common positive voltage source of +5 V. This arrangement is known as **common-anode type*. In order to light a particular LED, say *A*, we ground the point *A* in Fig. 7.9 (*ii*). It forward biases the LED *A* which will be lit.

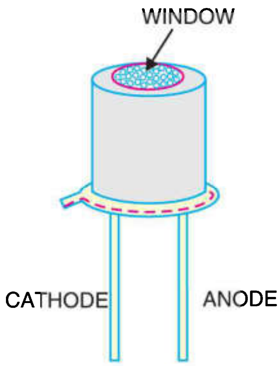
7.7 Photo-diode

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

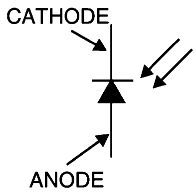
The reverse current in a photo-diode is directly proportional to the intensity of light falling on its *pn* junction. This means that greater the intensity of light falling on the *pn* junction of photo-diode, the greater will be the reverse current.

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 its pn junction is exposed to light, the reverse current increases with the increase in light intensity and vice-versa.* This is explained as follows. When light (photons) falls on the ***pn* junction, the energy is imparted by the photons to the atoms in the junction. This will create more free electrons (and more holes). These additional free electrons will increase the reverse current. As the intensity of light incident on the *pn* junction increases, the reverse current also increases. In other words, as the incident light intensity increases, the resistance of the device (photo-diode) ***decreases.

Photo-diode package. Fig. 7.10 (*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 case are labelled anode and cathode. The cathode is typically identified by a tab extending from the side of the case.



(*i*)



(*ii*)

Fig. 7.10

Fig. 7.10 (*ii*) shows the schematic symbol of a photo-diode. The inward arrows represent the incoming light.

* Also available is the *common-cathode type* where all cathodes are connected together.

** This is true only if the light energy is applied at the junction. If it is applied to the crystal at some distance from the junction, the free electrons and holes will recombine (thus neutralising each other) before they can join the flow of reverse current.

*** It is for this reason that semiconductor devices such as diodes and transistors are usually enclosed in opaque case to protect them from light. Those diodes or transistors which are used for light-detecting, on the other hand, must be encased in transparent plastic or glass so that light may fall on them.

7.8 Photo-diode Operation

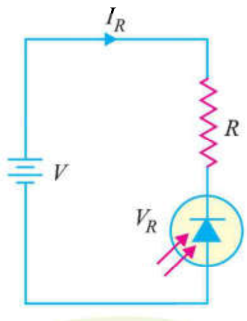


Fig. 7.11

Fig. 7.11 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 :

(*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).

$$\text{Dark resistance of photo-diode, } R_R = \frac{V_R}{\text{Dark current}}$$

(*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 atoms in the junction. This will create more free electrons (and more holes). These additional free electrons 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.**

Calibrated Photo-Diode

7.9 Characteristics of Photo-diode

There are two important characteristics of photo-diode.

(*i*) **Reverse current-Illumination curve.** Fig. 7.12 shows the graph between reverse current (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.

$$\therefore \quad I_R = m\,E$$

where m = slope of the straight line

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

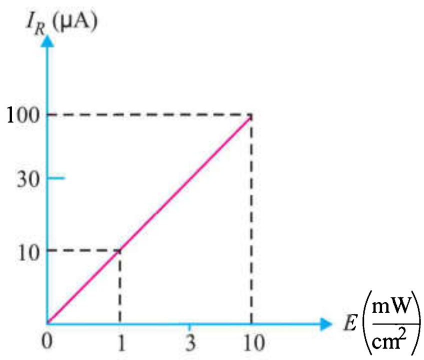


Fig. 7.12

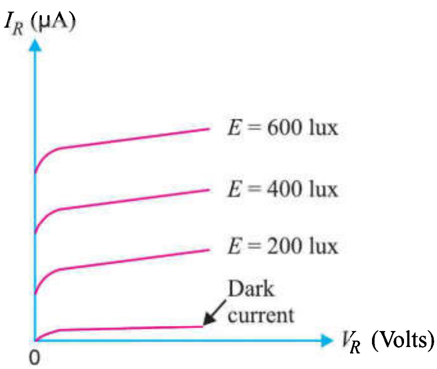


Fig. 7.13

(*ii*) **Reverse voltage-Reverse current curve.** Fig. 7.13 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 *pn* junction of photo-diode is increased.

7.10 Applications of Photo-diodes

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

(*i*) **Alarm circuit using photo-diode.** Fig. 7.14 shows the use of photo-diode in an alarm system. Light from a light source is allowed to fall on a photo-diode fitted in the doorway. The reverse current I_R will continue to flow so 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 current level. As a result, an alarm is sounded.

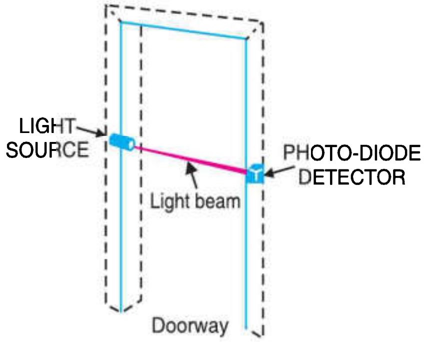


Fig. 7.14

(*ii*) **Counter circuit using photo-diode.** A photo-diode may be used to count items on a conveyor belt. Fig. 7.15 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, I_R drops to the dark current level and the count is increased by one.

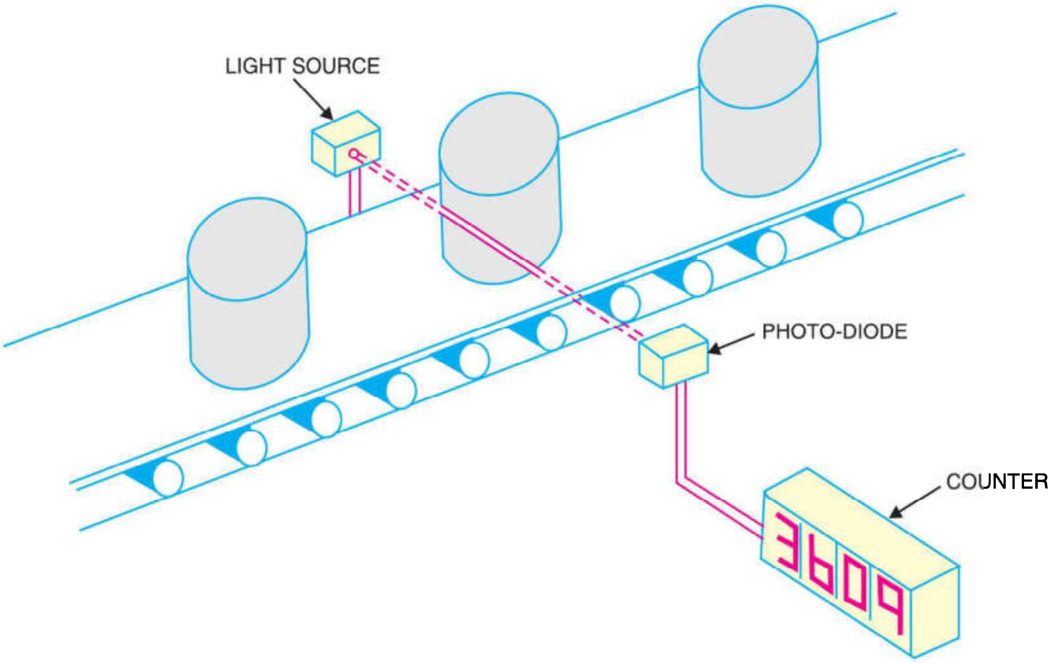


Fig. 7.15

Example 7.3. *From the reverse current-Illumination curve for a photo-diode shown in Fig. 7.16, determine the dark resistance. Assume a reverse-biased voltage of 10 V.*

Invented in 1948 by J. Bardeen and W.H. Brattain of Bell Telephone Laboratories, U.S.A.; transistor has now become the heart of most electronic applications. Though transistor is only slightly more than 58 years old, yet it is fast replacing vacuum tubes in almost all applications. In this chapter, we shall focus our attention on the various aspects of transistors and their increasing applications in the fast developing electronics industry.

8.1 Transistor

A **transistor** *consists of two pn junctions formed by *sandwiching either p-type or n-type semiconductor between a pair of opposite types.* Accordingly ; there are two types of transistors, namely;

(*i*) *n-p-n* transistor (*ii*) *p-n-p* transistor

An *n-p-n* transistor is composed of two *n*-type semiconductors separated by a thin section of *p*-type as shown in Fig. 8.1 (*i*). However, a *p-n-p* transistor is formed by two *p*-sections separated by a thin section of *n*-type as shown in Fig. 8.1 (*ii*).

Fig. 8.1

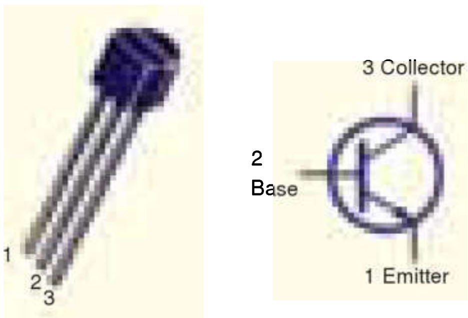
In each type of transistor, the following points may be noted :

(*i*) These are two *pn* junctions. Therefore, a transistor may be regarded as a combination of two diodes connected back to back.

(*ii*) There are three terminals, one taken from each type of semiconductor.

(*iii*) The middle section is a very thin layer. This is the most important factor in the function of a transistor.

Origin of the name "Transistor". When new devices are invented, scientists often try to devise a name that will appropriately describe the device. A transistor has two *pn* junctions. As discussed later, one junction is forward biased and the other is reverse biased. The forward biased junction has a low resistance path whereas a reverse biased junction has a high resistance path. The weak signal is introduced in the low resistance circuit and output is taken from the high resistance circuit. Therefore, a transistor *transfers* a signal from a low resistance to high resistance. The prefix 'trans' means the signal transfer property of the device while 'istor' classifies it as a solid element in the same general family with resistors.



* In practice, these three blocks *p, n, p* are grown out of the same crystal by adding corresponding impurities in turn.

8.2 Naming the Transistor Terminals

A transistor (*pnp* or *npn*) has three sections of doped semiconductors. The section on one side is the *emitter* and the section on the opposite side is the *collector*. The middle section is called the *base* and forms two junctions between the emitter and collector.

(*i*) Emitter. The section on one side that supplies charge carriers (electrons or holes) is called the *emitter*. *The emitter is always forward biased w.r.t. base* so that it can supply a large number of *majority carriers. In Fig. 8.2 (*i*), the emitter (*p*-type) of ***pnp*** transistor is forward biased and supplies hole charges to its junction with the base. Similarly, in Fig. 8.2 (*ii*), the emitter (*n*-type) of ***npn*** transistor has a forward bias and supplies free electrons to its junction with the base.

(*ii*) Collector. The section on the other side that collects the charges is called the *collector*. *The collector is always reverse biased.* Its function is to remove charges from its junction with the base. In Fig. 8.2 (*i*), the collector (*p*-type) of ***pnp*** transistor has a reverse bias and receives hole charges that flow in the output circuit. Similarly, in Fig. 8.2 (*ii*), the collector (*n*-type) of ***npn*** transistor has reverse bias and receives electrons.

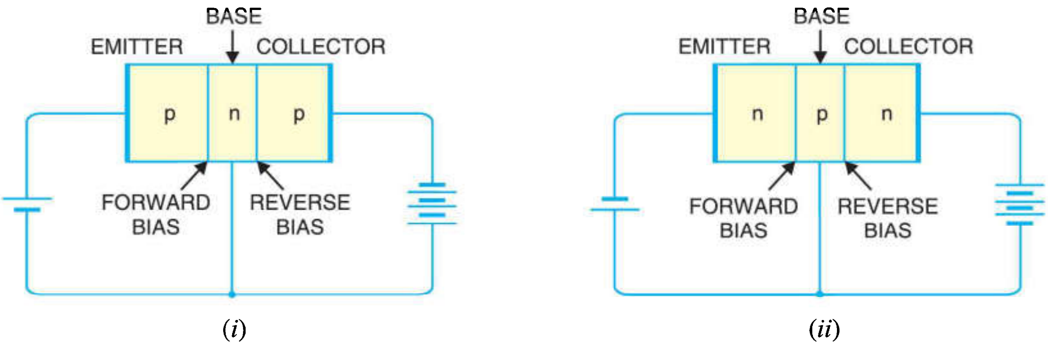


Fig. 8.2

(*iii*) Base. The middle section which forms two *pn*-junctions between the emitter and collector is called the *base*. The base-emitter junction is forward biased, allowing low resistance for the emitter circuit. The base-collector junction is reverse biased and provides high resistance in the collector circuit.

8.3 Some Facts about the Transistor

Before discussing transistor action, it is important that the reader may keep in mind the following facts about the transistor :

(*i*) The transistor has three regions, namely ; *emitter*, *base* and *collector*. The base is much thinner than the emitter while **collector is wider than both as shown in Fig. 8.3. However, for the sake of convenience, it is customary to show emitter and collector to be of equal size.

(*ii*) The emitter is heavily doped so that it can inject a large number of charge carriers (electrons or holes) into the base. The base is lightly doped and very thin ; it passes most of the emitter injected charge carriers to the collector. The collector is moderately doped.

* Holes if emitter is *p*-type and electrons if the emitter is *n*-type.

** During transistor operation, much heat is produced at the collector junction. The collector is made larger to dissipate the heat.

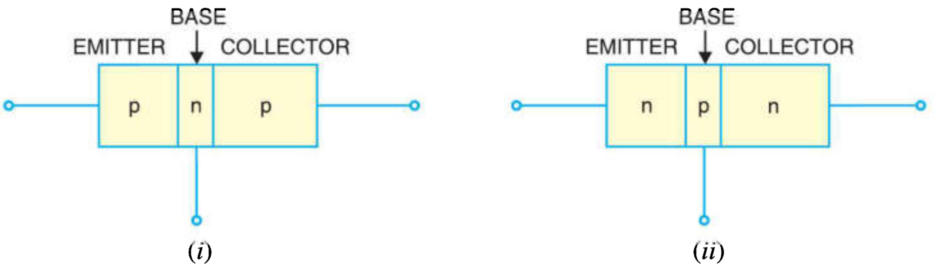


Fig. 8.3

(iii) The transistor has two *pn* junctions *i.e.* it is like two diodes. The junction between emitter and base may be called *emitter-base diode* or simply the *emitter diode*. The junction between the base and collector may be called *collector-base diode* or simply *collector diode*.

(iv) The emitter diode is always forward biased whereas collector diode is always reverse biased.

(v) The resistance of emitter diode (forward biased) is very small as compared to collector diode (reverse biased). Therefore, forward bias applied to the emitter diode is generally very small whereas reverse bias on the collector diode is much higher.

8.4 Transistor Action

The emitter-base junction of a transistor is forward biased whereas collector-base junction is reverse biased. If for a moment, we ignore the presence of emitter-base junction, then *practically** no current would flow in the collector circuit because of the reverse bias. However, if the emitter-base junction is also present, then forward bias on it causes the emitter current to flow. It is seen that this emitter current almost entirely flows in the collector circuit. Therefore, the current in the collector circuit depends upon the emitter current. If the emitter current is zero, then collector current is nearly zero. However, if the emitter current is 1mA, then collector current is also about 1mA. This is precisely what happens in a transistor. We shall now discuss this transistor action for *npn* and *pnp* transistors.

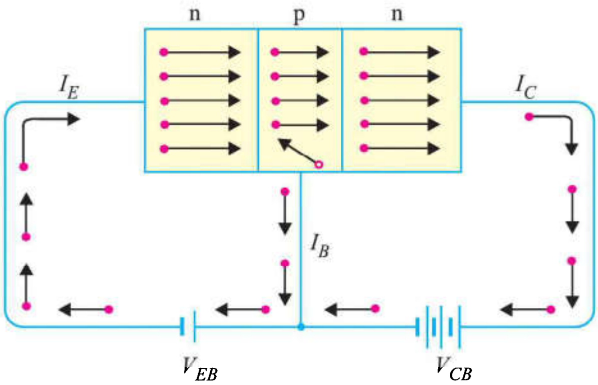
(i)* Working of npn transistor.** Fig. 8.4 shows the *npn* transistor with forward bias to emitter-base junction and reverse bias to collector-base junction. The forward bias causes the electrons in the *n*-type emitter to flow towards the base. This constitutes the emitter current I_E. As these electrons flow through the *p*-type base, they tend to combine with holes. As the base is lightly doped and very thin, therefore, only a few electrons (less than 5%) combine with holes to constitute base** current I_B. The remainder (more than 95%) cross over into the collector region to constitute collector current I_C. In this way, almost the entire emitter current flows in the collector circuit. It is clear that emitter current is the sum of collector and base currents *i.e.*

$$I_E = I_B + I_C$$

* In actual practice, a very little current (a few μA) would flow in the collector circuit. This is called collector cut off current and is due to minority carriers.

** The electrons which combine with holes become valence electrons. Then as valence electrons, they flow down through holes and into the external base lead. This constitutes base current I_B.

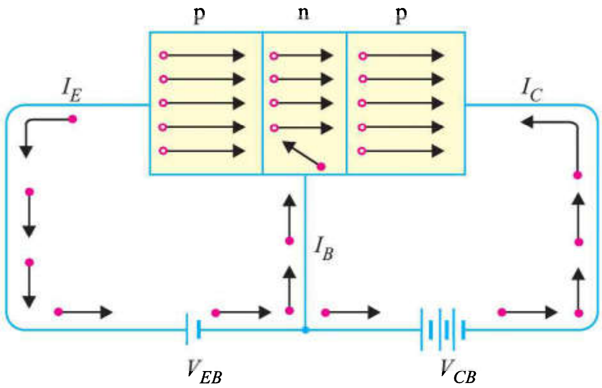
*** The reasons that most of the electrons from emitter continue their journey through the base to collector to form collector current are : (*i*) The base is lightly doped and very thin. Therefore, there are a few holes which find enough time to combine with electrons. (*ii*) The reverse bias on collector is quite high and exerts attractive forces on these electrons.



Basic connection of *npn* transistor

Fig. 8.4

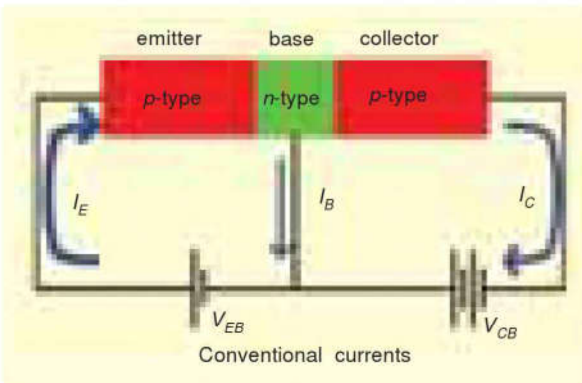
(*ii*) **Working of pnp transistor.** Fig. 8.5 shows the basic connection of a *pnp* transistor. The forward bias causes the holes in the *p*-type emitter to flow towards the base. This constitutes the emitter current I_E. As these holes cross into *n*-type base, they tend to combine with the electrons. As the base is lightly doped and very thin, therefore, only a few holes (less than 5%) combine with the



Basic connection of *pnp* transistor

Fig. 8.5

electrons. The remainder (more than 95%) cross into the collector region to constitute collector current I_C. In this way, almost the entire emitter current flows in the collector circuit. It may be noted that current conduction within *pnp* transistor is by holes. However, in the external connecting wires, the current is still by electrons.

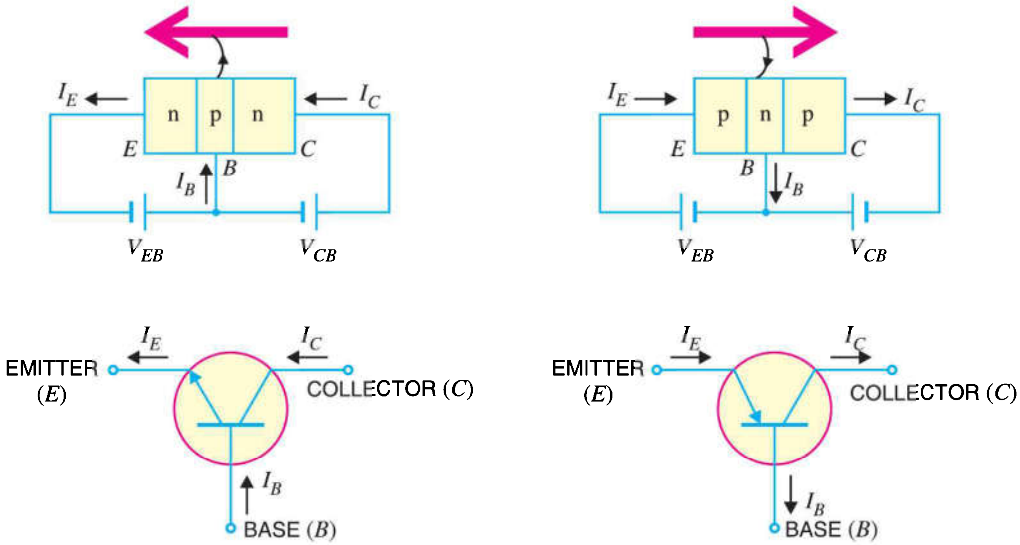


Importance of transistor action. The input circuit (*i.e.* emitter-base junction) has low resistance because of forward bias whereas output circuit (*i.e.* collector-base junction) has high resistance due to reverse bias. As we have seen, the input emitter current almost entirely flows in the collector circuit. Therefore, a transistor transfers the input signal current from a low-resistance circuit to a high-resistance circuit. This is the key factor responsible for the amplifying capability of the transistor. We shall discuss the amplifying property of transistor later in this chapter.

Note. There are two basic transistor types : the **bipolar junction transistor** (*BJT*) and **field-effect transistor** (*FET*). As we shall see, these two transistor types differ in both their operating characteristics and their internal construction. **Note that when we use the term transistor, it means bipolar junction transistor (*BJT*).** The term comes from the fact that in a bipolar transistor, there are *two* types of charge carriers (*viz*. electrons and holes) that play part in conductions. Note that bi means two and polar refers to polarities. The field-effect transistor is simply referred to as *FET*.

8.5 Transistor Symbols

In the earlier diagrams, the transistors have been shown in diagrammatic form. However, for the sake of convenience, the transistors are represented by schematic diagrams. The symbols used for *npn* and *pnp* transistors are shown in Fig. 8.6.



(*i*) (*ii*)

Fig. 8.6

Note that emitter is shown by an arrow which indicates the direction of conventional current flow with forward bias. For *npn* connection, it is clear that conventional current flows out of the emitter as indicated by the outgoing arrow in Fig. 8.6 (*i*). Similarly, for *pnp* connection, the conventional current flows into the emitter as indicated by inward arrow in Fig. 8.6 (*ii*).

8.6 Transistor Circuit as an Amplifier

A transistor raises the strength of a weak signal and thus acts as an amplifier. Fig. 8.7 shows the basic circuit of a transistor amplifier. The weak signal is applied between emitter-base junction and output is taken across the load R_C connected in the collector circuit. In order to achieve faithful amplification, the input circuit should always remain forward biased. To do so, a d.c. voltage V_{EE} is applied in the input circuit in addition to the signal as

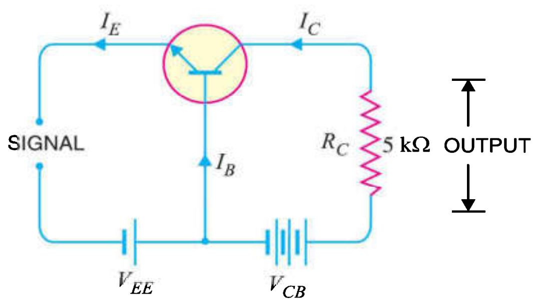


Fig. 8.7

shown. This d.c. voltage is known as bias voltage and its magnitude is such that it always keeps the input circuit forward biased regardless of the polarity of the signal.

As the input circuit has low resistance, therefore, a small change in signal voltage causes an appreciable change in emitter current. This causes almost the *same change in collector current due to transistor action. The collector current flowing through a high load resistance R_C produces a large voltage across it. Thus, a weak signal applied in the input circuit appears in the amplified form in the collector circuit. It is in this way that a transistor acts as an amplifier.

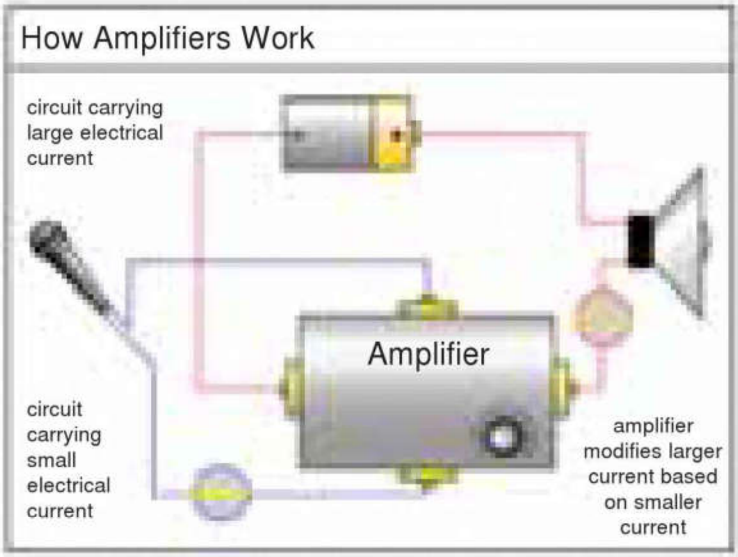


Illustration. The action of a transistor as an amplifier can be made more illustrative if we consider typical circuit values. Suppose collector load resistance R_C = 5 kΩ. Let us further assume that a change of 0.1V in signal voltage produces a change of 1 mA in emitter current. Obviously, the change in collector current would also be approximately 1 mA. This collector current flowing through collector load R_C would produce a voltage = 5 kΩ × 1 mA = 5 V. Thus, a change of 0.1 V in the signal has caused a change of 5 V in the output circuit. In other words, the transistor has been able to raise the voltage level of the signal from 0.1 V to 5 V *i.e.* voltage amplification is 50.

Example 8.1. *A common base transistor amplifier has an input resistance of 20 Ω and output resistance of 100 kΩ. The collector load is 1 kΩ. If a signal of 500 mV is applied between emitter and base, find the voltage amplification. Assume* α_{ac} *to be nearly one.*

Solution. **Fig. 8.8 shows the conditions of the problem. Note that output resistance is very high as compared to input resistance. This is not surprising because input junction (base to emitter) of the transistor is forward biased while the output junction (base to collector) is reverse biased.

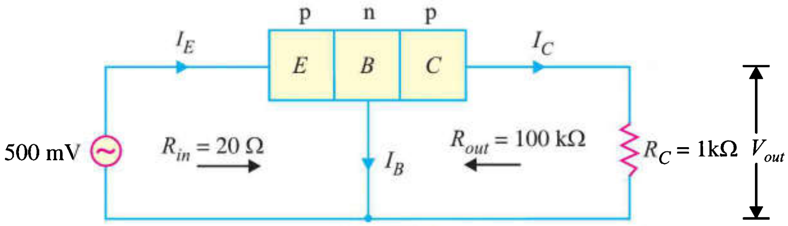


Fig. 8.8

* The reason is as follows. The collector-base junction is reverse biased and has a very high resistance of the order of mega ohms. Thus collector-base voltage has little effect on the collector current. This means that a large resistance R_C can be inserted in series with collector without disturbing the collector current relation to the emitter current *viz.* $I_C = \alpha I_E + I_{CBO}$. Therefore, collector current variations caused by a small base-emitter voltage fluctuations result in voltage changes in R_C that are quite high—often hundreds of times larger than the emitter-base voltage.

** The d.c. biasing is omitted in the figure because our interest is limited to amplification.

The liquid crystal display (LCDs) commonly used on notebook computers and handheld PDAs are also appearing on desktop. These flat panel displays promise great clarity at increasingly high resolutions and are available in screen sizes upto 15 inches. The LCD monitor offers benefits and drawbacks. The first benefit is size. Because of the need to house the tube itself, cathode-ray tube (CRT) monitors are big and heavy. LCD monitors are only a few inches deep and they are much lighter in weight. However LCD monitors are expensive than CRTs at present. Another problem is the viewing angle. The optimal viewing angle of an LCD is from straight in front and as you move further to the side the screen becomes harder to read, much more so than with a CRT. Moreover screen resolutions generally reach only as high as 1,024 × 768, which is insufficient for some applications. Fig. 53.7(*c*) shows the picture of an LCD used in portable instrument.

53.5. P-N Junction Photodiode

It is a two-terminal junction device which is operated by first reverse-biasing the junction and then illuminating it. A reverse-biased *P-N* junction has a small amount of reverse saturation current I_s (or I_0) due to thermally-generated electron-hole pairs. In silicon, I_s is the range of nanoamperes. The number of these minority carriers depends on the intensity of light incident on the junction. When the diode is in glass package, light can reach the junction and thus change the reverse current.

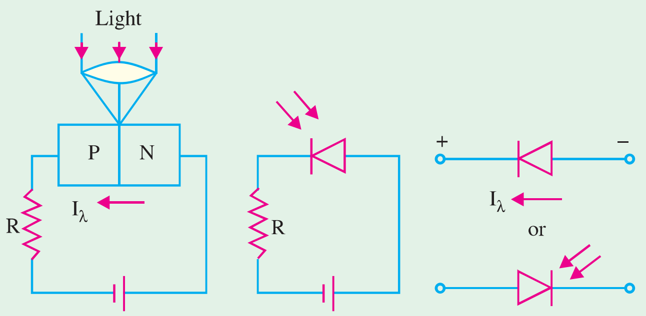
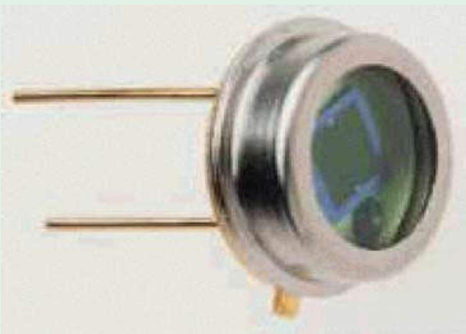


Fig. 53.8


Photodiode

The basic biasing arrangement, construction and symbols of a photodiode are shown in Fig. 53.8. As seen, a lens has been used in the cap of the unit to focus maximum light on the reverse-biased junction. The active diameter of these devices is about 2.5 mm but they are mounted in standard TO-5 packages with a window to allow maximum incident light.

The characteristics of Fig. 53.9 show that for a given reverse voltage, I_λ (or I_s) increases with increase in the level of illumination. The dark current refers to the current that flows when no light is incident. By changing the illumination level, reverse current can be changed. In this way, reverse resistance of the diode can be changed by a factor of nearly 20.

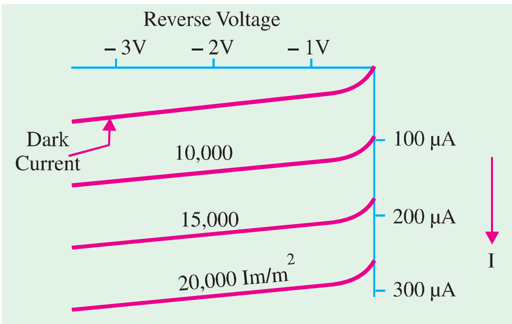


Fig. 53.9

A photodiode can turn its current ON and OFF in nanoseconds. Hence, it is one of the fastest photodetectors. It is used where it is required to switch light ON and OFF at a maximum rate. Applications of a photodiode include

1. detection, both visible and invisible ;
2. demodulation ;
3. switching ;
4. logic circuit that require stability and high speed ;
5. character recognition ;
6. optical communication equipment ;
7. encoders etc.

53.6. Dust Sensor

Fig. 53.10 shows a combination of an LED and a photodiode used as a dust sensor. As seen, the light emitted from the LED gets reflected by the dust particles. The reflected light is collected by the photodiode and is converted into an electrical signal. The dust sensor is employed in cleaners.

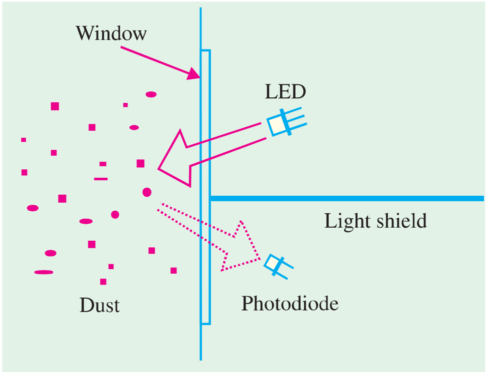
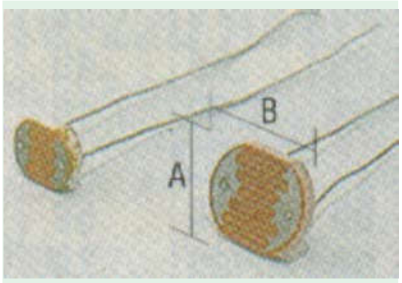


Fig. 53.10

The combination of an LED and a photodiode is also used as : **(1)** a paper sensor in facsimile machines, **(2)** as a tape-end sensor in videotape recorders/players, and **(3)** as a dirt detector for rinsing in washing machines.



CdS photo sensitive detectors

53.7. Photoconductive Cell

It is a semiconductor device whose resistance varies inversely with the intensity of light that falls upon it. It is also known as ***photoresistive*** cell or ***photoresistor*** because it operates on the principle of photoresistivity.

(*a*) Theory

The resistivity (and, hence, resistance) of a semiconductor depends on the number of free charge carriers available in it. When the semiconductor is not illuminated, the number of charge carriers is small and, hence, resistivity is high. But when light in the form of photons strikes the semiconductor, each photon delivers energy to it. If the photon energy is greater than the energy band gap of the semiconductor, free mobile charge carriers are liberated and, as a result, resistivity of the semiconductor is decreased.

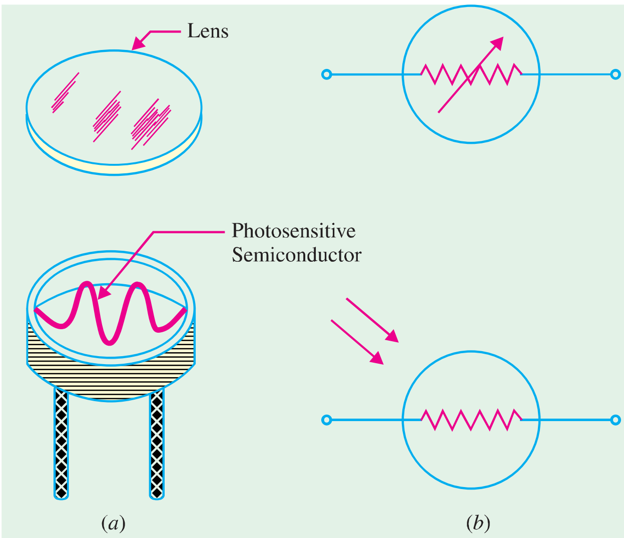


Fig. 53.11

(*b*) Construction and Working

Photoconductive cells are generally made of cadmium compounds such as cadmium sulphide (CdS) and cadmium selenide (CdSe). Spectral response of CdS cell is similar to the human eye, hence such cells are often used to simulate the human eye. That is why they find required from the solar cells = 6 Ah/12 h = 0.5 A.

Total number of groups of solar cells required to be connected in parallel is

= output current / cell current = $0.5 / 50 \times 10^3 = 10$

∴ total number of solar cells required for the earth satellite = $27 \times 10 =$ **270**

53.11. Laser Diode

Like LEDs, laser diodes are typical *PN* junction devices used under a forward-bias. The word LASER is an acronym for ***Light Amplification*** by ***Stimulated Emission of Radiation.*** The use of laser is (becoming increasing common) in medical equipment used in surgery and in consumer products like compact disk (CD) players, laser printers, hologram scanners etc.

(*a*) Construction

Broadly speaking, the laser diode structure can be divided into two categories :

1. ***Surface-emitting laser diodes :*** These laser diodes emit light in a direction **perpendicular** to the PN junction plane.

2. ***Edge-emitting laser diodes :*** These laser diodes emit light in a direction **parallel** to the *PN* junction plane.

Fig. 53.21 (*a*) shows the structure of an edge-emitting laser diode. This type of structure is called Fabry-Perot type laser. As seen from the figure, a *P-N* junction is formed by two layers of doped gallium arsenide (GaAs). The length of the *PN* junction bears a precise relationship with the wavelength of the light to be emitted. As seen, there is a highly reflective surface at one end of the junction and a partially reflective surface at the other end. External leads provide the anode and cathode connections.

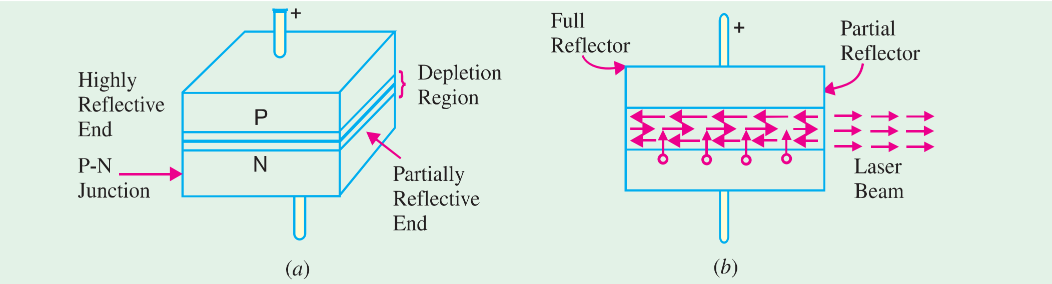


Fig. 53.21

(*b*) Theory

When the *P-N* junction is forward-biased by an external voltage source, electrons move across the junction and usual recombination occurs in the depletion region which results in the production of photons. As forward current is increased, more photons are produced which drift at random in the depletion region. Some of these photons strike the reflective surface perpendicularly. These reflected photons enter the depletion region, strike other atoms and release more photons. All these photons move back and forth between the two reflective surfaces. [Fig. 53.21 (*b*)] The photon activity becomes so intense that at some point, a strong beam of laser light comes out of the partially reflective surface of the diode.

Laser diode

(*c*) Unique Characteristics of Laser Light

The beam of laser light produced by the diode has the following unique characteristics :

1. It is coherent *i.e.* there is no path difference between the waves comprising the beam;

2. It is monochromatic *i.e.* it consists of one wavelength and hence one colour only;

3. It is collimated *i.e.* emitted light waves travel parallel to each other.

Laser diodes have a threshold level of current above which the laser action occurs but below which the laser diode behaves like a LED emitting incoherent light. The schematic symbol of a laser diode is similar to that of LED. Incidentally, a filter or lens is necessary to view the laser beam.

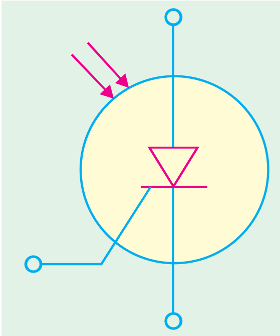


Fig. 53.22

(*d*) Applications

Laser diodes are used in variety of applications ranging from medical equipment used in surgery to consumer products like optical disk equipment, laser printers, hologram scanners etc. Laser diodes emitting visible light are used as pointers. Those emitting visible and infrared light are used to measure range (or distance). The laser diodes are also widely used in parallel processing of information and in parallel interconnections between computers. Some of these applications are discussed in the following articles.

53.12. Optical Disks

The major application field for laser diodes is in optical disk equipment. This equipment is used for reading or recording information and can be broadly divided into two groups :

1. Reading-only and **2.** Recording-and-reading type.

The optical disk equipment of either type make use of a laser diode, lenses and photodiodes. During recording, it changes electrical information into optical information and then records the information on the optical disk. During reading (or playback), the head optically reads the recorded information and changes the optical information into electrical information. Fig. 53.22 shows the different types of optical disks used in practice. The commercial systems make use of disks that are 90, 120, 130 and 300 mm in diameter. A mini disk, 64 mm in diameter is also used for digital audio.

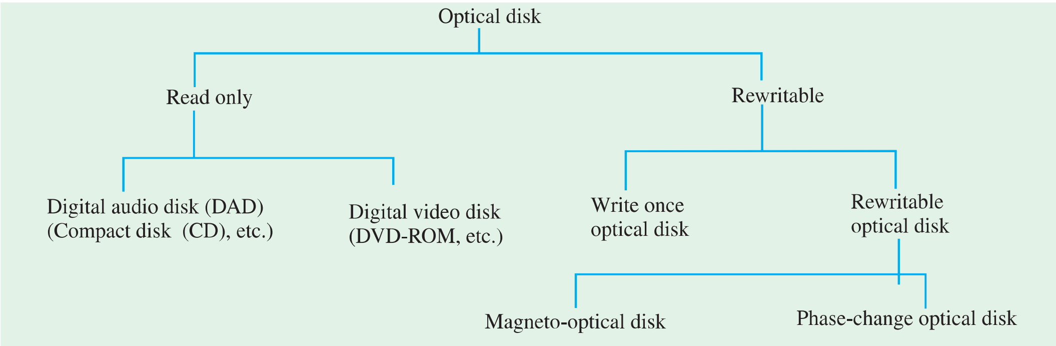


Fig. 53.23

The optical disks have several advantages over semiconductor memories. Some of these include their larger data storage capacity, shorter access time and smaller size. Therefore they are used in terminal equipment of computers as well as in audio visual equipment.

53.13. Read-only Optical Disks Equipment

Fig. 53.24 shows an optical equipment for reading data from digital audio (compact) disks. Compact disks (CDs) which are 120 mm in diameter are typical digital audio disks. Compact disks usually means digital audio compact disk, but it also includes the read-only memory (CD-ROM) for data memory and interactive compact disk (CD-I) for multimedia use.