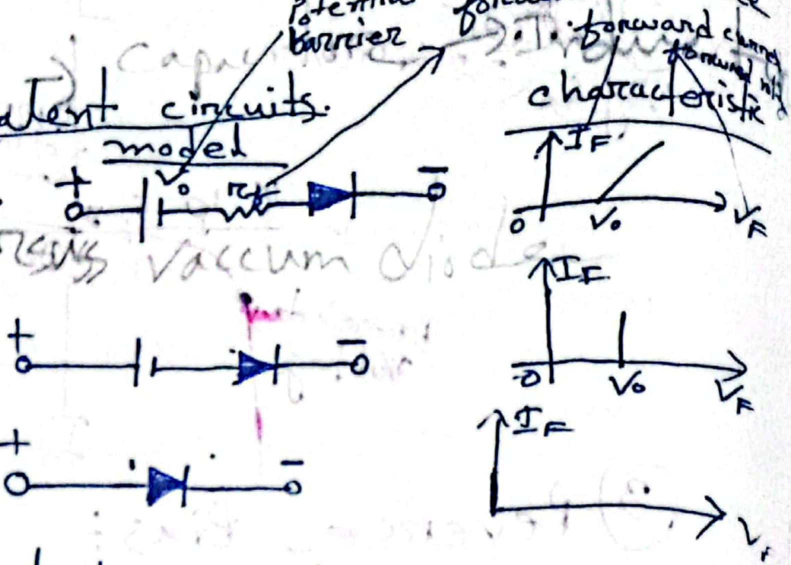
Crystal diode: A crystal diode also known as a semiconductor diode, is a type of electronic component that allows current to flow in one direction only.

Crystal diode equivalent circuits.

Type	model	characteristic
① Approximate model		
② Simplified model		
③ Ideal model		



(i) **Forward current:** It is the current that flows through a forward biased diode.

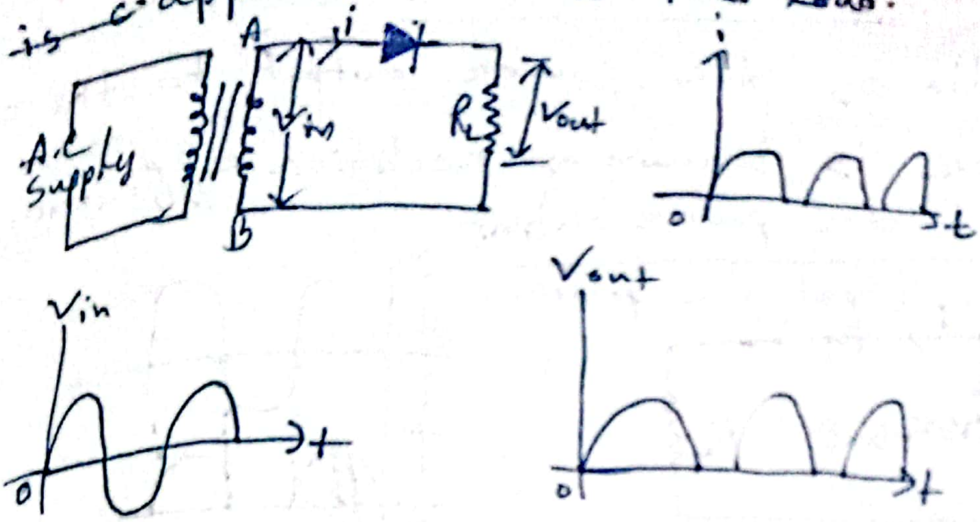
(ii) **Peak inverse voltage:** It is the maximum reverse ~~curr~~ voltage that a ~~dido~~ diode can withstand without destroying the junction.

(iii) **Reverse current / leakage current:** It is the current that flows through a reversed biased diode.

Half-Wave Rectifier:

In a half-wave rectifier, the rectifier conducts current only during the positive half-cycles of input ac supply. During negative half-cycles, no current is conducted and hence no voltage

~~is c~~ appears across the load.

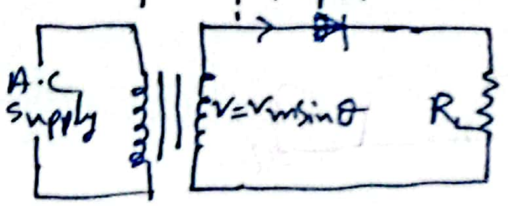


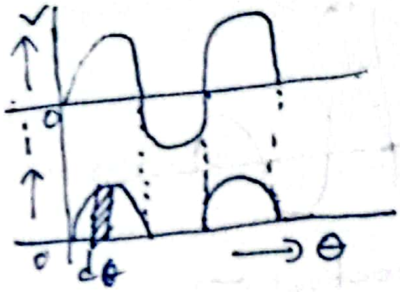
Operation: The a.c voltage across the secondary winding AB changes polarities after every half-cycle. During the positive half-cycle of input a.c voltage, end A becomes positive w.r.t end B. This makes the diode forward biased and it conducts current. During the negative half-cycle, ~~of inpu~~ end A becomes negative w.r.t end B. This makes the diode reverse biased and it conducts no current. ~~therefore~~ the current flows only positive half-cycle of input a.c voltage. only. Current flows through load R_L. Hence dc output ~~across~~ is obtained across R_L.

Efficiency of Half-Wave Rectifier:

The ratio of d.c. power output to the input a.c power is known as rectifier efficiency.

$$\eta = \frac{\text{d.c power output}}{\text{input a.c power}}$$





d.c power output: The output current is pulsating dc current

$$I_{dc} = \frac{1}{2\pi}\int_0^{\pi} i\,d\theta = \frac{1}{2\pi}\int_0^{\pi}\frac{V_m \sin\theta}{R_L + r_f}d\theta = \frac{V_m}{2\pi(R_L + r_f)}\int_0^{\pi}\sin\theta\,d\theta$$

$$= \frac{V_m}{2\pi(r_f + R_L)}\left[-\cos\theta\right]_0^{\pi} = \frac{V_m}{2\pi(r_f + R_L)} \times 2 = \frac{V_m}{r_f + R_L} \times \frac{1}{\pi}$$

$$= \frac{I_m}{\pi} \qquad \left[\because I_m = \frac{V_m}{r_f + R_L}\right]$$

$\therefore$ dc power $P_{dc} = I_{dc}^2 \times R_L = \left(\frac{I_m}{\pi}\right)^2 R_L$.

a.c power input:

$$P_{ac} = I_{rms}^2 \times (r_f + R_L)$$

$$\therefore P_{ac} = \left(\frac{I_m}{2}\right)^2 \times (r_f + R_L) \qquad \left[\text{For a half wave rectifier wave, } I_{rms} = \frac{I_m}{2}\right]$$

$\therefore$ Rectifier efficiency $= \dfrac{\text{d.c output power}}{\text{a.c input power}} = \dfrac{\left(\frac{I_m}{\pi}\right)^2 \times R_L}{\left(\frac{I_m}{2}\right)^2 (r_f + R_L)}$

$$= \frac{0.406 R_L}{r_f + R_L} = \frac{0.406}{1 + \frac{r_f}{R_L}}$$

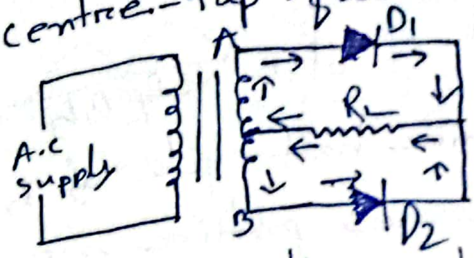
The efficiency will be maximum if r_f is negligible as compared to R_L

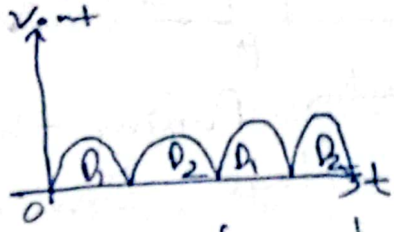
$\therefore$ Max. rectifier efficiency $= 40.6\%$.

Full wave rectifier:

In a full wave rectification, the rectifier conducts current ~~only du~~ during the positive and negative half both half-cycle of input ac supply.

(i) centre-tap full-wave rectifier:

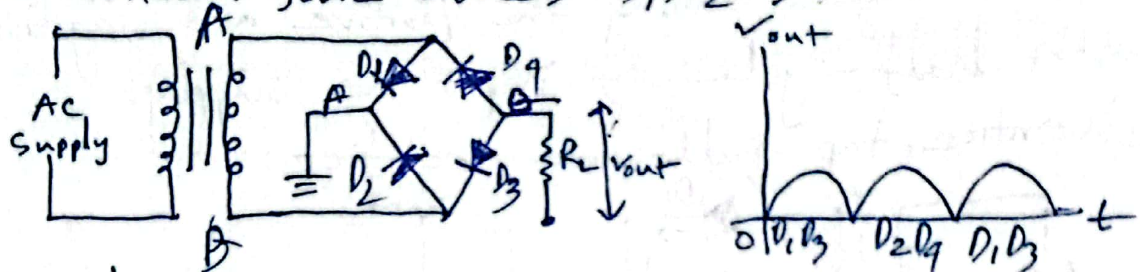




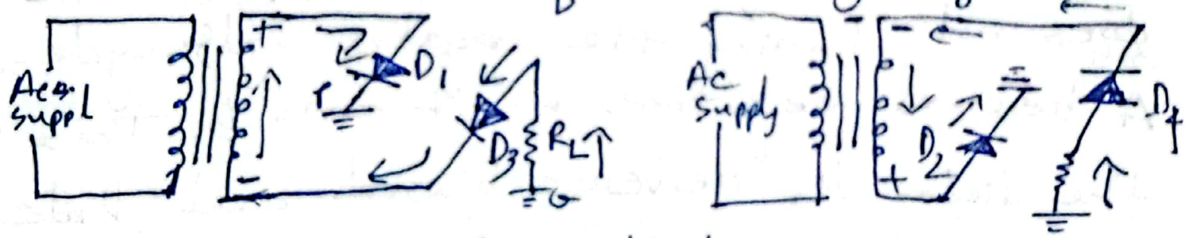
Operation: During the positive half-cycle of input ac voltage, end A becomes positive w.r.t end B. This makes the diode ~~D~~ D_1 forward biased and Diode D_2 reverse biased. Therefore, diode D_1 conducts while diode D_2 does not. During the negative half-cycle, end A becomes negative w.r.t end B. This makes the diode D_1 reverse biased and Diode D_2 forward biased. Therefore diode D_2 conducts while diode D_2 does not. It may be seen that current ind the load R_L is in the same direction for both half-cycle of input a.c voltage. D.C is obtained across the load.

(ii) Full-wave Bridge Rectifier:

It contains four dioded D_1, D_2, D_3 and D_4.

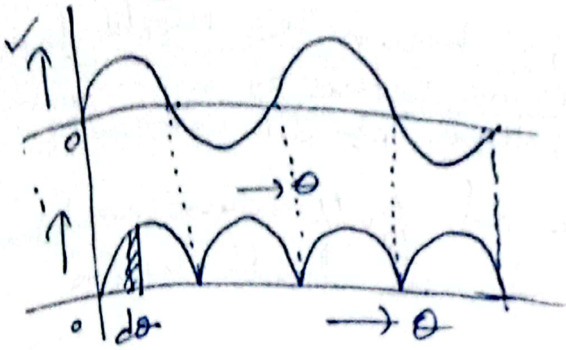


Operation: During the positive half-cycle of input ac voltage, end A becomes positive w.r.t end B. This makes the diode D_1 and D_3 forward biased while diode D_2 and D_4 are reverse biased. Therefore only diode D_1 and D_3 conduct. current flow A to B through the Load.



During the negative half-cycle, end A becomes negative w.r.t end B. This makes the diode D_1 and D_3 reversed biased and D_2 and d_2 are forward biased. Therefore only diode D_2 and D_4 conduct current. Therefore dc output is obtained across load R_L.

Efficiency of Full wave Rectifier:



dc output power: The output current is pulsating dc current. From the knowledge of electrical engineering.

$$I_{dc} = \frac{2I_m}{\pi}$$

$\therefore$ dc power output, $P_{dc} = I_{dc}^2 \times R_L = \left(\frac{2I_m}{\pi}\right)^2 \times R_L$

ac power input:

$$P_{ac} = I_{rms}^2 (r_f + R_L)$$

$$P_{ac} = \left(\frac{I_m}{\sqrt{2}}\right)^2 (r_f + R_L)$$

[For, a full wave rectified wave, we have $I_{rms} = \frac{I_m}{\sqrt{2}}$]

$\therefore$ efficiency is $\eta = \frac{P_{dc}}{P_{ac}} = \frac{\left(\frac{2I_m}{\pi}\right)^2 \times R_L}{\left(\frac{I_m}{\sqrt{2}}\right)^2 (r_f + R_L)}$

$$= \frac{8}{\pi^2} \times \frac{R_L}{(r_f + R_L)} = \frac{0.812 R_L}{r_f + R_L}$$

$$= \frac{0.812}{1 + \frac{r_f}{R_L}}$$

$\therefore$ Maximum efficiency is $= 81.2\%$.

This is double the effiiciency due to half-wave rectifier. Therefore, a ~~half wave~~ full wave n is twice as effective a a half-wave rectifier it is very important in deciding the effectiveness of a rectifier

Ripple Factor: The ratio of r.m.s value of a.c component to the d.c component in the rectifier output is known as ripple factor.

$$\text{Ripple factor} = \frac{\text{rms value of a.c component}}{\text{value of d.c component}} = \frac{I_{ac}}{I_{dc}}$$

Q1 The ripple factor of full-wave rectification is less than that of the half-wave rectification.'

For half-wave rectification:

$$I_{rms} = \frac{I_m}{2} \qquad I_{dc} = \frac{I_m}{\pi}$$

$$\therefore \text{ripple factor} = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

$$= \sqrt{\left(\frac{I_m/2}{I_m/\pi}\right)^2 - 1} = 1.21$$

This means that in half-wave rectification, the Ac component is larger than the DC component.

For Full-wave Rectification:

$$I_{rms} = \frac{\cancel{\pi} I_m}{\sqrt{2}} \qquad I_{dc} = \frac{2I_m}{\pi}$$

$$\therefore \text{Ripple factor} = \sqrt{\left(\cancel{\frac{I_{rms}}{I_{dc}}}\right)^2 - 1} = \sqrt{\left(\frac{I_m/\sqrt{2}}{\frac{2I_m}{\pi}}\right)^2 - 1} = 0.48.$$

This means in the output of a full-wave restifier, the dc component is more than the ac component. Finally, the ripple factor of full wave rectification is less than that of the half-wave rectification.

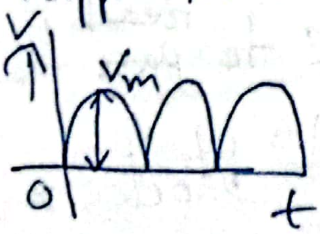
Filter circuit: A ~~filkter~~ filter circuit is a device which removes the a.c. component ~~to~~ of rectifier output but allows the d.c component to reach the load.

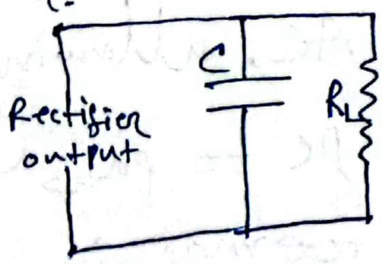
Q1 Describe the action of the following filter circuit: (i) Capacitor filter (ii) choke input filter (iii) capacitor input filter

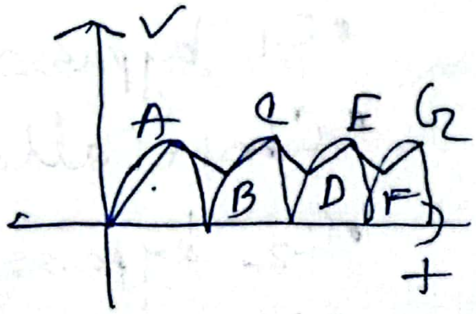
Ans:

Capacitor filter:

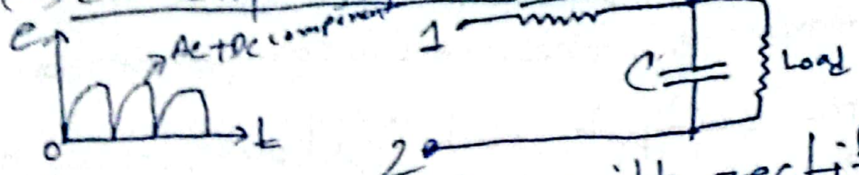
• A capacitor is connected across the rectifier output in parallel with the load. The pulsating dc voltage from the rectifier charges the capacitor. As the rectifier voltage increases, the capacitor charges, and as the rectifier voltage decreases, the capacitor discharge through the load. This process repeats, provides a smoothed output waveform with minimal ripple i.e. ABCDEFG.

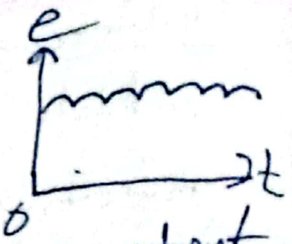






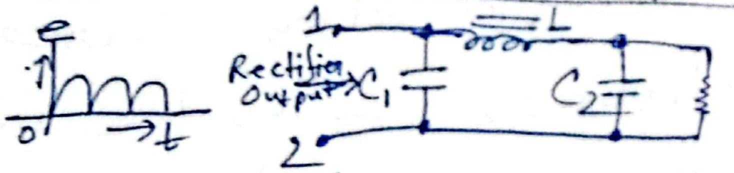
(ii) Choke input filter:

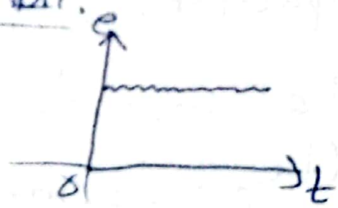




- Choke L in series with rectifier output and filter capacitor (c) across the load.
- choke opposes AC but allows DC to pass, reducing pulsations.
- Most AC appears across choke, while DC passes through the load.
- Filter capacitor bypasses remaining AC, allowing only DC to reach the load.
- Provides a smoother DC output.

(iii) Capacitor input filter / π-filter:





- ~~Consists of two~~
- Filter capacitor C1 across rectifier output choke(L) in series, and another filter capa C2 across the load.
- C_1 bypasses AC, allowing DC to reach ~~pass~~ the choke.
- Choke allows DC to pass but blocks most AC.
- C_2 bypasses remaining AC, allowing only DC to appear across the load.
- Effective in reducing ripple and improving the smoothness of the output voltage.

Zener Diode: A properly doped crystal diode which has a sharp breakdown voltage is known as a zener diode. 

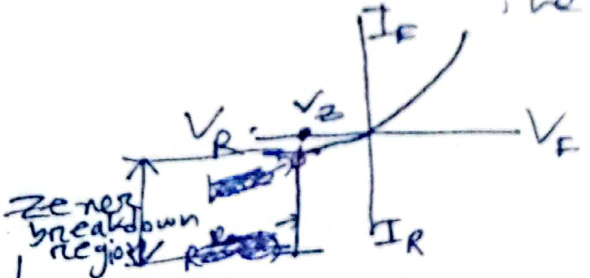
(i) A zener diode is like an ordinary diode except that it is properly doped so have a sharp breakdown voltage.

(ii) A zener diode is always reverse ~~connected~~ biased.

(iii) A " " has sharp breakdown voltage, ~~are~~ called zener voltage V_Z.

(iv) When forward biased, its characteristics are just ~~LED~~ those of ordinary diode.

(v) The zener diode is not immediately ~~burnt~~ burnt because it has entered the breakdown region.



Crystal diode versus ~~vacuum~~ vacuum diode

Crystal diode have a number of advant and disadvantages compared to vacuum diode; Advantages; (i) They are smaller, more rugged and have a longer life.

(ii) They are cheaper and inherently cheaper

(iii) They require no filament power. As a result they produce less heat than vacuum diode.

Disadvantages:

(i) Extremely heat sensitive

(ii) Limited temperature range; excess heat can damage the pn junction.

(3) Handle smaller currents and low inverse voltages compared to vacuum diod

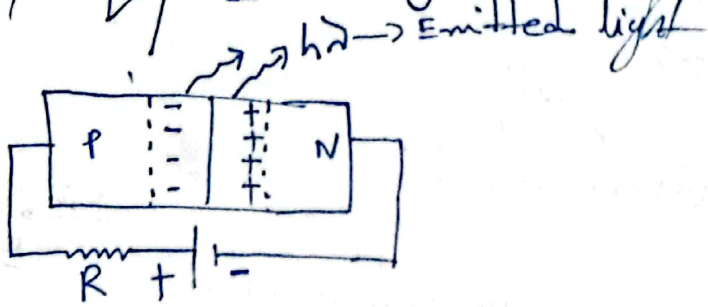
(4) They cannot stand an overload even for a short period.

(v) vacuum diode can withstand a wide range of temperature changes.

LED

Light Emitting Diode: It is havily dopped P.N. Junction diode which converts electrical energy in to light energy. This diode emits light under forward biasing.

Working:



When PN junction is forward biased, electron and holes move towards opposite side of junction. Therefore excess minority carriers on the either side of junction boundary, recombine with ~~minority~~ majority carriers near the junction. On the recombination of e^- and hole, the energy is given out in the form of light. The released energy is nearly equal to energy gap.

$$E_g = h\nu$$

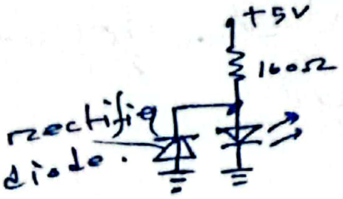
Advantages of LED:

(*) Low voltage.
(ii) Longer life (more than 20 years)
(iii) less power consume
(iv) Cheap and easy to handle.
(v) low operational voltage.

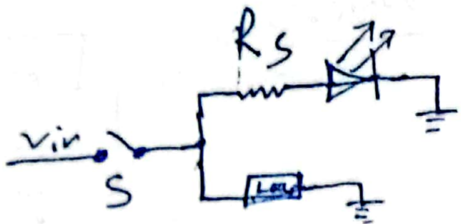
(vi) Fast-on of switching.

(vii) Protecting LED against reverse bias.

~~That is one way to protect a LED is to~~ ~~connect~~ A rectifier diode in parallel with LED. This protect the LED from damage



Application of LEDs:



(i) As a power indicator:

A LED can be used to indicate whether the power is on or ~~not~~ off. When the switch s is closed, power ~~flows through the~~ ~~load and~~ applied to the load and current flows through the LED which lights, indicating the power is on.

(ii) Seven-segment display:

purpose: To display numerical digits (0-9) using a combination of seven LEDs.

~~(i) Fig (i)~~ ~~to~~

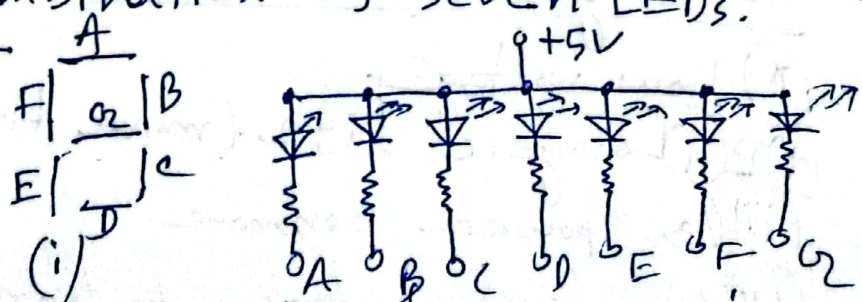
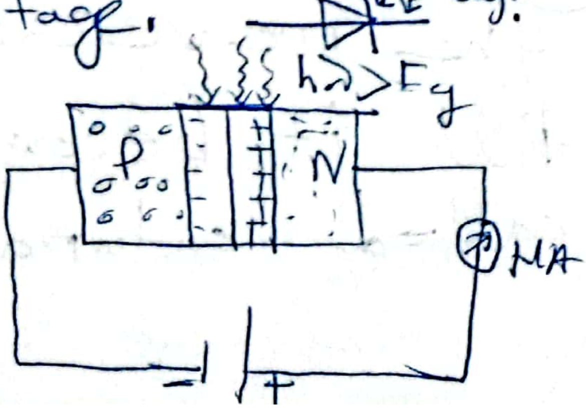


Fig (i) shows ~~a~~ the front of a seven-segment display. It contain seven LEDs (A, B, C, D, E, F, G). Each LED or segment, lights up when forward biased. For example, lighting up A, B, C, D, G shows the number 3.

Fig(ii) shows the schematic diagram of seven-segment display. External series resistors connected ~~to~~ for safe current levels. Anode of all seven LEDs are connected to voltage +5V. This is known common-andoe type. To light a specific LED, Like A, we ground the point A, It forward biased the LED A which will be lit.

Q/ What is photo diode? Explain the operating principle of photo diode with example and application.

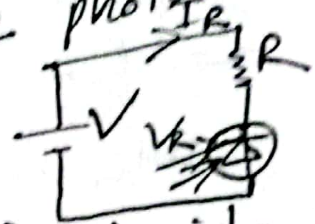
Photo-diode: It is a device used to detect and convert light energy in to electrical energy. It is operated under reverse bias below breakdown voltage.



Working: When the photodiode is illuminated with light, with energy greater than

semiconductor than
energy ~~ap~~ gap of the semiconductor than generated
that e⁻ hole pair are generated photons. These
due to the absorption of photons. These to the
charge carriers contribute to the
reverse current.

With example: Fig 6.) show basic photo diode circuit



(i) the circuit has reverse-biased photo-diode. When no is incident in the pn junction of photo.diodes the reverse current I_R is extremely small this is called dark current.

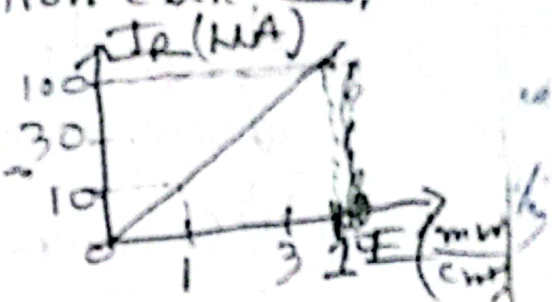
(ii) When light is incident on the pN junction of the photo diode, there is a transfer of energy (photons) to the atoms in the junction. This will create more free electrons and holes and increase reverse current.

(iii) As the intensity of light increase the reverse current increased till it becomes maximum, this is called saturation current.

V-I characteristics of photo-diode:

(i) Reverse current-Illumination curve:

The graph shows between reverse current (I_R) and illumination (E) of a photodiode.

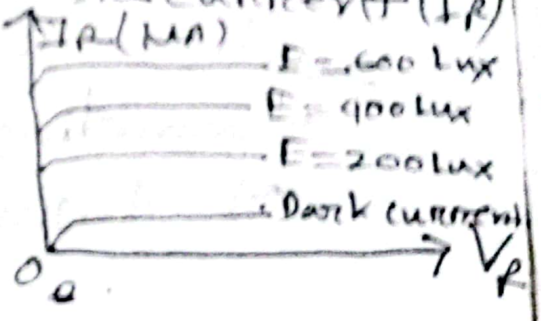


IR measured in MA and E is measured in mW/cm². Note the graph is a straight line passing through the origin.

$$I_R = mE \quad [m = \text{slope}]$$

(ii) Reverse voltage-Reverse current curve:

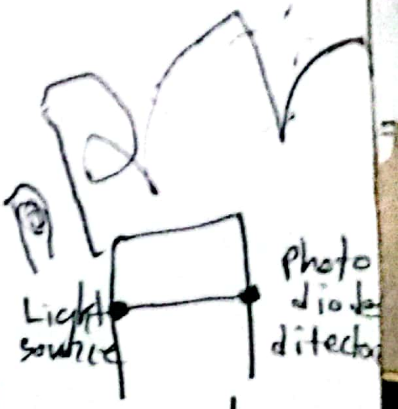
The graph between reverse current (I_R) and Reverse voltage (V_R).



It is cleared that for a given reverse-biased voltage V_R, the reverse current I_R increase.

Applications of Photo-diode:

(i) Alarm circuit using photo diode:



Light from a light source fall on a photo diode fitted. The reverse current I_R will continue to flow as long as the light beam is not broken. If a person passes through the door, light beam is broken and the reverse current drops to the dark level current and an alarm is sounded.

(ii) Counter circuit using photo-diode: A photo diode may be used to count items on a conveyor belt. If a object passes through the conveyor belt, light beam is broken, I_R drops to the dark current and the count is increased by one.

Q] What is tunnel diode? Explain the tunneling effect and VI characteristics of tunnel diode.