Q. No. 2 (i)

Q. No. 2 (ii) NUMERICAL

Data: $q_1 = 5\times10^{-8}C$ $\quad q_2 = -3\times10^{-8}C$

$r = 16cm = 0.16m$

Solution: Let P be point where $V=0$

then V at P due to q_1 $\quad V_1 = \frac{kq_1}{x}$

V at P due to q_2 $\quad V_2 = kq_2/r-x$

According to given $V_1 + V_2 = 0$

$\frac{kq_1}{x} + \frac{kq_2}{r-x} = 0$

$k\left(\frac{q_1}{x} + \frac{kq_2}{r-x}\right) = 0$

$\frac{q_1}{x} + \frac{q_2}{r-x} = 0$

$\frac{q_1}{x} = -\frac{q_2}{r-x}$

$\frac{r-x}{x} = \frac{-q_2}{q_1}$

$\frac{r}{x} = \frac{-q_2}{q_1} + 1$

$\frac{r}{x} = \frac{-(-3\times10^{-8}C)}{(5\times10^{-8}C)} + 1$

$\frac{r}{x} = \frac{8}{5}$

$5r = 8x$

$x = \frac{5}{8}r = \frac{5}{8}\times0.16 = 0.10m$

$x = 0.1m = 10cm$

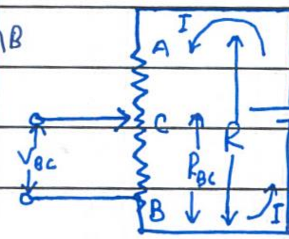
$r - x = 0.16 - 0.1 = 0.06m = 6cm$

Result: At 10 cm from q_1 and 6cm from q_2 potential is zero.

Q. No. 2 (iii)

POTENTIAL DIVIDER

A potential divider provides convenient way of getting **variable potential difference from fixed potential difference.**



With help of battery, potential V is applied across wire AB and resistance of AB is R then current in AB is

$$I = V/R$$

If R_{BC} is resistance of portion BC of wire and I is current through it then voltage between B and C is

$$V_{BC} = IR_{BC} = \frac{V}{R} R_{BC} \quad \text{or} \quad V_{BC} = \frac{R_{BC}}{R} V$$

Depending on position of sliding contact C, fraction R_{BC}/R can be varied from 0 to 1. If contact C is move towards B then length and hence resistance of wire BC decreases so voltage V_{BC} decreases and if C is move towards A, then length and resistance of wire increases so V_{BC} increases.

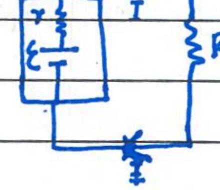
....

Q. No. 2 (iv)

MAXIMUM POWER TRANSFER

Statement: "Maximum power will be delivered to load R if its resistance is equal to source resistance r"

Prove: If current I flows through load R, applied with voltage V then charges move from point of high potential to low potential, and lose potential energy. loss in potential energy is power delivered by I to R.



so $P_{out} = I^2 R$

$$= \frac{\varepsilon^2 R}{(R+r)^2}$$

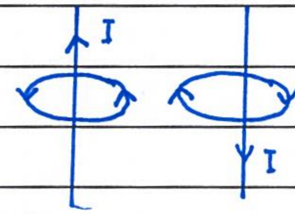
$$P_{out} = \frac{\varepsilon^2 R}{(R-r)^2 + 4Rr}$$

So when $r = R$ denominator of P_{out} is minimum and P_{out} is maximum

$$P_{max} = \frac{\varepsilon^2}{4R} = \frac{\varepsilon^2}{4r}$$

Q. No. 2 (v) **WIRES WITH OPPOSITE CURRENT**

When two long wires that are straight and parallel carry same current, then they will repel eachother. As field in middle is same so they repel eachother.



$$B_{net} = B_1 - B_2$$

Q. No. 2 (vi) **GALVANOMETER**

Definition:

"Galvanometer is a device that is used for detection and measurement of small currents."

Numerical:

Data: $I_g = 5mA = 5\times10^{-3} A$, $R_g = 100\Omega$

$V = 20V$

To Find: $R_h = ?$

Formula: $R_h = \frac{V}{I_g} - R_g$

Solution:

$R_h = \frac{20 V}{5\times10^{-3} A} - 100\Omega$

$R_h = 3900\Omega$

Q. No. 2 (vii)

Q. No. 2 (viii)

SECOND POSTULATE OF BOHR

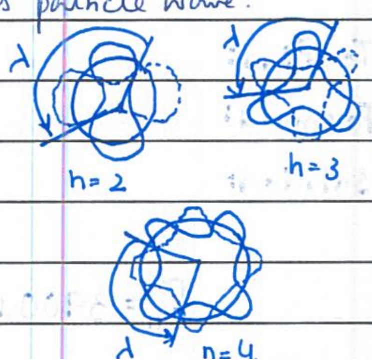
Statement: "An election cannot revolve around nucleus in any arbitary orbit. Only those orbits are possible for which **angular momentum** is **integral multiple of $h/2\pi$**." $L = mvr = nh/2\pi$

Prove: According to de-Broglie $\lambda = \frac{h}{p} = \frac{h}{mv}$ — (i)

An election in Bohr circular orbit is pictured as particle wave.

$$n\lambda = 2\pi r$$

$$\lambda = \frac{2\pi r}{n} \quad \text{— (ii)}$$



Equating equations (i) and (ii)

$$h/mv = \frac{2\pi r}{n}$$

$$mvr = nh/2\pi$$

Q. No. 2 (ix) **NO POWER DISSIPATION**

In a pure capacitor connected to AC source, **current leads voltage by 90°** so phase difference between current and voltage is 90° i.e. $\phi = 90°$.

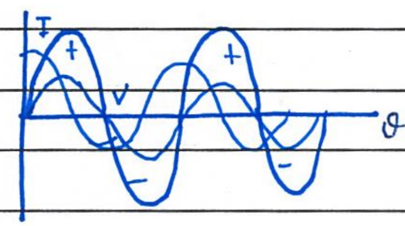
Average power dissipated is given by:

$$P = VI \cos\phi$$

$$P = VI \cos 90° \quad (\text{as } \cos 90° = 0)$$

$$P = 0$$

This proves that average power dissipated across capacitor is zero, so it dissipates no power.



Power curve also proves this as negative power is equal to positive power so net power is zero.

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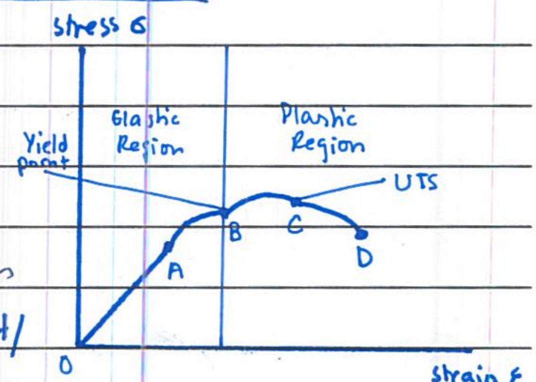
Q. No. 2 (x)

Q. No. 2 (xi)

Q. No. 2 (xii)

STRESS STRAIN CURVE



In region between **O and A**, solid behaves as elastic body. **Hooke's law is obeyed** and body regains original dimensions when load is removed. From **A to B**, stress and strain are not proportional but body regains original dimensions after force is removed. Point **B is elastic limit/ yield point** and corresponding stress is yield stress. If load is increased, stress increased beyond yield stress and strain changes rapidly even for small stress. Region of **plasticity is from B to C**. Point C is **ultimate tensile strength.** If stress increased beyond this point, material deforms permanently and doesn't regain original dimensions. Even when stress is removed ... This is **plastic deformation**. At point D material

Q. No. 2 (xiii)

Q. No. 2 (xiv)

TRANSISTOR AS AMPLIFIER

"Amplification is the process of increasing strength of signal (current, voltage, power) without change in original signal."

- The most common configuration is CE-configuration.

In transistor, emitter-base junction is forward biased and collector-emitter-junction is reverse biased. When current is supplied to emitter-base junction, forward bias increasing so base current (I_B) increases.

- As current gain is $\beta = I_C / I_B$

$$I_C = \beta I_B$$

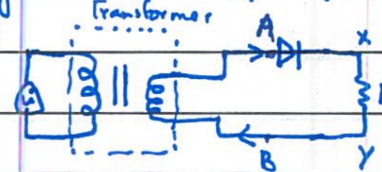
- So as I_B increases then collector current **I_C increases β times.** Therefore, in this way current is amplified.

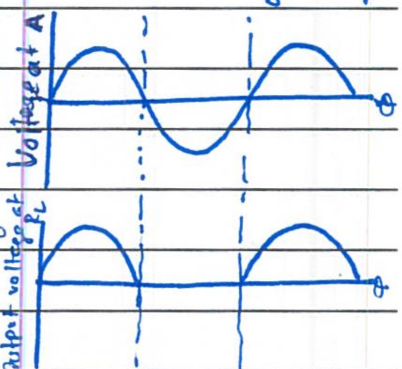
Q. No. 2 (xv)

HALF WAVE RECTIFIER

"It ~~rect~~ allows current to flow only during one half of input cycle."

Construction: Transformer couples source input voltage to rectifier. With transformer voltage can be stepped up or down and it prevents shock hazard in secondary as rectifier is electrically isolated from source. It has only **one PN junction diode.**





Voltage in secondary (between A and B) is $V = V_m \sin\omega t$.

During positive half of cycle, A is positive with respect to B, diode is forward biased and current flows through load R_L. During negative half, B is positive with respect to A, diode is reversed biased and no current through R_L.

During negative half, diode is reversed biased, no current flows through R_L so no voltage drop across R_L and entire voltage appears across diode.

Peak inverse voltage is maximum voltage diode has to withstand when reverse biased.

Q. No. 2 (xvi)

RELATION BETWEEN α and β

As amplification factor $\alpha = I_C / I_E$

and current gain $\beta = I_C / I_B$

$(\because I_E = I_C + I_B$
$I_B = I_E - I_C)$

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

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

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

Q. No. 2 (xvii) UNCERTAINTY IN ENERGY

Data: $\Delta t = 10^{-8} s$

$h = 6.63 \times 10^{-34} Js$

To Find: $\Delta E = ?$

Formula: $\Delta E . \Delta t \simeq h$

Solution: $\Delta E \simeq \frac{h}{\Delta t}$

$\Delta E \simeq \frac{6.63 \times 10^{-34} Js}{10^{-8} s}$

$\Delta E \simeq 6.63 \times 10^{-26} J$

Result:

Uncertainty in energy during this time is $6.63 \times 10^{-26} J$

Q. No. 2 (xviii) **PASCHEN SERIES 2ND LINE**

Data: $p = 3$

$n = 5$

$R_H = 1.0974 \times 10^7 m^{-1}$

To FIND: $\lambda = ?$

FORMULA: $\frac{1}{\lambda} = R_H \left(\frac{1}{p^2} - \frac{1}{n^2} \right)$

SOLUTION: $\frac{1}{\lambda} = (1.0974 \times 10^7 m^{-1}) \left(\frac{1}{3^2} - \frac{1}{5^2} \right)$

$\frac{1}{\lambda} = 780373.33 \ m^{-1}$

$\lambda = 1.2814 \times 10^{-6} m$ or $1281.4 \ nm$

RESULT:

Wavelength of second line of paschen series is 1281.4nm.

Q. No. 2 (xix) **FUSION**

"When two light nuclei combine to form heavy nucleus, the process is called fusion."

- In fusion, we need to **overcome** ~~attract~~ **repulsive force** between two nuclei by doing work.
- This repulsive force is large so high velocity and kinetic energy is required by particles/nuclei.
- This **high velocity and kinetic energy** can only be obtained at **very** high temperatures (about 10 million °C) so it is difficult to achieve fusion.

It occurs naturally at stars and sun because their surface temperature is very high.

Q. No. 2 (xx) **Equation:**

$$^{234}_{90}Th \longrightarrow ^{234}_{91}Pa + ^{0}_{-1}\beta + \bar{\nu} + Q$$

Data:

Mass of $^{234}_{90}Th$ = 234.04364

Mass of $^{234}_{91}Pa$ = 234.0428u

Mass of $^{0}_{-1}\beta$ = 0.00055u

Solution:

Mass of reactants = Mass of $^{234}_{90}Th$ = 234.0436u

Mass of products = Mass of $^{234}_{90}Pa$ + Mass of $^{0}_{-1}\beta$

= 234.0428u + 0.00055u

= 234.04335u

Q = Mass of reactants − Mass of products

= 234.0436u − 234.04335u

Q = 2.5×10^{-4} u 1u = 931.5 MeV

= $2.5 \times 10^{-4} \times 931.5$ MeV

Q = 0.233 MeV

Result:

0.233 MeV of energy is released.

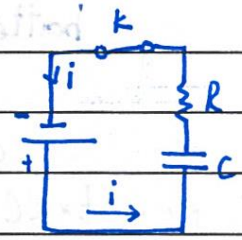
Q. No. 3 (Page 1/6) **a) CHARGING AND DISCHARGING CAPACITOR**

Capacitor:

"A device that stores electric charges."

CHARGING:

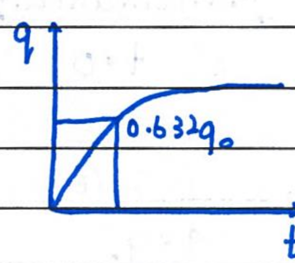
Suppose a resistance(R) and capacitance(C) are connected in series to a battery through key.



When key is open, capacitor is uncharged. These are the initial conditions of circuit i.e $t=0, i=0, q=0$.

When key is pressed, capacitor begins to store charge. If at any time during charging, q is charge on capacitor and current through circuit is I then it can be shown that as charges build up on capacitor it repels more charge than is arriving and charging current decreases as capacitor charges up.

Mathematical: As $q = q_0(1-e^{-t/RC})$ for charging



At $t=0$

$q = q_0(1-e^{-0/RC})$

$q = q_0(1-e^0)$

$q = q_0(1-1)$

$q = 0$

$t = RC$

$q = q_0(1-e^{-RC/RC})$

$q = q_0(1-e^{-1})$ ($e=2.718$)

$q = q_0(1-\frac{1}{2.718})$

$q = 0.632q_0$

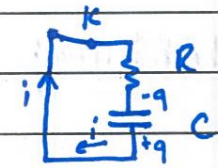
Graph: Graph shows that capacitor charges quickly if time constant is small. When $t=0$, $q=0$ and at certain time, charge reaches maximum value.

As capacitor charges up, potential between plates increase with actual time taken for capacitor to reach 63.2% of its maximum charge.

Q. No. 3 (Page 2/6) surface."

Maximum charge = capacitance × e.m.f of battery

DISCHARGING:



Now suppose an RC circuit when **battery is removed** and key is closed, capacitor begins to discharge.

Capacitor **discharges through resistance.**

For $t = RC$ the charge on either plate is q_o and drops gradually.

"Time duration is also time taken for capacitor to fall from maximum value to 36.8%."

Mathematical: For discharging: $q = q_o e^{-t/RC}$

At $t = 0$

$q = q_o e^{-0/RC}$

$q = q_o(e^0)$

$q = q_o$

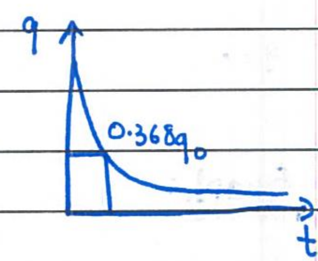
$t = RC$

$q = q_o e^{-RC/RC}$

$q = q_o e^{-1}$

$q = q_o/e = \frac{q_o}{2.718}$

$q = 0.368 q_o$



Graph: So ~~at~~ from graph at $t=0$, $q = q_o$ and after certain time it drops to 36.8% of its maximum value

APPLICATIONS:

Charging and discharging a capacitor has many applications. **Capacitor discharge ignition (CDI)** is a type of automotive ignition system used in chain saws, lawn mowers,

Q. No. 3 (Page 3/6) **b) AMPERE'S LAW**

Statement:

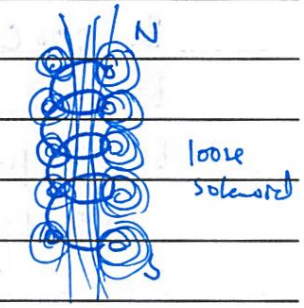
"For any closed loop, sum of length elements multiplied by component of magnetic field parallel to each element is directly proportional to current enclosed by loop/path."

$$\Sigma B.\Delta l = \mu_0 I$$

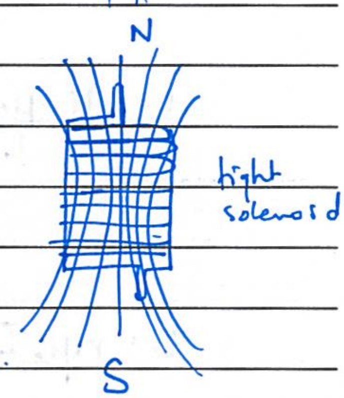
Magnetic field due to current carrying solenoid:

Solenoid: "A coil wound in spiral (helix) forms solenoid."

When current is passed through solenoid, it creates magnetic field. The field is strong along axis of solenoid and weaker outside.



⇒ The field lines surrounding **loosely wound solenoid** show that lines at interior are almost parallel, uniformly distributed and close to each other.



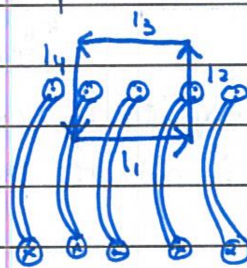
⇒ For a **tightly wound solenoid**, field is very uniform and strong. The field lines resemble bar magnet meaning solenoid effectively has north and south poles.

As length of solenoid increases, field outside becomes weaker and inside becomes uniform.

⇒ **Ideal solenoid** is approached when turns are closely spaced and its length is greater than radius of each turn. So field outside approaches zero and inside is uniform

Q. No. 3 (Page 4/6) **Calculations:**

Consider amperian path abcd in solenoid where l_1 is inside and l_3 is outside.



According to Ampere's law:

$$B \cdot L = \mu_0 I$$

Since there are four length elements:

$$B \cdot l_1 + B \cdot l_2 + B \cdot l_3 + B \cdot l_4 = \mu_0 I$$

$$Bl_1 \cos\theta_1 + Bl_2 \cos\theta_2 + Bl_3 \cos\theta_3 + Bl_4 \cos\theta_4 = \mu_0 I$$

As $\theta_1 = 0°$ $\theta_2 = 90°$ $\theta_3 = 180°$ $\theta_4 = 270°$
and field outside solenoid is weak and for ideal can be taken zero so ~~for~~ l_3 $B = 0$

$$Bl_1 \cos 0° + Bl_2 \cos 90° + (0)l_3 \cos\theta + Bl_4 \cos 270° = \mu_0 I$$

$$Bl_1 \cos 0 + 0 + 0 + 0 = \mu_0 I$$

$$B \cdot l_1 = \mu_0 I \quad \text{If we take } l = l_1$$

$$B = \frac{\mu_0 I}{L}$$

For N turns of solenoid:

$$B = N \frac{\mu_0 I}{L}$$

If n is number of turns per unit length $(n = N/L)$, then equation becomes

$$B = n\mu_0 I$$

Direction of Field: By right hand rule.
Curl fingers of right hand in direction of current around solenoid then thumb indicates north pole.

Q. No. 3 (Page 5/6)

C) NUMERICAL

DATA: $n = 15\ cm$

$n = \frac{N}{L} = \frac{15}{1cm} = \frac{15}{1 \times 10^{-2} m} = 1500$ turns/m

$A = 2 cm^2 = 2 \times 10^{-4} m^2$

$\Delta I = I_2 - I_1 = 4 - 2 = 2A$

$\Delta t = 0.1 s$

TO FIND: $\mathcal{E} = ?$

FORMULA:

$B = \frac{N \mu_o I}{L} = n \mu_o I$

$\mathcal{E} = \frac{\Delta \Phi}{\Delta t} = \frac{BA}{\Delta t}$

SOLUTION:

$B = (1500)(4\pi \times 10^{-7} Tm/A)(2A)$

$B = 3.77 \times 10^{-3} T$

$\mathcal{E} = \frac{BA}{\Delta t} = \frac{(3.77 \times 10^{-3})(2 \times 10^{-4})}{0.1}$

$\mathcal{E} = 7.54 \times 10^{-6} V$

The relevant question should be answered only in the allotted space and inside the outer mark

Space for diagram/rough work

Q. No. 3 (Page 6/6)

متعلقہ سوال کا جواب صرف مختص کردہ جگہ پر اور بیرونی نشان کے اندر دیا جائے۔

Q. No. 4 (Page 1/6) ~~a) IMPEDANCE~~

~~Definition:~~

"

Q. No. 4 (Page 2/6)

Q. No. 4 (Page 3/6)

Q. No. 4 (Page 4/6)

Q. No. 4 (Page 5/6)

The relevant question should be answered only in the allotted space and inside the outer mark

Space for diagram/rough work

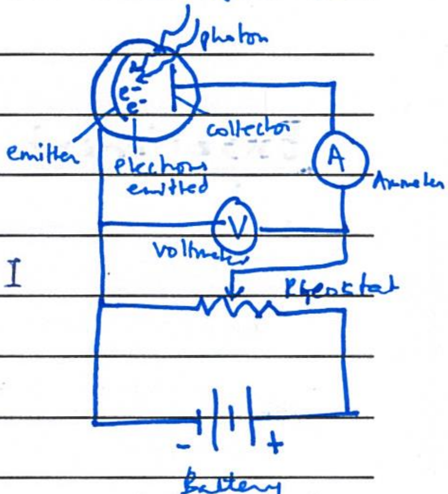
Q. No. 4 (Page 6/6)

Q. No. 5 (Page 1/6) **a) PHOTOELECTRIC EFFECT**

Definition:

"When light falls on metal surface, it emits electrons. This is called photoelectric effect and electrons emitted are photoelectrons."

Construction:



Light of suitable frequency falls on metallic emitter and ejects electrons. Voltage is applied across emitter and collector which causes photoelectric current I measured by sensitive ammeter A.

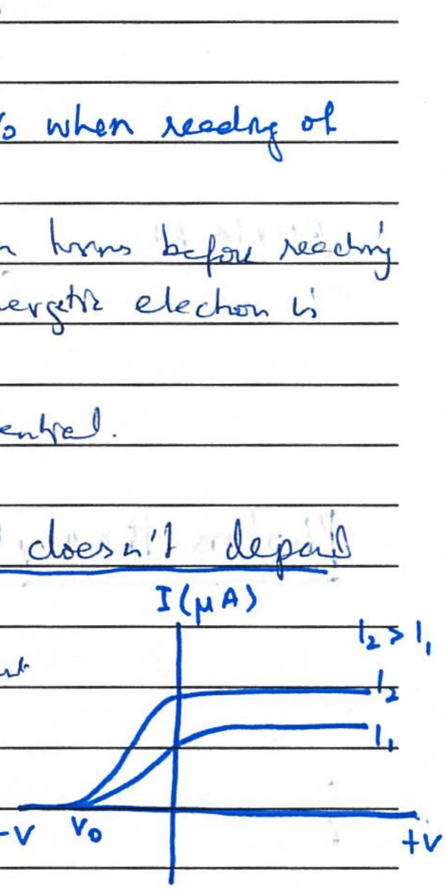
Experiment 1: Voltage is adjusted by rheostat and collector is made negative with respect to emitter. This slows down ejected electrons. We vary V until certain value called stopping potential V_0 when reading of ammemeter drops to zero.

At V_0 most energetic ejected electron turns before reaching collector. $K.E_{max}$, energy of most energetic electron is

$$K.E_{max} = eV_0$$

e = elementary charge V_0 = stopping potential.

At particular frequency of light, $K.E_{max}$ doesn't depend on intensity.



Graph between I and V at two different intensities is shown.

As intensity is increased, photoelectric current increased but stopping

Puzzle 1:

Q. No. 5 (Page 2/6) This result is a puzzle for ~~electromagnetic~~ classical physics as light is sinusoidally oscillating electromagnetic wave and it should get more energy if amplitude is increased ~~by~~ electrons while being emitted but it doesn't happen.

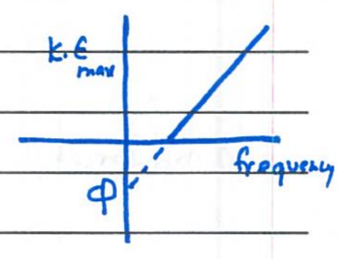
Experiment 2:

Now we vary frequency and see effect on $K.E_{max}$ and V_0.

Below certain threshold frequency f_0 (and above certain threshold wavelength λ_0) photoelectric effect doesn't occur.

Puzzle 2:

This is another puzzle as light if electromagnetic wave should emit electrons, no matter how low frequency is, if supplied with enough energy that is bright enough light source.



Puzzle 3:

Another puzzle for both experiments is that wave theory predicts time delay but first photoelectrons are emitted instantaneously when light source is turned on.

Photon theory:

Einstein used plank's concept of quantization of energy. According to him, energy of electromagnetic radiation is not continuously distributed over wavefront but ~~localized~~ concentrated in localized bundles ~~of~~ quanta.

Energy of photon associated with wave of frequency f is

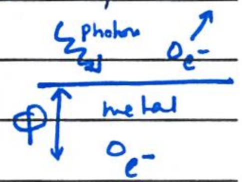
$E = hf$

Q. No. 5 (Page 3/6) He pictured that a ~~photon is~~ light quanta is so localized that it transfers its energy hf directly to single electron in metal. Therefore according to him,

$$hf = k.E_{max} + \varphi$$

$$\varphi = \text{work function}$$

$$k.E_{max} = hf - \varphi$$



Where φ is work function, minimum energy with which electron ~~metal~~ is bound in metal.

This equation explains independence of $k.E_{max}$ from intensity. For light of fixed frequency, more intensity means more photoelectrons but $k.E_{max}$ is unchanged.

It also explains phenomenon of threshold frequency. Light of threshold frequency f_0 has just energy to emit electrons from metal so they are emitted with no kinetic energy. So $f = f_0$ $k.E_{max} = 0$ then

$$0 = hf_0 - \varphi$$

$$hf_0 = \varphi$$

$$f_0 = \frac{\varphi}{h}$$

As $c = f_0\lambda_0$ so $f_0 = \frac{c}{\lambda_0}$

$$\frac{c}{\lambda_0} = \frac{\varphi}{h}$$

$$\lambda_0 = \frac{hc}{\varphi}$$

Q. No. 5 (Page 4/6)

b) NUCLEAR FUSION

Definition:

"When two light nuclei combine to form heavy nucleus, it is called nuclear fusion."

Release of Energy:

When two light nuclei combine, mass of heavy nucleus formed is less than nuclei forming it. This loss in mass appears as energy. The energy required for fusion is only possible at environment of suns and stars.

Fusion is achieved through
→ proton-proton cycle
→ carbon cycle

PROTON CYCLE:

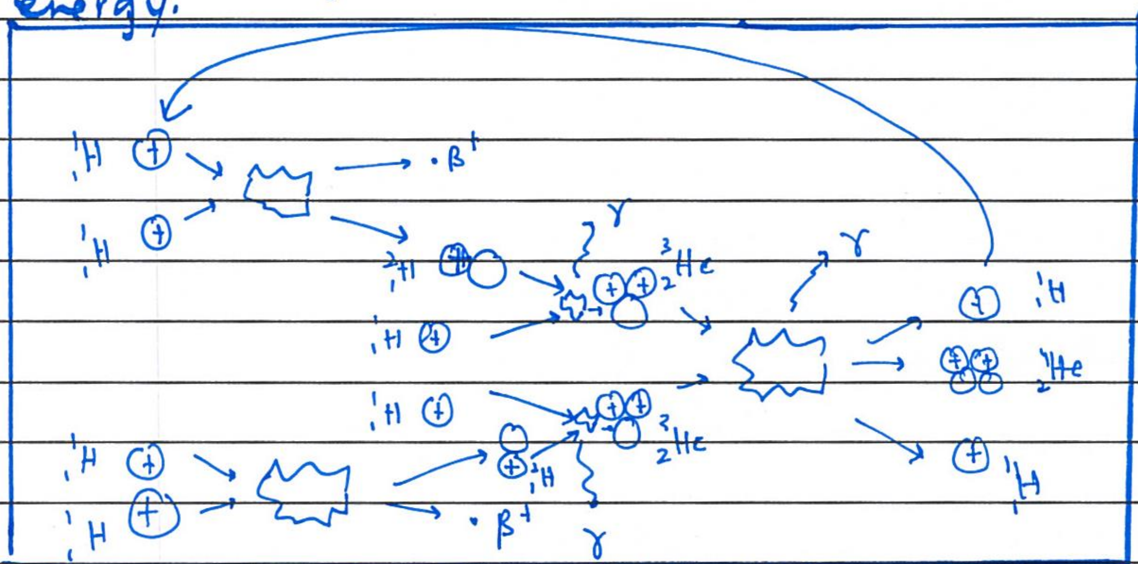
It is direct collision of protons which results in heavy nuclei which in turn collide to form helium nucleus.

REACTIONS		ENERGY
$^{1}_{1}H + ^{1}_{1}H \longrightarrow ^{2}_{1}H + \beta^{+} + \nu$	(x2)	0.42 MeV (x2)
$^{2}_{1}H + ^{1}_{1}H \longrightarrow ^{3}_{2}He + \gamma$	(x2)	5.49 MeV (x2)
$^{3}_{2}He + ^{3}_{2}He \longrightarrow ^{4}_{2}He + ^{1}_{1}H + ^{1}_{1}H + \gamma$		12.85 MeV
$^{0}_{-1}\beta + ^{0}_{+1}\beta \longrightarrow 2\gamma$	(x2)	1.02 MeV (x2)

Net: $4\,^{1}_{1}H \longrightarrow ^{4}_{2}He + 2\,^{1}_{1}H + 2\beta^{+} + 2\nu + 7\gamma$ 26.71 MeV

Q. No. 5 (Page 5/6) Proton cycle is favored at lower temperatures so stars cooler than sun fuel their energy from proton cycle while carbon cycle is favored at higher temperatures.

The energy released in fusion is called **thermonuclear energy.**



PROTON - CYCLE

Difficulty to achieve:

Fusion is difficult to achieve as high temperature is required for particles to gain high velocity and k.E to overcome repulsive force between them. This is possible only at stars and suns.

Worldwide effort is underway to harness energy from fusion in laboratory after test of successful thermonuclear bomb.

Energy per nucleon: Energy per nucleon is greater for fusion than fission

The relevant question should be answered only in the allotted space and inside the outer mark

Space for Diagram/rough work

Q. No. 5 (Page 6/6)