Photo-diode:

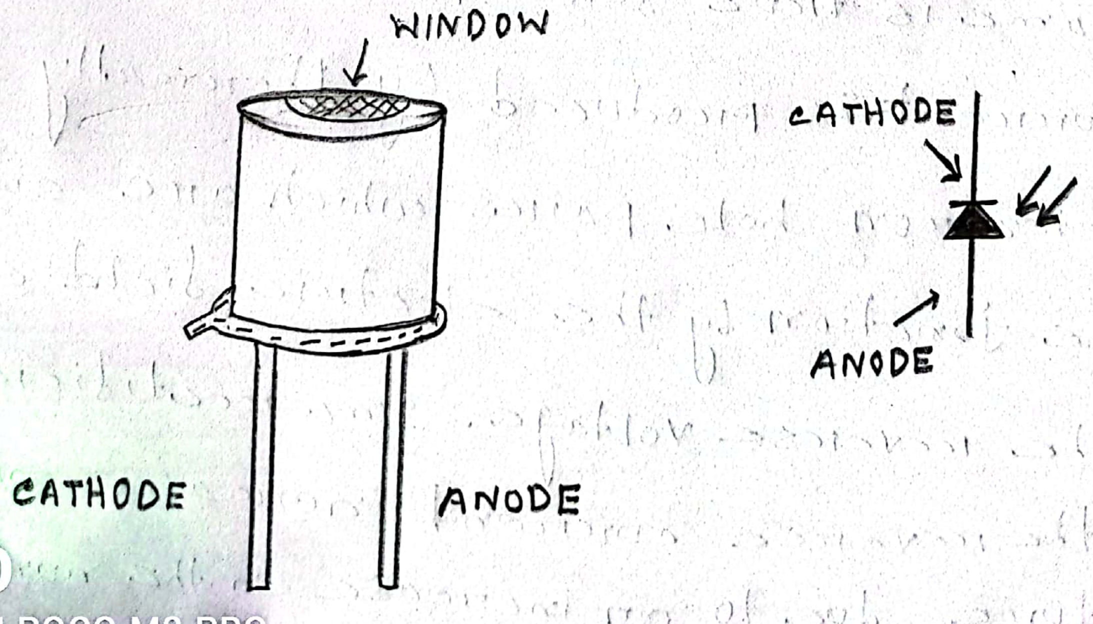
A photo diode is a reverse-biased silicon or germanium pn junction in which reverse current increases when the junction is exposed to light.

The reverse current in a photo-diode is directly proportional to the intensity of light falling on it's pn junction. This means that greater the intensity of light falling on the pn junction of photo-diode the greater will be the reverse current.

Principle:

When a rectifier diode is reverse biased. it has a very small reverse leakage current. The same is true for a photo-diode. The reverse current is produced by thermally generated electron hole pairs which are swept across the junction by the electric field created by the reverse voltage. In a rectifier diode, the reverse current increases with temperature due to an increase in the number of electron-hole pairs. A photo-diode differs from a rectifier diode in that when it's pn junction is exposed to light, the reverse current increases with the increase in light intensity and vice-versa. When light falls on the pn junction, the energy is imparted by the photons to the atoms in the junction. This will create more free-electrons. These additional free electron will increase the reverse current. As the intensity of light incident on the pn junction increases, the resistance of the device decreases.

photo-diode package:



(i)

Fig. (i) shows a typical photo-diode package. It consists of a pn junction mounted on an insulated substrate and sealed inside a metal case. A glass window is mounted on top of the case to allow light to enter and strike the pn junction. The two leads extending from the side of the case.

Photo-diode operation:

Fig. 2 shows the basic photo diode circuit. The circuit has reverse-biased photo-diode resistor R and d.c supply. The operation of the photo diode is as under:

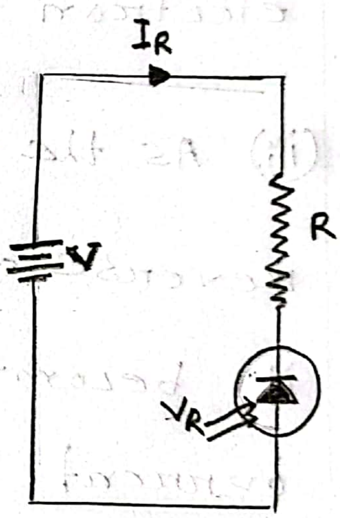


Fig. 2.

(i) When no light is incident on the pn-junction of photo-diode. the reverse current I_R is extremely small. This is called dark current.

The resistance of photo-diode with no incident light is called dark resistance (R_R).

Dark resistance of photo diode,

$$R_R = \frac{V_R}{\text{Dark current}}$$

(ii) When light is incident on the pn junction of the photo-diode, there is a transfer of energy from the incident light (photons) to the atom in the junction. This will create more free electrons. These additional free electron will increase the reverse current.

(iii) As the intensity of light increases, the reverse current I_R goes on increasing till it becomes maximum. This is called saturation current.

Characteristics of photo-diode:

There are two important characteristics of photo diode.

(i) Reverse current - Illumination curve:

Fig. 3 shows the graph between reverse

(I_R) and illumination (E) of a photo-diode. The reverse current is shown on the vertical axis and is measured in μA. The illumination is indicated on the horizontal axis and is measured in mW/cm^2. Note that graph is a straight line passing through the origin.

$$I_R = mE$$

m = slope of the straight line.

The quantity m is called the sensitivity of the photo-diode.

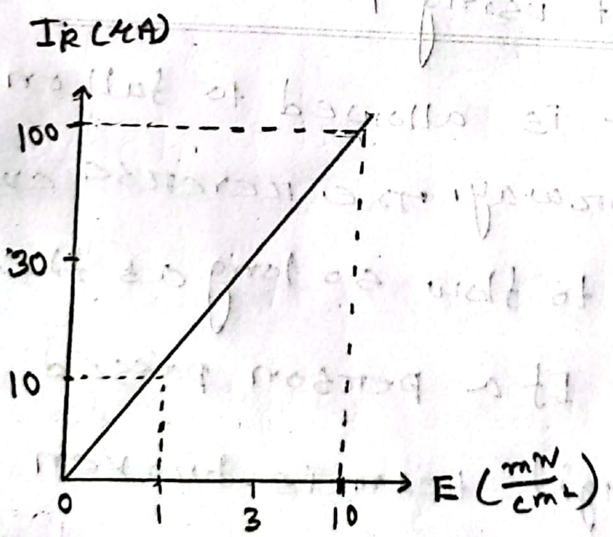


Fig. (3)

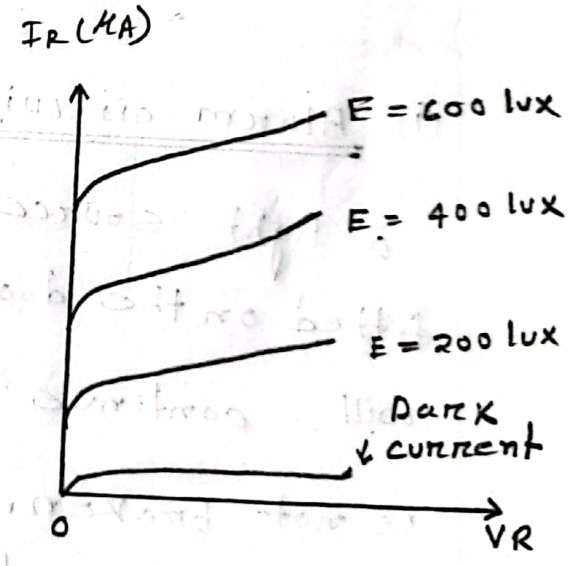


Fig. (4)

(ii) Reverse voltage - Reverse current curve:

Fig. (4) shows the graph between reverse current

(I_R) and Reverse voltage (V_R) for various illumination levels. It is clear that for a given reverse-biased voltage V_R, the reverse current (I_R) increases as the illumination (E) on the p-n junction of photo-diode is increased.

Application of Photo-diodes: There are a large number of application of photo diodes. However, we shall give two applications of photo diode by way of illustration.

(i) **Alarm circuit using photo diode:** Light from a light source is allowed to fall on photo-diode fitted on the doorway. The reverse current I_R will continue to flow so long as the light beam is not broken. If a person passed through the door, the light beam is broken and the reverse current drops to the dark current level. As a result an alarm is sounded.

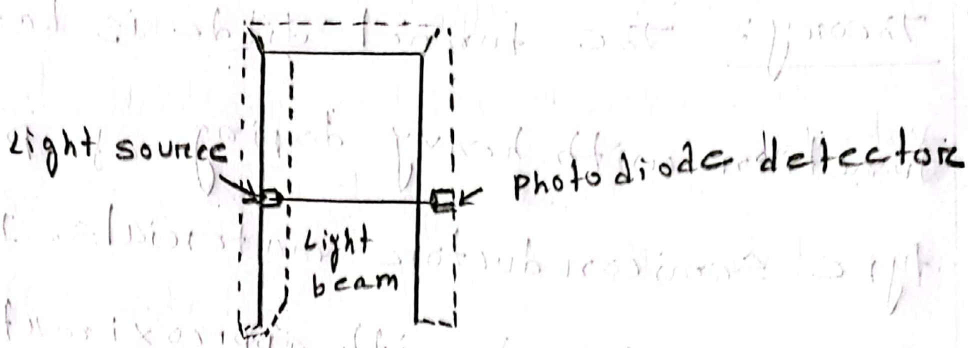


Fig. (5)

(ii) <u>counter circuit using photo-diode</u>: A photo-diode may be used to count items on a conveyor belt. Fig.(6) shows a photo- diode circuit used in a system that counts objects as they pass by on a conveyor. In this circuit, a source of light sends a concentrated beam of light across a conveyor to a photo-diode. As the object passes, the light beam is broken, IR drops to the dark current level and the count is increased by one.

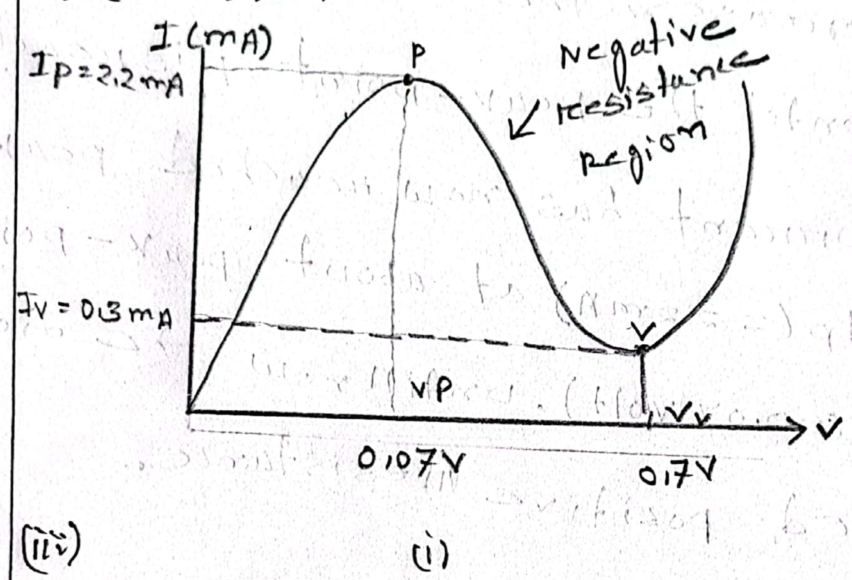
<u>Tunnel diode</u>: A tunnel diode is a pn junction that exhibits negative resistance between to values of forward voltage. (i.e between peak-point voltage and valley-point voltage).

Theory: The tunnel diode is basically a pn junction with heavy doping of p type and n type semiconductor materials. In fact, a tunnel diode is doped with approximately 100 times as heavily as a conventional diode. This heavy doping results in a large number of majority carriers. Because of the large number of carriers. most are not used during the initial recombination that produces the depletion layer. As a result, depletion layer is very narrower. In comparison with conventional diodes, the depletion layer of a tunnel diode is 100 times narrower. The operation of a tunnel diode depends upon the tunneling effect and hence the name.

V-I characteristic: V-I characteristic of a typical tunnel diode is given below:

(i) As the forward voltage across the tunnel diode is increased from zero, electrons from the n region "tunnel" through the potential barrier to the p-region. As the forward voltage increases, the diode current also increases until the peak-point p is reached. The diode current has now reached peak current I_p (= 2.2mA) at about peak-point voltage V_p (= 0.07 volt), until now the diode has exhibited positive resistance.

(ii) As the voltage is increased beyond V_p, the tunneling action starts decreasing and the diode current decreases as the forward voltage is increased, until valley-point v is reached at valley point voltage V_v (= 0.7v). In the region between peak-point and valley point (i.e between points p and v), the diode exhibits negative resistance. i.e as the forward bias is increased the current decreases. This suggests that tunnel diode, when operated in the negative resistance region, can be used as an oscillator or a switch.



When forward bias is increased beyond valley-point voltage V_v (= 0.7V), the tunnel diode behaves as a normal diode. In other words, from point V onwards, the diode current increases with the increase in forward voltage. It may be noted that a tunnel diode has a high reverse current but operation under this condition is not generally used.

Tunnel diode oscillator: A tunnel diode is always operated in the negative resistance again. when operated in the region, it works very well as an oscillator. Fig. 7 shows a parallel resonant circuit. Note that Rp is the parallel equivalent of the series winding resistance of the coil. when the tank circuit is set into oscillations by applying voltage as shown in Fig. 7. It is because energy is lost in the resistance Rp of the tank circuit.

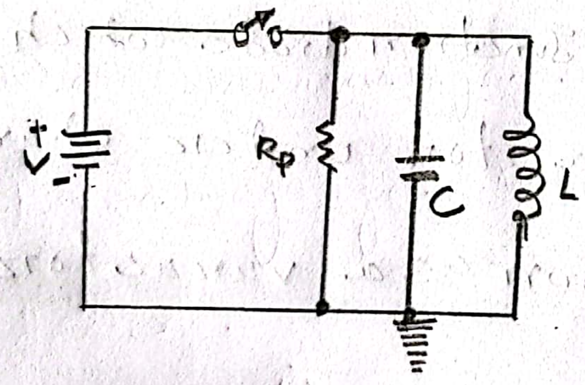


Fig. 7

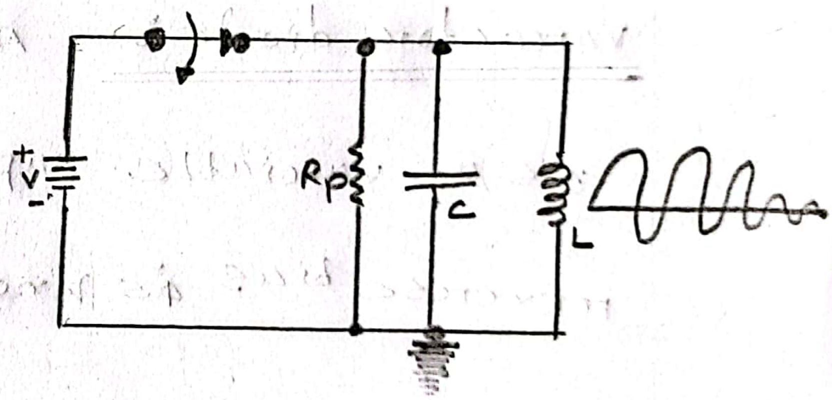
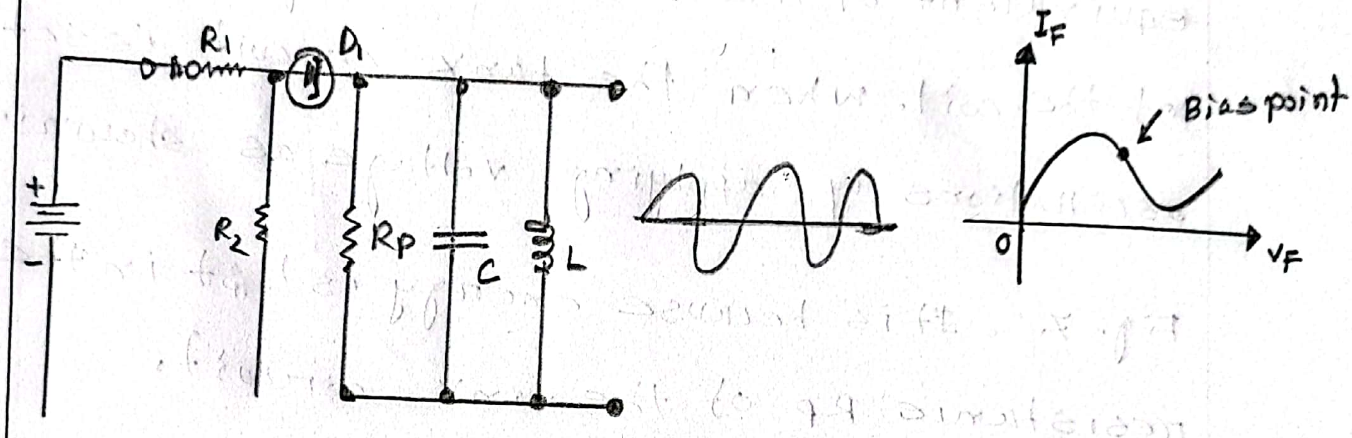


Fig. 8

The circuit shown in Fig. 8 is called tunnel diode oscillator or negative resistance oscillator. negative resistance oscillator has one negative major drawback, while the circuit works very well at extreme high frequencies (upper megahertz range), it cannot be used efficiency at low frequencies. Low frequency oscillators use transistors.



<u>varactor diode:</u> A Junction diode which acts as a variable capacitor under changing reverse bias is known as a varactor diode.

<u>Theory:</u> when for a formal operation, a varactor diode is always reverse biased. The capacitance of varactor diode is found as,

$$C_T = \varepsilon \frac{A}{W_d}$$

Where,

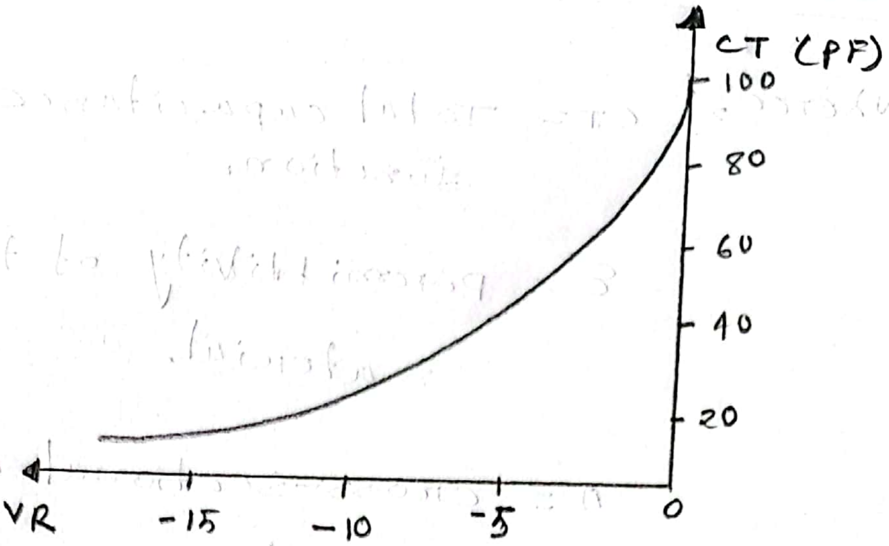
C_T = Total capacitance of the junction.

ε = Permittivity of the semiconductor material.

A = cross-sectional Area of the junction.

W_d = width of the depletion layer.

When reverse voltage across a varactor diode is increased, the width W_d of the depletion layer increases. Therefore the total junction capacitance C_T of the junction decreases. On the other hand, if the reverse voltage across the diode is lowered, the width W_d of the depletion layer decreases, consequently the total junction capacitance C_T increases. C_T can be changed simply by changing the voltage V_R. For this reason varactor diode is sometimes called voltage controlled capacitor.



Application of varactor diode:

we have discussed that we can increase or decrease the junction capacitance of varactor diode simply by changing the reverse bias on the diode. This makes a varactor diode ideal for use in circuits that require voltage-controlled tunning. The capacitance of the varactor is in parallel with the inductor. For normal operation a varactor diode is always operated under reverse bias. The resistance Rw in the circuit is the winding resistance of the Inductor.

The winding resistance is in series with the potentiometre R_1. Thus R_1 and RW from a voltage dividar that is used to determine the amount of reverse bias across the varactor diode D_1 and therefore it's capacitance. By adjusting the setting of R_1, we can vary the diode capacitance, This is turn, varies the resonant frequency of the LC circuit. The resonant frequency fr of the LC circuit is given by,

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

If the amount of varactor bias is decreased, the value of C of the varactor increases. Thus, a decrease in reverse bias causes a decrease in resonent frequency and vice-versa.

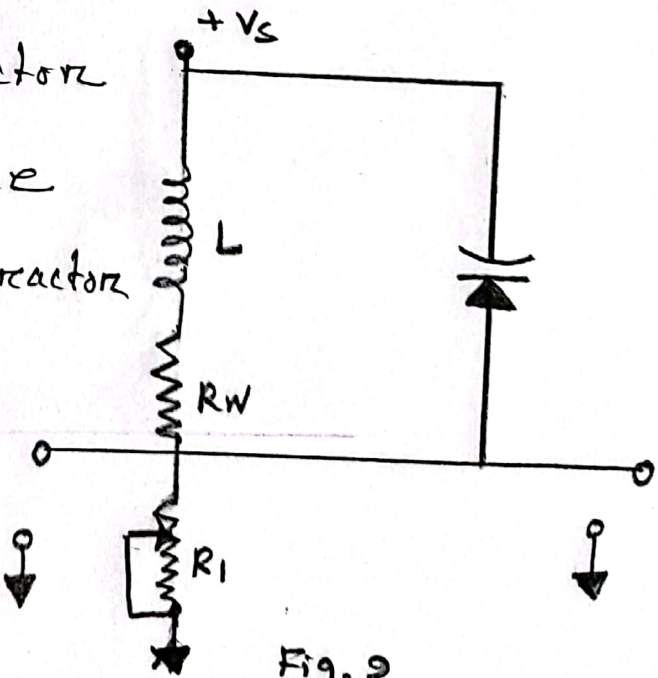


Fig. 9