CHAPTER

17 ELECTRONICS

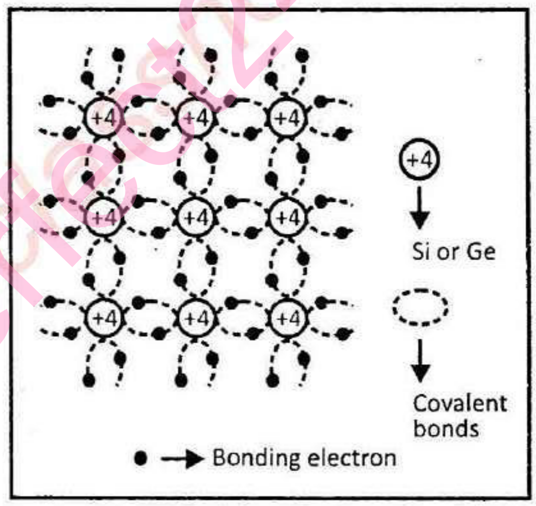
Q1: Write a note on intrinsic semi conductor. (ETEA 2012)

Answer: Intrinsic Semiconductor:

Definition: "A perfect, pure semiconductor crystal which contains no impurities is known as intrinsic semiconductor."

Explanation:

Consider a silicon crystal at absolute zero temperature. The bonding arrangement is represented by two dimensional model as shown in the figure.



The hatched circles represent the core of the silicon atom. The four valence electrons are shown by the small black dots. The probability of valence electrons between the bonding atoms is indicated by the dotted curves. At the temperature of a Kelvin, all the valence electrons are strongly bound to their atoms and they spend most of the time between neighbouring atoms. The valence electrons are engaged in covalent bonds. Thus there are no free electrons in semiconductors at OK. and they behave like an insulator.

Intrinsic Semiconductor and Room Temperature:

If the temperature of intrinsic semiconductor is allowed to increase, then each atom in the crystal begins to vibrate violently due to finite thermal energy. At this stage, the electrons absorb sufficient energy and break the covalent bonds.

The electrons thus become free and they vibrate randomly in the empty spaces inside the atoms. During this process, some part of thermal energy of electrons is converted into potential energy. At this stage, the electrons having P.E equal to or greater than band gap energy "E_g" are able to jump from valence band to the conduction band.

> The band gap energy "E_g" is the minimum amount of energy required to excite an electron from valence band to conduction band.

The number of electrons excited to the conduction band depends on the amount of thermal energy received by the crystal.

When the electron jumps from valence band to the conduction band, a vacancy is produced. This vacancy is called hole and is positively charged. The electron and hole are created as a pair and the phenomenon is called "electron-hole pair generation".

When an electric field is applied to an intrinsic semiconductor at room temperature or above, then the electrons in conduction band and holes in valence band causes current through the material. If "I_e" represents the current due to flow of electrons and "I_h" represents the current due to motion of holes, then the total current through the material is given by,

$$\boxed{I = I_e + I_h}$$

Q2: What is meant by "doping"? Explain.

Answer: **Doping:**

Definition: "An addition of impurity into an intrinsic semiconductor for increasing its conductivity is known as doping."

Explanation:

We know that an intrinsic semiconductor posses low conductivity. We can increase their conductivity by adding small amount of impurity to them. The impurity which we add is called dopant. The doped semiconductor is called extrinsic semiconductor.

Q3: What is meant by extrinsic semiconductor? Explain N-type and P-type materials in detail.

Answer: **Extrinsic Semi Conductor:**

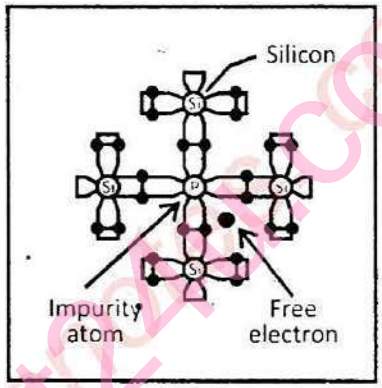
"A doped semiconductor is known as extrinsic semiconductor."

There are two types of extrinsic semiconductor which are given below:

1. N-Type Materials: (ETEA 2015)

Definition: "Those materials in which the electrons act as majority carriers are known as N-type materials."

Explanation:



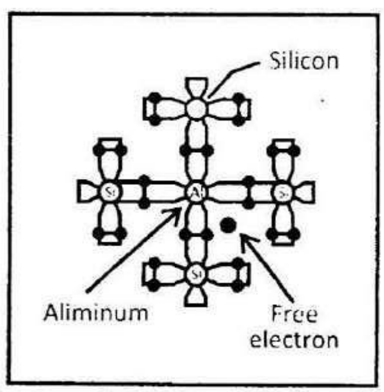
When a silicon crystal is doped with a pentavalent element like phosphorus, then the four electrons of phosphorus "P" forms covalent bonds with the four electrons of silicon "Si" atoms. While the fifth valence electron of phosphorus remains free in the crystal. In this case, the phosphorus is called donor atom, because it provides the electrons for bond formation, while the silicon atom is called accepter atom, because it accepts the electrons for bond formation. In this case, the electrons are in majority, so they are called majority carriers and the material is called N-type extrinsic semiconductor.

2. P-Type Materials: (ETEA 2015)

Definition: "These are those materials in which the electrons act as minority carriers and holes acts as majority carriers are known as P-type materials."

Explanation:

When a trivalent element like aluminum is doped with silicon, then the three valence electrons of aluminum form covalent bond with the three electrons of silicon atom.



There is deficiency of one electron in aluminum atom to form covalent bond with the fourth electron of silicon. Such deficiency or vacancy is known as hole. The hole acts as positive charge carriers.

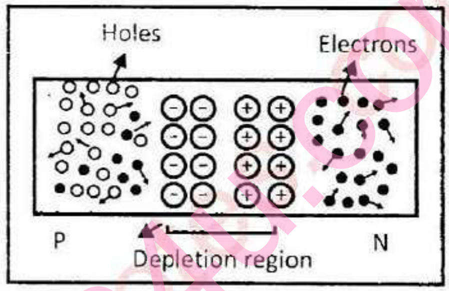
In case of P-type materials, the holes act as majority charge carriers while the electrons act as minority charge carriers.

Q4: What is P-N junction? Describe its characteristics.

Answer: **P-N Junction: (ETEA 2010-11)**

"The junction which separates P-type materials from N-type material is known as P-N junction."

Explanation:

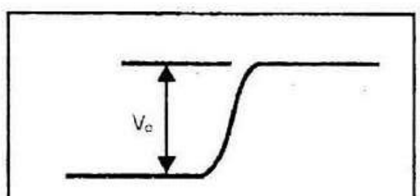


The combination of P-type and N-type material form P-N junction diode.—In P-type region, the holes are in majority, while in N-type region, the free electrons are in majority.

When the junction is produced, then the free electrons near the junction moves across the junction in P-region. While the holes near the junction moves across the junction into N-region. In this way, a layer of positive charges occurs in N-region near the junction and a layer of negative charges occur in P-region near the junction, as shown in the figure.

After the production of layers of positive and negative charges, the transfer of charges across the junction becomes stop. It is because the positive layer present in N-region opposes the movement of holes from P-region to N-region.

Similarly, the negative layer present in P-region opposes the movement of electron from N-region to P-region. The layers of positive and negative charges on both sides of the junction are collectively known as depletion region. Due to such layers on both sides of the junction, a potential difference is developed across the depletion region.



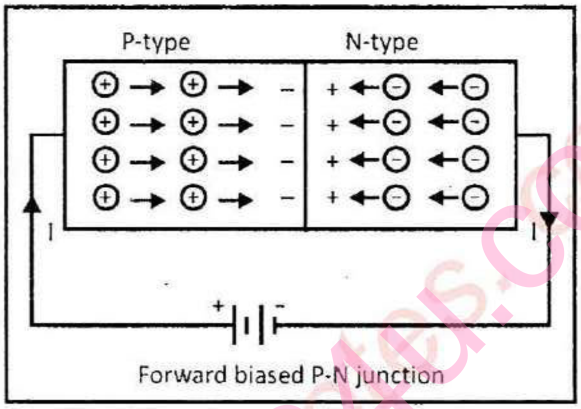
P-N junction potential barrier

Then width of depletion region [layer] depends upon carrier concentration. Thus a potential barrier or wall is formed at the junction.

Characteristics of P-N Junction:

1. Forward Biased P-N Junction:

In case of forward biased, the P-type is connected to positive terminal and N-type is connected to the negative terminal of D.C power supply, as shown in the figure. Under such conditions, the potential drop is increased slowly and as a result the height of barriers decreases. The electrons moves across the junction from N-type to P-type region and the holes moves from P-type region to N-type region, as shown in the figure. The diode offers very little resistance and thus large current is flowing through the circuit.

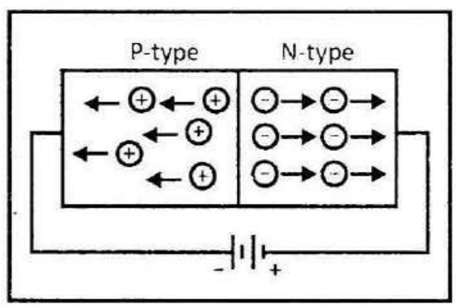


Forward biased P-N junction

2. Reverse Biased P-N Junction:

In case of reverse biased P-N junction, the P-type is connected to the negative terminal and the N-type is connected to the positive terminal of D.C power supply.

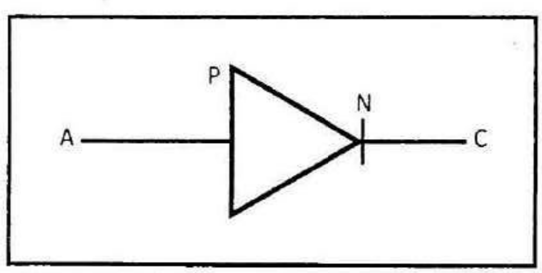
The electrons and holes moves away from the junction towards the terminals due to opposite polarity. The height of barrier increases and the diode offers greater resistance. As a result very small amount of current [few micro ampere] will pass through the junction.



Symbol of P-N Junction Diode:

A P-N junction diode is also called semiconductor diode.

The given figure, represent a semiconductor diode symbolically. The arrow represents the P-region and is known as anode.

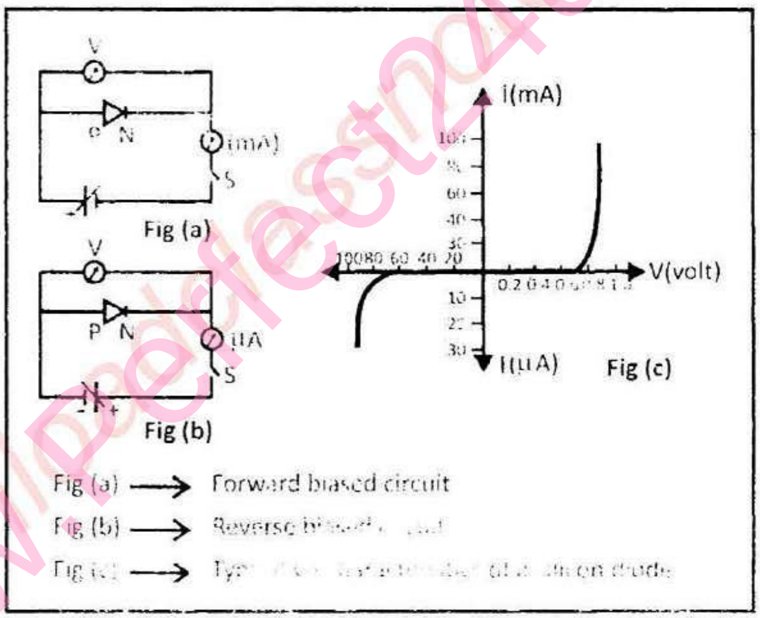


The vertical line represents the N-region and is known as cathode. The current flows in the direction of the arrow head when the diode is forward biased.

Q5: Discuss the V-I characteristics of PN junction.

Answer:

The V-I characteristics of P-N junction are shown in the figure. The knee voltage for germanium is 0.3 volts and for silicon is 0.7 volts. The curve shows that the forward biased current increases rapidly beyond the knee voltage. The values of the current for different positive values of biased voltage are noted. Then the polarity of battery connection in the circuit is changed and the value of the current for different negative values of biased voltage is also noted. If we plot a graph for different values of "V" and "I", we get a curve as shown in figure (c). Such curve represents the V-I characteristics of P-N junction.



When the reverse biased voltage is allowed to increased from "0", the reverse current rises quickly to its saturation value "I_o". As the reverse voltage is increased further, the velocity of minority charge carriers becomes maximum and knock down the bound electrons from covalent bonds. As a result the current increases. This is called as avalanche effect. If the reverse voltage is further increased, the junction breaks down and reverse current rises sharply. Such high current will damage the junction. To avoid such situation, the reverse voltage must not reach the break down voltage.

Q6: What is meant by rectification? Explain the action of semi-conductor diode as: (a) Half wave rectifier (b) Full wave rectifier

Answer: Rectification: (ETEA 2012, 2014)

Definition: "The conversion of AC into DC is called rectification. While the device used for rectification is known as rectifier."

Explanation:

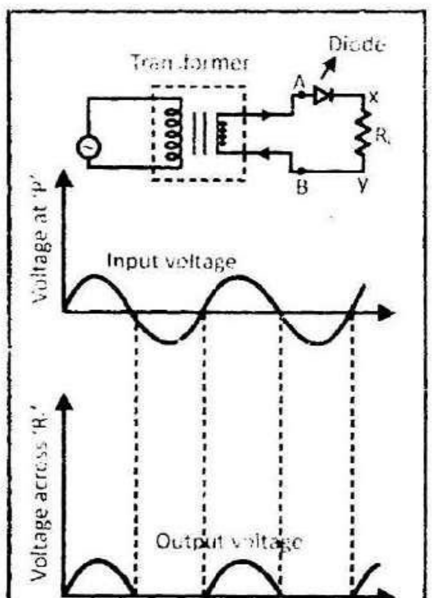
We know that the alternating current is efficient and safe than DC, so AC is mostly used for providing electrical power. But some electronic devices like electronically tuned radio and TV receivers require DC for their operation. For such process we cannot use cells, batteries etc, because they are expensive, low power and short-lived. Therefore, we generate a DC supply from AC supply for operation such devices for longer period of time.

For the conversion of AC into DC, we mostly used diodes, because they provide compact and inexpensive means of rectification. In case of forward bias, the diode allows larger amount of current and in case of reverse bias, the diode almost stops the current. Thus the diodes can be used as unidirectional device i.e. rectifiers for converting AC into DC.

(a) Half Wave Rectifier:

In case of half wave rectification, the current flows only during alternate half cycle. In case of half wave rectifier, the positive part of AC is allowed to pass through the diode and the negative part of AC is prevented from passing.

In given figure, an AC is allowed to pass through the diode circuit. During positive half cycle of AC, the P-type of diode is positive and N-type is negative. The diode is in state of forward bias and thus the positive part of AC can pass through the diode easily.



Negative part of each A.C voltage is prevented from passing

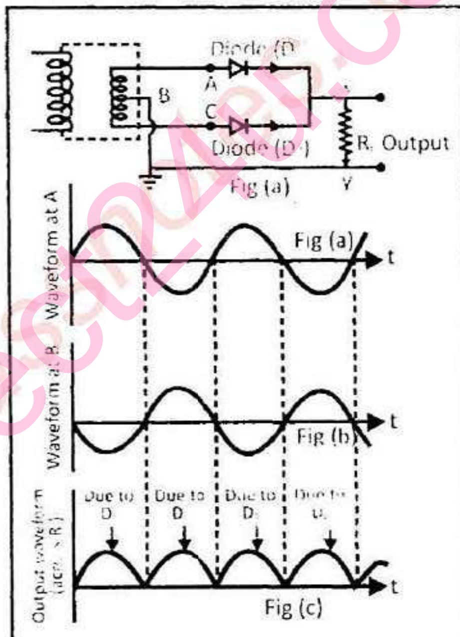
During the negative half cycle of AC,

the P-type of diode is negative and the N-type is positive. The diode is in state of reverse bias and thus the negative part of AC is prevented from passing through the diode. This phenomenon is known as half wave rectification.

(b) Full Wave Rectification:

In case of full wave rectification, both the positive and negative part of AC passes in one direction, as shown in figure (c).

In figure (a), an alternating voltage is applied across a centre-tapped transformer, load resistor "R_L", two diodes "D_1" and "D_2". During the 1st half cycle of AC, the diode "D_1" is forward bias and conducts the positive part of AC through the load resistor "R". While the diode "D_2" is reverse bias and conducts no current.



(a) A full-wave rectifier circuit, **(b)** Input waveforms given to the diode D_1 at A and to the diode D_2 at B, **(c)** Ouput waveform across the load R connected in the full-wave rectifier circuit

During 2nd half cycle of AC, the transformer reverses the polarity of the circuit. As a result, the diode "D_1" becomes reverse bias and the diode "D_2" becomes forward bias. So "D_1" conducts no current while "D_2" conducts the negative part of AC. In this way, both parts of AC are conducted to produce direct current.

Q7: What is a transistor? Describe the construction and operation of a transistor. (ETEA 2006-2008, 2010)

Answer: **Transistor:**

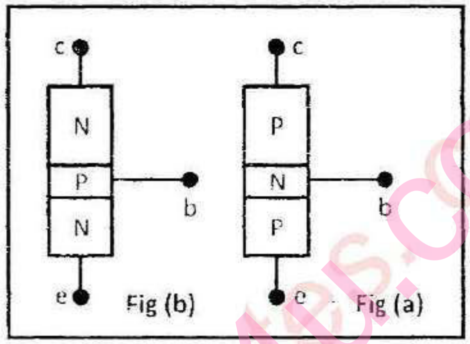
Definition: It is a semiconductor device which work on small voltage and consume very little power.

Construction:

It consists of three semiconductor pieces. The central thin piece is sandwiched between two pieces of other materials. The central part is called base (b), one side is called emitter (e) and the 3rd side is called collector (c).

Types of Transistor:

There are two types of transistors which are given below:



1. P-N-P Transistor:

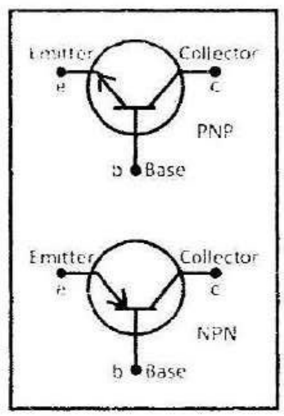
In case of P-N-P transistors, the central part is N-type material and the sided parts are P-type material, as shown in figure (a).

2. N-P-N Transistor:

In case of N-P-N transistor the central part is P-type material and sided parts are N-type material, as shown in figure (b).

Operation of Transistors:

The transistor consists of two P-N junctions. One junction is known as emitter-base [e-b] junction and the other is known as collector-base junction [c-b].



When [e-b] junction is forward bias and [c-b] junction is reversed bias, then the current starts from emitter circuit and flows through the base and collector circuit. Thus the emitter current "I_e" is equal to the sum of base current "I_b" and collector current "I_c" i.e.

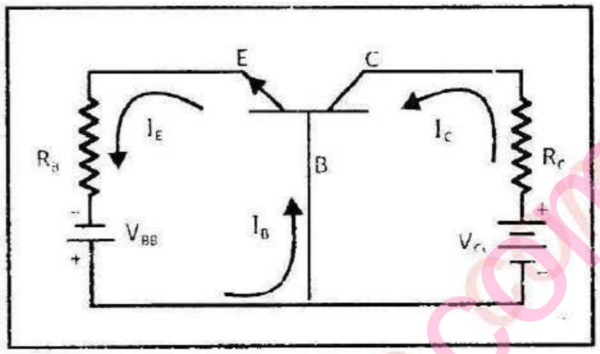
$$\boxed{I_e = I_b + I_c}$$

Expression for Current Gain:

The ratio between collector current and base current is known as current gain of the transistor. It is represented by "β" and is given by,

$$\boxed{\beta = \frac{I_c}{I_b}}$$

Uses of Transistors:



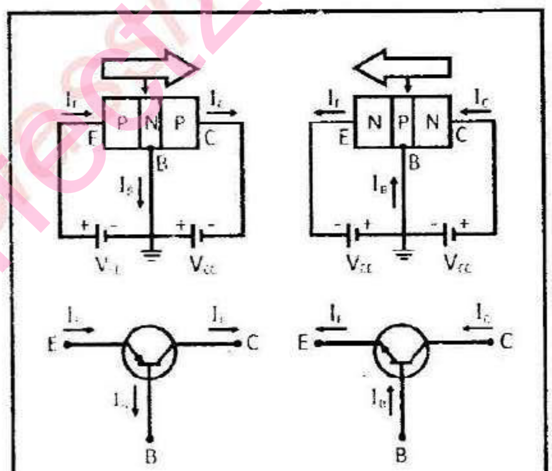
1. It is used in radio sets.
2. It is used in TV sets.
3. It is used in cassette recorders.
4. It is used in stabilizer.
5. It is used in telephone sets.
6. It is used in computers.

Q8: Describe the types of configuration in transistor circuit.

Answer: Types of Configuration:

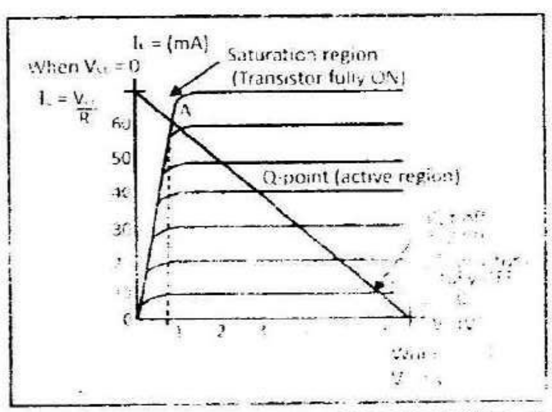
1. Common Base Configuration:

When a base is common to both input and output circuits, then it is called common base configuration. The circuit diagram and input and output characteristic of CB configuration is shown in the figure.



Transistors in CB mode: (a) circuit

The variation in the emitter current "I_E" with respect to change in the base to emitter voltage "V_{BE}" at the constant collector to base voltage "V_{CB}" represents the input characteristics. While the variation in the collector current "I_c" with charge in collector to base voltage "V_{CB}" at the constant emitter current "I_E" represent the output characteristics.



The output characteristics have three region of operation which are called active region, cut off region and saturation region.

When the base-emitter junction is forward biased and the collector-base junction is reverse biased, it is called active region. When both collector-base and base-emitter junctions are reverse biased, it is called cut-off region. The output current is zero in cut-off region. When both the junctions are forward biased, it is called saturation region.

Alpha Factor:

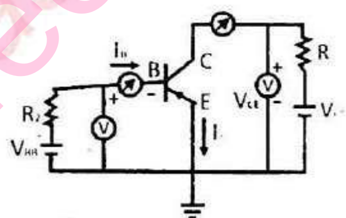
The ratio of "I_C" and "I_E" is called alpha factor. It is also called an amplification factor. It is given by,

$$\boxed{\alpha = \frac{I_C}{I_E}}$$

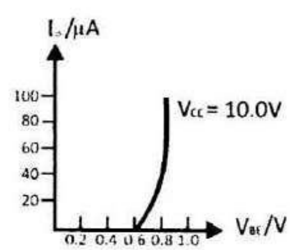
2. Common Emitter Configuration:

In common emitter configuration, the base emitter junction is forward biased while base-collector junction is reverse biased.

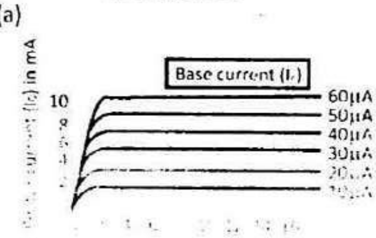
The circuit diagram, input and output characteristics of common emitter configuration are shown in the figure.



(i) Circuit arrangement for CE configuration



(a)



The variation in base current "I_B" with change in base to emitter voltage "V_{BE}" at constant collector to emitter voltage "V_{CE}" are the input characteristics. While the variation in collector current "I_C" with change in collector to emitter voltage "V_{CE}" at constant base current "I_B" represent the output characteristics.

Beta Factor:

The ratio of collector current "I_C"

and base current "I_B" is called as beta factor. i.e.

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

β-Factor in Terms of ∝-Factor:

As $\beta = \dfrac{I_C}{I_B}$ ______________ (1)

Here $I_B = I_E - I_C$, so equation (1)

$\Rightarrow \beta = \dfrac{I_C}{(I_E - I_C)}$ ______________ (2)

$\Rightarrow \beta = \dfrac{I_C}{I_E\left(1 - \dfrac{I_C}{I_E}\right)}$ ______________ (3)

As $\dfrac{I_C}{I_E}$ = alpha factor = α, so equation (3)

$$\Rightarrow \boxed{\beta = \frac{\alpha}{(1 - \alpha)}}$$

Q9: Describe the use of transistor as an amplifier and calculate its voltage gain.

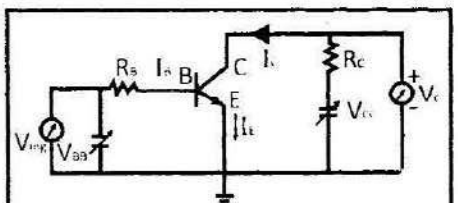
Answer:

Definition: The process in which a small signal of current or voltage is converted into large signals, is known as amplification. The device used for amplification is called amplifier. We can use the transistors as amplifiers.

Explanation:

Consider a circuit which consists of emitter-base junction and collector-base junction as shown in the figure.

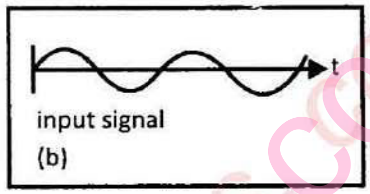
The emitter-base junction acts as input circuit. While the collector-base junction acts as output circuit. The voltage "V_{BB}" makes the emitter-base junction [e-b] as forward biased and the voltage "V_{CC}" makes the collector-base junction [c-b] as reverse biased.



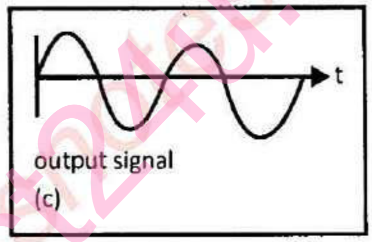
(a) A simple circuit of a CE-transistor amplifier

Working:

When a small input voltage "V_{inp}" is applied across the resistance "R_B", it adds a small AC "I_{in}" into the base current. This small AC is amplified by the transistor "β" times and as a result, we get large output current or voltage, as shown in figure (c).



input signal
(b)



output signal
(c)

Here the current "I_{in}" is equal to the change in base current, so we have,

$$I_{in} = \Delta I_B \quad \text{\_\_\_\_\_\_\_\_\_\_(1)}$$

Similarly, the current "I_{out}" is equal to the change in collector current. i.e.

$$I_{out} = \Delta I_C \quad \text{\_\_\_\_\_\_\_\_\_\_(2)}$$

Now we have,

$$I_{in} = \frac{V_{in}}{r_{ie}} \quad \text{\_\_\_\_\_\_\_\_\_\_(3)}$$

In equation (3) "r_{ie}" represents the internal resistance between its base and emitter terminal. Now we know that the current gain is given by,

$$\beta = \frac{\Delta I_C}{\Delta I_B} \quad \text{\_\_\_\_\_\_\_\_\_\_(4)}$$

Putting equation (1), (2) in equation (4), we get,

$$\beta = \frac{I_{out}}{I_{in}} \quad \text{\_\_\_\_\_\_\_\_\_\_(5)}$$

Here $$I_{out} = \frac{V_{out}}{R_C} \quad \text{\_\_\_\_\_\_\_\_\_\_(6)}$$

Putting equations (3), (6) in equation (5), we get,

$$\beta = \frac{\left(\frac{V_{out}}{R_C}\right)}{\left(\frac{V_{in}}{r_{ie}}\right)}$$

$$\Rightarrow \boxed{\beta = \frac{V_{out} \cdot r_{ie}}{V_{in} \cdot R_C}} \quad \text{\_\_\_\_\_\_\_\_\_\_(7)}$$

Equation (7) represents the expression for current gain.

Voltage Gain:

The ratio between output voltage and input voltage is called voltage gain. It is represented by "A" and is given by,

$$A = \frac{V_{out}}{V_{in}} \quad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_} (8)$$

From equation (7), we have,

$$\frac{V_{out}}{V_{in}} = \beta \frac{R_c}{r_{ie}} \quad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_} (9)$$

Putting equation (9) in equation (8), we get,

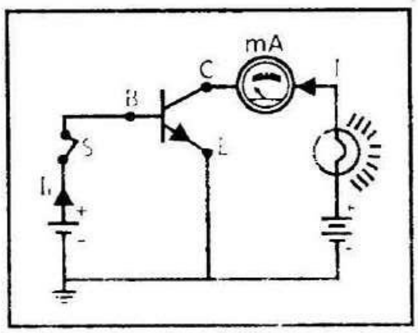
$$\boxed{A = \frac{V_{out}}{V_{in}} = \beta \frac{R_c}{r_{ie}}}$$

Q10: Discuss how a transistor can be used as a switch?

Answer: Transistor as a Switch:

We can use the transistor for switch-ON and switch-OFF purposes.

Explanation:



Consider a circuit in which the transistor, galvanometer and light bulb are connected with each other as shown in the figure.

In this case, the base and emitter terminals of the transistors act as control terminals. i.e. these terminals can provide current or can stop current according to the needs and desires.

Now for switching-ON, large voltage is applied between the control terminals "B" and "E". The switch "S" is closed. Thus current flows through the circuit and the bulb glows.

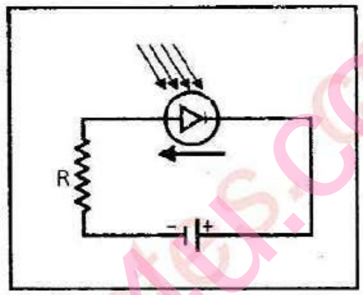
For switch-OFF purposes, the switch "S" is opened. As a result, the current stops due to which the bulb does not glow and the galvanometer shows no deflection. In this way, the transistor can be used for ON-OFF purposes.

Q11: (a) What are optoelectronic junction devices?
(b) Explain the working of photo diode.

Answer: (a) Optoelectronic Junction Devices: "In semiconductor diodes, the carriers are generated by photons. All such devices are called optoelectronic junction devices."

(b) Photo Diode:

The photo diode is a semiconductor diode which converts light energy into electrical energy.



Working:

When light is allowed to fall on the depletion region of P-N junction, then the photons are converted into electrons and holes pair in the depletion region. The diode is in state of reverse bias, so small amount of current is produced due to movement of electrons and holes. This current is allowed to pass through "R" and can be utilized for various purposes. The amount of current increases when the intensity of incident light increases and vice versa.

Uses of Photo Diode:

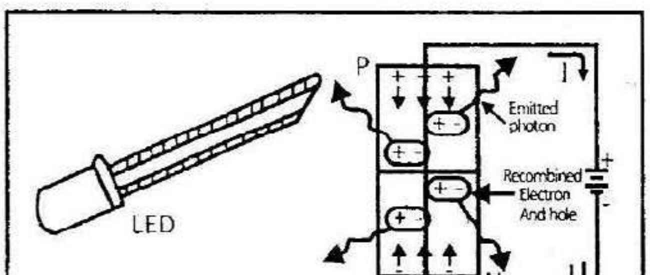
1. It is used in the receivers of optical fibres.
2. It is used in detective instruments.
3. It is used in logic circuits.

Q12: Discuss the working of light emitting diode [LED]. (ETEA 2011)

Answer: **Light Emitting Diode [LED]:**

- The LED is basically a P-N junction diode which emits energy in the form of light called photons.

Working:



Operation of LED

When the LED is forward biased, then the electrons flow from battery into N-type region and reach the P-N junction. These electrons combine with holes near the junction and as a result emit light photons, as shown in the figure. The frequency and wavelength of the emitted light depends upon the energy levels of electrons and the nature of semiconductor diode.

Uses of LED:

1. It is used as optical fibre transmitter.
2. It is used as light indicator in electric circuits.
3. It is used for displaying calculators, locks and other measuring instruments.

Q13: Discuss the working of solar cell.

Answer: Solar Cell:

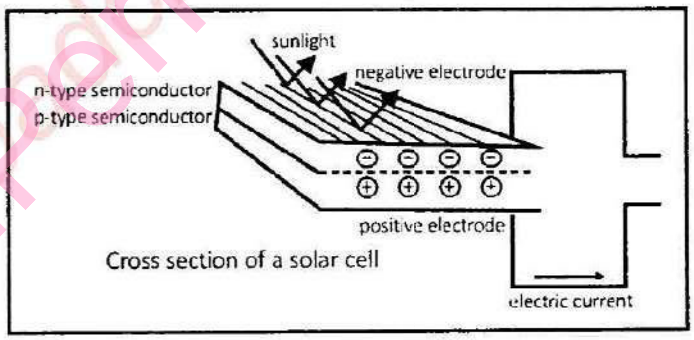
It is a P-N junction diode which generates emf when solar radiations fall on its P-N junction.

Principle:

It works on the same principle of photo diode, except that no external bias is applied and the junction area is kept much larger.

Working:

A simple P-N junction solar cell is shown in the figure. The generation of emf by a solar cell when light falls upon it occurs due to the following reasons:



Cross section of a solar cell

1. Generation of electrons-holes pair.
2. Separation of electrons and holes. The electrons are swept to N-region and holes to P-region.
3. The electrons reaching N-region are collected by the front contact. The holes reaching P-region are collected by the back contact. Thus the P-region becomes positive and N-region becomes negative and thus give rise to photo voltage.

When an external load is connected, the current flows through the load.

Uses of Solar Cells:

The solar cells are used to power electronic devices in satellites and space vehicles and calculators.

SOLUTIONS OF EXAMPLES & ASSIGNMENTS

EXAMPLE 17·1:

A transistor is connected in a CE configuration. The collector supply voltage is 10V and the voltage drop across the 500Ω connected in the collector circuit is 0·6V. If $\alpha = 0{\cdot}96$, find the (a) collector-emitter voltage (b) base current and (c) the emitter current.

Solution:

Given Data:

Collector supply voltage = V_{CC} = 10V

Resistance collector = R_C = 500Ω

Collector voltage = V_C = 0·6V, α = 0·96

Required:

a) Collector-emitter voltage = V_{CE} = ?

b) Base current = I_B = ?

c) The emitter current = I_E = ?

Calculation:

$$\text{Collector current} = I_C = \frac{V_C}{R_C} = \frac{0{\cdot}6}{500} = 1{\cdot}2 \times 10^{-3}A$$

$$\Rightarrow \boxed{I_C = 1{\cdot}2mA}$$

a) Collector-emitter voltage = $V_{CE} = V_{CC} - V_C = 10 - 0{\cdot}6$

$$\Rightarrow \boxed{V_{CE} = 9{\cdot}4V}$$

b) We know that,

$$\alpha = \frac{I_C}{I_E} \Rightarrow I_E = \frac{I_C}{\alpha} = \frac{1{\cdot}2}{0{\cdot}96} = 1{\cdot}25mA$$

$$\Rightarrow \boxed{I_E = 1{\cdot}25mA}$$

c) We know that,

$$I_E = I_B + I_C$$

$$\Rightarrow I_B = I_E - I_C = 1{\cdot}25 - 1{\cdot}25 = {\cdot}05mA$$

$$\Rightarrow \boxed{I_B = 0{\cdot}05mA}$$

EXAMPLE 17·2:

The constant α of a transistor is 0·95· What would be the change in the collector current corresponding to a change of 0·4mA in the base current in a common-emitter arrangement?

Solution:

Given Data:

Current gain = α = 0·95

Base current = I_B = 0·4mA

Required:

Change in the collector current = I_C = ?

Calculation:

The current gain of a transistor in common-emitter arrangement is "β", which is given by,

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

$$\Rightarrow \beta = \frac{0{\cdot}95}{1-0{\cdot}95} = 19$$

But "β" is the ratio of change in collector current to the change in base current·

$$\beta = \frac{\Delta I_c}{\Delta I_b}$$

$$\Rightarrow \Delta I_c = \beta \times \Delta I_b = 19 \times 0{\cdot}4 \times 10^{-3} A = 7{\cdot}6mA$$

$$\Rightarrow \boxed{\Delta I_c = 7{\cdot}6mA}$$

Exercise

Choose the best possible answer:

1. In an N-type silicon, which of the following statement is true?
   a) Electrons are majority carriers and trivalent atoms are the dopants.
   b) Electrons are minority carriers and pentavalent atoms are the dopants.
   c) Holes are minority carriers and pentavalent atoms are the dopants.✓
   d) Holes are majority carriers and trivalent atoms are the dopants.

2. The barrier potential of silicon diode at room temperature is:
   a) 0.3V b) 0.7V✓ c) 0.9V d) 1.0V

3. The width of depletion region of a junction:
   a) Increases under forward bias
   b) Is independent of applied voltage
   c) Increases under reverse bias✓
   d) Remains same

4. For common emitter configuration of N-P-N transistor, current gain is given by,
   a) $\frac{I_C}{I_B}$ ✓ b) $\frac{I_C}{I_E}$ c) $\frac{I_E}{I_B}$ d) $\frac{I_B}{I_E}$

5. The reverse saturation current in a P-N junction diode is only due to:
   a) Majority carriers b) Minority carriers✓
   c) Acceptor ions d) Donor ions

6. P-N junction when reversed biased act as a............
   a) Capacitor b) ON switch c) inductor d) OFF switch✓

7. Improper biasing of a transistor circuit produces:
   a) Heavy loading of emitter current
   b) Distortion in the output signal✓
   c) Excessive heat at collector terminal

d) Faulty location of load line

8. When transistors are used in digital circuits they usually operate in the:

a) Active region b) Breakdown region
c) Saturation and cutoff regions✓
d) Linear region

9. Most of the electrons in the base of an N-P-N transistor flow:

a) Out of the base lead b) Into the collector✓
c) Into the emit d) Into the base supply

10. In a transistor, collector current is controlled by:

a) Collector voltage b) Base current✓
c) Collector resistance d) All of the above

11. The minimum number of diode required for full wave rectifications are:

a) 3 b) 4 c) 2✓ d) 1

12. In a transistor both collector-base and base-emitter junctions are reversed biased then it is.........

a) Active region b) Cutoff region✓
c) Saturation region d) Q-point

CONCEPTUAL QUESTIONS

Q1: Why in a transistor (a) the base is thin lightly doped and (b) the collector is large in size?

Answer:

Part (a): The middle section of the transistor is called base. The base is lightly doped and is very thin (10^{-6}m) as compared to either emitter or collector so that it may pass of the injected charge carriers to the collector. In P-type base, a few electrons (less than 5%) combine with holes to constitute base current "I_b". The remaining electrons (more than 95%) cross over into the collector region which constitutes the collector current "I_c".

Part (b): The right hand side of the transistor is called collector.

The main function of the collector is to collect majority charge carriers through the base, therefore, it is large in size and is doped moderately. Due to the interaction of charge carriers, this region may heat up, so it is made larger in size. For shorter collector region, the transistor may burn out due to heat dissipation.

Q2: Explain why the base current is weak as compared to the collector current?

Answer:

The base current of a transistor is weak as compared to the collector current. It is because, the base of the transistor is doped lightly and is very thin in size as compare to the collector. Very small number of electrons and holes recombine to constitute the base current. Majority of charge carriers flow emitter towards collector and thus large current is constituted in collector region. So the base current is weak than collector current.

Q3: Why the emitter base junction is forward biased and the collector base junction is reversed biased?

Answer:

In a transistor, the input circuit i.e. emitter-base junction is forward biased so that it may have low resistance and thus to minimize the depletion region. As a result, the charges can flow easily from emitter towards the base.

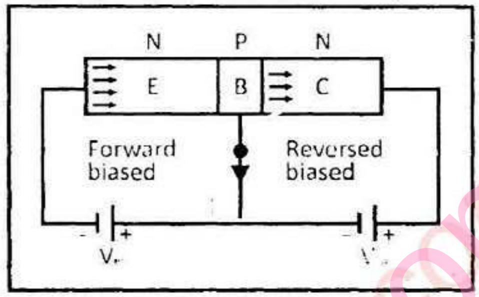
The base is thin in size and is lightly doped so it can bear very less number of charges. To avoid the base from excess charges, the collector base junction is made reversed biased. In doing so most of the charges flows towards the collector.

Q4: How N-P-N and P-N-P works?

Answer: **(1) Working of N-P-N Transistor:**

The N-P-N transistor with forward biased to e-b junction and reverse biased to c-b junction is shown in the figure.

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, so only a few electrons [less than 5%] combine with holes to constitute the base current "I_b".



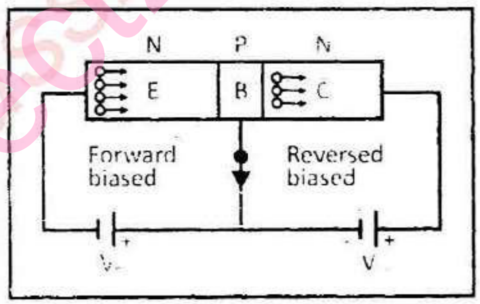
The remaining electrons [more than 95%] cross over into the collector region to constitute the collector current "I_c". In this way, almost the entire emitter current flows in the collector circuit. The emitter current is equal to the sum of collector and base current. i.e.

$$\boxed{I_e = I_b + I_c}$$

(2) <u>Working of a P-N-P Transistor:</u>

The basic connections of a P-N-P transistor is shown in the figure.

The forward biased causes the holes in the P-type emitter to flow towards the base and constitute the emitter current "I_e". As these holes cross into N-type base, they tend to combine with the electrons. As the base is very thin and doped lightly, so very few of the holes [less than 5%] combine with electrons and thus constitute weak base current "I_b". The remaining electrons [more than 95%] cross into the collector region and 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 P-N-P transistor is by holes. However, in the external connecting wires, the current is still by electrons.

The sum of base current and collector current is equal to the emitter current. i.e.

$$\boxed{I_e = I_b + I_c}$$

Q5: Distinguish between N-type and P-type semiconductors.

Answer:

The comparison between N-type and P-type semiconductor is given below:

S.#	N-type	P-type
1.	It is produced by adding a pentavalent impurity atom to a pure intrinsic semiconductor.	It is produced by adding a trivalent impurity atom to a pure intrinsic semiconductor.
2.	The number of free electrons are more than holes.	The number of holes are more than free electrons.
3.	The current conduction is mainly due to free electrons.	The current conduction is mainly due to holes.
4.	The donor energy level is just below the bottom of the conduction band.	The acceptor energy level is just above the top of valence band.

Q6: A P-type semiconductor has a larger number of holes but still it is electrically neutral. Why?

Answer:

A P-type semiconductor has a large number of holes but still it is electrically neutral.

Reason and Explanation:

In case of P-type semiconductor the holes [positive charges] are in majority while in N-type semiconductor, the electrons [negative charges] are in majority. But still the P-type semiconductor is neutral. It is because the total number of electrons and holes [protons] are equal in number. Thus each atom remains neutral. There is no net charge on the crystal. Thus the P-type semiconductor remains neutral electrically.

Q7: Why CE configuration is widely used in amplifier circuit?

Answer:

The CE configuration is widely used in amplifier circuit.

Reason and Explanation:

A transistor in common-emitter configuration (mode) is preferred because of the following advantages:

1. Common-emitter configuration (mode) has higher current gain than common-base (CB) and common-collector (CC) mode.
2. It has higher voltage gain than CB mode and CC mode.
3. Common emitter mode has highest power gain than other two configurations.
4. High input resistance and low output resistance as required for a good transistor is found in CE configuration.
5. Signal received at the output is more stable in CE configuration than the other two configurations.

Q8: Why transistor is called current amplification device?

Answer:

A transistor is called current amplification device due to the following reasons:

1. In CE-connection, the input impedance is high and output impedance is low. So the output current is larger than the input current.
2. We get high voltage and power gain in CE-circuit of transistor.
3. There is moderate ratio between the input and output impedance in transistors.
4. The transistor circuit raises the strength of weak signal.

Q9: A doped semi-conductor has 10^{10} silicon atoms and 10 trivalent atoms. If the temperature is 25°C, then how many free electrons and holes are there inside the semiconductors?

Answer:

Absolute temperature $= T = 25°C + 273 = 298K$

Total number of atoms $= N = 10^{10} + 10^{1} = 1.0 \times 10^{10}$ atoms

Boltzmann gas constant $= K = 1.38 \times 10^{-23} J/K$

Total kinetic energy supplied is given by,

$$K.E = \frac{3}{2}NKT = \frac{3}{2} \times 1.0 \times 10^{10} \times 1.38 \times 10^{-23} \times 298$$

$$\Rightarrow K.E = 6.1686 \times 10^{-11} J \quad \text{\_\_\_\_\_\_\_\_}(1)$$

$$\Rightarrow K \cdot E = \frac{6 \cdot 1686 \times 10^{-11}}{1 \cdot 6 \times 10^{-19}} = 3 \cdot 86 \times 10^{8}\, eV \quad \text{\_\_\_\_\_\_\_\_\_\_} (2)$$

In case of silicon 1·09eV energy is required to break a covalent bond of electron and hole· So the number of free electrons is:

$$\text{No· of free electrons} = \frac{3 \cdot 86 \times 10^{8}\, eV}{1 \cdot 09 eV} = 3 \cdot 54 \times 10^{8} \text{ electrons}$$

$$\Rightarrow \text{No· of holes} = \text{number of electrons} = 3 \cdot 54 \times 10^{8} \text{ holes}$$

$$\Rightarrow \boxed{\text{No· of holes in silicon} = 3 \cdot 54 \times 10^{8} \text{ holes}}$$

In case of germanium 0·72eV energy is required to break the bond· So the number of electrons in case of germanium is:

$$\text{No· of electrons} = \frac{3 \cdot 86 \times 10^{8}\, eV}{0 \cdot 72 eV} = 5 \cdot 36 \times 10^{8} \text{ electrons}$$

$$\Rightarrow \boxed{\text{No· of electrons in silicon} = N = 3 \cdot 56 \times 10^{8} \text{ electrons}}$$

$$\text{No· of holes} = \text{No· of electrons} = 5 \cdot 36 \times 10^{8} \text{ holes}$$

$$\Rightarrow \boxed{\text{No· of holes in germanium} = N' = 5 \cdot 36 \times 10^{8} \text{ holes}}$$

COMPREHENSIVE QUESTIONS

Q1: Describe the energy band structure of insulator, semiconductor and conductor·

Answer: See answer of question # 12 in the text·

Q2: Explain the significance of depletion layer in an equilibrium state in a PN junction· Given energy band diagram·

Answer: See answer of question # 4 in the text·

Q3: Explain how PN-junction acts as a half-wave rectifier?

Answer: See answer of question # 6 (a) in the text·

Q4: Explain the working of transistor as an amplifier·

Answer: See answer of question # 9 in the text·

Q5: Draw the circuit for a half wave rectifier and full wave rectifier·

Answer: See answer of question # 6 in the text·

Q6: Compare the advantages and disadvantages of full wave rectifier and half wave rectifier.

Answer:

The comparison of half wave and full wave rectifier is given below:

S.#	Half Wave Rectifier	Full Wave Rectifier
1.	It is less expensive.	It is more expensive.
2.	Its construction is simple.	Its construction is complicated and need more circuits.
3.	Ripple factor is high.	Ripple factor is low.
4.	It needs an elaborate filter to get steady DC output.	It needs a simple filter to get steady DC voltage.
5.	The power is delivered only during one half cycle of the input alternating voltage.	The power is delivered during both half cycles of the input alternating voltage.
6.	The output power is low.	The output power is high.
7.	The rectification efficiency is low.	The rectification efficiency is high.
8.	Transformer utilization factor is low.	Transformer utilization factor is high.

Q7: Deduce the relation between "α" and "β" of a transistor.

Answer:

The ratio of "I_C" and "I_E" is called alpha factor and is given by,

$$\alpha = \frac{I_C}{I_E} \quad \text{---------- (1)}$$

While the ratio of "I_C" and "I_b" is called β-factor and is given by,

$$\beta = \frac{I_C}{I_b} \quad \text{---------- (2)}$$

Here $I_b = I_E - I_C$, so equation (2) ⇒

$$\beta = \frac{I_C}{(I_E - I_C)} \quad \text{---------- (3)}$$

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

$$\Rightarrow \beta = \left(\frac{I_c}{I_E}\right) \times \frac{1}{\left(1 - \frac{I_c}{I_E}\right)} \quad \text{————} (4)$$

Putting equation (1) in equation (4), we get,

$$\boxed{\beta = \frac{\alpha}{(1 - \alpha)}}$$

Q8: Discuss the conductivity of extrinsic semiconductor and its band gap energy.

Answer: See answer of question # 3 in the text.

NUMERICAL QUESTIONS

Q1: In a certain circuit, the transistor has a collector current of 10mA and a base current of 40μA. What is the current gain of the transistor?

Solution:

Given Data:

Collector current = I_c = 10mA = 10×10^{-3}A

Base current = I_b = 40μA = 40×10^{-6}A

Required:

Current gain = β = ?

Calculation:

We know that,

$$\beta = \frac{I_c}{I_b}$$

$$\Rightarrow \beta = \frac{10 \times 10^{-3}}{40 \times 10^{-6}} = 0.250 \times 10^{3}$$

$$\Rightarrow \boxed{\beta = 250}$$

Q2: The current flowing into the base of a transistor is 100μA. Find its collector current I_c, its emitter current I_E, and the ratio I_c/I_E if the value of current gain β is 100.

Solution:

Given Data:

Base current = I_b = 100μA

$\Rightarrow I_b = 100 \times 10^{-6} A = 0.0001A$

Current gain $= \beta = 100$

Required:

a) Collector current $= I_c = ?$

b) Emitter current $= I_e = ?$

c) $\frac{I_c}{I_e} = ?$

Calculation:

a) We know that,

$$\beta = \frac{I_c}{I_b}$$

$$\Rightarrow I_c = \beta I_b = 100 \times 0.0001 = 0.01A$$

$$\Rightarrow I_c = 0.01 \times 10^{-3} mA$$

$$\Rightarrow \boxed{I_c = 10mA}$$

b) We know that,

$$I_e = I_b + I_c = 0.0001 + 0.01 = 0.0101A$$

$$\Rightarrow I_e = 0.0101 \times 10^{-3} mA = 10.1mA$$

$$\Rightarrow \boxed{I_e = 10.1mA}$$

c) $$\frac{I_c}{I_e} = \frac{0.01}{0.0101} = 0.99$$

$$\Rightarrow \boxed{\frac{I_c}{I_e} = 0.99}$$

Q3: A transistor is connected in CE configuration. The voltage drop across the load resistance (R_C) 3kΩ is 6V. Find the base current. The current gain β of the transistor is 0.97.

Solution:

Given Data: $R_C = 3k\Omega = 3 \times 10^3\Omega$, $V_C = 6V$

Current gain $= \beta = 0.97$

Required: Base current $= I_b = ?$

Calculation: We know that,

$$\beta = \frac{I_c}{I_b} \Rightarrow I_b = \frac{I_c}{\beta} \quad (1)$$

Here $I_c = \frac{V_c}{R_c}$ ________________ (2)

Putting equation (2) in equation (1), we get,

$$I_b = \frac{V_c}{R_c\beta} \quad \text{________________ (3)}$$

Putting the values in equation (30, we get,

$$I_b = \left(\frac{6}{3 \times 10^3 \times 0.97}\right) A$$

$$\Rightarrow \boxed{I_b = 2.06 \times 10^{-3} A}$$

Q4: In a common base circuit, the current gain is 0.96. If the collector current is 60μA. Find the emitter current.

Solution:

Given Data:

Current gain = β = 0.96

Collector current = I_c = 60μA

Required:

Emitter current = I_e = ?

Calculation:

We know that,

$$\beta = \frac{I_c}{I_b} \Rightarrow I_b = \frac{I_c}{\beta}$$

$$\Rightarrow I_b = \frac{60\mu A}{0.96} = 62.5\mu A \Rightarrow \boxed{I_b = 62.5\mu A}$$

Now the emitter current is given by,

$$I_e = I_b + I_c \Rightarrow I_e = 62.5\mu A + 60\mu A$$

$$\Rightarrow \boxed{I_e = 122.5\mu A}$$

Note: The answer of the book i.e. 62.5μA is the value of base current.

Q5: In a transistor, the emitter current "I_e" is 3.5A and collector current is "I_c" is 2.35A. Find the base current.

Solution:

Given Data:

Emitter current = $I_e = 3.5A$

Collector current = $I_c = 2.35A$

Required:

Base current = I_b = ?

Calculation:

We know that,

$$I_e = I_b + I_c \Rightarrow I_b = I_e - I_c$$

$$\Rightarrow I_b = (3.5 - 2.35)A$$

$$\Rightarrow \boxed{I_b = 1.15A}$$