PRACTICE PAPER – 6

SOLUTIONS

SECTION – A

1. What is the principle of superposition of waves ?

Ans. When two or more waves are acting simultaneously on the particle of the medium, the resultant displacement is equal to the algebraic sum of individual displacements of all the waves. This is the principle of superposition of waves.

If y_1, y_2, ... y_n be the individual displacements of the particles,then resultant displacement $y = y_1 + y_2 + ... + y_n$.

2. What is Malus law ?

Ans. Malus' law : It states that the intensity of polarised light transmitted through the analyser varies as a square of cosine of the angle between the plane of transmission of analyser and polariser.

$I \propto \cos^2\theta;\ I = I_0 \cos^2\theta.$

3. The electric field in a region is given by $\vec{E} = a\hat{i} + b\hat{i}$. Here a and b are constants. Find the net flux passing through a square area of side L parallel to Y-Z plane.

Sol. Given $\vec{E} = a\hat{i} + b\hat{j}$

$$\vec{S} = L^2\hat{i}$$

$$\phi = \vec{E}\cdot\vec{S} = (a\hat{i} + b\hat{j})\cdot L^2\hat{i}$$

$$\therefore \phi = aL^2 \quad [\because \hat{i}\cdot\hat{i} = 1 \text{ and } \hat{i}\cdot\hat{j} = 0]$$

4. Three capacitors of capacitances 1 μF, 2 μF and 3 μF are connected in series.

(a) What is the ratio of charges ?

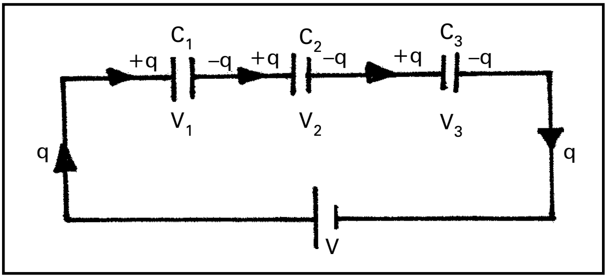
(b) What is the ratio of potential differences ?

Ans. When capacitors are connected in series

$q_1 : q_2 : q_3 = q : q : q = 1 : 1 : 1$

$$V_1 : V_2 : V_3 = \frac{q}{C_1} : \frac{q}{C_2} : \frac{q}{C_3} = \frac{1}{1} : \frac{1}{2} : \frac{1}{3}$$

$\therefore V_1 : V_2 : V_3 = 6 : 3 : 2$



5. Why are household appliances connected in parallel ?

Ans. In parallel, the voltage (V) across each appliance is same. The current (I) through them depends upon the power (P) of the appliance. The higher power appliance draws more current and lower power appliance draws less current.

($\because P = VI$ or $I \propto P$)

6. Distinguish between ammeter and voltmeter.

Ans.

Ammeter	Voltmeter
1) It is used to measure current.	1) It is used to measure P.D between two points.
2) Resistance of an ideal Ammeter is zero.	2) Resistance of ideal volt meter is infinity.
3) It is connected in series in the circuits.	3) It is connected in parallel in the circuits.

7. Magnetic lines from continous closed loops. Why ?

Ans. Magnetic lines of force always start from north pole and forming curved path, enter south pole and travel to north pole inside the magnet. Thus lines of force are forming closed loops.

8. Write the expression for the reactance of

i) an inductor and ii) a capacitor.

Ans. i) Inductive reactance $(X_L) = \omega L$

ii) Capacitive reactance $(X_c) = \omega C$

9. If the wavelength of Electromagnetic radiation is doubled, what happens to the energy of photon ?

Ans. Photon energy (E) = $h\nu = \frac{hc}{\lambda}$

$E \propto \frac{1}{\lambda}$

Given $\lambda_1 = \lambda, \lambda_2 = 2\lambda, E_1 = E$

$\frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1}$

$\frac{E}{E_2} = \frac{2\lambda}{\lambda}$

$E_2 = E/2$.

∴ The energy of photon reduces to half of its initial value

10. Define Modulation. Why is it necessary ?

Ans. Modulation : The process of combining low frequency audio signal with high frequency carrier wave is called modulation.

SECTION – B

11. What are beats ? When do they occur ? Explain their use if any.

Ans. Two sound waves of nearly same frequency are travelling in the same direction and interfere to produce a regular waxing (maximum) and waning (minimum) in the intensity of the resultant sound waves at regular intervals of time is called beats.

It two vibrating bodies have slightly difference in frequencies, beats can occur.

No. of beats can be heard $\Delta\upsilon = \upsilon_1 \sim \upsilon_2$

Importance : 1. It can be used to tune musical Instruments

2. Beats are used to detect dangerous gases.

Explanation for tuning musical instruments with beats :

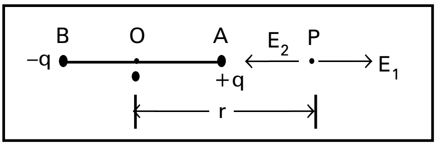
Musicians use the beat phenomenon in tuning their musical instruments. If an instrument is sounded against a standard frequency and tuned until the beats disappear then the instrument is in tune with the standard frequency.

12. Derive an expression for the intensity of the electric field at a point on the axial line of an electric dipole.

Ans. Electric field at a point on the axis of a dipole :

1) Consider an electric dipole consisting of two charges –q and +q separated by a distance '2a' with centre 'O'.

2) We shall calculate electric field E at point P on the axial line of dipole, and at a distance OP = r.



3) Let E_1 and E_2 be the intensities of electric field at P due to charges +q and –q respectively.

4) Therefore, $E_1 = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{(AP)^2} = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{(r-a)^2}$ along AP

and $E_2 = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{(BP)^2} = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{(r+a)^2}$ along PB

The resultant intensity at P is $E = E_1 - E_2$

[∵ They are opposite and $E_1 > E_2$]

$$\Rightarrow E = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{(r-a)^2} - \frac{1}{4\pi\varepsilon_0} \times \frac{q}{(r+a)^2}$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{(r+a)^2 - (r-a)^2}{(r^2-a^2)^2}\right]$$

$$= \frac{q}{4\pi\varepsilon_0} \times \frac{4ra}{(r^2-a^2)^2}$$

$\therefore E = \frac{1}{4\pi\varepsilon_0} \frac{2pr}{(r^2 - l^2)^2}$ Where P = 2 aq

If r >> a then a^2 can be neglected in comparision to r^2.

$\therefore E = \frac{1}{4\pi\varepsilon_0} \times \frac{2Pr}{r^4} = \frac{1}{4\pi\varepsilon_0} \times \frac{2P}{r^3}$

In vector form, $\vec{E} = \frac{2\vec{P}}{4\pi\varepsilon_0 r^3}$

13. Derive an expression for the energy stored in a capacitor.

Ans. Expression for the energy stored in a capacitor : Consider an uncharged capacitor of capacitance 'c' and its initial will be zero. Now it is connected across a battery for charging then the final potential difference across the capacitor be 'v' and final charge on the capacitor be 'Q'

$\therefore$ Average potential difference $V_A = \frac{0 + V}{2} = \frac{V}{2}$

Hence workdone to move the charge $Q = W = V_A \times Q = \frac{VQ}{2}$

This is stored as electrostatic potential energy 'U'

$\therefore U = \frac{QV}{2}$

We know Q = CV then 'U' can be written as given below.

$U = \frac{QV}{2} = \frac{1}{2} CV^2 = \frac{Q^2}{2C}$

$\therefore$ Energy stored in a capacitor

$U = \frac{QV}{2} = \frac{1}{2} CV^2 = \frac{1}{2} \frac{Q^2}{C}$

14. A potentiometer wire is 5m long and a potential difference of 6 V is maintained between its ends. Find the emf of a cell which balances against a length of 180 cm of the potentiometer wire.

Sol. Length of potentiometer wire L = 5m

Potential difference V = 6 Volt

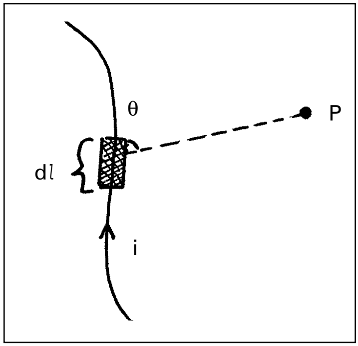
Potential gradient $\phi = \frac{V}{L} = \frac{6}{5} = 1.2 V/M$

Balancing length l = 180cm = 1.80m

Emf of the cell E = ϕl = 1.2 × 1.8 = 2.16V.

15. State and explain Biot-Savart law.

Ans. Consider a very small element of length dl of a conductor carrying current (i). Magnetic induction due to small element at a point p distance r form the element.



Magnetic induction (dB) is directly proportional to i) current (i) ii) Length of the element (dl) iii) sine angle between r and dl and iv) Inversely proportional to the square of the distance from small element to point P.

$$dB \propto \frac{i\, d\boldsymbol{l} \sin\theta}{r^2}$$

$$dB = \frac{\mu_0}{4\pi} \cdot \frac{i\, d\boldsymbol{l} \sin\theta}{r^2}$$

where μ_0 = permeability in free space.

$$\frac{\mu_0}{4\pi} = 10^{-7}\ \text{Wb m}^{-1}\ \text{A}^{-1}$$

In vector form $d\vec{B} = \frac{\mu_0\, i}{4\pi} \frac{\left(d\vec{l} \times \vec{r}\right)}{r^3}$

16. What is Green house effect and its contribution towards the surface temperature of earth ?

Ans. Green house effect : Temperature of the earth increases due to the radiation emitted by the earth is trapped by atmospheric gases like CO_2, CH_4, N_2, Chlorofluoro carbons etc is called green house effect.

i) Radiation from the sun enters the atmosphere and heat the objects on the earth. These heated objects emit infrared rays.

ii) These rays are reflected back to Earth's surface and trapped in the Earth's atmosphere. Due to this temperature of the earth increases.

iii) The layers of carbon dioxide (CO_2) and low lying clouds prevent infrared rays to escape Earth's atmosphere.

iv) Since day–by–day the amount of carbondioxide in the atmosphere increases, more infrared rays are entrapped in the atmosphere.

v) Hence the temperature of the Earth's surface increases day by day.

17. Explain the different types of spectral series.

Ans. The atomic hydrogen emits a line spectrum consisting of five series.

1) Lyman series : $\upsilon = Rc\left(\frac{1}{1^2}-\frac{1}{n^2}\right)$ where n = 2, 3, 4, ...

2) Balmer series : $\upsilon = Rc\left(\frac{1}{2^2}-\frac{1}{n^2}\right)$ where n = 3, 4, 5, ...

3) Paschen series : $\upsilon = Rc\left(\frac{1}{3^2}-\frac{1}{n^2}\right)$ where n = 4, 5, 6, ...

4) Brackett series : $\upsilon = Rc\left(\frac{1}{4^2}-\frac{1}{n^2}\right)$ where n = 5, 6, 7, ...

5) Pfund series : $\upsilon = Rc\left(\frac{1}{5^2}-\frac{1}{n^2}\right)$ where n = 6, 7, 8, ...

18. Distinguish between zener breakdown and avalanche breakdown.

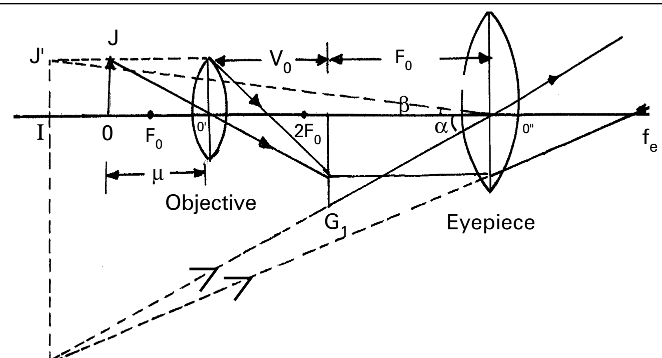
Zener break down	Avalanche break down
1. Zener break down occurs at heavily doped diodes.	1. Avalanche break down occurs at lightly doped diodes.
2. This occurs at low reverse bias voltages.	2. This occurs at high reverse bias voltages.

3. This occurs due to field emission.	3. This occurs due to ionisation by collision.
4. Width of depletion layer is small.	4. Width of depletion layer is also small.

SECTION – C

19. Draw a neat labelled diagram of a compound microscope and explain its working. Derive an expression for its magnification.

Ans. Description : It consists of two convex lenses separated by a distance. The lens near the object is called objective and the lens near the eye is called eye piece. The objective lens has small focal length and eye piece has of larger focal length. The distance of the object can be adjusted by means of a rack and pinion arrangement.



Ray diagram of compound microscope

Working : The object OJ is placed outside the principal focus of the objective and the real image is formed on the other side of it. The image I_1 G_1 is real, inverted and magnified.

This image acts as the object for the eyepiece. The position of the eyepiece is so adjusted that the image due to the objective is between the optic centre and principal focus to form the final image at the near point. The final image IG is virtual, inverted and magnified.

Magnifying Power : It is defined as the ratio of the angle subtended by the final image at the eye when formed at near point to the angle subtended by the object at the eye when imagined to be at near point.

Imagining that the eye is at the optic centre, the angle subtended by the final image is α. When the object is imagined to be taken at near point it is represented by I J' and OJ = I J'. The angle made by I J' at the eye is β. Then by the definition of magnifying power.

$$m = \frac{\alpha}{\beta} \simeq \frac{\tan\theta}{\tan\beta} \text{ for small angles } \begin{bmatrix} \because \Delta IGO'' \Rightarrow \tan\alpha = \dfrac{IG}{IO''} \\ \because \Delta IJ'O'' \Rightarrow \tan\beta = \dfrac{IJ'}{IO''} \end{bmatrix}$$

$$= \frac{IG/IO''}{IJ'/IO''} = \frac{IG}{IJ'} = \frac{IG}{OJ}. \ (\because IJ' = OJ)$$

Dividing and multiplying by $I_1\,G_1$ on the right side, we get

$$m = \left(\frac{IG}{I_1\,G_1}\right)\left(\frac{I_1\,G_1}{OJ}\right)$$

Magnifying power of the objective $(m_0) = I_1\,G_1 / OJ$ = Height of the image due to the objective. Height of its object.

Magnifying power of the eye piece $(m_e) = IG/I_1G_1$ = Height of the final image / Height of the object for the eyepiece.

$$\boxed{\therefore \quad m = m_0 \times m_e} \quad ..... (1)$$

To find m_0 : In figure OJ O' and $I_1\,G_1$ O' are similar triangles.

$$\left(\frac{I_1\,G_1}{OJ}\right) = \frac{O'I_1}{O'O}.$$

Using sign convention, we find that $O'I_1 = +v_0$ and $O'O = -u$ where v_0 is the image distance due to the objective and u is the object distance for the objective or the compound microscope. I_1G_1 is negative and OJ is positive.

$$\therefore m_0 = \frac{v_0}{u} \cdot \left(\because \frac{I_1G_1}{OJ} = m_0 \right)$$

To find m_e : The eyepiece behaves like a simple microscope. So the magnifying power of the eye piece.

$$\therefore \quad m_e = \left(1 + \frac{D}{f_e}\right)$$

Where f_e is the focal length of the eyepiece.

Substituting m_0 and m_e in equation (1),

$$m = + \frac{v_0}{u}\left(1 + \frac{D}{f_e}\right)$$

When the object is very close to the principal focus F_0 of the objective, the image due to the objective becomes very close to the eyepiece.

$u \approx -f_0$ and $v_0 \approx L$

Where L is the length of the microscope. Then

$$m \approx -\frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$$

20. Describe the working of a AC generator with the aid of simple diagram and necessary expressions.

Ans. "An electrical machine used to convert mechanical energy into electrical energy is known as A.C generator/alternator".

Principle : It works on the principle of electromagnetic induction.

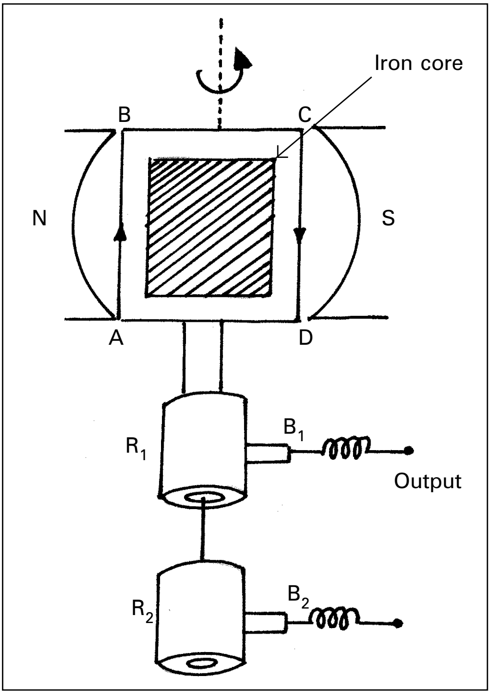
Construction :

i) Armature : Armature coil (ABCD) consists of a large number of turns of insulated copper wire wound over a soft iron core.

ii) Strong field magnet : A strong permanent magnet (or) an electromagnet whose poles (N and S) are cylindrical in shape used as a field magnet. The armature coil rotates between the pole pieces of the field magnet.

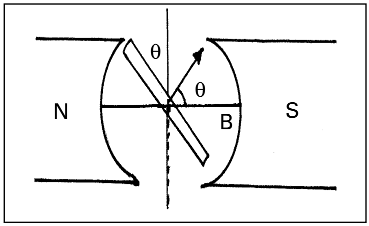
iii) Slip rings : The two ends of the armature coil are connected to two brass slip rings R_1 and R_2. These rings rotate along with the armature coil.

iv) Brushes : Two carbon brushes B_1 and B_2 are pressed against the slip rings. The brushes remain fixed while slip rings rotate along with the armature. These brushes are connected to the load through which the out put is obtained.



Working : When the armature coil ABCD rotates is the magnetic field provided by the strong field magnet, it cuts the magnetic line of force. The magnetic flux linked with the coil changes due to the rotation of the armature and hence induced e.m.f is set up in the coil.

The current flows out through the brush B, in one direction of half of revolution and through the brush B_2 in the next half revolution in the reverse direction. This process is repeated, therefore e.m.f produced is of alternating nature.



Theory :

i) When the coil is rotated with a constant angular velocity (ω)

ii) The angle between the normal to the coil and magnetic field $\vec{B}$ at any instant is given by

$\theta = \omega t$ —— (1)

iii) The component of magnetic field normal to the plane of the coil

$= B\cos\theta = B\cos\omega t$ —— (2)

iv) Magnetic flux linked with the single turn of the coil

$= (B\cos\omega t)A$ —— (3)

where A is the area of the coil, if the coil has n turns

v) Total magnetic flux linked with the coil

$(\phi) = n(B\cos\omega t)A$ —— (4)

According to Faraday's law,

$$\varepsilon = -\frac{d\phi}{dt} = -\frac{d}{dt}(nBA\cos\omega t)$$

$$= -nBA(-\omega\sin\omega t)$$

$\varepsilon = nBA\,\omega\sin\omega t$ —— (5)

Where nBAω is the maximum value of e.m.f (ε_0)

$\varepsilon = \varepsilon_0 \sin\omega t$ —— (6) ($\because \omega = 2\pi\upsilon$)

Instantaneous current is the circuit is given by

$$I = \frac{\varepsilon}{R} = \frac{\varepsilon_0}{R}\sin\omega t \quad \left(\because i = \frac{\varepsilon_0}{R}\right)$$

$I = I_0 \sin \omega t$ —— (7)

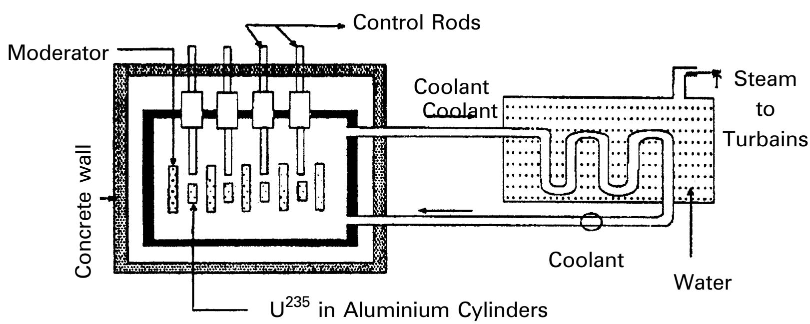
The direction of the current changes periodically and therefore the current is called alternating current (a.c.).

21. Explain the principle and working of a nuclear reactor with the help of a labelled diagram.

How much ^{235}U is consumed in a day in an atomic power house operating at 400MW, provided the whole of mass ^{235}U is converted into energy ?

Ans. Principle : A nuclear reactor works on the principle of achieving controlled chain reaction in natural Uranium ^{238}U enriched with ^{235}U, consequently generating large amounts of heat.

A nuclear reactor consists of (1) Fuel (2) Moderator (3) Control rods (4) Radiation shielding (5) Coolant.



Nuclear Reactor

1. Fuel and clad : In reactor the nuclear fuel is fabricated in the form of thin and long cylindrical rods. These group of rods treated as a fuel assembly. These rods are surrounded by coolant, which is used to transfer of heat produced in them. A part of the nuclear reactor which use to store the nuclear fuel is called the core of the reactor. Natural uranium, enriched uranium, plutonium and uranium – 233 are used as nuclear fuels.

2. Moderator : The average energy of neutrons released in fission process is 2 MeV. They are used to slow down the velocity of neutrons. Heavy water or graphite are used as moderating materials in reactor.

3. Control Rods : These are used to control the fission rate in reactor by absorbing the neutrons. Cadmium and boron are used as controlling the neutrons, in the form of rods.

4. Shielding : During fission reaction beta and gamma rays are emitted in addition to neutrons. Suitable shielding such as steel, lead, concrete etc are provided around the reactor to absorb and reduce the intensity of radiations to such low levels that do not harm the operating personnel.

5. Coolant : The heat generated in fuel elements is removed by using a suitable coolant to flow around them. The coolants used are water at high pressures, molten sodium etc.

Working : Uranium fuel rods are placed in the aluminium cylinders. The graphite moderator is placed in between the fuel cylinders. To control the number of neutrons, a number of control rods of cadmium or beryllium or boron are placed in the holes of graphite block. When a few ^{235}U nuclei undergo fission fast neutrons are liberated. These neutrons pass through the surrounding graphite moderator and loose their energy to become thermal neutrons. These thermal neutrons are captured by ^{235}U. The heat generated here is used for heating suitable coolants which in turn heat water and produce steam. This steam is made to rotate steam turbine and there by drive a generator of production for electric power.

Problem : $P = 400 \text{ MW} = 400 \times 10^6 \text{ W}$,

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

$t = 24 \text{ hours} = 24 \times 60 \times 60 \text{ sec}$

$E = mc^2$

$$\frac{Pt}{c^2} = m \quad \left[\because P = \frac{E}{t}\right]$$

$$m = \frac{400 \times 10^{-6} \times 24 \times 60 \times 60}{9 \times 10^6} = 384 \times 10^{-6} \text{ kg}$$

$\therefore$ Mass required $= 384 \times 10^{-6} \times 10^3 \text{ g} = 0.384 \text{ g}$

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