Q. No. 2 Part (i) **MODERATOR:**

Moderator is a material used to slow down or moderate the speed of neutrons in atomic reactors i.e, THERMAL ENERGY REACTORS which require slow moving neutrons to cause fission of ^{235}U.

In thermal energy reactors, neutrons of energy **0.025eV or 0.04eV** can cause fission of ^{235}U nuclei. However, neutrons released as a result of fission process have very high energy of order several mega electron volts. Therefore, a moderator is required to slow down or moderate the speed of electrons so that they can fission additional ^{233}U. **REQUIREMENT:** Material of moderator should be light and should not absorb neutrons. **EXAMPLE:** **Water, Graphite.**

Q. No. 2 Part (ii) **CAPACITANCE OF PARALLEL PLATE CAPACITOR:**

Capacitance of parallel plate capacitor is given as:

$$C = \frac{A\epsilon_o\epsilon_r}{d}$$

Thus, capacitance of capacitor is directly proportional to Area $(C \propto A)$ and inversely proportional to separation between plates $(C \propto 1/d)$. As given that Area of plates is doubled and separation is halved, then capacitance:

$A' = 2A$ $\quad$ $d' = d/2$

$$C' = \frac{2A\epsilon_o\epsilon_r}{d/2}$$

$$C' = 4\frac{A\epsilon_o\epsilon_r}{d} \Rightarrow C' = 4C$$

Thus capacitance is increased by 4 times.

Q. No. 2 Part (iii) **WORK AND BACK E.M.F:**

When coil of motor is rotated in magnetic field, by applying potential 'V', back e.m.f is induced in it which opposes the growth of current. This back e.m.f is proportional to speed of coil. If speed of coil increases, back e.m.f increases.

MORE WORK: However when load is increased on motor, to do more work, the speed of coil decreases. As a result, back e.m.f decreases. Due to this back e.m.f. decrease, more current is supplied to the coil, to generate power. And as a result, rate of doing work increases. Thus, as rate of doing work increases back e.m.f is decreased.

Back e.m.f = V − IR → Increase in load R, decreases e.m.f.

$P = IV = I^2R$, Thus increase in current increase power i.e, rate of doing work.

Q. No. 2 Part (iv) **ALPHA FACTOR:** The ratio of collector current to emitter current is called alpha factor. As $I_C \approx I_E$ thus $\alpha \approx 1$. $\alpha_{static} = I_C/I_E$ $\alpha_{dynamic} = \Delta I_C/\Delta I_E$

β-FACTOR: The ratio of collector current to base current is called Beta factor. Its value ranges from 50 to 400.

$\beta_{static} = I_C/I_B$ $\beta_{dynamic} = \Delta I_C/\Delta I_B$

RELATION BETWEEN α AND β:

$$\beta = \frac{I_C}{I_B}$$

$$\beta = \frac{I_C}{I_E - I_E} \quad \left[\because I_E = I_C + I_B \quad I_B = I_E - I_C\right]$$

$$\beta = \frac{I_C}{I_E - I_E\left(\frac{I_E}{I_E}\right)}$$

$$\beta = \frac{I_C}{I_E\left(1 - \frac{I_C}{I_E}\right)}$$

$$\beta = \frac{I_C/I_E}{1 - I_C/I_E}$$

$$\beta = \frac{\alpha}{1-\alpha}$$

Q. No. 2 Part (v) NUMERICAL:

DATA:

$\mathcal{E} = 100V$

$R = 1500\,\Omega$

$r = 0.01\,\Omega$

TO FIND:

$I = ?$

FORMULA:

$V = IR$

$\mathcal{E} = I(R+r)$

$$I = \frac{\mathcal{E}}{R+r}$$

SOLUTION:

$$I = \frac{100\ V}{(1500+0.01)\,\Omega}$$

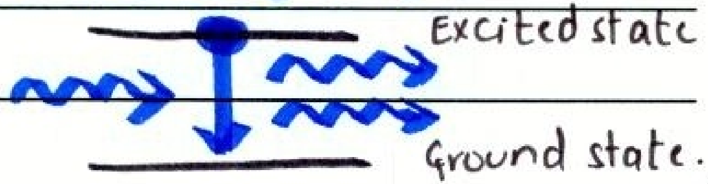
$$I = \frac{100\ V}{1500.01\,\Omega}$$

$= 0.0666\ A$

$= 66.6\ mA$

Q. No. 2 Part (vi)

SPONTANEOUS	STIMULATED
• In spontaneous emission, an atom in excited state mate spontaneous transition to lower state with the emission of photon	• In stimulated emission, a passing photon of energy equal to energy difference between two energy levels induces the atom in excited state to make transition to ground state.
• Spontaneous emission results in the production of single photon.	Stimulated emission results in two photons that are in phase.
• $\text{atom}^* \longrightarrow \text{atom} + \text{photon}$	$\text{atom}^* + \text{photon} \rightarrow \text{atom} + 2\text{photons}$
• It occurs during normal deexcitation of atom and does not require meta-stable state.	• It occurs during operation of LASER and requires meta-stable state (10^{-3}s).



Q. No. 2 Part (vii) **COMMON-EMITTER CONFIGURATION AS AMPLIFIER:**

CE configuration is most widely used as amplifier because of its large current gain β.
Amplifier is a circuit which is used to increase the strength of signal (current, voltage, power).
The current gain in CE configuration is given as:- $\beta = I_C/I_B$. As I_B is very small, so this results in large current gain. Output current or collector current is given as: $I_C = \beta I_B$. As the value of β ranges from 50-400, thus a small change in I_B causes a large change in I_C. Thus CE configuration is used as amplifier as it increases or amplifies the current. Also, voltage output by CE configuration is high given as: $V_o = -\beta \frac{\Delta V_{in}}{r_{ei}} R_C$, Due to β, voltage output is also high.

Q. No. 2 Part (viii) **CHOKE-COIL:**

Choke is an inductor used in A.C. circuit. It offers high impedence to frequencies above certain frequency range without appreciably limiting the flow of energy. Its reactance is given as: $X_L \propto 2\pi f L$

As $X_L \propto f$, thus increase in frequency increases inductive reactance. Choke performs same job as resistor in DC; ie, opposing flow of current. but $X_L \gg R$

IMPORTANCE:

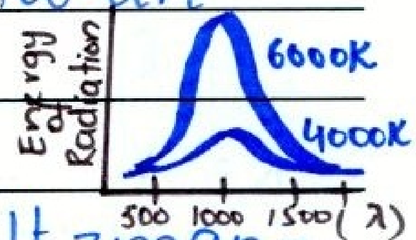
- Choke is used to prevent signal from undesired paths.
- It is used as a filter in A.C. circuit and prevents the formation of ripple.
- It prevents the entry of signals in other parts of circuit. e.g: Radio frequency choke prevents the entry of radio signals in audio circuits.

Q. No. 2 Part (ix) **STEFAN- BOLTZMANN LAW:**

Stefan Boltzman law states that:

"The area under the curve represent the amount of energy radiated per second per square metre over all wavelength that occur at a particular temperature."

The area under the curve (i.e, energy of emitted radiations) is directly proportional to fourth power of absoluted temperature.

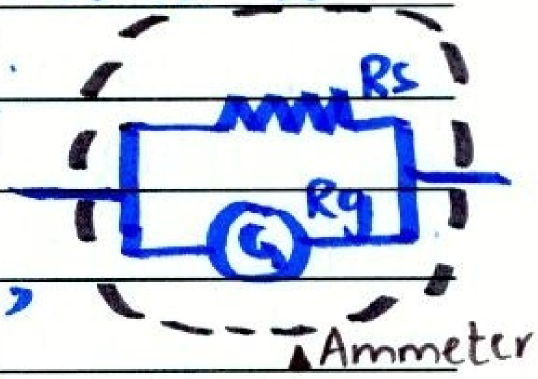


$$E \propto T^4 \qquad E = \sigma T^4$$

The above equation is called stefan Boltzmann equation and σ is stephan's Boltzmann constant having value: **$5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$!** This law is used to explain BLACK-BODY SPECTRUM.

Q. No. 2 Part (x) **CONVERSION TO AMMETER:**

Galvanometer can be converted to ammeter by connecting of shunt resistance in parallel to it. Consider 'R_s' represent shunt resistant. 'R_g' represents internal resistance of galvanometer. let 'I_g' is the current flowing through galvanometer and 'I' is the current flowing the circuit. As R_s and R_g is in parallel. $V_s = V_g$ — (i)



$V_g = I_g R_g$ —(ii) $V_s = I_s R_s = (I - I_g) R_s$ —(iii)

Using (i), (ii) and (iii) $I_g R_g = (I - I_g) R_s$

$$R_s = \frac{I_g R_g}{I - I_g}$$

This shunt resistance will convert galvanometer into ammeter.

Q. No. 2 Part (xi) **NUMERICAL:**

DATA:

$\mathcal{E} = 24V$

$P = 30W$

TO FIND:

Number of charges: ? $Q = ?$

SOLUTION:

$P = IV$

$I = \frac{P}{V}$

$= \frac{30W}{24V}$

$= 1.25A.$

$I = \frac{ne}{t}$

$n = \frac{It}{e}$

$= \frac{1.25A \times 1s}{1.6 \times 10^{-19}C}$

$= 0.781 \times 10^{19}$

$n = 7.81 \times 10^{18}$ electrons

$Q = ne$

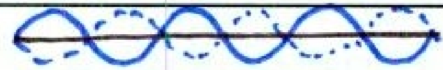
$= 7.81 \times 10^{18} \times 1.6 \times 10^{-19}$

$Q = 1.25C$

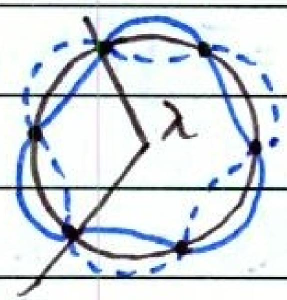
Q. No. 2 Part (xii) **DE- BROGLIE:**

According to Bohr's theory: "Electron cannot revolve in any arbitrary state, only those energy levels are possible for which angular momentum of electron is an integral multiple of $nh/2\pi$"

De-broglie solved this and proved this postulated by considering electron as wave whose wavelength is given as: $\lambda = h/p \Rightarrow \lambda = h/mv$ -(ii)



If we consider electron as a standing wave then, $2\pi r = n\lambda$



$\lambda = 2\pi r/n$ -(i)

Comparing (i) and (ii): $\frac{h}{mv} = 2\pi r/n$

$mvr = nh/2\pi$.

Thus De-broglie, proved the postulated of Bohr's theory by considering electron as a standing wave.

Q. No. 2 Part (xiii) **DEPLETION LAYER IN PN-JUNCTION:** (Act as a potential barrier at junction).

PN-Junction is formed by keeping N-type crystal in close contact with P-type crystal, under pressure to formed a single piece. At the junction, electrons from N type fill vacancies in P-type and as a result positive and negative ions are formed that result in electric field directed from N-type to P-type. This results in further diffusion of charges and mantains separation of charges on either side. As a result, the junction region is free of mobile charges and is called depletion region. Thus depletion region is defined as: **"A region formed at PN-Junction without any mobile charge carriers is called depletion region."**

Q. No. 2 Part (xiv) **BASIC FORCES OF NATURE:**

There are four basic forces of nature

(1) Strong force (2) Electromagnetic force

(3) Weak force (4) Gravitational force.

STRONG FORCE:

It is a short range (10^{-14}m) force and binds the nucleons together in nucleus. If viewed as exchange force, the exchange particle are gluons. It is the strongest of all force and has been assigned a relative strength of 1.

ELECTROMAGNETIC FORCE:

Fundamentally, electric and magnetic forces are considered as exchange forces where exchange particles are photons. It holds atoms and molecules together. It has infinite range and relative strength of 10^{-2}.

Q. No. 3 (Page 1)

ELECTRIC POTENTIAL:

Electric potential is defined as the amount of work done in carrying a unit positive charge from infinity to a point in electrical field without producing any acceleration.

$$\frac{\Delta W}{q_0} = V_A - V_B.$$

If B is at infinity then $V_B = 0$. Thus V_A

$$V_A = \frac{\Delta W_{\infty \to A}}{q}$$

By dropping substripts :-

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

POTENTIAL DUE TO POINT CHARGE:

Consider a charge +Q fixed in space as shown in the figure. Electric field is given as:

$$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$$

Suppose a charge q is at infinity and it is moved towards charge +Q. Since work is done against electric field, negative charge is inserted in the equation.

$$W = -\vec{F} \cdot \Delta\vec{r}$$

$$W = -F \Delta r \cos\theta \qquad \theta = 180° \quad \cos 180° = -1$$

Thus,

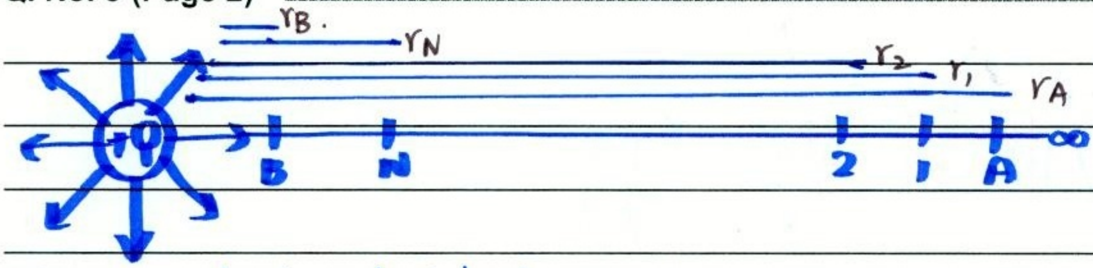
$$W = F\Delta r$$

$$W = qE\Delta r$$

Putting value of 'E' we get.

$$W = \frac{1}{4\pi\epsilon_0} \frac{Qq}{r^2} \Delta r$$

Q. No. 3 (Page 2)



Since, electric field doesnot remain constant, we divide the path into small displacements and assume that electric field is constant over it. Thus,

$$\Delta W_{r_A \to r_1} = \frac{Qq}{4\pi\epsilon_0}\left[\frac{r_A - r_1}{r_A r_1}\right]$$

$$= \frac{Qq}{4\pi\epsilon_0}\left(\frac{1}{r_1} - \frac{1}{r_A}\right)$$

Similarly,

$$\Delta W_{r_1 \to r_2} = \frac{Qq}{4\pi\epsilon_0}\left(\frac{1}{r_2} - \frac{1}{r_1}\right).$$

$$\Delta W_{r_N \to r_B} = \frac{Qq}{4\pi\epsilon_0}\left(\frac{1}{r_B} - \frac{1}{r_n}\right)$$

Total work done is calculated as:-

$$\Delta W_{r_A \to r_B} = \Delta W_{r_A \to r_1} + \Delta W_{r_1 \to r_2} + \cdots + \Delta W_{r_N \to r_B}.$$

$$= \frac{Qq}{4\pi\epsilon_0}\left(\frac{1}{r_1} - \frac{1}{r_A} + \frac{1}{r_2} - \frac{1}{r_1} + \cdots\cdots + \frac{1}{r_B} - \frac{1}{r_n}\right)$$

$$= \frac{Qq}{4\pi\epsilon_0}\left(\frac{1}{r_B} - \frac{1}{r_A}\right).$$

Suppose A is at Infinity

$$\Delta W = \frac{Qq}{4\pi\epsilon_0}\left(\frac{1}{r_B} - \frac{1}{\infty}\right)$$

Q. No. 3 (Page 3)

$$\frac{Qq}{4\pi\epsilon_0}\left(\frac{1}{r_B}\right) = \Delta W$$

$$\Delta W = \frac{Qq}{4\pi\epsilon_0}\left(\frac{1}{r}\right)$$

This work is stored as electric potential energy:

$$\Delta U = \frac{Qq}{4\pi\epsilon_0}\left(\frac{1}{r}\right)$$

As electric potential is potential energy per unit charge:

$$V = \frac{\Delta U}{q}$$

$$V = \frac{Qq/4\pi\epsilon_0\left(\frac{1}{r}\right)}{q}$$

$$= \frac{Q}{4\pi\epsilon_0}\left(\frac{1}{r}\right).$$

$$= \frac{1}{4\pi\epsilon_0}\left(\frac{Q}{r}\right)$$

$$= k\frac{Q}{r}.$$

EMF:

Emf is the work done by the battery to carry 1 coloumb charge through the source. If W Joules of work is done by the source to carry q coulomb charge through source then E.m.f is given as:

$$\mathcal{E} = \frac{W}{q}$$

Its unit is $J/C = V$.
It is the potential difference at the end of battery when it is not driving current in external circuit.

TERMINAL POTENTIAL DIFFERENCE:

It is the potential difference across the terminals of battery when it is not driving current in external circuit. It is less than E.m.f.

INTERNAL RESISTANCE:

All electrical supplies (cells, batteries e.t.c) have internal resistance. However small. It is called internal resistance.

RELATION BETWEEN V_T AND $\mathcal{E}$

When circuit is open, V_T is equal to $\mathcal{E}$. However, when current starts flowing in the circuit, it causes potential drop across resistance of source Ir and as a result $V_T < \mathcal{E}$. Relation can be

Q. No. 4 (Page 2) established as:-

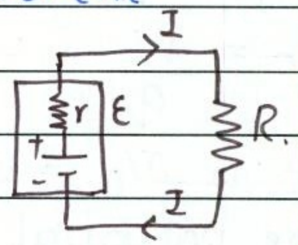
Using Ohm's law

$$V = IR$$

$$\mathcal{E} = IR.$$

As both R and r are present

$$\mathcal{E} = I(R+r).$$



$$\mathcal{E} = IR + Ir.$$

$$IR = \mathcal{E} - Ir$$

$$V_t = \mathcal{E} - Ir.$$

When $I = 0$. (Circuit open).

Then,

$$V_t = \mathcal{E}.$$

However when current is flowing, it causes potential drop across 'Ir' and hence

$$V_t < \mathcal{E}.$$

CONDITION FOR $V_t > \mathcal{E}$

Normally inside the battery, current flows from negative to positive termiaal across battery.

But when battery is charging, current flows from battery's positive terminal to negative terminal, inside battery

Hence, in this condition

$$V_t > \mathcal{E}.$$

$$V_t = \mathcal{E} - Ir.$$

Q. No. 4 (Page 3)

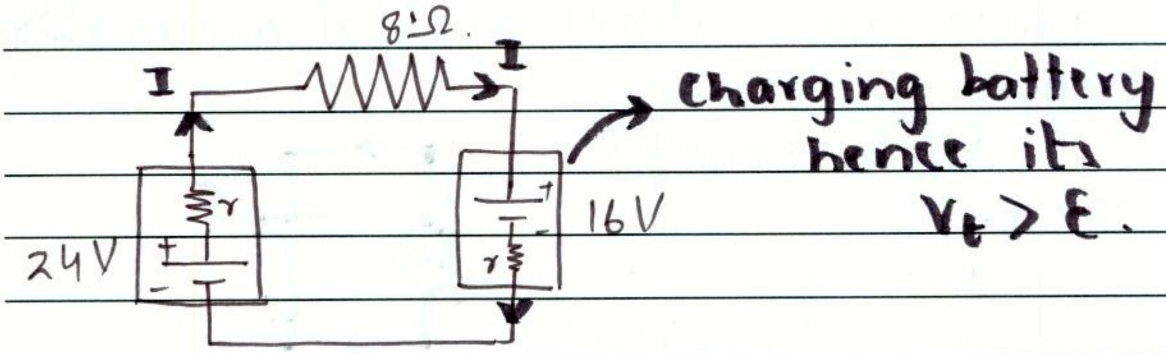
During Charging:

$$V_t = \mathcal{E} - (-I)r$$
$$V_t = \mathcal{E} + Ir$$

Thus

$$V_t > \mathcal{E}.$$

Consider circuit,



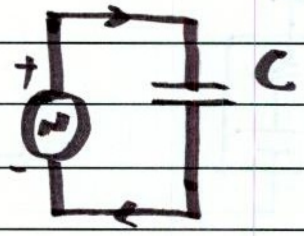
AC- ACROSS CAPACITOR:

Consider an A.C. voltage is applied to capacitor, capacitor is first charged in one direction and then in other. As a result, charges flow to and fro and constitute Alternating current.

Relation between q and V i.e, $q = CV$ holds at every instant.

Suppose,
Instantaneous value of applied alternating voltage.

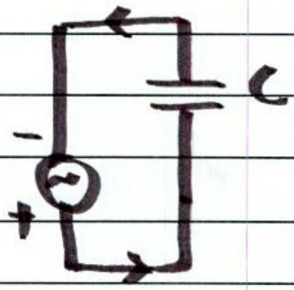
$$V = V_m \sin \omega t.$$



Then.

$$q = CV$$
$$q = CV_m \sin \omega t.$$

Sinosoidal current is given as:



$$I = \frac{\Delta q}{\Delta t}$$

$$= \frac{\Delta(CV_m \sin \omega t)}{\Delta t}$$

$$I = CV_m \frac{\Delta(\sin \omega t)}{\Delta t}.$$

$$I = CV_m \lim_{\Delta t \to 0} \frac{\Delta(\sin \omega t)}{\Delta t}.$$

$$\frac{\Delta(\sin \omega t)}{\Delta t} = (\omega \cos \omega t)$$

$$I = CV_m \omega \cos \omega t.$$

Q. No. 5 (Page 2)

$I_m = CV_m w$.

Thus,

$I = I_m \cos wt$.

$I = I_m \sin\left(wt + \frac{\pi}{2}\right)$

Thus in capacitive circuit current leads voltage by 90° or $\pi/2$. Capacitance opposes the change in voltage and causes delay in increase and decrease of voltage. Thus voltage lags behind current by 90°.

$$V = V_m \sin wt$$

$$I = I_m \sin\left(wt + \frac{\pi}{2}\right)$$

Capacitor offers resistance to current which is called capacitive reactance and is given as:

$V_m = I_m X_c$

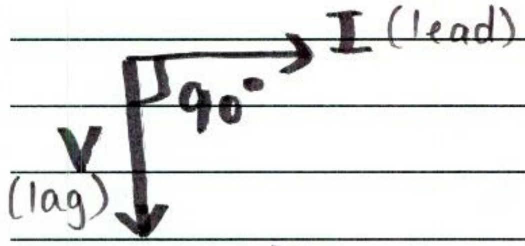
$\frac{V_m}{I_m} = X_c$

$X_c = \frac{V_m}{CV_m w}$

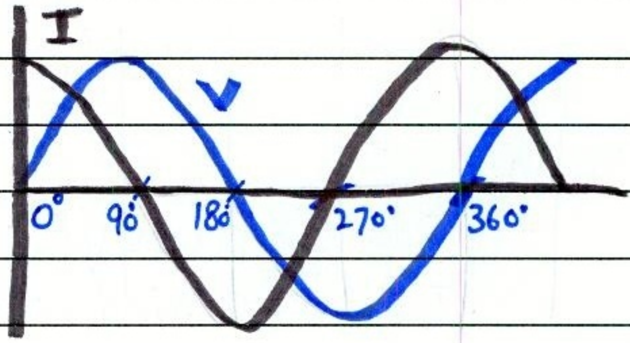
$X_c = \frac{1}{wC}$

$X_c = \frac{1}{2\pi f C}$.

Q. No. 5 (Page 3)



phasor diagram.



POWER DISSIPATION:

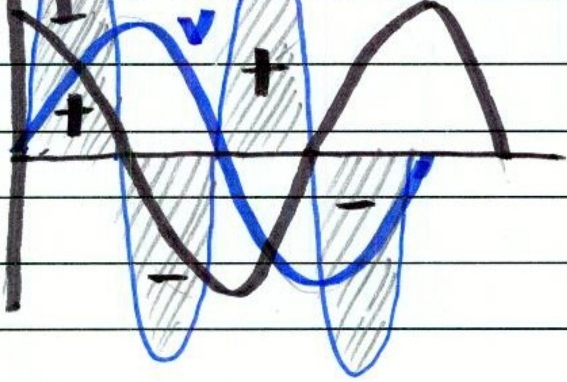
Power curve, for pure capacitive circuit is shown in the figure.

During 1st 90° of cycle, both, V and I are positive and thus power is positive. In next 90°, I is negative, V is positive. Hence P = negative. In the next 90°, power is positive and in last 90°, power is negative.

Positive power means power is delivered to load and negative power means power delivered back to source.

Positive power is equal to negative power. So, no net power is dissipated in circuit.

$$P = \langle IV \rangle = \langle I_m \cos \omega t \rangle \langle V_m \sin \omega t \rangle$$
$$= I_m V_m \langle \cos \omega t \rangle \langle \sin \omega t \rangle$$
$$= 0.$$

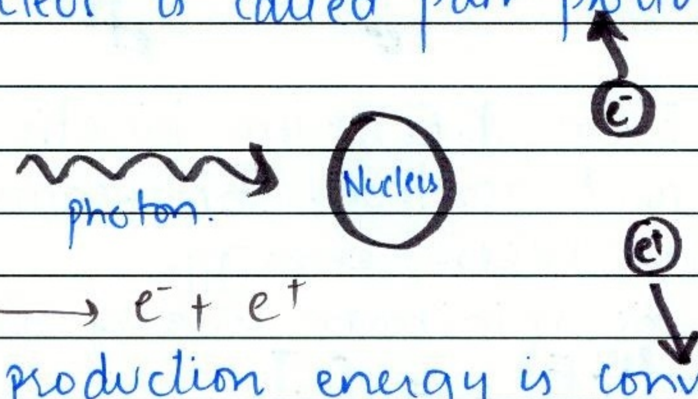


Average power dissipated = 0 in pure capacitive circuit per 1 cycle.

Q. No. 6 (Page 1)

PAIR PRODUCTION:

The creation of particle and its antiparticle (electron and positron) when photon interacts with nucleus is called pair production.



photon ⟶ $e^- + e^+$

In pair production energy is converted into mass by Einstein's mass-energy relation

$$E = \Delta mc^2$$

When photon interacts with nucleus it, disintegrates into electron and positron. Positron has same mass as electron but opposite charge.

Conservation Laws:-

- Photon cannot create an electron alone, because that would violate law of conservation of charge. Thus, in order to conserve charge, positron is produced.
- In pair production for any energy of photon, an additional massive object is required to carry some of momentum. Thus in order to conserve momentum, nucleus is required.

Q. No. 6 (Page 2)

Photon is converted to electron and positron as:-

$$hf = 2m_oc^2 + (K.E.)_{e^-} + (K.E.)_{e^+}$$

Where $(K.E.)_{e^-}$, $(K.E.)_{e^+}$ are kinetic energies of electron and positron. This occurs when photon has excess energy.

However for minimum energy photon.

$$(K.E)_{e^-} = (K.E)_{e^+} = 0\,J$$

Thus,

$$hf = 2m_oc^2.$$
$$hf = 2(9.1\times10^{-31})(3\times10^{8})^2$$
$$hf = 163.8\times10^{-15}$$
$$hf = 16.4\times10^{-14}\,J.$$

$$E = 16.4\times10^{-14}\,J.$$
$$E = \frac{16.4\times10^{-14}}{1.6\times10^{-19}}$$
$$= 10.25\times10^{5}$$
$$= 1.02\times10^{6}\,eV$$
$$= 1.02\,MeV.$$

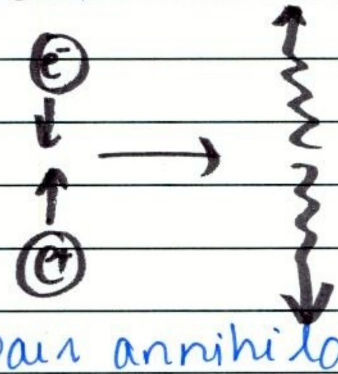
Thus pair-production requires minimum **1.02 MeV photon**. Thus γ-ray or X-ray photon is used.

Q. No. 6 (Page 3)

PAIR-ANMHILATION:

When electron and positron combine, they annihilate and two gamma-ray photons are produced.

$$e^- + e^+ \longrightarrow 2\gamma$$



In pair annihilation, electron and positron combine to produce photons, thus matter is converted to energy by Eeinstein's equation.

$$E = \Delta mc^2$$

Decay into single photon will not conserve energy and momentum.

Energies of photons produced can be calculated as:

$$2m_oc^2 = 2hf$$

$$hf = m_oc^2$$

$$E = (9.1 \times 10^{-31})(3 \times 10^8)^2$$

$$= 81.9 \times 10^{-15}$$

$$= 8.19 \times 10^{-14} J.$$

In eV $E = \dfrac{8.19 \times 10^{-14} J}{1.6 \times 10^{-19}} = 5.1 \times 10^{5}$

$$= 0.51 \times 10^{6} eV$$

$$= 0.51 MeV.$$

Thus each photon will have an energy of **0.51 MeV**. electron and positron can interact without annihilating by electron scattering.

Space for rough work

Space for rough work

$F = qvB$

$= 1.6 \times 10^{-19} \times 3 \times 10^{2} \times 2T$ $B = \frac{N\mu_0 I}{l}$

9.6×10^{-17}

$P = \frac{V^2}{R}$

$R = \frac{V^2}{P}$

$=$

$R = 19.2$

$V = IR$

$I = \frac{V}{R} = \frac{24}{19.2}$

1.25

$I = \frac{Q}{t}$

$I = \frac{ne}{t}$

$\frac{It}{e} = n.$

$1.25 \times 1s$

$Q = ne$

1.25