CHAPTER

9

ELECTRONIC DEVICE

SEMICONDUCTORS

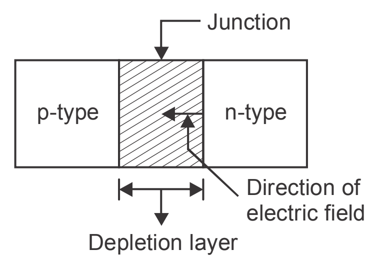
Semiconductors are certain elements (e.g., Ge, Si, Ga, As and Se) which behave like good conductors under certain conditions (generally at shightly elevated temperatures) and as bad conductors when those conditions do not exist. Their resistivities lie between 10^{-5} and 10^{7} ohm m at room temperature.

Intrinsic and Extrinsic Semiconductors: Pure semiconductors are called intrinsic semi-conductors to enhance the desirable characteristics of pure semiconductors, certain impurities are added to them. This is called doping. Suppose we take the case of Germanium (Ge) crystal. It's atom has 4 electrons in its valence band. Thus, it needs 4 more electrons to complete its octet. Let we dope it with phosphorus (P) which has 5 electrons in its valence band. This doping will complete octets for both Ge and P, but one electron will become extra in the lattice. Such doped semiconductors are called ***n*-type** (*i.e.*, negative-type) semiconductors. Similarly, doping Ge with Boron (B) will make it a ***p*-type** (*i.e.*, positive-type) semiconductor.

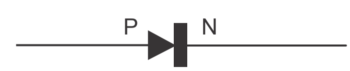
SEMICONDUCTOR DIODE

A diode made of semiconductor components, usually silicon. The cathode, which is negatively charged and has an excess of electrons, is placed adjacent to the anode, which has an inherently positive charge, carrying an excess of holes.

Junction Diode: It is a device in which *p*-type semi-conductor is joined with an *n*-type semiconductor, back to back. At their junction, within a limited width, holes of *p*-type are neutralised by extra eletrons of *n*-type semiconductor. This is called depletion layer.

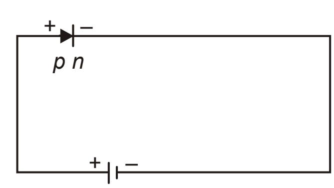


Circuit Symbol of pn-junction

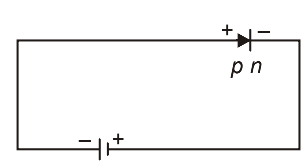


Forward and reverse biasing on a junction diode.

Forward Bias: When a battery is connected across the junction diode with its positive terminal connected to the *p*-side and the negative terminal connected to the *n*-side of the diode it is said to be forward biased. If the bias voltage is greater than the barrier potential across the depletion layer, the majority carriers move towards the junction and cross it, causing a flow of current.



Reverse Bias: When a battery is connected across the junction diode with its negative terminal connected to *p*-side and positive terminal connected to *n*-side, the diode is said to be reverse biased.



Zener Breakdown

If the reverse bias is continuously increased, then at a certain value, the covalent structure breaks down and large number of electrons are released causing an abrupt increase in current. This voltage is called *Zener voltage*.

Dynamic Resistance (R): We have,

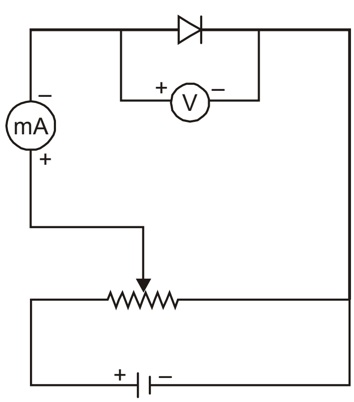
$$R = \frac{\Delta V}{\Delta I}$$

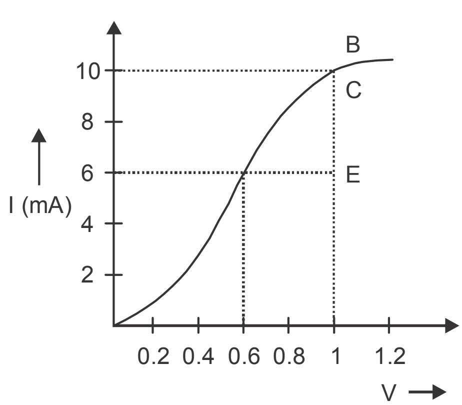
ΔV = small change in applied voltage

ΔI = corresponding change in current

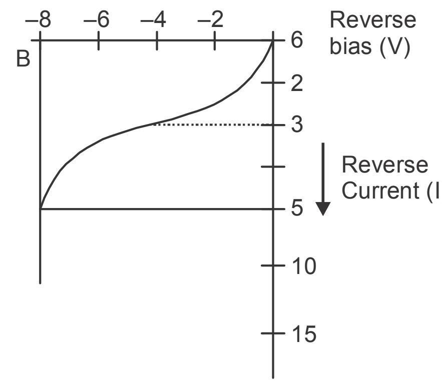
I-V CHARACTERISTICS IN FORWARD AND REVERSE BIAS

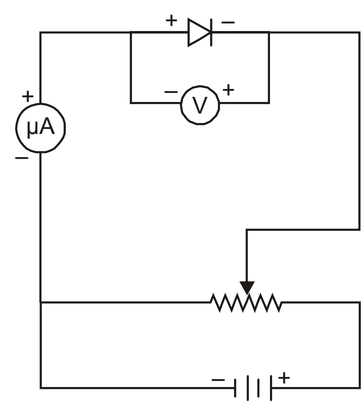
Forward Characteristics: For a given low forward bias voltage (V) note the forward current (ImA) which due to migration of majority carriers across the *pn* junction. On plotting, the graph between forward bias and forward current, we get the curve OPQ. This is called forward characteristics.





Reverse characteristics: For a reverse bias voltage (V) applied to the *pn* junction not the reverse current (μA) which is due to magnetic of majority charge carrier across the *pn* junction so on increasing the reverse biased voltage and note the corresponding reverse current. On plotting the graph between reverse bias and reverse current, we note the reverse biasing of *pn* junction diode, the reverse current is very small and voltage independent upto certain reversed bias voltage known as breakdown voltage. It is called reverse saturation current.





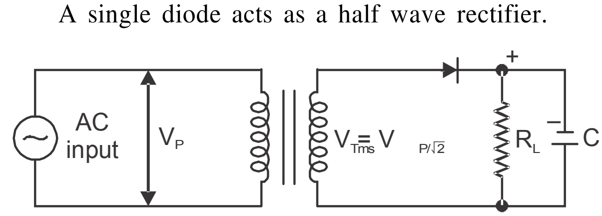
Knee voltage: It is forward bias voltage beyond which the current through the junction starts increasing rapidly with voltage, showing the linear variation but below the knee voltage the variation is non-linear.

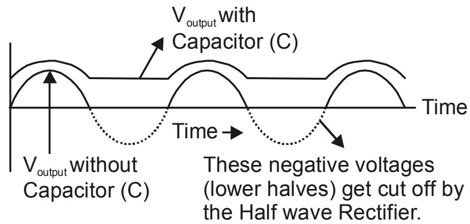
DIODE AS A RECTIFIER

Rectifier: It is a device which used for converting alternating current/voltage in direct current (DC). A *pn* junction can be used as a rectifier in two types.

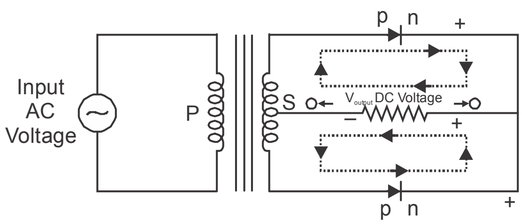
(a) Half Wave Rectifier: It is based on the fact that the resistance *pn* junction becomes low, when forward biased and becomes high when reversed biased.

A single diode acts as a half wave rectifier.

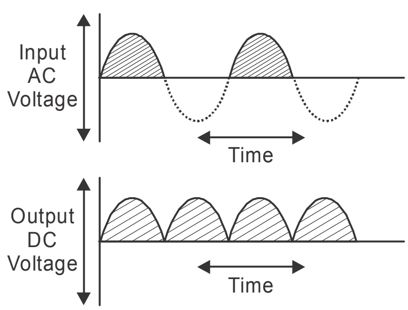




(*b*) ***Full Wave Rectifier:*** A rectifire which rectifies both halves of the A.C. input is called a Full Wave Rectifier. To make use of both the halves of the input cycle, two junction diodes are used.

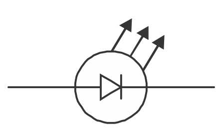


Step down transformer

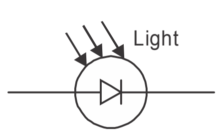


I-V CHARACTERISTICS

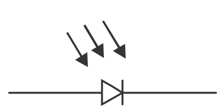
LED (Light Emitting Diode): It is photoelectric device which converts electrical energy into light energy. It is heavily doped *pn* junction diode. LED is made of GaAsP, GaP etc.



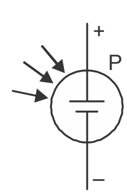
Photodiode: It is an opto-electronic device in which current carriers are generated by photons through photo excitation *i.e.*, photo conduction of light.

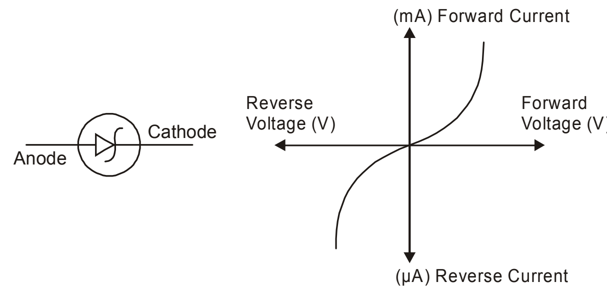


Solar Cell: It is basically a solar energy converter. It is a *pn* junction device, which converts solar energy into electrical energy.



Zener Diode: It is highly doped *pn* junction which is not damaged by high reverse current. It can operated continuously, without damage in the region of reverse breakdown voltage. In the forward biased, the zener diode acts as ordinary diode. It can be used as voltage regulator.





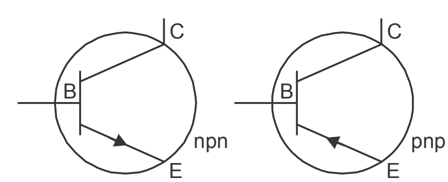
ZENER DIODE AS A VOLTAGE REGULATOR

Zener diode is connected to the positive terminal of the d.c. It is more heavily doped than ordinary diodes, due to which it has narrow region. While regular diode gets damaged when the voltage across them exceeds the reverse breakdown voltage, zener diode works exclusively in depletion region. The depletion region in zener diode goes back to its normal state when the reverse voltage gets removed. This particular property of zener diode makes it useful as a voltage regulator.

JUNCTION TRANSISTOR

If a single crystal continuous crystal of a semiconductor is grown in such a way that it is equivalent to two diodes (either *p-n* and *n-p*, or *n-p* and *p-n*) fused together back to back, such that the middle sandwitched layer is thin, it is called a Junction Transistor.

Junction transistors are two types *npn* and *pnp*. In a *npn* transistor, a thin *p* layer is sandwiched between two thick *n* type layers; and in a *pnp* transistor a thin *n* type layer is sandwiched between two thick *p* type layers.



Emitter (E): It is that electrode which supplies majority carriers (*i.e.*, positive holes in case of *p*-type and electrons in case of *n*-type semiconductors) to the base for current flow within the transistor.

Base (B): This is the electrode which is attached to the middle sandwitched layer. Through it, current passes from emitter to collector.

Collector (C): It is the other end of the transistor, which collects the current which comes to it from the emitter via the base.

Note: In the symbol of a transistor, arrow is put on the emitter. The direction of this arrow indicates the direction of current within a transistor.

Whether the transistor is a *pnp* or an *npn*, base-emitter junction is Always forward-biased; and base-collector junction is always reverse biased.

α-value

The portion of I_E in the collector is called α-value.

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

where,

I_C = Collector current

I_E = Emitter current

β-value

The portion of base-current (IE) in the collector is called β-value.

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

Relationship between α and β

We known $I_E = I_C + I_B$

From this we can derived easily

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

and $$\alpha + \frac{\beta}{1+\beta}$$

dc current gains

α and β are called

dc current gains.

α is generally ≃ 0.9 and

β is generally ≃ 1.

Transistor is used in a circuit: It is used in any one of the following three ways:

(*i*) Common Base

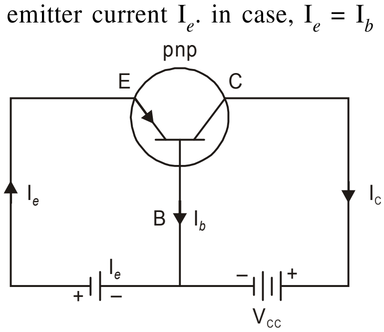
(*ii*) Common Emitter

(*iii*) Common Collector

'Common' mean 'grounded', *i.e.*, 'earthed'.

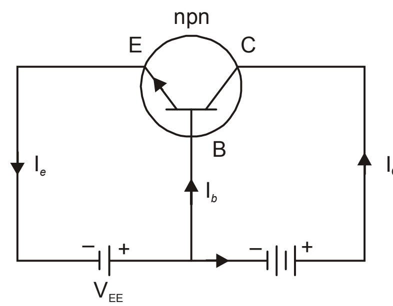
TRANSISTOR ACTION

pnp transistor: The EB junction is forward biased. It means the positive pole of emitter-base battery V_{EE} is connected to emitter and its negative pole the base. Holes are majority carriers in emitter *p*-type semiconductor are repelled towards the base by positive potential an emitter due to bettery V_{EE}, resulting in emitter current I_e. in case, $I_e = I_b + I_c$.



npn transistor: The EB junction is forward biased, the positive pole of the emitter-base battery V_{EE} is connected to base and its negative pole to emitter.

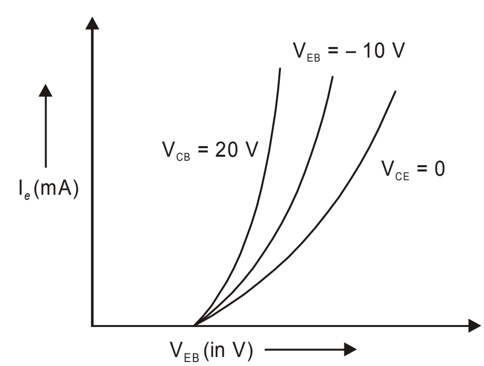
The resistance of emitter base junction is very low. So the voltage of V_{EE} (*i.e.*, V_{EB}) is quite small is 1.5 V, then in this case, $I_e = I_b + I_c$.



CHARACTERISTICS OF TRANSISTOR

CB configuration: Base in common to both emitter and collector.

Input characteristics: When V_{CE} is constant, curve between I_e and V_{EB} is known as input characteristics. It is also known as emitter characteristics.



Input characteristics of *npn* transistor are also similar to the figure but I_e and V_{EB} both are negative and V_{CB} is positive. Dynamic input resistance of a transistor is given by

$$R_i = \left(\frac{\Delta V_{EB}}{\Delta I_e}\right)_{V_{CB} = \text{constant}}$$

[R_i is order of 100 Ω]

Output characteristics: Taking the emitter current I_e constant, the curve drawn between I_C and V_{CB} are known as output characteristics of CB configuration.

Dynamic output resistance,

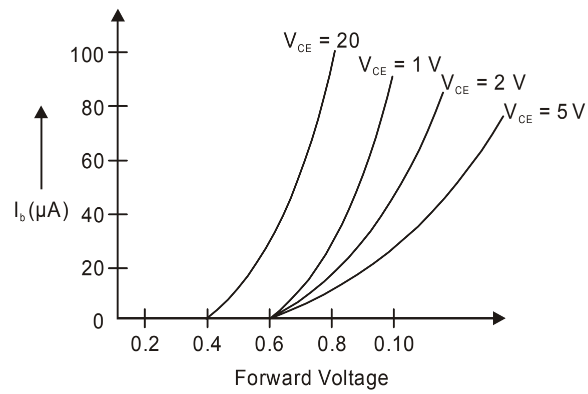
$$R_o = \left(\frac{\Delta V_{CB}}{\Delta I_C}\right)_{I_e = \text{constant}}$$

CE configuration: Emitter is common to both base and collector.

Input characteristics: Input characteristics curve is drawn between base current I_b and emitter base voltage V_{EB} at constant emitter voltage V_{CE}.

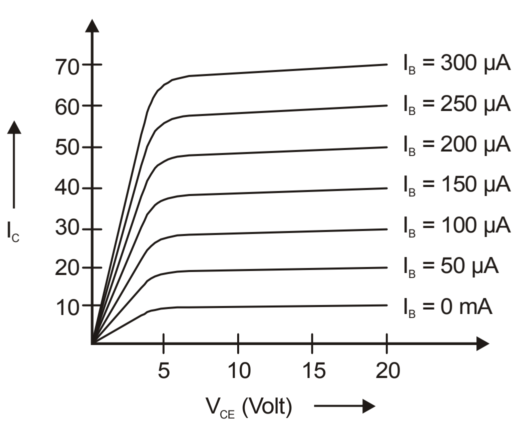
Dynamic input resistance,

$$R_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE} = \text{constant}}$$



Output characteristics: Variation of collector current I_C with V_{CE} can be noticed for V_{CE}, between O and V. The value of V_{CE} upto which the I_C charges with V_{CE} is called Knee voltage. The transistors are operated in the region above Knee voltage.

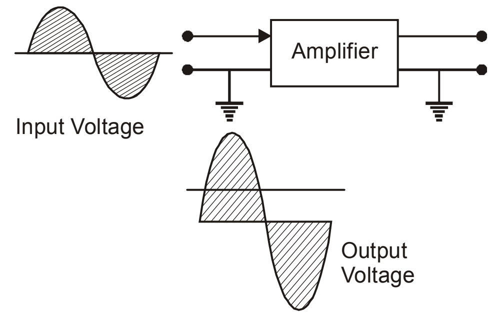
Dynamic out resistance, $R_o = \left(\frac{\Delta V_{CB}}{\Delta I_C}\right)_{I_B = \text{constant}}$



TRANSITOR AS AN AMPLIFIER

An amplifier is a device, which is used for increasing the amplitude of variation of alternating voltage/current or power. The amplifier thus produces an enlarged version of input signal.

To amplify means to increase the amplitude of the input signal without changing its frequency or wavelength. The general concept is represented below:



ac Volatge Gain (A_V)

$$A_v = \frac{\delta V_0}{\delta V_i} = \frac{v_0}{v_i}, \text{ where}$$

δV_0 = small change in output voltage corresponding to δV_i (small) change in input voltage.

ac Current gains (β_{ac}) and (α_{ac})

$$\beta_{ac} = \frac{\delta I_C}{\delta I_B} = \frac{i_C}{i_B}$$

$$\alpha_{ac} = \frac{\delta I_C}{\delta I_e} \text{ at constant } V_C$$

Transconductance (g_m) of the transistor: It is also called mutual conductance.

$$g_m = \frac{\beta_{ac}}{R_i}, \text{ where } R_i = \text{input resistance}$$

$$= \frac{\delta I_C}{\delta I_B} + \frac{\delta V_{BE}}{\delta I_B}, \text{ at constant } V_{CE}$$

$$= \frac{\delta I_C}{\Delta V_{BE}}, \text{ at constant } V_{CE}$$

= Rate of change of output current w.r.t. input voltage keeping output voltage constant.

Power Gain (A_p)

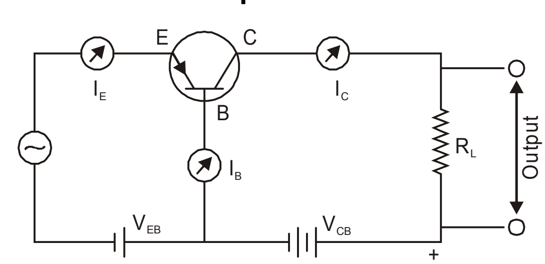
A_p = Current gain × Voltage gain

$$A_p = \beta_{ac}^2 \frac{R_L}{R_i}$$

Resistance Gain

$$\text{Resistance gain} = \frac{R_{out} \text{ or } R_L}{R_{input} \text{ or } R_i}$$

Common Base Amplifier



(*a*) ***Voltage Gain***

δ_{IE} = increment change in I_E

δ_{IC} = incremental change in I_C

E_i = Input voltage

R_i = Input Resistance

E_0 = Output voltage

R_L = Load Resistance

$$\therefore \quad E_i = R_i \times \delta I_E$$

$$E_0 = R_L \times \delta I_C$$

$$\text{Voltage gain} = \frac{E_0}{E_i} = \frac{R_L\ \delta I_C}{R_i\ \delta I_E}$$

$$= \alpha_{ac} \times \frac{R_L}{R_i} \qquad \left[\because \frac{\delta I_C}{\delta I_E} = \alpha\right]$$

$$= \alpha_{ac} \times \text{Resistance gain}$$

(*b*) ***Power Gain***

$$\text{Power Output} = E_0 \times \delta I_C$$

$$\text{Power Input} = E_i \times \delta I_E$$

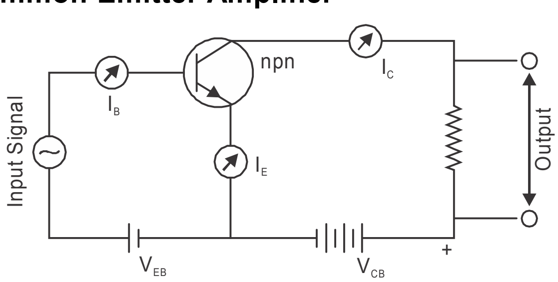
$$\therefore \quad \text{Power Gain} = \frac{E_0 \times \delta I_C}{E_i \times \delta I_E}$$

$$= \frac{(R_L \times \delta I_C) \times \delta I_C}{(R_i \times \delta I_E) \times \delta I_E}$$

$$= \left(\frac{\delta I_C}{\delta I_E}\right)^2 \times \frac{R_L}{R_i}$$

$$= \alpha_{ac}^2 \times \text{Resistance gain}$$

Common Emitter Amplifier



(*a*) ***Voltage Gain***

$$\text{Voltage input} = \delta I_B \times R_i$$

$$\text{Voltage output} = \delta I_C \times R_L$$

$$\therefore \quad \text{Voltage Gain} = \frac{\delta I_C \times R_L}{\delta I_B \times R_i}$$

$$= \beta_{ac} = \text{Resistance Gain}$$

(*b*) ***Power Gain***

$$\text{Power Output} = E_0 \times \delta I_C$$

$$\text{Power Input} = E_i \times \delta I_B$$

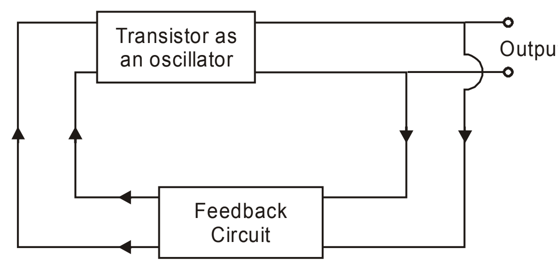
$$\therefore \quad \text{Power Gain} = \frac{E_0 \times \delta I_C}{E_i \times \delta I_B} = \frac{(R_L \times \delta I_C) \times \delta I_C}{(R_i \times \delta I_B) \times \delta I_B}$$

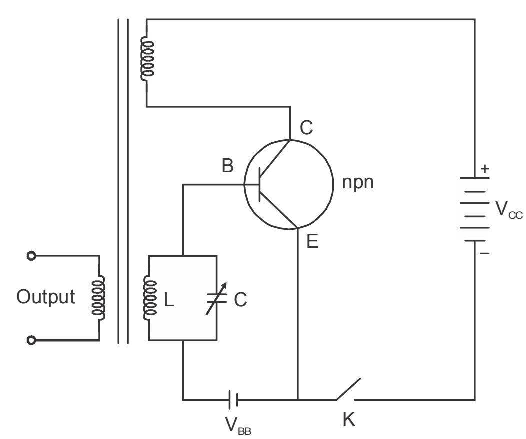
$$= \left(\frac{\delta I_C}{\delta I_B}\right)^2 \times \frac{R_L}{R_i}$$

$$= \beta_{ac^2} \times \text{Resistance gain}$$

Transistor as an Oscillator

The radio waves which are used as carrier waves in radio communication are produced by the circuits called oscillators. The damped em wave suitable for the transmission of code messages on telegraphic messages but to transmit speech or music, we require undamped em waves or carrier waves. The block diagram of feedback oscillator.





LOGIC GATES COR, AND, NOT, NAND AND NOR

Logic gates are the building blocks of a digital system. A gate is a electronic circuit which follows a logical relationship between input and output voltages and for this reason, it is called a logic gate.

There are three basic logic gates.

1. OR gate
2. AND gate and
3. NOT gate.

Each logic gate has its characterisitics symbol its function is defined either by a truth table or by a Boolean expression.

In digital circuit, low and high voltage are often represented by 0 and 1 respectively.

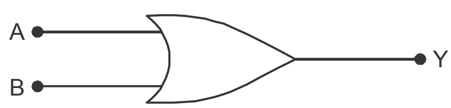
Truth Table: It is a table that shows all input/output possibilities for a logic gate. It is also called a table of combinations.

Boolean Expression: George Boolean invented a different kind of algebra based on binary nature (two valued) of logic. It was first applied to switching circuits, as a switch is a binary device (on or off).

Logic gates are applied in digital circuits.

'OR' GATE

In Boolean algebra, addition symbol (+) is referred to as OR gate.



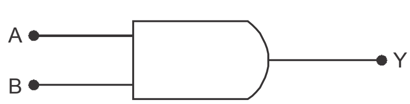
y = A + B ⇒ Y = equals A or B.

Truth table of the 'OR' gate

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

'AND' GATE

The multiplication sign [either × or] is referred to an AND gate.



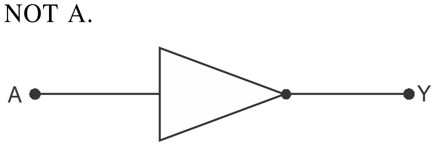
Y = A.B implies Y equals A and B

Truth table of 'AND' gate.

A	B	Y
0	0	0
1	0	0
0	1	0
1	1	1

'NOT' GATE

The bar symbol (¯) is referred to NOT gate. Y = $\overline{A}$ implies Y equals NOT A.



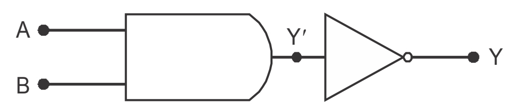
$\overline{0}$ = 1 and $\overline{1}$ = 0

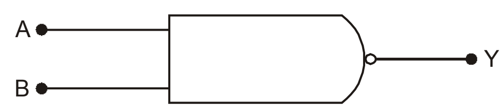
The NOT operation is also called negation or inversion.

A	Y
1	0
0	1

The NAND gate

If the output of AND gate is connected to the input of NOT gate, the gate so obtained is called NAND gate.





Boolean expression for the NAND gate is

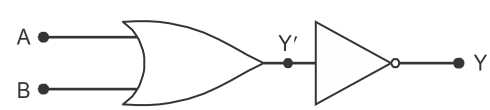
$$y = \overline{A \,.\, B}$$

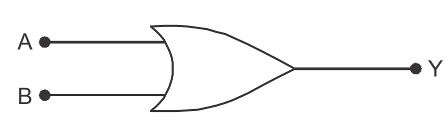
Truth Table

A	B	y	y'
0	0	0	1
1	0	0	1
0	1	0	1
1	1	1	0

The NOR gate

If the output (y') of OR gate is connected to the input of a NOT gate, the gate so obtained is called the NOR gate.





Boolean expression for the NOR gate is

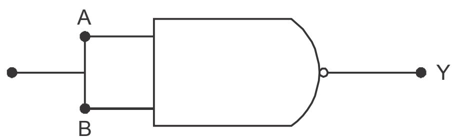
$$y = \left(\overline{A + B}\right)$$

Truth Table

A	B	y'	y
0	0	0	1
1	0	1	0
0	1	1	0
1	1	1	0

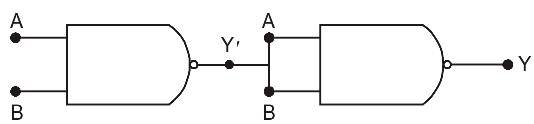
NAND or NOR gate is building block in digital circuit

(*i*) To create Not gate by NAND gate

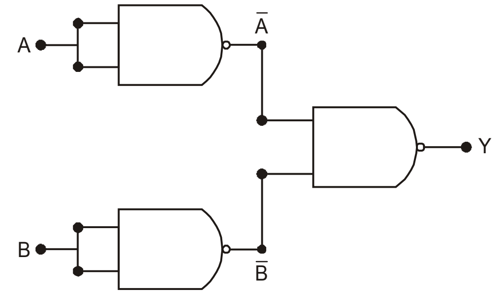


If the two input terminals are joined together, you get a NOT gate

(*ii*) To create AND gate by NAND gates



(*iii*) To create OR gate by NAND gates



TRANSISTOR AS A SWITCH

The transistors that are full 'OFF' are said to be in their cut off region. When using the transistor as a switch, a small base current controls a much larger collector load current, when using transistors to switch inductive loads such as relays and solonoids, a fly wheel diode is used.

EXERCISE

1. A piece of semiconductor is connected in series in an electric circuit on increasing the temperature, the current in the circuit will

A. stop flowing B. decrease
C. increase D. remain unchanged

2. A common emitter transistor amplifier has a current gain of 50. If the load resistance is 4 kΩ and the input resistance is 500 Ω, find the voltage gain of the amplifier.

A. 700 B. 400
C. 500 D. 900

3. In a pn-junction photo cell, the value of photo electro motive force produced by monochromatic light proportional to the

A. frequency of light falling on the cell
B. voltage applied at pn-junction
C. intensity of light falling on the cell
D. barrier voltage at pn-junction

4. A transistor is connected in common emitter (CE) configuration. The collector supply is 8 V and the voltage drop across a resistor of 800 Ω in the collector circuit is 0.5 V. If the current gain factor (α) is 0.96, find the base current.

A. 40 μA B. 35 μA
C. 26 μA D. 15 μA

5. The input resistance of a common emitter amplifier is 665 Ω and the load resistance is 5 kΩ. A change of base current by 15 μA results in the change of collector current by 2 mA. Find the voltage gain of the amplifier.

A. 1002 B. 4300
C. 2100 D. 6103

6. A triode has a mutual conductance of 2.5 m A/V and a plate resistance of 20 kΩ. Calculate the load resistance required for a voltage gain of 30.

A. 10 kΩ B. 20 kΩ
C. 30 kΩ D. 40 kΩ

7. In a triode, the plate current changes by 0.5 mA when the plate potential is changed by 12 V. Find the plate resistance. If the amplification factor is 16, find the change in the grid voltage necessary to produce a change of 4 mA in the plate current.

A. 4 V B. 2 V
C. 7 V D. 6 V

8. A *p*-type semiconductor has acceptor level 57 MeV above the valence band. The maximum wavelength of light required to create a hole is

A. 57 Å B. 57×10^{-3} Å
C. 217100 Å° D. 11.61×10^{-33} Å

9. A triode value has amplification factor 33 and anode resistance of 16 kilo ohm. It is required to amplify a sinusodial signal of 0.5 V to give on output of 12.5 volt. Determine the load resistance required.

A. 70×10^3 Ω B. 40×10^3 Ω
C. 50×10^3 Ω D. 80×10^3 Ω

10. The slope of anode and mutual characteristics of a triode value are 0.02 mA/volt and 1 mA/volt. Then the amplification factor of the value is

A. 5 B. 50
C. 500 D. 0.5

11. 14×10^{15} electrons reach the anode per second. If the power consumed is 448 milli-watts, the anode voltage is

A. 150 V B. 200 V
C. 14 × 448 V D. 448/14 V

12. A change of 0.5 mA in the plate current of a triode occurs when the plate potential is changed by 12 V. Find the plate resistance. If the amplification factor is 16, find the change in grid voltage required to produce a change of 4 mA in the anode current.
A. 600 V B. 0.006 V
C. 6 V D. 60 V

13. The voltage amplification of a triode is 20 with 50 kΩ and 25 with 75 kΩ load resistance. Determine the value constant.
A. 6.66×10^{-4} mho B. 5.55×10^{-4} mho
C. 2.22×10^{-4} mho D. 8.88×10^{-4} mho

14. A diode operating in sapce charge limited region has an anode voltage of 80 V when the current is 100 mA. What is the anode voltage and anode dissipation if the current is 60 mA?
A. 50.2 V, 4.20 W B. 54.6 V, 3.38 W
C. 60.3 V, 8.29 W D. 30.1 V, 6.53 W

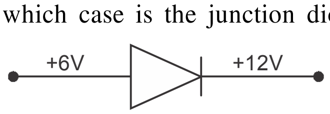
15. A transistor, connected in common emitter configuration, has input resistance R_{in} = 2 kΩ and load resistance of 5 kΩ. If β = 60 and an input signal 12 mV is applied. Calculate the resistance gain, voltage gain, the power gain and the value of output signal.
A. 2.5, 1.8 V, 9000 B. 5.2, 8.1 V, 7000
C. 6.2, 9.8 V, 6000 D. 7.6, 4.3 V, 2000

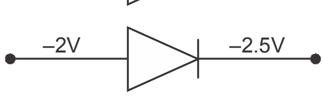
16. The current gain of a common base circuit is 0.97. Calculate the current gain of common emitter circuit.
A. 4.41 B. 8.13
C. 5.62 D. 32.3

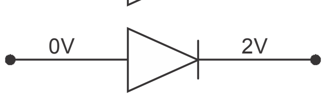
17. In a common base circuit of a transistor, current amplification factor is 0.95. Calculate the base current when emitter current is 2 mA.
A. 0.1 mA B. 100 mA
C. 10 mA D. 1 mA

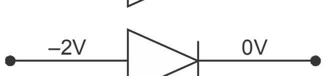
18. In a common-base circuit of a transistor, current amplification factor is 0.95. Calculate the emitter current when base current is 0.2 mA.
A. 6 mA B. 2 mA
C. 9 mA D. 4 mA

19. In which case is the junction diode forward biased

A. 

B. 

C. 

D. 

20. The probability of electrons to be found in the conduction band of an intrinsic semiconductor at a finite temperature.
A. decreases exponentially with increasing band gap.
B. decreases with increasing temperature
C. increasing exponentially with increasing band gap
D. is independent of the temperature and the band gap

21. The electrical conductivity of a semiconductor increases when electromagnetic radiation of wavelength shorter than 2480 nm is incident on it. The band gap (in eV) for the semiconductor is
A. 0.8 B. 0.5
C. 0.7 D. 0.9

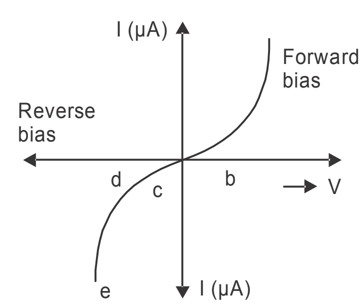
22. A Light Emitting Diode (LED) has a voltage drop 2 V across it and passed a current of 10 mA, when it operates with a V battery through a limit resistor R. The value of R is
A. 5 Ω B. 250 Ω
C. 400 Ω D. 300 Ω

23. The part of transistor, which is heavily doped to produce a large number of majority carriers is called
A. emitter B. base
C. collector D. diode

24. In a transistor amplifier, the two ac current gains α and β are defined as $\alpha = \frac{\Delta I_C}{\Delta I_E}$ and $\beta = \frac{\Delta I_C}{\Delta I_B}$. The relation between α and β is
A. $\beta = \frac{\alpha}{1-\alpha}$ B. $\beta = \frac{\alpha}{\alpha+1}$
C. $\beta = \frac{1+\alpha}{\alpha}$ D. $\beta = \frac{1-\alpha}{\alpha}$

25. In an *npn* transistor, 108 electrons enter the emitter in 10^{-8} s. If 1% electrons are lost in the base, the fraction of current that enters the collector and current amplification factor are respectively.
A. 0.9 and 90 B. 0.8 and 49
C. 0.99 and 99 D. 0.7 and 50

26. The graph given below represents the I-V characteristics of zener diode, which part of the characteristics curve is most relevant for its operation as voltage regulator?



A. ab B. bc
C. cd D. de

27. The saturation current of a *pn* junction germanium at 27°C, is 10^{-5}. What will be the required potential to be applied in order to obtained a current of 250 mA in forward bias?
A. 0.26 V B. 0.34 V
C. 0.41 V D. 0.54 V

28. A transistor is connected in common emitter configuration. The collector supply is 8 V and the voltage drop across a resistor of 800 Ω in the collector circuit is 0.5 V. If the current gain factor (α) is 0.96, then the base current will be
A. 0.125 mA B. 0.0256 mA
C. 0.041 mA D. 0.098 mA

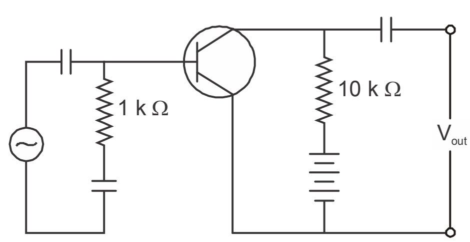
29. A *pn* photodiode is fabricated from a semiconductor with band gap of 2.8 eV. Which of the following wavelengths it can detect?
A. 442 nm B. 580 nm
C. 820 nm D. 950 nm

30. A Ge specimen is dopped with Al. The concentration of accepter atoms is ≃ 10^2 atom m^{-3}. Given the intrinsic concentration of electron hole pair is ≃ 10^{19} m^{-3}. The concentration of electrons in the specimen is
A. 10^2 m^{-3} B. 10^4 m^{-3}
C. 10^{17} m^{-3} D. 10^{15} m^{-3}

31. In a semiconducting material, the mobilities of electrons and holes are μ_e and μ_h respectively. Which of the following is true?
A. $\mu_e < \mu_h$ B. $\mu_0 < 0, \mu_h > 0$
C. $\mu_e = \mu_h$ D. $\mu_e > \mu_h$

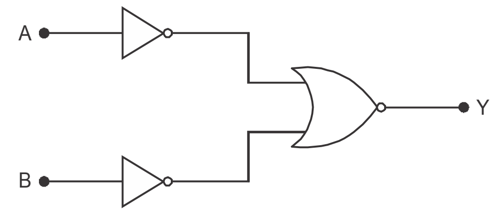
32. A small impurity is added to germanium to get *p*-type semiconductor. This impurity is a
A. pentavalent substance B. bivalent substance
C. monovalent substance D. trivalent substance

33. In the following CE configuration, an *npn* transistor with current gain = 100 is used. The output voltage of the amplifier will be



A. 10 V B. 1 V
C. 0.1 V D. 10 mV

34. Which logic gate is represented by the following combination of logic gates?



A. NOR B. OR
C. AND D. NAND

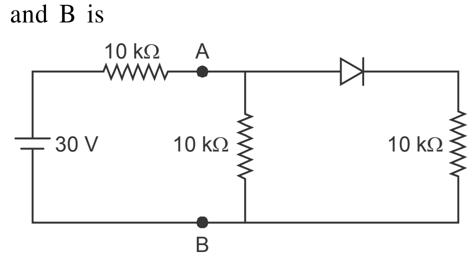
35. A certain logic circuit has A and B as the two inputs and *y* as the output. What is the logic gate in the circuit, if the truth table of circuit is shown?

A	B	Y
0	0	0
1	0	1
0	1	1
1	1	0

A. NAND B. XOR
C. NOR D. OR

36. When the inputs of two input logic gate are 0 and 0, the output is 1. When the inputs are 1 and 0, the output is zero. The type of logic gate is
A. XOR B. NAND
C. NOR D. OR

37. In the given circuit, the potential difference between A and B is



A. 15 V B. 10 V
C. 18 V D. 20 V

38. The common emitter amplifier has a voltage gain 50, an input impedance of 100 Ω and an output impedance of 200 Ω. The power gain of the amplifier is
A. 1000 B. 1250
C. 100 D. 500

39. A transistor is operated in CE configuration at constant collector voltage V_C = 1.5 V, such that a change in the base current from 100 μA to 150 μA produces. A change in the collector current from 5 mA to 10 mA. The current gain β is
A. 50 B. 67
C. 100 D. 75

40. The number of density of electrons and holes in pure silicon at 27°C are equal and its value is 2.0×10^{16}

m^{-3} on doping within, the hole density increases to 4.5×10^{22} m^{-3}, the electron density dopes silicon is

A. 3.57×10^8 m^{-3} B. 8.89×10^9 m^{-3}
C. 3.25×10^9 m^{-3} D. 0.89×10^9 m^{-3}

41. In *pn* junction diode, the reverse saturation current is 10^{-5} A at 27°C. Find the forward current for a voltage 0.2 V. Given exp 7.62 = 2038, K = 1.4×10^{-23} JK^{-1}

A. 2.04×10^{-3} A B. 2.04×10^{-2} A
C. 1.04×10^{-2} A D. 0.34×10^{-2} A

42. A transistor has a current amplification factor (current gain) of 50. In a CE amplifier circuit, the collector resistance is chosen as 5 Ω and the input resistance is 1 Ω. Calculate the outvolt, if input voltage is 0.01 V.

A. 1.5 V B. 0.5 V
C. 2.5 V D. 3.5 V

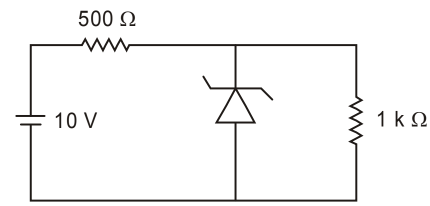
43. Three photodiodes D_1, D_2 and D_3 are made of semiconductors having band gaps of 2.5 eV, 2 eV and 3 eV respectively. Which ones will be able to detect light of wavelength 6000 Å?

A. D_1 B. D_2
C. D_3 D. D_1 and D_3

44. A zener diode has a contact potential of 0.8 V in the absence of biasing. It undergoes zener breakdown for an electric field of 10^6 V/m at the depletion region of *pn* junction. If the width of the depletion region is 2.4 μm, what should be the reverse biased potential for the zener breakdown to occur?

A. 2.4 V B. 3.4 V
C. 4.1 V D. 5.6 V

45. In the following circuit, the current flowing through 1 kΩ resistor is



A. 5 mA B. 1 mA
C. 3 mA D. 0 mA

ANSWERS

1	2	3	4	5	6	7	8	9	10
C	B	C	C	A	C	D	C	C	B
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
B	C	A	B	A	D	A	D	B	A
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
B	C	A	A	C	D	A	B	A	C
31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
D	D	B	D	B	C	B	B	C	B
41	**42**	**43**	**44**	**45**					
B	C	B	A	A					

EXPLANATORY ANSWERS

1. It is because with rise in temperature, the resistance of semiconductor decreases, therefore, overall resistance of circuit decreases. Which in turn increases the current in the circuit.

2. Voltage gain $A_v = \frac{\beta_{ac} R_L}{R_i}$

$$= \frac{50 \times 4000}{500} = 400.$$

3. If a light wavelength sufficient to break the covalent bond falls on the junction, new hole electron pairs are created. Number of produced electron hole pairs depend upon number of photons. Hence, current is proportional to intensity of light.

4. Collector current $I_e = \frac{0.5}{800}$ A

Current gain $\beta = \frac{I_c}{I_b} = \frac{\alpha}{1-\alpha} = \frac{0.96}{1-0.96} = 24$

$\therefore$ $I_b = \frac{I_c}{24} = \frac{0.5}{800 \times 24} = 26\ \mu A$

5. $\beta_{ac} = \frac{\delta I_c}{\delta I_b} = \frac{2 \times 10^{-3}}{15 \times 10^{-6}} = \frac{2}{15} \times 10^3$

Voltage gain

$$A_V = \frac{\beta_{ac} R_L}{R_i} = \frac{2}{15} \times \frac{10^3 \times 5000}{665}$$
$$= 1002$$

6. We have, Voltage gain $A = \frac{\mu R_L}{R_P + R_L} = \frac{R_P\, g_m\, P_L}{R_P + R_L}$

$$30 = \frac{20\times10^3 \times 2.5\times10^{-3} \times R_L}{20\times10^3 + R_L}$$

$\therefore$ $R_L = 30\ k\Omega$

7. Plate Resistance $R_P = \frac{\Delta V_P}{\Delta I_P} = \frac{12}{0.5\times10^{-3}}$

$= 24\ k\Omega$

Mutual Conductance

$$g_m = \frac{\mu}{R_P} = \frac{16}{24000}\Omega^{-1}$$

But $g_m = \frac{\Delta I_P}{\Delta V_g}$

$\therefore$ $\Delta V_g = \frac{\Delta I_P}{\Delta V_g} = \frac{4\times10^{-3}}{16}\times 2400 = 6\text{ V}$

8. As, $\frac{hc}{\lambda} = E \Rightarrow \lambda = \frac{hc}{E}$

$$= \frac{6.6\times10^{-34}\times3\times10^{8}}{57\times10^{-3}\times1.6\times10^{-19}}$$

$= 0.2171 \times 10^{-4}$ m

$= 217100$ Å

9. We have, A = Voltage gain

$$= \frac{\text{Output voltage}}{\text{Input voltage}}$$

$$= \frac{12.5}{0.5} = 25$$

As, $A = \frac{\mu r_L}{r_P + r_L}$ or 25

$$= \frac{33 r_L}{16\times10^3 + r_L}$$

$33 r_L = 25 \times 16 \times 10^3 + 25\ r_L$

or $r_L = (25 \times 16 \times 10^3)/8$

$= 50 \times 10^3\ \Omega$

10. As, $(\Delta i_p/\Delta V_p) = 02$ mA/Volt $(\Delta i_p/\Delta V_g)$

$= 1$ mA/volt

$\therefore$ $\mu = (\Delta V_p/\Delta V_g)$

$= 1/0.2 = 50$

11. As, $V = \frac{P}{i} = \frac{P}{ne} = \frac{448\times10^{-3}}{14\times10^{15}\times1.6\times10^{-19}}$

$= 200$ V

12. As, $r_p = \left(\frac{\Delta V_P}{\Delta i_P}\right)V_g = \frac{12\text{ V}}{0.5\ mA} = 24000\ \Omega$

$$g_m = \frac{\mu}{r_p} = \frac{16}{24}\times10^{-3}\text{ mho}$$

$g_m = (\Delta i_p/\Delta V_g)\ V_P$ or $\Delta V_g = \frac{\Delta i_p}{g_m}$

$$= \frac{4\ mA}{(16/24)\times10^{-3}} = 6\text{ volt}$$

13. As, $A = \frac{\mu RL}{r_p + R_L}; 20 = \frac{\mu\times(50\times10^3)}{r_p + (50\times10^3)}$

$$25 = \frac{\mu\times(75\times10^3)}{r_p + (75\times10^3)}$$

$\therefore$ $r_p = 75\ k\Omega$ and $\mu = 50$

$$g_m = \frac{\mu}{r_p} = \frac{50}{75\times10^3} = 6.66\times10^{-4}\text{ mho}$$

14. As, $I_p = KV_p^{3/2}$ or $100 = K\ (80)^{3/2}$

$60 = K\ (V_p)^{3/2}$

$\therefore$ $\left(\frac{V_P}{80}\right)^{3/2} = \frac{60}{100}$

or $V_P = 54.6$ volt

Anode dissipation

$= I_P\ V_P = 54.6 \times 60 \times 10^{-3} = 3.38$ W

15. The resistance gain $= \frac{R_c}{R_{in}} = \frac{5}{2} = 2.5$

Voltage gain $= \frac{\text{Output voltage}}{\text{Input voltage}} = \beta\frac{R_c}{R_{in}}$

$A = 60 \times 2.5 = 150$

$\therefore$ Output voltage $= 150 \times$ Input voltage

$= 150 \times 12 \times 10^{-3}$

$= 1.8$ V

As, Power gain $= \frac{\beta^2 R_c}{R_{in}} = 60\times60\times2.5 = 9000$

16. As, $\beta = \frac{\alpha}{1-\alpha} = \frac{0.97}{1-0.97} = \frac{0.97}{0.03} = 32.3$

17. As, $\alpha = \frac{I_C}{I_E}$ or $0.95 = \frac{I_C}{2\times10^{-3}}$

$\therefore$ $I_C = 1.90 \times 10^{-3} = 1.9$ mA

$I_B = I_E - I_C = 2$ mA $- 1.9$ mA $= 0.1$ mA

18. As, $\alpha = \frac{I_C}{I_e}$

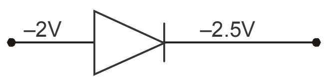
or $I_C = 0.95\ I_e$

$\therefore$ $I_c = I_b + I_c$

$= 0.2\ mA + 0.95\ I_e$

$\therefore$ $I_e = 4\ mA$

19. We have,



20. At finite temperature, the probability of jumping an electron from valence band to conduction band decreases exponentially with the increasing band gap.

$$(E_g)n = n_0 e^{-E_g/K_BT}$$

21. As, $E_g = \frac{hc}{\lambda_{max}} = \frac{1237.5\ eV}{2480\ nm} = 0.5\ eV$

22. A LED is connected to a battery through resistance in series, hence the current flowing is 10 mA.

The voltage drop across LED = 2 V

As the battery has 6 V, the potential difference across,

R = 4 V

$\therefore$ IR = 4 V

or $R = \frac{4\ V}{10 \times 10^{-3}\ A} = 400\ \Omega$

23. The emitter of transistor is heavily dopped so to act as source of majority charge carriers.

24. Clearly, the relation between

α and β is, $\beta = \frac{\alpha}{1-\alpha}$

25. 108 electrons enter the emitter is 10^{-8} s

$$I_E = \frac{108 \times 106 \times 10^{-19}}{10^{-8}} A = 5\ mA$$

$\therefore$ 1% of I_E is lost in base *i.e.*, $I_B = \frac{I_E}{100}$

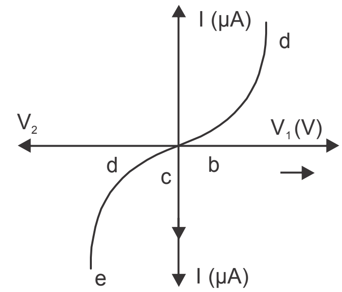
$\Rightarrow$ 90% I_E *i.e.*, $\frac{99}{100}$ I_E enters the collector,

$I_C = 0.99\ I_E$

So, the amplification factory, $\beta = \frac{I_C}{I_B} = \frac{0.99\ I_E}{0.01\ I_E} = 99$

26. When reverse bias is greater than the V_i, there is breakdown condition

For the breakdown region,



Thus, the characteristics curve *de* is most relevant for its operation as voltage regulator.

27. $I = I_0[e^{ev/kT} - 1]$ or $e^{eV/kT}$

$$= \frac{1}{I_0} + 1$$

$$= \frac{250 \times 10^{-3}}{10^{-5}} + 1 = 25001$$

or $\frac{eV}{kT} = 10.126$

or $V = \frac{10.126 \times kT}{e}$

$$= \frac{10.126 \times 1.38 \times 10^{-23} \times 300}{1.6 \times 10^{-19}}$$

$\therefore$ V = 0.26 V

28. As, $I_C = \frac{V_L}{R_L} = \frac{0.5}{800} = \frac{5}{8} mA$

$$I_b = I_e - I_c = \frac{I_c}{\alpha} - I_c = I_c\left(\frac{1}{\alpha} - 1\right)$$

$$= \frac{5}{8}\left(\frac{1}{0.96} - 1\right) = 0.0256\ mA$$

29. As, $\lambda = \frac{1240}{2.8}$ nm = 442 nm

30. Given, As $n_i = 10^{19}\ m^{-3}$ and $n_h = 10^{21}\ m^{-3}$

$n_i^2 = n_e n_h$

$\therefore$ $n_e = \frac{n_i^2}{n_h} = \frac{10^{19} \times 10^{19}}{10^{21}} = 10^{17}\ m^{-3}$

31. The mobility of an electron in the conduction band is more than the mobility of a hole in valence band, i.e., $\mu_e > \mu_h$.

32. A trivalent impurity added to germaniam produces a *p*-type semiconductor.

33. As, $A_V = \frac{V_o}{V_i} = \beta \frac{R_o}{R_i}$

or $V_a = V_i\beta \frac{R_o}{R_i} = 10^{-3} \times 100 \times \frac{10}{1} = 1$ V

34. NAND gate is a universal gate because it repeated, it can give all basic gate like OR, AND and NOT gates.

35. XOR gate gives high output for two difference values of inputs.

36. The logic gate must be a NOR gate, whose output is high, if both the inputs are low.

37. The forward biased *p-n* junction does not offer any resistance,

$\therefore$ $R_{AB} = \frac{10 \times 10}{10 + 10} = 5\ k\Omega$

Total resistance, R = 10 + 5 = 15 kΩ

Current in the circuit, $I = \frac{V}{R} = \frac{30}{15 \times 10^3}$ A

$\therefore$ $I = 2 \times 10^{-3}$ A

Current through each arm $= \frac{I}{2} = 10^{-3}$ A

$\therefore$ $V_{AB} = 10 \times 10^3 \times 10^{-3}$

$= 10$ V

38. $A_p = A_v, A_i = \frac{A_v^2}{A_r} = \frac{(50)^2}{200/100} = 1250$

39. Current gain, $\beta = \frac{\Delta I_C}{\Delta I_B} = \frac{(10-5)\ mA}{(150-100)\ \mu A}$

$= \frac{5 \times 10^{-3}}{50 \times 10^{-6}} = 100$

40. Given, $n_i = 2 \times 10^6\ m^{-3}$,

$n_h = 4.5 \times 10^{22}\ m^{-3}$

As, $n_e = \frac{n_i^3}{n_h} = \frac{(2 \times 10^6)^3}{4.5 \times 10^{22}}$

$= 8.89 \times 10^9\ m^{-3}$

41. As, $I = I_0\left[\exp\left(\frac{eV}{kT}\right) - 1\right]$ since, $I_0 = 10^{-5}$A

$I = 10^{-5}\left[e\frac{1.6 \times 10^{-19} \times 0.2}{1.4 \times 10^{-23} \times 300} - 1\right] = 10^{-5}[e^{7.62} - 1]$

$= 10^{-5}\ (2038.6 - 1) = 2037.6 \times 10^{-5}$

$= 2.04 \times 10^{-2}$ A

42. Given, $\beta = 50$, $R_c = 54\ \Omega = 5 \times 10^3\ \Omega$

$R_B = 14\ \Omega = 1 \times 10^3\ \Omega$,

$V_2 = 0.01$ V, $V_0 = ?$

The voltage given of CE amplifier,

$A_V = \beta\frac{R_o}{R_i}$ or $\frac{V_o}{V_i} = \beta\frac{R_C}{R_B}$

$\therefore$ $V_o = \beta\frac{R_C V_i}{R_B}$

$= \frac{50 \times 5 \times 10^3 \times 0.01}{1 \times 10^3} = 2.5$ V

43. As, $E = hv = hc$

$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{6 \times 10^{-7} \times 1.6 \times 10^{-19}}$

$= 2.06$ eV

For the incident radiation to be detected by the photodiode, energy incident radiation photon should be greater than that the band gap. This is true only for D_2.

44. Given, the breakdown field $E = 10^6\ Vm^{-1}$

The width of the depleton region,

$d = 2.4 \times 10^{-6}$ m

$\therefore$ $V_{breakdown} = E \times d = 10^6 \times 2.4 \times 10^{-6}$

$= 2.4$ V

45. From fig, we see that, the zener diode is used as a voltage regulator device.

So, the voltage across 1 kΩ is 5 V

$\therefore$ Current flowing through 1 kΩ resistor,

$I = \frac{5\ V}{1 \times 10^3\ \Omega}$

$= 5 \times 10^{-3}\ A = 5\ mA$