Sample Paper-04
Class – XII Physics (Theory)

Time allowed: 3 hours **Maximum Marks: 70**

Solutions

1. Only integral number of electrons can be transferred from one body to the other.
2. Slow moving neutron whose energy is absorbed by moderators in reactor is known as thermal neutrons.
3. $M^0 L^0 T^4$
4. ${}_{15}P^{32} \xrightarrow{\beta} {}_{16}S^{32} + {}_{-1}e^0 + Q$
5. $P = \frac{1}{f} = \frac{1}{\infty} = 0$
6. This is due to the increase in intensity, no effect on K.E. of photo electrons as well as on potential difference. As due to increase in intensity there is only an increase in the number of photons per unit area and not the energy incident.
7. When a current is circular, it means the current is passing through a circular coil. The magnetic field produced due to the current through circular coil is in the form of straight and parallel magnetic lines of force at the centre of the circular coil, lying in a plane perpendicular to the plane of coil. It means the magnetic field is straight at the centre of the circular coil carrying current.

Or

Given B = 10^{-4} T then v =?
m = 9 x 10^{-31} kg
e = 1.6 x 10^{-19} C

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

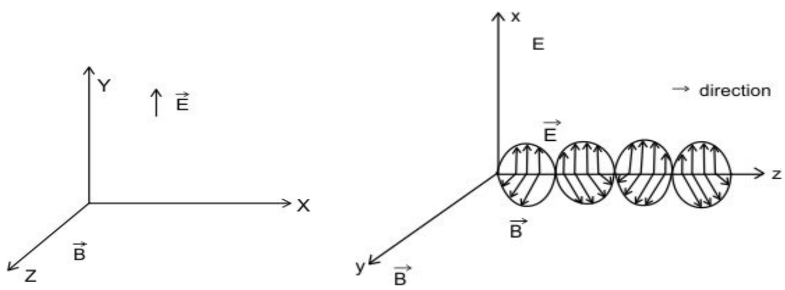
$$v = \frac{Be}{2\pi m} = \frac{10^{-14} x 1.6 x 10^{-19}}{2x3.14x9x10^{-31}} = 2.83x10^6 \, Hz$$

8. $E = n\frac{hc}{\lambda} = nh\upsilon$

10 x 1000 = n x 6.6 x 10^{-34} x 6 x 10^5

$$n = \frac{10000}{6.6 \text{ x } 6 \text{ x } 10^{-29}} = 2.5 \text{ x } 10^{31} \text{ per second}$$

9.



10. V_P = 200 V η = 80%
V_S = 20v

R =20Ω

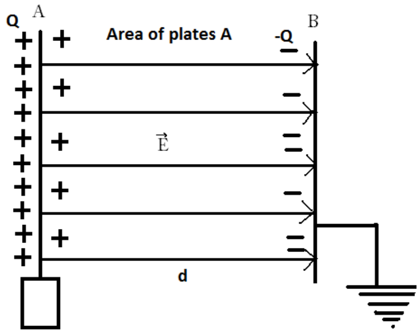
$$\eta = \frac{V_p I_p}{V_s I_s} = \frac{V_p I_p}{V_s \frac{V_s}{R}} = \frac{V_p I_p R}{V_s^2}$$

$$I_p = \eta \frac{V_s^2}{V_p R} = \frac{80}{100} \text{ x } \frac{20 \text{ x } 20}{200 \text{ x } 20} = 0.08A$$

11. A capacitor is an arrangement of two conductors separated by a dielectric medium. It is used to store the electrical energy in small amount.

Expression for the capacitance of a parallel plate capacitor:

Let us consider the two plates of area of crossection A are separated by a distance d. The space between the plates is filled by an insulating material like, air, mica, glass, etc. One of the plates is insulated and the other plate is earthed as shown in the diagram.



When charge +Q is given to the insulated plate, then a charge –Q is induced on the nearer face of the other plate and +Q is induced on the farther face of the other plate. As this plate is earthed, the charge +Q being free and flows to the earth.

The surface charge density of the insulating plate, σ = Q /A and the other plate has the surface charge density of - σ.

The electric fields outside the plates is zero.

Electric field between the plates, E = $\frac{\sigma}{\epsilon_0} = \frac{1}{\epsilon_0}\frac{Q}{A}$

Let V be the potential difference between the plates, so V = E × d = $\frac{1}{\epsilon_0}\frac{Q}{A}d$ Capacitance between the plates, C = $\frac{Q}{V} = \frac{Q}{\frac{Qd}{\epsilon_0 A}} = \frac{\epsilon_0 A}{d}$

C = $\frac{\epsilon_0 A}{d}$

If the medium is filled with a dielectric of relative permitivity ϵ_r, then the capacitance, C = $\frac{\epsilon_0 \epsilon_r A}{d}$.

12. The materials whose electrical resistance is zero at a certain temperature are called superconductors. For example, mercury becomes superconductor at 4.2 K temperature.

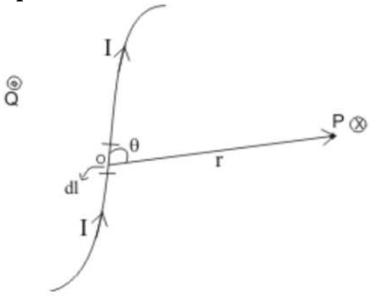
Applications of superconductors:

(i) They are used to make very strong electromagnets.

(ii) They are used to produce very high speed computers.

(iii) they are used for the transmission of electric power.

13. Let us consider a small element AB of length dl carrying current I. Let $\vec{r}$ be the position vector of the point P from the current element $I\vec{dl}$ and θ be the angle between $\vec{dl}$ and $\vec{r}$.



According to the Biot Savart's law, the magnitude of the magnetic field induction dB at a point P due to the current element depends upon the factors:

(i) dB ∝ I

(ii) dB ∝ dl

(iii) dB ∝ Sin θ

(iv) dB ∝ $\frac{1}{r^2}$

By combining all these factors, we get

dB ∝ $\frac{I\,dl\,Sin\,\theta}{r^2}$

dB = $K\frac{I\,dl\,Sin\,\theta}{r^2}$

Where, K is the constant of proportionality and the value of K is $\frac{\mu_0}{4\pi}$. The value of K in S.I. system is 10^{-7} Tm/A and in C.G.S. system the value is 1.

So, dB = $\frac{\mu_0}{4\pi}\frac{I\,dl\,Sin\,\theta}{r^2}$ (in S.I. system)

And dB = $\frac{I\,dl\,Sin\,\theta}{r^2}$ (in C.G.S. system)

In vector form, we can write as

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\left(\vec{dl}\times\vec{r}\right)}{r^3}$$

Features of Biot Savart's law:

(i) It is valid for symmetrical current distribution.

(ii) It is applicable to very small length conductor carrying current.

(iii) It cannot be easily verified experimentally.

(iv) The direction of magnetic field vector is perpendicular too current element and distance vector both.

14. The scattering of light is basically change in the direction of light. Lord Rayleigh was the first to deal with scattering of light from air molecules.
According to the Rayleigh's law of scattering, the amount of light scattered is inversely proportional to the square of the wavelength of the light.

Amount of scattering of light $\propto \frac{1}{(wavelength)^2}$

The colour of sky is blue due to the scattering of sunlight. The light coming from the sun, while travelling from through the earth's atmosphere, gets scattered by the number of molecules in the earth's atmosphere. As blue colour has shorter wavelength than red, therefore, blue colour is scattered much more strongly. Thus, the sky appears to be blue.

15. (a) An electron microscope is based on de Broglie hypothesis, according to which a beam of electron behaves as a wave which can be converged or diverged by magnetic or electric field lenses like a beam of light using optical lenses.

(b) For electron: let λ be the de Broglie wavelength of an electron.

Kinetic energy of electron, $E_1 = ½ mv^2$

Or, $mv^2 = 2E_1$

mv = $\sqrt{2E_1 m}$

As we know that, $\lambda = \frac{h}{mv}$

$$\lambda = \frac{h}{\sqrt{2E_1 m}}$$

For photon of wavelength λ, Energy, $E_2 = \frac{hc}{\lambda}$

$$\frac{E_2}{E_1} = \frac{hc}{\lambda} \times \frac{2\lambda^2 m}{h^2} = \frac{2c\lambda m}{h} = \frac{2\times3\times10^8\times10^{-10}\times9\times10^{-31}}{6.6\times10^{-34}} = \frac{90}{1.1} > 1$$

So, $E_2 > E_1$

Thus, the kinetic energy of photon is greater than that of electron.

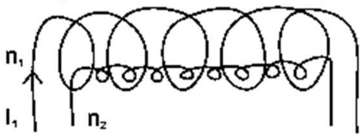
16. (a) A good moderator has two properties. It slows down neutrons by elastic collision and it does not remove them from the core by absorbing them. That is why lighter elements are better moderators.

(b) Heavy water is used in reactors using natural uranium a fuel. This is because it has lesser absorption probability of neutrons than ordinary water.

(c) Cadmium rods have a high cross section for neutrons absorption. They are used for controlling the nuclear chain reaction responsible for producing nuclear energy.

17. During the formation of a nucleus, the protons and neutrons come closer to a distance of 10^{-14} m. The energy required for the purpose is spent by the nucleons at the expense of their masses. So mass of the nucleus formed is less than the sum of the masses of the individual nucleons.

18. Mutual inductance is numerically equal to the induced emf produced in coil when the rate of change of current is unity in the neighbouring coil.



Derivation:

Let n_1 = number of turns per unit length in first and

n_2 = number of turns unit length in secondary coil

$\varphi_{21} = M_{21} I_1$

$= N_2 BA$

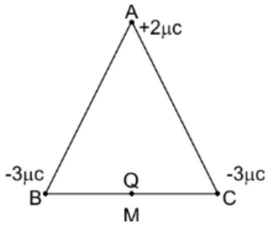
$= N_2 (\mu_0 n_1 I_1) A$

$M_{21} I_1 = \mu_0 N_1 N_2 I_1 A/L$

$M_{21} = \mu_0 n_1 n_2 AL$
Similarly $M_{12} = n_1 n_2 AL$

19. (a) The link, which transfers information from the information source to the destination, is called transmission medium.
(b) The radio waves in the frequency range 500 kHz to 1500 kHz is called medium wave band while those in the frequency range from a few MHz to 30 MHz is called short wave band.
(c) A device which converts energy in one form to another is called a transducer.

20. For equilibrium of charges A, the nature of charge at M must be



$\vec{F}_{AB} + \vec{F}_{AC} + \vec{F}_{AM} = 0$

$\Rightarrow \vec{F}_{AB} + \vec{F}_{AC} = -\vec{F}_{AM}$

$\left|\vec{F}_{AB} + \vec{F}_{AC}\right| = \sqrt{F^1 + F^2 + 2FF\cos 60} = F\sqrt{3}$

$= \dfrac{9 \text{ x } 10^9 \text{ x } 3 \text{ x } 10^{-6} \text{ x } 2 \text{ x } 10^{-6}}{400 \text{ x } 10^{-4}} N$

$= \dfrac{9 \text{ x } 10^9 \text{ x } 3 \text{ x } 10^{-6} \text{ x } 2 \text{ x } 10^{-6}}{400 \text{ x } 10^{-4}} \sqrt{3}$

$\dfrac{{}^3 9 \text{ x } 10^9 \text{ x } Q \text{ x } 2 \text{ x } 10^{-6}}{300 \text{ x } 10^{-4}}$

$\Rightarrow \dfrac{\sqrt{3}}{4} \text{ x } 10^{-6} Q$

$Q = 0.43\mu C$

21. (a) The actual length of a magnet is called the geometric length of the magnet. The distance between the poles of a magnet is called the magnetic length of the magnet.
(b) The geometric length of the magnet is nearly 8/7 times the magnetic length of the magnet.
(c) It is the angle made by the direction of earth's total magnetic field with the horizontal direction.

22. $B = B_0 \sin(\omega t + bx)$
$B_Y = 8 \text{ x } 10^{-5} \sin(2 \text{ x } 10^{11} t + 300\pi x)$
$\Omega = 2 \text{ x } 10^{11}$ rad/s , $K = 300\pi = 2\pi/\lambda$
$= 2\pi / 300 = 1/.150m = 0.006$
Then, $E_Z = E_0 \sin(\omega t + kx)$
Where $E_0 = CB_0 = 3 \text{ x } 108 \text{ x } 8 \text{ x } 10^{-5} = 2400 N/C$
$E_Z = 2400 \sin(2 \text{ x } 10^{11} t + 300\pi x)$

23. (i) Responsibilities, makes his child to understand the concepts and to generate the interest in the subjects.
(ii) The magnetic field lines in a toroid are concentric circles and the magnetic field lines in a solenoid are straight lines inside the solenoid.

24. (i) (a) The electric force between an electron and a proton at a distance r apart is

$$F_e = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

Where the negative sign indicates that the force is attractive and the corresponding gravitational force is

$$F_G = -G\frac{m_p m_e}{r^2}$$

Where m_p and m_e are the masses of a proton and an electron respectively

$$\left|\frac{F_e}{F_G}\right| = \frac{e^2}{4\pi\varepsilon_0 G m_p m_e} = 2.4 \times 10^{39}$$

(b) On similar lines, the ratio of the magnitudes of electric force to the gravitational force between two protons at a distance r apart is

$$\left|\frac{F_e}{F_G}\right| = \frac{e^2}{4\pi\varepsilon_0 G m_p m_e} = 1.3 \times 10^{36}$$

However, it may be mentioned here that the signs of the two forces are different. For two protons, the gravitational force is attractive in nature and the Coulomb force is repulsive. The actual values of these forces between two protons inside a nucleus (distance between two protons is ~ 10^{-15} m inside a nucleus) are Fe ~ 230 N whereas FG ~ 1.9×10^{-34} N. The (dimensionless) ratio of the two forces shows that electrical forces are enormously stronger than the gravitational forces.

(ii) The electric force F exerted by a proton on an electron is same in magnitude to the force exerted by an electron on a proton; however the masses of an electron and a proton are different. Thus, the magnitude of force is

$$|F| = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2} = \frac{8.987 \times 10^9}{\frac{1.6 \times 10^{-19}}{10^{-10}}} = 2.3 \times 10^{-8}\text{ N.}$$

Using Newton's second law of motion, $F = ma$, the acceleration that an electron will undergo is

$$a = \frac{2.3 \times 10^{-8}}{9.11 \times 10^{-31}} = 2.5 \times 10^{22}\text{m/s}^2$$

Comparing this with the value of acceleration due to gravity, we can conclude that the effect of gravitational field is negligible on the motion of electron and it undergoes very large accelerations under the action of Coulomb force due to a proton. The value for acceleration of the proton is

$$a = \frac{2.3 \times 10^{-8}}{1.67 \times 10^{-27}} = 1.4 \times 10^{19}\text{m/s}^2$$

Or

Consider a closed path of radius r inside the cross section of the wire. The current enclosed by this path is

$$I' = \left(\frac{I}{\pi a^2}\right)\pi r^2 = I\frac{r^2}{a^2}$$

Therefore, by Ampere's circuital law,

$$\oint \overrightarrow{B_r}, dl = \mu_0 I'$$

$$B_r 2\pi r = \mu_0 I \frac{r^2}{a^2}$$

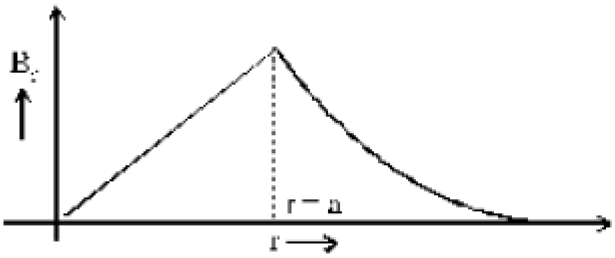
$$\therefore B_r = \frac{\mu_0 I}{2\pi a^2} r \quad [\because B \alpha r, \text{ for } r < a]$$

Outside the wire, the field of the wire is given by,

$$B.2\pi r = \mu_0 I$$

$$\therefore B = \frac{\mu_0 I}{2\pi r} \quad [\text{for } r > a]$$

The graph is shown as follows:



Therefore, B_1 and B_2 denote respectively, the values of the magnetic field points a/2 above and a/2 below the surface of the wire,

$$B_1 = \frac{\mu_0 I}{2\pi\left(3\frac{a}{2}\right)} = \frac{\mu_0 I}{3\pi a}$$

$$B_2 = \frac{\mu_0 I}{2\pi a^2} = \frac{a}{2} = \frac{\mu_0 I}{4\pi a}$$

$$\therefore \frac{B_1}{B_2} = \frac{4}{3}$$

The maximum value of the field is at r = a, we have

$$B_{\max} = \frac{\mu_0 I}{2\pi a}$$

25. (a) The main features of the Rutherford's atom model are given below:

(i) Every atom consists of a tiny central core, called the atomic nucleus, in which the entire positive charge and almost entire mass of the atom are concentrated.

(ii) The size of nucleus is of the order of 10^{-15} m, which is very small as compared to the size of the atom which is of the order of 10^{-10} m.

(iii) The atomic nucleus is surrounded by certain number of electrons. As atom on the whole is electrically neutral, the total negative charge of electrons surrounding the nucleus is equal to total positive charge on the nucleus.

(iv) These electrons revolve around the nucleus in various circular orbits as do the planets around the sun. The centripetal force required by electron for revolution is provided by the electrostatic force of attraction between the electrons and the nucleus.

(b) From the relation, $\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For K_α line, $n_1 = 1$, $n_2 = 2$

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{3}{4}RZ^2$$

$$RZ^2 = \frac{4}{3\lambda}$$

Ionisation energy of K shell electron is

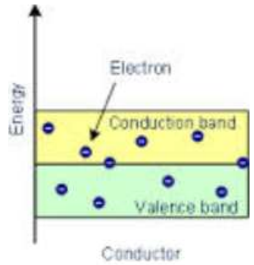
$$E = \frac{2\pi^2 mK^2Z^2e^4}{h^2}\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = \frac{2\pi^2 mK^2Z^2e^4}{h^2(ch)}(ch) = RZ^2(ch)$$

By using equation (1), $E = \frac{4}{3\lambda}(ch) = \frac{4\times3\times10^8\times6.63\times10^{-34}}{3\times1.38\times10^{-10}} = 19.5\times10^{-16}\,J$

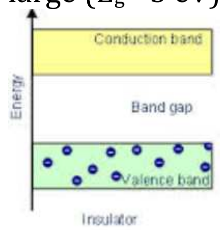
$$E = \frac{19.5\times10^{-16}}{1.6\times10^{-19}}eV = 1.22\times10^4 eV$$

So, the ionization potential = 1.22×10^4 V

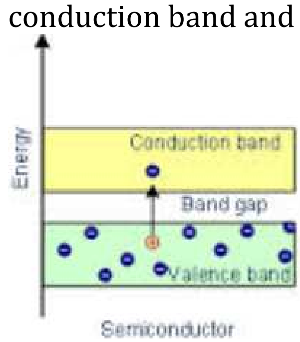
26. (a) Metals: The energy band diagram for a metal is such that either the conduction band is partially filled with electrons, or the conduction and valence band partly overlap each other and there is no forbidden energy gap in between as shown in the diagram.



Insulators: The energy band diagram of insulators is shown in the diagram given below. Here, the valence band is completely filled, the conduction band is empty and the energy gap is quite large (E_g> 3 eV).



Semiconductors: The energy band diagram of a semiconductor is shown below. Here, the valence band is totally filled and the conduction band is empty but the energy gap between the conduction band and the valence band is quite small.



(b) Here, $n_i = 2 \times 10^{16}\ m^{-3}$, $n_h = 4.5 \times 10^{22}\ m^{-3}$

$$n_e = \frac{n_i^2}{n_h} = \frac{(2\times10^{16})^2}{4.5\times10^{22}} = 8.89\times10^9 m^{-3}$$