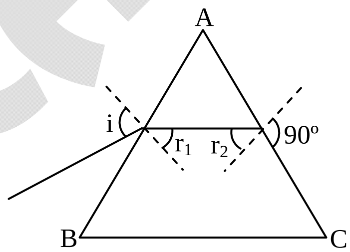
$$R_L = \frac{8}{4\times10^{-3}} = \frac{8000}{4} = 2000\Omega$$

**Q.21** (a) When a convex lens of focal length 30 cm is in contact with a concave lens of focal length 20 cm, find out if the system is converging or diverging.

(b) Obtain the expression for the angle of incidence of a ray of light which is incident on the face of a prism of refracting angle A so that it suffers total internal reflection at the other face. (Given the refractive index of the glass of the prism is μ). **[3]**

**Sol.** (a) $\frac{1}{f_{net}} = \frac{1}{30} - \frac{1}{20} = -\frac{1}{60} \Rightarrow f_{net} = -60$ diversing lens

(b)




At face AB

$$\frac{\sin(i)}{\sin(r_1)} = \mu$$

At face AC

$$\frac{\sin(r_2)}{\sin(90^\circ)} = \frac{1}{\mu}$$

$$\sin(r_2) = \frac{1}{\mu} \Rightarrow r_2 = \sin^{-1}\left(\frac{1}{\mu}\right)$$

We know

$r_1 + r_2 = A$

$r_1 = A - r_2$

$$\boxed{\sin(i) = \mu.\sin\left(A - \sin^{-1}\left(\frac{1}{\mu}\right)\right)}$$

**Q.22** Why is it difficult to detect the presence of an anti-neutrino during β-decay? Define the term decay constant of a radioactive nucleus and derive the expression for its mean life in terms of the decay constant. **[3]**

**OR**

(a) State two distinguishing features of nuclear force.

(b) Draw a plot showing the variation of potential energy of a pair of nucleons as a function of their separation. Mark the regions on the graph where the force is (i) attractive, and (ii) repulsive.

**Sol.** Since neutrino and antinutrino are very small particles which rarely intracts with the matter thus its very difficult to detect them.

Decay constant ⇒ It is the reciprocal of that time in which $N_0$ of active nuclei reduces to 37% of initial active nuclei.

Mean life ⇒ $\because\ \tau = \dfrac{\int (dN)t}{\int dN}$ ...(i)

$$\because \left|-\frac{dN}{dt}\right| = \lambda N \Rightarrow dN = \lambda N\, dt$$

Thus from (i)

$$\tau = \frac{\int \lambda N t dt}{N_0} = \frac{\int \lambda N_0 t e^{-\lambda t} dt}{N_0} \quad \{\because\ N = N_0 e^{-\lambda t}\}$$

$$\tau = \lambda \int_0^\infty t e^{-\lambda t} dt$$

$$= \lambda\left(\frac{1}{\lambda^2}\right)$$

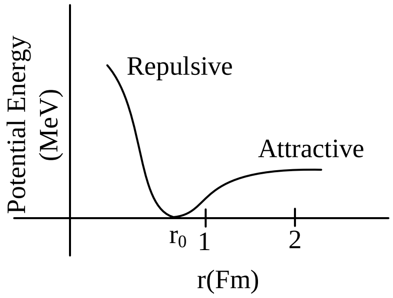
$$\tau = \frac{1}{\lambda}$$

**OR**

(a) (i) Short range force

(ii) Very strong force

(b)



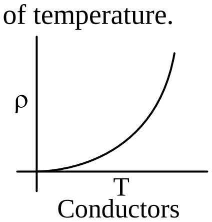

(i) if $r > r_0$ attractive

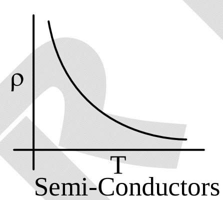
(ii) if $r < r_0$ repulsive

**Q.23** Show, on a plot, variation of resistivity of (i) a conductor, and (ii) a typical semiconductor as a function of temperature.

Using the expression for the resistivity in terms of number density and relaxation time between the collisions, explain how resistivity in the case of a conductor increases while it decreases in a semiconductor, with the rise of temperature. **[3]**

**Sol.**




As we know

$$j = \frac{I}{A}$$

$$j = \frac{neV_dA}{A}$$

$$j = ne\left(\frac{eE}{m}\tau\right)$$

$$\sigma E = \frac{ne^2E}{m}\tau$$

$$\sigma = \frac{ne^2\tau}{m}$$

$$\rho = \frac{m}{ne^2\tau}$$

$$\rho \propto \frac{1}{\tau} \;\&\; T \propto \frac{1}{\tau}$$

$$\rho \propto T$$

in conductors the collision of $e^-$ will be increases & in semi-conductors the new $e^-$ holes pair creates & conductivity increases.

**Q.24** A signal of low frequency $f_m$ is to be transmitted using a carrier wave of frequency $f_c$. Derive the expression for the amplitude modulated wave and deduce expressions for the lower and upper sidebands produced. Hence, obtain the expression for modulation index. **[3]**

**Sol.** $m(t) = A_m\sin(\omega_m t)$

$C(t) = A_C \sin(\omega_c t)$

AM Modulation Wave

$C(t) = [A_c + A_m\sin(\omega_m t)] \sin (\omega_c t)$

$C(t) = A_c\left[1 + \frac{Am}{Ac}\sin(\omega_m t)\right]\sin(\omega_c t)$

$= A_c[1 + \mu\sin(\omega_c t)]\sin(\omega_c t)$

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

$= A_c\sin(\omega_c t) + \frac{A_c\mu}{2}[cs(\omega_c - \omega_m)t - cs(\omega_c + \omega_m)]$

$= A_c\sin(\omega_c t) + \frac{A_c\mu}{2}\cos(\omega_c - \omega_m)t - \frac{A_c\mu}{2}\cos(\omega_c + \omega_m)$

Here $\mu = \frac{A_m}{A_c}$

(Modulating index)

## SECTION D

**Q.25** Explain, with the help of a diagram, how plane polarized light can be produced by scattering of light from the Sun.

Two polaroids $P_1$ and $P_2$ are placed with their pass axes perpendicular to each other. Unpolarised light of intensity I is incident on $P_1$. A third Polaroid $P_3$ is kept between $P_1$ and $P_2$ such that its pass axis makes an angle of 45º with that of $P_1$. Calculate the intensity of light transmitted through $P_1$, $P_2$ and $P_3$. **[5]**

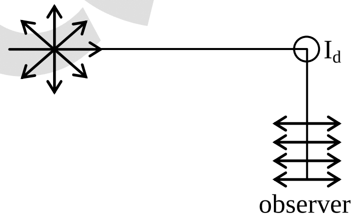
**OR**

(a) Why cannot the phenomenon of interference be observed by illuminating two pin holes with two sodium lamps?

(b) Two monochromatic waves having displacements $y_1 = a \cos \omega t$ and $y_2 = a \cos (\omega t + \phi)$ from two coherent sources interfere to produce an interference pattern. Derive the expression for the resultant intensity and obtain the conditions for constructive and destructive interference.

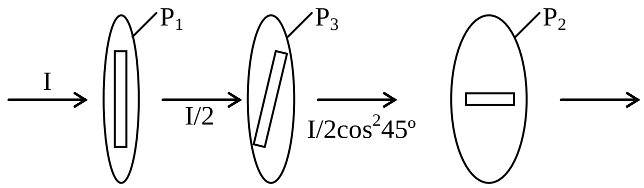
(c) Two wavelengths of sodium light of 590 nm and 596 nm are used in turn to study the diffraction taking place at a single slit of aperture $2 \times 10^{-6}$ m. If the distance between the slit and the screen is 1·5 m, calculate the separation between the positions of the second maxima of diffraction pattern obtained in the two cases.

**Sol.**




$d \simeq \lambda$

if object size around wavelength of light get scattered & at 90º placed observer get the polarised light due to all vibration of light used for oscillating molecules except perpendicular




Intensity of light after passing $P_1 = \frac{I}{2}$

Intensity of light after passing $P_2 = \frac{I}{2} \times \left(\frac{1}{\sqrt{2}}\right)^2 = \frac{I}{4}$

Intensity of light after passing $P_3 = \frac{I}{4}\cos^2 45^\circ$

$= I \times \left(\frac{1}{\sqrt{2}}\right)^2 = \frac{I}{8}$

**OR**

(a) Two lamps not a coherent source that why their phase difference not constant with time.

(b) $y = y_1 + y_2$

$y = a\cos(\omega t) + a\cos(\omega t + \phi)$

$y = a\cdot\cos(\omega t) + a[\cos(\omega t)\cdot\cos\phi - \sin(\omega t)\sin\phi]$

$y = a\cdot\cos(\omega t) + a\cdot\cos(\omega t)\cdot\cos\phi - a\cdot\sin(\omega t)\sin\phi$

$y = (a + a\cdot\cos\phi)\cdot\cos(\omega t) - a\cdot\sin\phi\cdot\sin(\omega t)$

$a + a\cos\phi = R\cdot\sin\theta$ ...(i)

$-a\sin\phi = R\cdot\cos\theta$ ...(ii)

$y = R\cdot\sin\theta\cdot\cos(\omega t) + R\cdot\cos\theta\cdot\sin(\omega t)$

$y = R\sin(\omega t + \theta)$

$(i)^2 + (ii)^2$

$(a + a\cdot\cos\phi)^2 + (-a\sin\phi)^2 = R^2$

$a^2 + a^2\cdot\cos^2\phi + 2a^2\cos\phi + a^2\sin^2\phi = R^2$

$a^2 + a^2 + 2a^2\cdot\cos\phi = R^2$

$R^2 = 2a^2 + 2a^2\cdot\cos\phi$

$R^2 = 2a^2(1 + \cos\phi)$

$R^2 = 2a^2(1 + 2\cos^2\frac{\phi}{2} - 1)$

$R^2 = 4a^2\cdot\cos^2\frac{\phi}{2}$

$I_{Net} = 4\cdot I_0\cdot\cos^2\frac{\phi}{2}$

constructive $\phi = 0, 2\pi, 4\pi$ ....

$I_{Net} = 4I_0\cdot\cos^2(0^\circ)$

$\boxed{I_{Net} = 4I_0}$

Destructive $\phi = \pi, 3\pi, 5\pi$

$I_{Net} = 4I_0\cos^2\left(\frac{\pi}{2}\right)$

$\boxed{I_{Net} = 0}$

(c) $y_1 = \frac{D}{a}\cdot\frac{5\lambda_1}{2}$

$y_2 = \frac{D}{a}\cdot\frac{5\lambda_2}{2}$

$\Delta y = \frac{5D}{2a}[\lambda_2 - \lambda_1]$

$\Delta y = \frac{2\times10^{-6}\times5}{2}\ \frac{1.5\times5}{2\times2\times10^{-6}}\ [6 - 10^{-9}]$

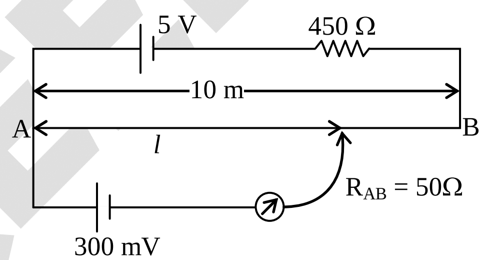
$\Delta y = \frac{7.5}{4}\times 6\times\ 10^{-3}$

$\Delta y = 7.5\times 1.5\times 10^{-3} = 11.5\times 10^{-3}$

**Q.26** (a) Describe briefly, with the help of a circuit diagram, the method of measuring the internal resistance of a cell.

(b) Give reason why a potentiometer is preferred over a voltmeter for the measurement of emf of a cell.

(c) In the potentiometer circuit given below, calculate the balancing length *l*. Give reason, whether the circuit will work, if the driver cell of emf 5V is replaced with a cell of 2 V, keeping all other factors constant. **[5]**




**OR**

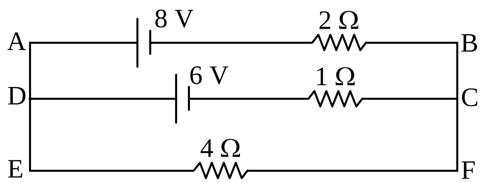
(a) State the working principle of a meter bridge used to measure an unknown resistance.

(b) Give reason

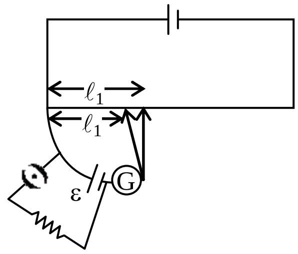
(i) why the connections between the resistors in a metre bridge are made of thick copper strips.

(ii) why is it generally preferred to obtain the balance length near the mid-point of the bridge wire.

(c) Calculate the potential difference across the 4 Ω resistor in the given electrical circuit, using Kirchhoff's rules.



**Sol.** (a)




$\varepsilon = V_S \cdot \ell_1$

$V = V_S \cdot \ell_2$

$$\frac{\varepsilon}{V} = \frac{\ell_1}{\ell_2}$$

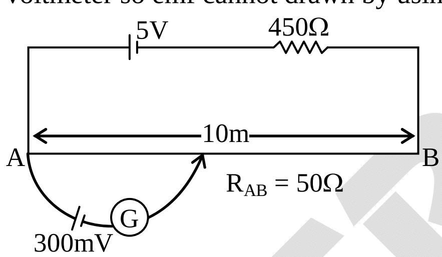
$$\frac{Ir + IR}{IR} = \frac{\ell_1}{\ell_2}$$

$$\frac{r}{R} = \frac{\ell_1}{\ell_2} - 1$$

$$r = R\left(\frac{\ell_1}{\ell_2} - 1\right)$$

(b) Potentiometer work on no current flow method but voltmeter work on current flow through voltmeter so emf cannot drawn by using voltmeter.

(c)




$R_{Net} = 500\Omega$

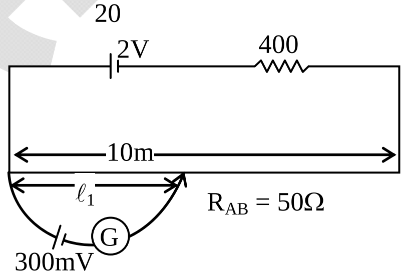
$$i = \frac{5}{500} = \frac{1}{100} \text{ A}$$

$$V_{AB} = \frac{1}{100} \times 50 = \frac{1}{2}$$

$\varepsilon = V_S \cdot \ell$

$$\ell = \frac{\varepsilon}{V_S}$$

$$\ell = \frac{300 \times 10^{-3}}{\frac{1}{20}} = 6\text{m}$$




$$i = \frac{2}{500} = \frac{1}{250} \text{ A}$$

$$V_{AB} = \frac{1}{200} \times 50 = \frac{1}{5} \text{ Volt}$$

$$V_S = \frac{\frac{1}{5}}{10} = \frac{1}{50} \text{ V/m}$$

$$\varepsilon = V_S \cdot \ell_1$$

$$\ell_1 = \frac{300\times10^{-3}}{\frac{1}{50}}$$

$$\ell_1 = 15000 \times 10^{-3}$$

$$\ell_1 = 15\text{m}$$

So, the circuit will not work due to balancing length is greater than original length of wire.

**OR**

(a) meter bridge work on the principle of wheat stone bridge

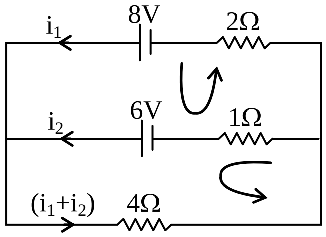
(b) (i) because thick wire has low resistance which can not alter the value of unknown resistance

(ii) If balance length become at mid point so that R = S

$$\frac{R}{\ell} = \frac{S}{(100-\ell)}$$

Unknown resistance become equal to standard resistance.

(c)




$-2i_1 + 8 - 6 + i_2 = 0$

$2i_1 - i_2 = 2$ …(i)

$-i_2 + 6 - 4i_1 - 4i_2 = 0$

$-4i_1 - 5i_2 = -6$

$4i_1 + 5i_2 = 6$ …(ii)

$2 \times (2i_1 - i_2 = 2)$

$\quad - \quad + \quad -$

$7i_2 = 2$

$i_2 = \frac{2}{7}$

$2i_1 - \frac{2}{7} = 2$

$2i_1 = 2 + \frac{2}{7}$

$2i_1 = \frac{16}{7}$

$\boxed{i_2 = \frac{8}{7}}$

Voltage at 4Ω will be

$V = (i_1 + i_2)\cdot 4$

$= \left(\frac{10}{7}\right) \times 4 = \frac{40}{7}$ Volt

**Q.27** (a) Derive an expression for the induced emf developed when a coil of N turns, and area of cross-section A, is rotated at a constant angular speed $\omega$ in a uniform magnetic field B.

(b) A wheel with 100 metallic spokes each 0·5 m long is rotated with a speed of 120 rev/min in a plane normal to the horizontal component of the Earth's magnetic field. If the resultant magnetic field at that place is $4 \times 10^{-4}$ T and the angle of dip at the place is 30º, find the emf induced between the axle and the rim of the wheel. **[5]**

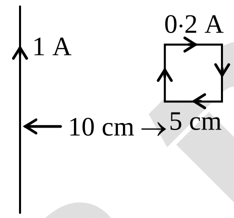
**OR**

(a) Derive the expression for the magnetic energy stored in an inductor when a current I develops in it. Hence, obtain the expression for the magnetic energy density.

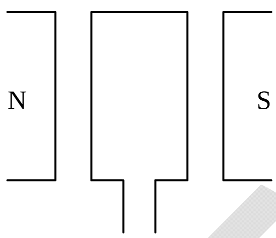
(b) A square loop of sides 5 cm carrying a current of 0·2 A in the clockwise direction is placed at a distance of 10 cm from an infinitely long wire carrying a current of 1 A as shown. Calculate

(i) the resultant magnetic force, and

(ii) the torque, if any, acting on the loop.




**Sol.** (a)




$N\phi = N \cdot BA \cdot \cos(\omega t)$

$\frac{Nd\phi}{dt} = N \cdot BA(-\sin(\omega t) \cdot \omega$

$\because \ \varepsilon = -N\frac{d\phi}{dt}$

$-\varepsilon = -NBA\omega \sin(\omega t)$

$\varepsilon = NBA\omega\sin(\omega t)$

$\boxed{\varepsilon = \varepsilon_0 \sin(\omega t)}$

Induce emf in coil

(b) induced emf $= \frac{1}{2}B\ell^2\omega$

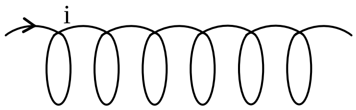
$= \frac{1}{2} \times 4 \times 10^{-4} \times \cos30º \times 0.5 \times 4\pi$

$$= \sqrt{3} \times 10^{-4} \times \frac{1}{2} \times 4\pi$$

$$= 2\pi\sqrt{3} \times 10^{-4}\ \text{V}$$

The number of spokes is immaterial because the emf's across the spokes are in parallel.

**OR**

(a) 


$$\varepsilon = \frac{Ldi}{dt}$$

Power = $\varepsilon \cdot i$

$$\frac{dW}{dt} = \frac{Ldi}{dt} \cdot i \Rightarrow \int dW = \int Lidi$$

$$W = \frac{1}{2}Li^2$$

$$L = \mu_0\left(\frac{N}{\ell}\right)^2 A\ell$$

$$L = \frac{\mu_0 N^2 A}{\ell}$$

$$B = \mu_0 ni$$

$$B = \mu_0 \frac{N}{\ell} i$$

$$i = \frac{B\ell}{\mu_0 N}$$

$$W = \frac{1}{2}\left(\frac{\mu_0 N^2 A}{\ell}\right)\left(\frac{B\ell}{\mu_0 N}\right)^2$$

$$= \frac{\mu_0 N^2 A}{2\ell} \times \frac{B^2\ell^2}{\mu_0^2 N^2}$$

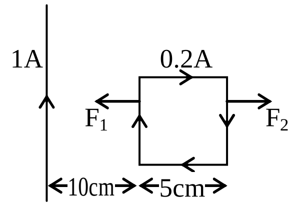
$$W = \frac{1}{2}\frac{B^2\ell A}{\mu_0}$$

$$\text{Energy density} = \frac{W}{A \cdot \ell}$$

$$= \frac{1}{2}\frac{B^2\ell A}{\mu_0} \times \frac{1}{A\ell}$$

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

(b)




$$F_1 = \frac{\mu_0(1)}{2\pi(10^{-1})} \times 0.2 \times 5 \times 10^{-2}$$

$$= \frac{24\pi \times 10^{-7} \times 0.2 \times 5 \times 10^{-2}}{2\pi \times 10^{-1}}$$

$$F_1 = 2 \times 10^{-8}\text{ N}$$

$$F_2 = \frac{\mu_0(1)}{2\pi(15 \times 10^{-2})} \times 0.2 \times 5 \times 10^{-2}$$

$$= \frac{4\pi \times 10^{-7} \times 10^{-2}}{2\pi \times 15 \times 10^{-2}}$$

$$= \frac{2}{15} \times 10^{-7}$$

$$F_{Net} = F_1 - F_2$$

$$= 2 \times 10^{-8} - \frac{2}{15} \times 10^{-7}$$

$$= 2 \times 10^{-8} - \frac{4}{3} \times 10^{-8}$$

$$= 10^{-8}\left(2 - \frac{4}{3}\right)$$

$$F_{Net} = 10^{-8}\left(\frac{2}{3}\right)\text{N}$$

No torque will be act on coil.