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Answer Sheet No.____________

Sign. of Candidate ___________

Sign. of Invigilator ___________

PHYSICS HSSC–II (2^{nd} Set Solution)

SECTION – A (Marks 17)

Time allowed: 25 Minutes

Section – A is compulsory. All parts of this section are to be answered on this page and handed over to the Centre Superintendent. Deleting/overwriting is not allowed. **Do not use lead pencil.**

Q.1 Fill the relevant bubble for each part. Each part carries one mark.

(1) Two charges are placed at a certain distance apart in vacuum. If an insulating slab is placed between them, then force will:

A. Increase ○ B. Decrease ●
C. Remains constant ○ D. Be zero ○

(2) Potential inside a hollow charged spherical conductor:

A. is constant ●
B. varies directly as distance from centre ○
C. varies inversely as distance from centre ○
D. varies directly as square of distance from the centre ○

(3) The dimension of electric potential is same as that of:

A. work ○
B. work done per unit charge ●
C. electric field per unit charge ○
D. electric force per unit charge ○

(4) When the hot and cold junctions of a thermocouple are interchanged, the thermo-emf:

A. becomes zero ○ B. doubles ○
C. remain the same ● D. changes the sign ○

(5) If the resistivity of a conductor is $2 \times 10^{-6}\Omega m$, then its conductivity is:

A. $2 \times 10^{6}\Omega^{-1}m^{-1}$ ○ B. $5 \times 10^{6}\Omega^{-1}m^{-1}$ ○
C. $5 \times 10^{-5}\Omega^{-1}m^{-1}$ ○ D. $5 \times 10^{5}\Omega^{-1}m^{-1}$ ●

(6) The source of emf transfers its maximum power to the external circuit when (r = internal resistance and R= load resistance):

A. r = 0 ○ B. r = R ●
C. r < R ○ D. r > R ○

(7) A galvanometer is made sensitive by:

A. using a small and thick suspension wire ○
B. decreasing the area of the coil ○
C. Increasing the magnetic field ●
D. reducing the number of turns of the coil ○

(8) A coil of 150 loops is pulled in 0.06s from poles of the magnet, which decreases the magnetic flux linked with the coil from 6×10^{-4}Wb to 2×10^{-4}Wb. The average emf induced in the coil is:

A. 1.5 V ○ B. 1 V ●
C. 0.1 V ○ D. 0.15 V ○

(9) For long distance electrical power transmission, we use:

A. low current and low voltage ○
B. high current and high voltage ○
C. low current and high voltage ●
D. highcurrent and small voltage ○

(10) The quantity that remains constant in a transformer is:

A. current ○ B. voltage ○
C. resistance ○ D. power ●

(11) The minimum number of diodes required for full wave rectification are:

A. 1 ○ B. 2 ●
C. 3 ○ D. 4 ○

(12) A force of 500 N is applied to one end of a cylindrical steel rod of diameter 50 cm, the tensile stress is:

A. 2.5×10^5 Nm^{-2} ○ B. 1.5×10^5 Nm^{-2} ○
C. 1.0×10^5 Nm^{-2} ○ D. $2.5 \times 10^3 Nm^{-2}$ ●

(13) The potential difference across the silicon PN junction is:

A. 0.3 V ○ B. 0.7 V ●
C. 0.5 V ○ D. 5.0 V ○

(14) The radius of 10th orbit in hydrogen atom is

A. 0.053 nm ○ B. 0.53 nm ○
C. 5.3 nm ● C. 53 nm ○

(15) A radioactive nuclide $^{228}_{86}Ra$ decays by a series of emissions of 3 alpha particles and 1 beta particle, the nuclide finally formed is:

A. $^{220}_{84}Ra$ ○ B. $^{222}_{86}Ra$ ○
C. $^{216}_{83}Ra$ ● D. $^{215}_{88}Ra$ ○

(16) Which phenomenon does **NOT** verify particle nature of light?

A. Photoelectric effect ○ B. Compton effect ○
C. Pair Production ○ D. Diffraction ●

(17) The half-life of a certain radioactive nucleus is 1.6×10^3 years. Its decay constant is:

A. 1.4×10^{-11} s^{-1} ● B. 1.4×10^{-12} s^{-1} ○
C. 2.0×10^{-11} s^{-1} ○ D. 2.0×10^{-12} s^{-1} ○

Federal Board HSSC-II Examination
Physics Model Question Paper
(Curriculum 2006)

Time allowed: 2.35 hours Total Marks: 68

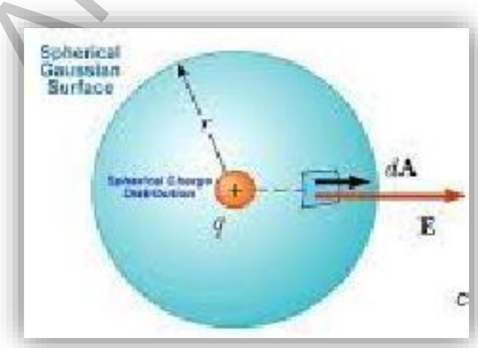
Note: Answer any fourteen parts from Section ‘B’ and attempt any two questions from Section ‘C’ on the separately provided answer book. Write your answers neatly and legibly.

SECTION – B (Marks 42)

Q.2 Attempt any **FOURTEEN** parts. All parts carry equal marks. (14 × 3 = 42)

i. Prove that electric flux $\varphi e = \frac{q}{\varepsilon o}$ for charge ‘q’ enclosed in a sphere, where ε_o is the permittivity of free space.

Ans.



1 mark

Divide the surface into small patches of area

$\Delta A_1, \Delta A_2, \Delta A_3$ ……………….. ΔA_n

$\Phi_1 = \mathbf{E}.\ \mathbf{\Delta A_1}, \Phi_2 = \mathbf{E}.\ \mathbf{\Delta A_2}, \Phi_3 = \mathbf{E}.\ \mathbf{\Delta A_3}, \ldots\ \Phi_n = \mathbf{E}.\ \mathbf{\Delta A_n}$ (1 mark)

$\Phi_e = \Phi_1 + \Phi_2 + \Phi_3 + \ldots\ldots + \Phi_n$

$\Phi_e = \Sigma_{surface}\ E\ \Delta A$……………………….(1)

$E = \frac{1}{4\pi\varepsilon}\frac{Q}{r2}$, $\Sigma_{surface}\ \Delta A = 4\pi r^2$ putting value of E and $\Sigma_{surface}$ ΔA in eq(1)

$\Phi_e = \frac{q}{\varepsilon_o}$ (1 mark)

ii. Define resistivity. How does it depend upon temperature?

Ans. Resistivity or specific resistance is the resistance of a meter cube of a material. Its unit is Ωm. (1mark)

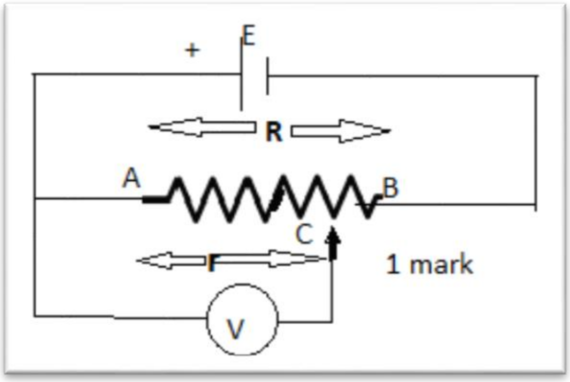
$\rho = \frac{RA}{L}$ since $R \propto T$ for conductors so $\rho \propto R$ and $\rho \propto T$ (1 mark)

Temperature coefficient of resistivity $= \propto = \frac{\rho_{t-}\rho_o}{\rho_o\, t}$ (1mark)

Hence resistivity increases with temperature.

iii. Describe a circuit which will give continuously varying potential.

Ans.



A potential divider will act as a continuously varying potential. (0.5 mark)

The total current through circuit is $I = \frac{E}{R}$. When contact C is moved from A to B, then resistance between A and C varies from 0 to RΩ. By Ohm’s law voltage drop across A and C will be

$V_{AC=}$ Ir. (1 mark)

If r changes from 0 to R then V_{AC} changes from 0 to E volts (0.5 mark)

iv. What factors cause induced emf?

Ans. Factors causing induced emf are:

(a) Relative movement speed of bar magnet and coil.
(b) Number of turns of coil.
(c) Rate of change of magnetic flux.
(d) Conductivity of coil.
(e) Area of coil.
(f) Strength of bar magnet. (Students can write any three of them, 3 x1 mark)

v. What will happen if the frequency of AC across an inductor is increased?

Ans. The inductive reactance of an inductor is given by $X_{L=}\ 2\pi f L$(1 mark)
If the frequency of A.C supply increases then its inductive reactance will increase (1 mark)
And the current passing through inductor will decrease. (1 mark)

vi. What do you know about the impedance in RLC series circuit of AC?

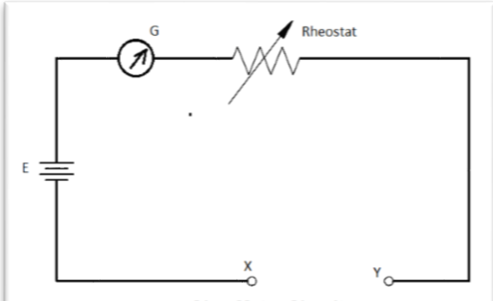
Ans. The impedance of RLC series circuit is the collective reactance of the circuit in which capacitors, inductors and resistors etc. are used. (1 mark)
It is given by Z = $\sqrt{R^2 + (X_L - X_C)^2}$ (1 mark)
At resonance frequency $X_L = X_C$ and the impedance of the RLC series circuit is pure resistive. Both voltage and current are in phase.

vii. Draw and elaborate resistance measuring part of Avometer.

Ans. When a battery and a variable resistor are connected in series with a galvanometer then it behaves as an ohmmeter (resistance measuring device), as shown below :(1 mark)

Condition I: When X and Y are short circuited by a wire galvanometer shows maximum deflection which shows 0Ω resistance between X and Y. (1 mark)

Condition II : When X and Y are disconnected galvanometer shows 0 reading which represents ∞ Ω resistance between X and Y and its value is measured by galvanometer (1 mark)



Ohm Meter Circuit

viii. What are eddy currents and how are they minimized in Transformers?

Ans. Due to change of magnetic flux through a solid conductor, the induced current set up within the body of a conductor in a direction perpendicular to the changing flux is known as eddy current. ($1\frac{1}{2}$ marks)
Eddy currents can be minimized by using lamination sheets between plates of core material of transformer. ($1\frac{1}{2}$ marks)

ix. A 220V, 50Hz, AC source is connected to an inductance of 0.2H and a resistance of 20 Ω in series. What is the current in the circuit?

Ans. Given

V_{rms} = 220 V
f = 50 Hz
L = 0.2 H

R = 20 Ω
I_{rms} = ?

Formula: $Z=\sqrt{R^2+{X_L}^2} = \sqrt{R^2+(2\pi fL)^2}$ (1 mark)

$Z = \sqrt{4344} = 65.91\ \Omega$ (1 mark)

$I_{rms}=\frac{V_{rms}}{Z} = \frac{220}{65.91} = 3.34$ A (1 mark)

x. Determine the energy associated with the following nuclear reaction:
$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{16}_{8}O + ^{1}_{1}H$
$m(^{14}_{7}N) = 14.003074u$
$m(^{4}_{2}He) = 4.002603u$
$m(^{17}_{8}O) = 16.999131u$
$m(^{1}_{1}H) = 1.007825u$

Ans. Mass of reactants = $m(^{14}_{7}N) + m(^{4}_{2}He)$ = 14.003074 u + 4.002603 u

= 18.005677 u (1 mark)

Mass of product = $m(^{17}_{8}O) + m(^{1}_{1}H)$ = 16.999131 u + 1.007825u

= 18.006956 u

Δm = (18.005677 u) - 18.006956 u = -1.279×10^{-3} u (1 mark)

1 u = 931 MeV

Δm = (-1.279×10^{-3} u) x 931 = -1.19 MeV (1 mark)

xi. Young's modulus for particular wood is 1.0×10^{10} Nm^{-2}. A wooden chair has four legs each of length 42 cm and cross-sectional area of 20 cm^2. A man has a mass of 100 kg, find the stress on each leg of the chair when he stands on the chair.

Ans. Given

Y = 1.0×10^{10} Nm^{-2}

L = 42 cm = 0.42 m (1 mark)

A = 20 cm^2 = 20×10^{-4} m^2

m = 100 kg

W= F = mg

= 100 x 9.8 = 980 N (1 mark)

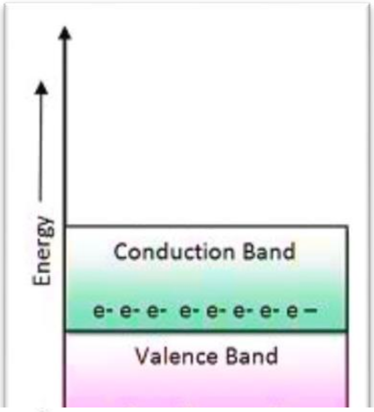
Stress = ?

Stress $=\frac{F}{A} = \frac{980}{220 \times 10-4} = 4.9 \times 10^5$ Nm^{-2}

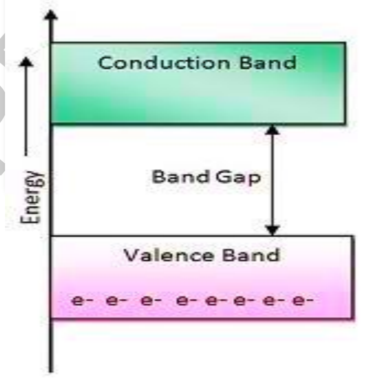
Thus stress on each leg is $4.9 \times 10^5\ Nm^{-2}$

xii. Differentiate between conductors, insulators and semiconductor in terms of energy theory.

Ans. **<u>Conductor:</u>** They have large number of free electrons for electrical conduction. In terms of energy band, the valence band and conduction band are overlapped i.e. there is no distinction between these bands.

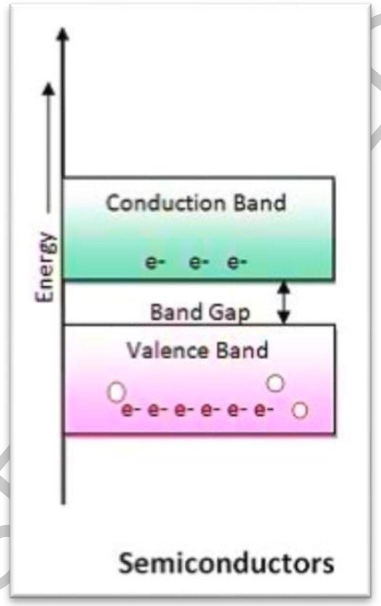


<u>Insulator:</u> Electrons are tightly bound in their valence shells and they are not free to move in insulators. Here V.B is completely filled but C.B. is empty. There is a large energy gap between V.B. and C.B. They can move from V.B. to C.B. (1 mark)



Insulators

<u>Semiconductor</u>: They have partially filled V.B. & C.B. A very narrow energy gap between the two bands exists and normally of the order 1eV.



xiii. Prove that $\beta = \frac{\alpha}{1-\alpha}$ where α = amplification factor and β = current amplification factor of a transistor.

Ans. $\beta = \frac{I_C}{I_B}$……………….(1)

$\alpha = \frac{I_C}{I_E}$……………..(2) (1 mark)

$I_E = I_C + I_B$

$I_B = I_E - I_C$ ………...(3) (1 mark)

Using eq (3) in eq (1)

$$\beta = \frac{I_C}{I_E - I_C}$$

$$\beta = \frac{I_C/I_E}{I_E/I_E - I_C/I_E} = \frac{\alpha}{1-\alpha}$$ hence proved (1 mark)

xiv. Suppose one of a pair of 20 years old twins takes off in a spaceship travelling at a very high speed to a distant star and back again, while the other twin remains on Earth. Will there be any difference in their ages? Why?

Ans. Yes, there will be difference in their ages. Time for the twin who was on Earth, will be normal. His age passes normally but apparent time for the twin who had gone to space ship and came back will pass slowly. As a result, twin on Earth becomes aged and twin in space ship remains young.

xv. Prove that in Pair Production at least 1.02 MeV energy photon is required.

Ans. Energy required for pair production= 2* rest mass energy of electron or positron. (1 mark)

$= 2m_{\circ}C^2 = 2 \times 9.1\times10^{-31} \times (3\times10^8)^2$

$= 16.38 \times 10^{-14}$ J (1 mark)

$= \frac{16.38 \times 10^{-14}}{1.6 \times 10^{-19}}$ eV

$= 1.02$ MeV (1mark)

xvi. What are the essential conditions for the biasing of a transistor?

Ans. (i) Base emitter junction should be forward biased by battery V_{BB}.

(ii) Collector base junction should be reverse biased by battery V_{CC}

(iii) $V_{CC} >> V_{BB}$.

xvii. How can we calculate kinetic energy of photoelectrons?

Ans. From Einstein's photoelectric equation.

$E = \varphi + (K.E)_e$ (1 mark)

Where E= energy of incident light

φ = work function (1 mark)

$(K.E)_e = E - \varphi = hf - \varphi$ (1 mark)

xviii. Calculate ionization energy and ionization potential for hydrogen atom.

Ans. The quantized energy of electron is n[th] state of hydrogen atom is $E_n = \frac{E_0}{n^2}$ (1 mark)

Where $E_0 = \frac{2\pi k^2 me^4}{h^2}$ = 2.17 x 10^{-18} J or 13.6 eV (1 mark)

E_0 is the ionization energy of hydrogen atom in its ground state (i.e. an energy which when electron will get, it will knock out of atom) whereas ionization potential is 13.6 Volt (i.e. a potential difference at which electron knocks out of Hydrogen atom).

xix. What is the wavelength of the second line of Paschen series?

Ans. For Paschen series

$\frac{1}{\lambda} = R_H\left(\frac{1}{3^2} - \frac{1}{n^2}\right)$ where n= 4, 5, 6, …………… (1 mark)

For second line n = 5

$\frac{1}{\lambda} = R_H\left(\frac{1}{3^2} - \frac{1}{5^2}\right)$

$\frac{1}{\lambda} = R_H\left(\frac{1}{9} - \frac{1}{25}\right)$

$\frac{1}{\lambda} = R_H\left(\frac{16}{225}\right)$ (1 mark)

$\lambda = \frac{225}{16 x R_H} = \frac{225}{16 \text{ x } 1.0974 \text{ x } 10^7}$ = 1.2814 x 10^{-6} m

λ = 1281.4 x 10^{-9} m = 1281.4 nm (1 mark)

xx. What is the least energy does the proton has, to make the following reaction possible?

$$^1_1H + ^{13}_6C \longrightarrow ^{14}_7N + ^1_0n$$

The mass of hydrogen ^1H is 1.007825 u, carbon ^{13}C is 13.003355 u, nitrogen is 13.005739 u and neutron is 1.008665 u.

Ans. Mass of reactants = $m(^1_1H) + m(^{13}_6C)$

= 1.007825 + 13.003355 = 14.01118 u (1 mark)

Total mass of Products= 13.005739 + 1.008665 = 14.014404 (1 mark)

Δm = -3.224 x 10^{-3} u

ΔE = = -3.224 x 10^{-3} x 931= -3 MeV (1 mark)

SECTION – C(Marks 26)

Note: Attempt any **TWO** questions. All questions carry equal marks. **(2 × 13 = 26)**

Q.3 a. Define electric potential. Find an expression for electric potential energy and electric potential due to a point charge. **(1+4+1)**

Ans. **Electric Potential:**

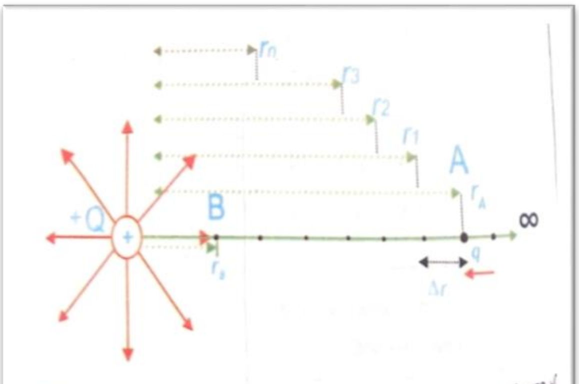
Electric potential at any point is equal to the work done in bringing a unit positive charge from infinity to that point without producing any acceleration.

$$\mathbf{V} = \frac{\mathbf{W}}{\mathbf{q}}$$

Unit: Unit of electric potential is volt 1 volt $= \frac{1 \text{ Joule}}{1\text{Coulomb}}$

Electric Potential Energy:

Consider an isolated charge +Q fixed in space. The electric field intensity E is given by the equation $E = \frac{1}{4\pi\varepsilon}\frac{Q}{r^2}\mathbf{r}$



Work done on a test charge q in moving it towards source charge +Q

As the test charge moves q is at infinity which is moved towards charge as +Q a force of repulsion acts on it. Since external work is required to be done to bring charge from infinity to point A therefore negative sign is inserted in equation.

The work done is

$$\Delta W = -qE.\Delta r = qE\Delta r\cos 180°$$
$$\Delta W = qE\Delta r$$

Now putting the value of E

$$\Delta W = \frac{1}{4\pi\varepsilon_\circ}\frac{Qq}{r^2}\Delta r$$

Let the test charge is at distance r_A from charge Q. Electric field does not remain constant but varies as the square of the distance from the charge. We divide the distance between r_A and r_B into infinitesimally small displacements so that the field intensity over each displacement remains constant.

Work done between point r_A and r_1 is

$$\Delta W_{r_A \to r_1} = \frac{Qq}{4\pi\varepsilon_o}\left(\frac{r_A - r_1}{r_A r_1}\right)$$

By division

$$\left(\frac{r_A}{r_A r_1} - \frac{r_1}{r_A r_1}\right) = \left(\frac{1}{r_1} - \frac{1}{r_A}\right)$$

And

$$\Delta W_{rA \to r1} = \frac{Qq}{4\pi\varepsilon_\circ}\left(\frac{1}{r_1} - \frac{1}{r_A}\right)$$

Similarly for second small displacement $\Delta r = r_1 - r_2$. Work done is

$$\Delta W_{r1 \to r2} = \frac{Qq}{4\pi\varepsilon_\circ}\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$$

And

$$\Delta W_{rn \to rB} = \frac{Qq}{4\pi\varepsilon_\circ}\left(\frac{1}{r_B} - \frac{1}{r_n}\right)$$

The total work done in moving a charge q from r_A to r_B can be calculated by taking its sum.

$$\Delta W_{rA \to rB} = \frac{Qq}{4\pi\varepsilon_\circ}\left(-\frac{1}{r_A} + \frac{1}{r_1} - \frac{1}{r_1} + \frac{1}{r_2} - \frac{1}{r_2} + \cdots \ldots \ldots + \frac{1}{r_B}\right)$$

$$\Delta W_{rA \to rB} = \frac{Qq}{4\pi\varepsilon_\circ}\left(\frac{1}{r_B} - \frac{1}{r_A}\right)$$

The work done to move a test charge q from infinity to a distance r from Q is

$$\Delta W_{\infty \rightarrow r_B} = \frac{Qq}{4\pi\varepsilon_\circ}\left(\frac{1}{r_B} - \frac{1}{\infty}\right)$$

$$\Delta W_{\infty \rightarrow r_B} = \frac{Qq}{4\pi\varepsilon_\circ}\left(\frac{1}{r_B}\right)$$

The electric potential energy at distance r from Q is

$$U = \frac{Qq}{4\pi\varepsilon_\circ}\left(\frac{1}{r}\right)$$

As electric potential at a point in an electric field is defined as the amount of work done in moving a unit positive charge from infinity to that point with uniform velocity.
The electric potential at distance r from Q is

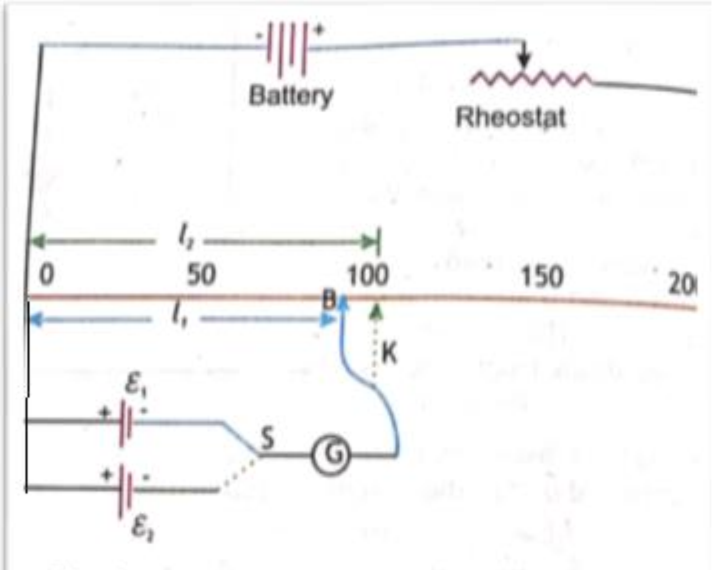
$$\mathbf{V} = \frac{\mathbf{W}}{\mathbf{q}} = \frac{\mathbf{U}}{\mathbf{q}}$$

b. What is potentiometer? How can it be used to find emf of a cell? **(1+3)**

A potentiometer is a null type resistance network device for measuring potential differences. For the accurate measurement of potential difference, current and resistance the potentiometer is most useful instrument. Its principle of action is that an unknown emf or potential difference is measured by balancing it, wholly or in part, against a known potential difference.
A simplest potentiometer consists of wire AC of uniform cross-section stretched alongside a scale and connected across battery of potential V as shown in figure. The battery through the rheostat and slide wire supply the working current. The working current may vary by changing the setting of the rheostat. A standard cell of known emf $\mathcal{E}_1$ is connected between A and terminal 1 of a two way switch S.
Slider B is pressed momentarily against wire AC and its position is adjusted until the galvanometer deflection is zero when B is making contact with AC. Let l_1 be the corresponding distance between A and B. The fall of potential over length l_1 of the wire is then the same as the emf $\mathcal{E}_1$. Then move the switch to 2, thereby replacing the standard cell by another cell, the e.m.f $\mathcal{E}_2$ of which is to be measured.
Adjust the slider B again to give zero deflection on G. If l_2 be the new distance between A and B, then

$$\frac{\mathcal{E}_2}{\mathcal{E}_1} = \frac{l_2}{l_1}$$

$$\mathcal{E}_2 = \frac{l_2}{l_1} * \mathcal{E}_1$$



Simplest potentiometer circuit

Applications of potentiometer:

Following are the applications of potentiometer:

1. Measurement of small e.m.f (upto 2V) and high e.m.f (say 250V).
2. Comparison of e.m.f of two cells.
3. Measurement of resistance and current.
4. Calibration of ammeter and voltmeter.

c. A 6 μF is charged to a potential difference of 200 V and then connected in parallel with an uncharged 3 μF capacitor. Calculate the potential difference across the parallel plate capacitors. **(3)**

Ans. **Given:**

Capacitance of charged Capacitor $C_1 = 6\ \mu F$ Capacitance of un-charged capacitor $C_2 = 3\ \mu F$,
Potential Difference of Capacitor C_1 is $V = 200$ V

Required:

Potential Difference across the parallel plate capacitors V = ?

Solution:

Charge on capacitor C_1 is $Q = C_1V = 6 \times 10^{-6} \times 200 = 0.0012$ C

The equivalent capacitance of parallel combination of capacitors is

$C_{eq} = C_1 + C_2 = 6\ \mu F + 3\ \mu F = 9\ \mu F$

The charge 0.0012 C is distributed between the two capacitors to have a common potential difference

$$V = \frac{Q}{Ceq} = \frac{0.0012}{9 \times 10^{-6}}$$

V= 133.3 V

Q.4 a. State Ampere's law and apply it to find magnetic field inside a solenoid. **(2+4)**

Ans.

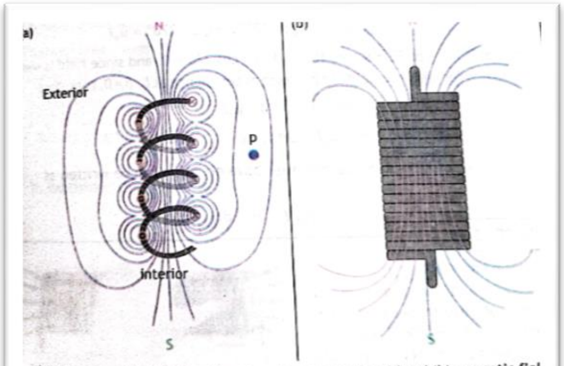
Ampere Circuital Law

Ampere's circuital law states that for any closed loop, the sum of the length elements multiplied by the component of magnetic field parallel to each element is proportional to the current enclosed by the path.

$$\Sigma\, B.\Delta l = \mu_o I$$

Magnetic Field Due To A Current Carrying Solenoid

A coil wounded in the form of a spiral (helix) forms a solenoid. When current is passed through a solenoid a reasonably uniform magnetic field can be produced. This field is strong along the axis of solenoid and weaker outside as shown in figure.

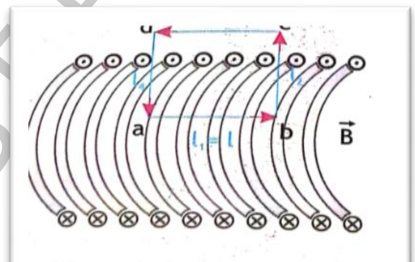


(a) The magnetic field lines for a loosely wound solenoid and (b) magnetic fiel lines for a tightly wound solenoid, carrying a steady current.

The magnetic field lines surrounding a loosely wound solenoid, shows that these lines in the interior are nearly parallel to one another, are uniformly distributed and are close together. For a tightly wound solenoid the field in the interior space is very uniform and strong. The field lines resemble those of a bar magnet, meaning that the solenoid effectively has north and south poles. As the length of the solenoid increases, the interior field becomes more uniform and the exterior field becomes weaker.

Calculations: Consider a closed amperian loop a-b-c-d, with lengths l_1, l_2, l_3 and l_4. l_1 is inside the solenoid and l_4 is outside the solenoid as shown in the figure. By Ampere's law

$$\Sigma \mathbf{B} . \Delta \mathbf{l} = \mu_o I$$



Magnetic field of Solenoid

Since there are four length elements, therefore

$\mathbf{B} . \mathbf{l_1} + \mathbf{B} . \mathbf{l_2} + \mathbf{B} . \mathbf{l_3} + \mathbf{B} . \mathbf{l_4} = \mu_o I$

$B\, l_1 \cos\theta_1 + B l_2 \cos\theta_2 + B\, l_3 \cos\theta_3 + B\, l_4 \cos\theta_4 = \mu_o I$

From the figure

$\theta_1 = 0°$, $\theta_2 = 90°$, $\theta_3 = 180°$ and $\theta_4 = 270°$ hence

$B\, l_1 \cos 0° + B l_2 \cos 90° + B\, l_3 \cos 180° + B\, l_4 \cos 270° = \mu_o I$

Since $\cos 0° = 1$, $\cos 90° = 0$, $\cos 180° = -1$ and $\cos 270° = 0$

Field ouside the ideal solenoid is weak and hence can be taken eual to zero.

$B\, l_1 + 0 + 0 + 0 = \mu_o I$

$B\, l_1 = \mu_o I$ let $l_1 = l$ $B\, l = \mu_o I$

For N number of turns in a solenoid, the above equation can be written as

$B\, l = N \mu_o I$ or $B = \frac{N}{l} \mu_o I$

Let n be the number of turns per unit length ($n = N/l$), hence

$B\, l = \mu_o n I$

b. A loop resistance 0.1 Ω is placed in a magnetic field of 2T. If a conductor of length 0.2m is sliding along a loop with a velocity of 0.2 ms^{-1}. Find (i) the e.m.f produced in the conductor if the motion of a conductor is perpendicular to the field (ii) the current through the loop (iii) the electrical power generated **(3)**

Ans.

Given:

Resistance = R= 0.1 Ω

Magnetic Induction =B = 2 T

Length of conductor = L = 0.2 m

Velocity of conductor = v = o.2 ms^{-1}

Motional EMF induced = Ɛ =?

Induced Current = I=?

Electrical Power = P =?

Θ = 90°

Motional EMF induced = Ɛ = vBLsinθ

= 0.2 x 2 x 0.2 x sin9 0°

= 0.08 V

Current = I = Ɛ/R

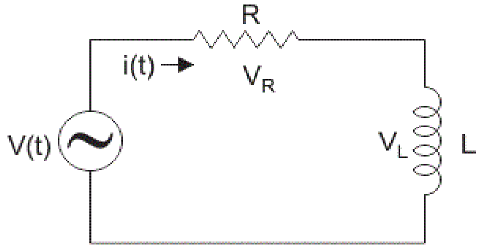
= 0.08/0.1

= 0.8 A

Electrical Power = P = V x I
= 0.08 x 0.8
= 0.064 W

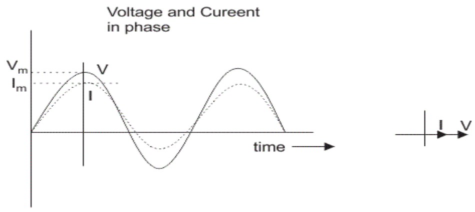
c. In an R-L circuit, will the current lead or lag the applied voltage? Justify through phasor diagram. **(4)**

Ans. **<u>R-L Series Circuit</u>**



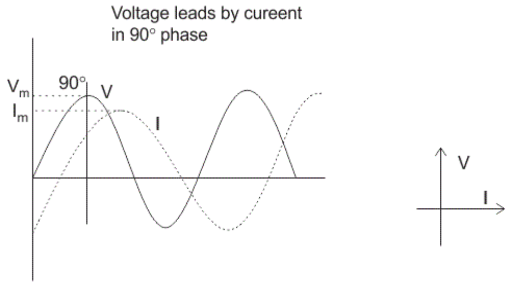
Resistor

In case of resistor, the voltage and the current are in same phase or we can say that the phase angle difference between voltage and current is zero.

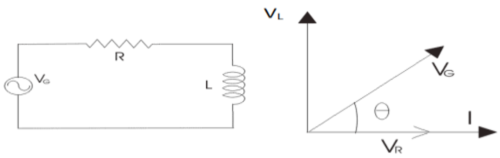


Inductor

In inductor, the voltage and the current are not in phase. The voltage leads that of current by 90^o or in other words, voltage attains its maximum and zero value 90^o before the current attains it.



Combined Resistor and Inductor



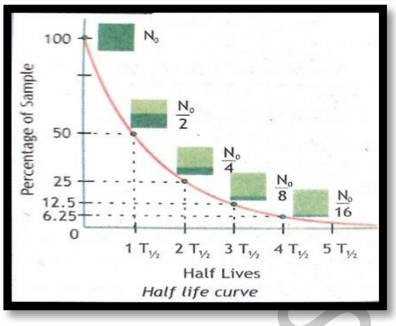
Phasor diagram reveals that the circuit current lags behind the applied voltage V.

In case of pure resistive circuit, the phase angle between voltage and current is zero and in case of pure inductive circuit, phase angle is 90^o but when we combine both resistance and inductor, the phase angle of a series RL circuit is between 0^o to 90^o.

Q.5 a. What is meant by half-life and decay rate of a radioactive isotope? Find a relation between them. **(2+4)**

Ans. **<u>Half Life:</u>**

The time it takes for half of the radioactive nuclei in a sample to decay is called half-life.



Half life curve

The amount of radioactive isotope in the sample decrease with time as shown in the figure. The number of nuclei present at t = 0 s is $N = N_\circ$, and the number present at $t = T_{1/2}$ is $N = N_\circ/2$. The number present at $t = 2T_{1/2}$ is $N = N_\circ/4$ and so on.

Rate of Decay or Activity:

The Rate of decay or activity of radioactive sample is defined as the number of disintegrations per second.

If ΔN is the number of radioactive nuclei that disintegrate in timeΔt, then

$\Delta N \ \alpha - N$ and $\Delta N \ \alpha \ \Delta t$ hence $\Delta N \ \alpha - N\Delta t$

$$\Delta N = -\lambda N \ \Delta t$$

Where λ is proportionality constant called Decay Constant. The negative sign shows that N decreases with time, the above equation can also be written as

$$\frac{\Delta N}{\Delta T} = -\lambda N$$

The above equation leads to $N = N_\circ e^{-\lambda t}$-------------(A)

For half-life, at $t = T_{1/2}$, $N = N_\circ/2$

Putting these values in eq (A)

$$\frac{N_\circ}{2} = N_\circ e^{-\lambda T1/2}$$

$$\frac{1}{2} = e^{-\lambda T1/2}$$

Taking inverse $2 = e^{\lambda T1/2}$ or $\ln 2 = \lambda T_{1/2}$ or $T_{1/2} = \frac{\ln 2}{\lambda}$

$$T_{1/2} = \frac{0.693}{\lambda}$$

This is the relation between decay constant and half-life.

b. What is laser? Explain the principle and operation of laser. List two practical uses of lasers. **(1+4+2)**

Ans. **LASER**

A Laser is a device that emits light through a process of optical amplification based on stimulated emission of electromagnetic radiation. Intense monochromatic and coherent beam of light is emitted from LASER source.

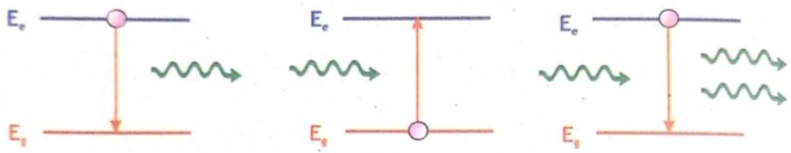
The term LASER is abbreviation of Light Amplification by Stimulated Emission of Radiation. To understand how a LASER works the terms stimulated emission and population inversion must be understood first.

Spontaneous Emission:

In this kind of interaction, an atom in an excited state makes a transition to a lower state, with the emission of a photon.

Induced Absorption:

In this interaction an atom in the ground state absorbs a photon and makes a transition to an excited state.

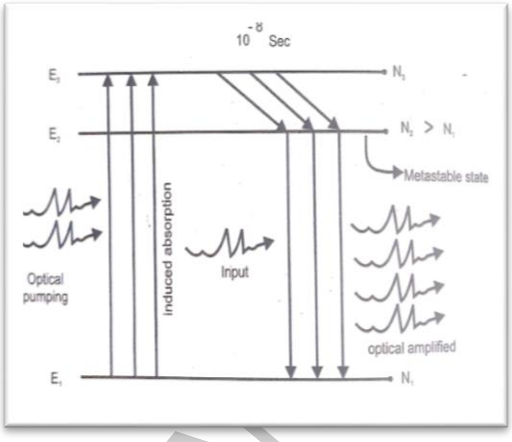


(a) Spontaneous emission *(b) induced absorption* *(c) stimulated (or induced) emission*

Stimulated Emission:

This interaction is responsible for the operation of LASER. In this process an atom is in initially in an excited state. A passing photon equal to the energy difference of the two levels, induces the atom to emit a photon by making a transition to the lower or ground state. The two photons that emerge travel in the same direction and are coherent too.

Population Inversion and Laser Action



Let us consider a simple case of a material whose atoms can reside in three different states as shown in figure. State E_1 which is ground state, the excited state E_3 in which atoms can reside only for 10^{-8} s and the metastable state E_2 in which the atoms can reside for 10^{-3}s, much longer than 10^{-8} s.

The incident photons energy $hf = E_1 - E_3$ raise the atom from ground state E_1 to the excited stateE_3, but the excited atoms back to E_1. Thus the only alternative for the atoms in the excited state E_3 is to decay spontaneously to state E_2. This eventually leads to the situation that the state E_2 contains more atoms than the state E_1. This situation is known as population inversion. Once the population inversion is achieved, the lasing action becomes simple to get.

The emitted photons must be confined in the assembly long enough to stimulate further emission from other excited atoms. This is achieved by using mirrors at the two ends of the assembly. One end is made totally reflecting and the other end is partially reflecting to allow the laser beam to escape.

Applications

1. Lasers in the medical field

   Used in eye surgery, ulcer removal and disease prevention

2. Supermarket Scanners

   These scanners contain a laser, which reads the information on the barcode of the product.

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