Q19. (a) In a typical nuclear reaction, e.g.

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}H + n + 3.27MeV$$

Although number of nucleons is conserved, yet energy is released. How? Explain.

(b) Show that nuclear density in a given nucleus is independent of mass number A.

Answer: (a) Right hand side has helium and neutron, Left hand side has two deuterons the sum of mass of right hand side component that is Helium and Neutron is less than the sum of two deuterons. This difference of mass called mass defect is emitted in the form of energy by Einstein mass energy equivalence formula $E = \Delta mc^2, where\ \Delta m = mass\ defect, c = velocity\ of\ light.$

(b) Nuclear density is the density of the nucleus of an atom. The nuclear density for a typical nucleus can be approximately calculated from the size of the nucleus, which itself can be approximated based on the number of protons and neutrons in it.

Thus $Nuclear\ Density(d) = \frac{Mass\ of\ Nucleus}{Volume}$

Given: m =Mass per nucleon
A = Mass number
R = Radius of Nucleus=$r_0A^{1/3}$, r_0=1.25fm

$$d = \frac{mA}{\frac{4}{3}\pi R^3} = \frac{mA}{\frac{4}{3}\pi\left(r_0 A^{1/3}\right)^3} = \frac{3mA}{4\pi r_0^3 A} = \frac{3m}{4\pi r_0^3}$$

Thus from the final expression($\frac{3m}{4\pi r_0^3}$), we find nuclear density is independent of mass number (A).

Q20. (a) Why photoelectric effect cannot be explained on the basis of wave nature of light? Give reasons.

(b) Write the basic features of photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based.

Answer: (A) As per wave nature of light, intensity is the measure of energy carried by light. Therefore higher intensity light falling on metal surface should impart higher energy to electrons and ejected electrons should have higher Kinetic Energy, however in photo electric effect we know Kinetic energy of emitted electron is independent of Intensity of incident light.

(B) We know if the frequency of incident light is less than a minimum required frequency called threshold frequency, electron will not emit. This threshold frequency cannot be explained by wave nature of light.

(C) There is absolutely no time gap between incidence of light and emission of electron. However in classical wave theory we know that imparting energy to electrons and distribution of energy to atomic electrons should take some time, thus instantaneous energy emission in photo electric effect cannot be explained by wave nature of light.

(b) **Basic feature of photon**

(i) Light energy carrier is not ordinary particle but quantum mechanical particle called photon, ordinary particle has non zero rest mass (i.e. mass of particle when velocity is zero), rest mass of photon is zero $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$, m= mass of photon when moving with velocity v, m_0 = rest mass of photon.

(ii) Energy of each photon is given by $E = h\nu$, $where\ frequency\ \nu = \frac{c}{\lambda}, h = Planks\ constant$

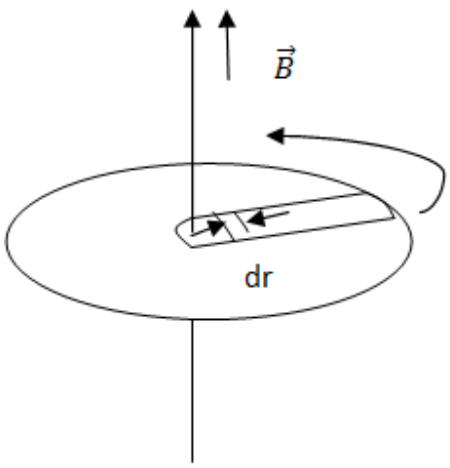
(iii) Incident photon energy is used to eject electron (work function) and remaining part converted as Kinetic energy of ejected electron. E = $h\nu + \frac{1}{2}mv^2$

(iv) Electron emission depends on frequency of incident light (photon) not on Intensity of light.

(v) There is a minimum frequency of photon which if satisfied called threshold frequency then only electrons will come out from metal surface on collision with photon.

Q21. A metallic rod of length 'l' is rotated with a frequency v with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius r, about an axis passing through the centre and perpendicular to the plane of the ring. A constant uniform magnetic field B parallel to the axis is present everywhere. Using Lorentz force, explain how emf is induced between the centre and the metallic ring and hence obtain the expression for it.

Answer: Free electrons of the rotating rod moves outward due to Lorentz force and distributed on the circumference of the ring, this separation creates emf across the terminal of the rod.



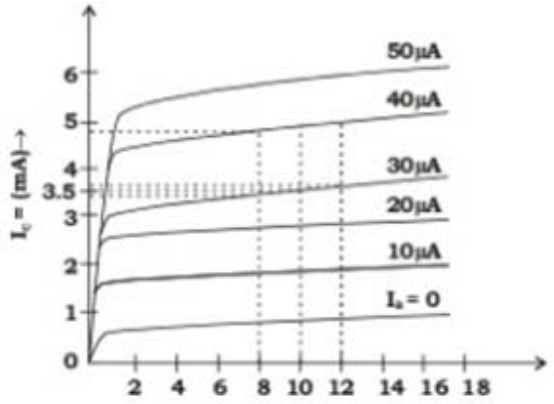
Given B= Magnetic Field,
ν = frequency
r= radius
Let dE be the emf produced across length dr then

dE= BVdr= Brωdr

therefore total emf can be obtained by integrating dE

$$\int dE = \int_0^r B\omega r dr = B\omega\frac{r^2}{2} = B2\pi\nu\frac{r^2}{2} = \pi\nu Br^2$$

Q22. Output characteristics of an n-p-n transistor in CE configuration is shown in the figure.



Determine:

(a) Dynamic output resistance

(b) DC current gain and AC current gain at an operating point
V_{CE}=10V, when I_b=30μA.

Answer:

(a) Dynamic output resistance $r_0 = \left(\frac{\Delta V_{CE}}{\Delta I_c}\right)_{I_b} = \left[\frac{12-8}{(3.6-3.4)\times 10^{-3}}\right]_{30\mu A} = \left[\frac{4000}{0.2}\right]_{30\mu A} = 20000\Omega = 20K\Omega$

(b) DC Current Gain $\beta_{dc} = \frac{I_c}{I_b} = \frac{3.5\times 10^{-3}}{30\times 10^{-6}} = 0.116 \times 10^3$=116

AC Current Gain $\beta_{ac} = \left(\frac{\Delta I_c}{\Delta I_b}\right)_{V_{CE}}$

From the figure above when base current is 30μA, collector current is 3.5 mA also when base current is 40 μA, collector current is 4.6 mA.

Therefore collect current change $\Delta I_c = 4.6 - 3.5 = 1.1\, mA = 1.1 \times 10^{-3} A$

Base current change $\Delta I_b = 40 - 30 = 10\mu A = 10 \times 10^{-6} A$

Therefore $\beta_{ac} = \left(\frac{\Delta I_c}{\Delta I_b}\right)_{V_{CE}} = \frac{1.1\times 10^{-3}}{10\times 10^{-6}} = 110$