UNIT IX

ELECTRONIC DEVICES

Weightage Marks : 07

TOPICS TO BE COVERED

Semiconductors

Semiconductors diode-I-V characteristics in forward and reverse bias, diode as rectifier.

I-V characteristics of LED, Photodiodes, solarcell and Zener diode as a voltage regulator, Junction transistor, transistor action, characteristics of a transistor.

Transistor as an amplifier (common emitter configuration)

Oscillator

Logic gates (OR, AND, NOT, NAND and NOR)

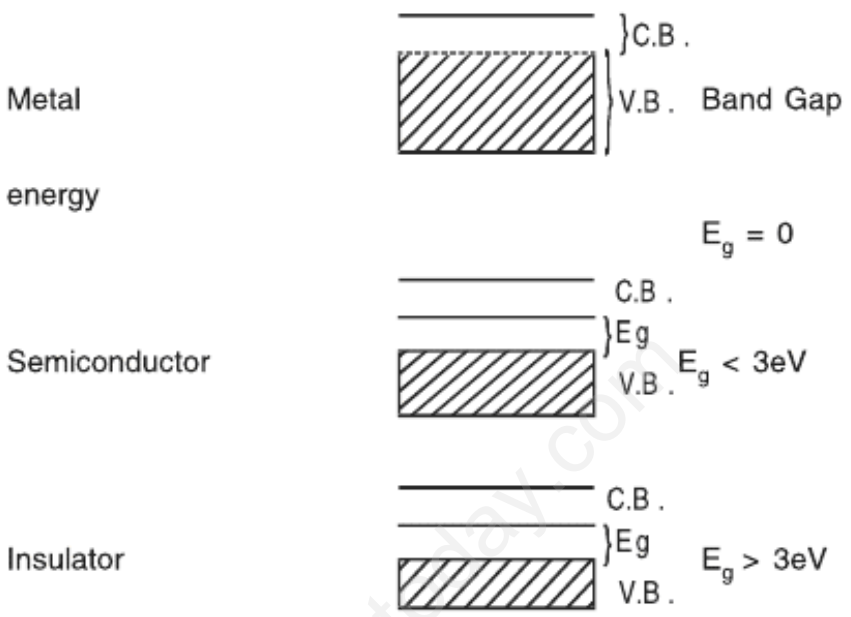
Transistor as a switch—

KEY POINTS

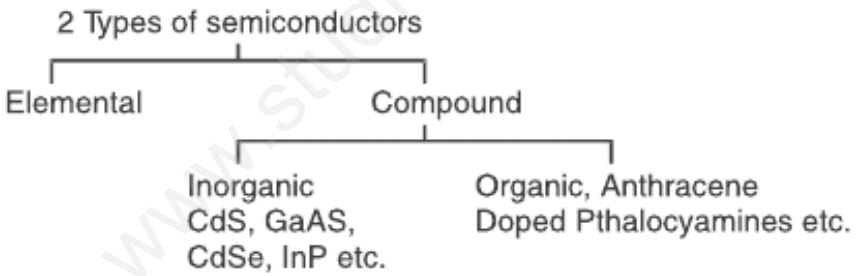
1. Solids are classified on the basic of

(i)	**Electrical conductivity**	**Resistivity**	**conductivity**
	Metals	$\rho(\Omega m)$	$\sigma(Sm^{-1})$
		$10^{-2} - 10^{-8}$	$10^{2} - 10^{8}$
	Semiconductors	$10^{-5} - 10^{6}$	$10^{-6} - 10^{5}$
	Insulators	$10^{11} - 10^{19}$	$10^{-19} - 10^{-11}$

(ii) **Energy Bands**



2. Types of Semiconductors



3. In intrinsic semiconductors (Pure Si, Ge) carrier (electrons and holes) are generated by breaking of bonds within the semiconductor itself. In extrinsic semiconductors carriers (e and h) are increased in numbers by 'doping'.

4. A semiconductor at 0 K temperature behaves as an insulator.

5. Pentavalent (donor) atom (As, Sb, P etc.) when doped to Si or Ge give *n*-type and trivalent (acceptor) atom (In, Ga, Al etc.) doped with Si or Ge give *p*-type semiconductor.

6. Net charge in *p*-type or *n*-type semiconductor remains zero.

7. Diffusion and drift are the two process that occur during formation of *p-n* junction.

8. Diffusion current is due to concentration gradient and direction is from p to n side drift current is due to electric field and its direction is from *n* to *p*-side.

9. In depletion region movement of electrons and holes depleted it of its free charges.

10. Because of its different behaviours in forward biasing (as conductor for V > V_b) and reverse biasing (as insulator for V < V_B) a *p–n* junction can be used as Rectifier, LED, photodiode, solar cell etc.

11. In half wave rectifier frequency output pulse is same as that of input and in full wave rectifier frequency of output is double of input.

12. When a zener diode is reverse biased, voltage across it remains steady for a range of currents above zener breakdown. Because of this property, the diode is used as a voltage regulator.

13. In a transistor current goes from low resistances (forward biasing) to high resistance (reverse biasing).

14. Current relationship in a transistor

$$I_e = I_b + I_c \ (I_b \text{ is only 2\% to 8\% of } I_e)$$

15. In common emitter transistor characteristic we study

I_b versus V_{BE} at constant V_{CE} (Input characteristic)

I_c versus V_{CE} at constant I_B (output characteristic)

Input resistance $$r_i = \left(\frac{\delta V_{BE}}{\delta I_B}\right) V_{CE}$$

Output resistance $$r_0 = \left(\frac{\delta V_{CE}}{\delta I_C}\right) I_B$$

16. Current amplifications factors

$$\beta_{ac} = \left(\frac{\delta I_c}{\delta I_b}\right) V_{CE}$$

$\beta_{dc} = I_c/I_b$.

$\beta_{ac} \approx \beta_{dc}$.

Both β_{ac} and β_{dc} vary with V_{CE} and I_B Slightly.

17. Transistor is used (i) as a switch in cut off and saturation state. (ii) as amplifier in active region.

18. In CE configuration, the output & input of transistor as amplifier differ in phase by π

19. Transistor as an amplifier with positive feedback works as an oscillator.

20. Gates used for performing binary operations in digital electronics mainly consist of diodes and transistors.

21. NAND gates alone can be used to obtain OR gate and similarly a NOR gates alone can be used to obtain AND gate, OR gate.
NAND gates alone can be used to obtain OR AND and NOT gate similarly a NOR gate alone can be used to obtain AND gate, OR gate and NOT gate.

QUESTIONS

VERY SHORT ANSWER QUESTIONS (1 Mark)

1. Write the relation between number density of holes and number density of free electrons in an intrinsic semiconductor.

2. Write the value of resistance offered by an ideal diode when (i) forward based (ii) reverse biased.

3. Write any one use of (i) photodiode (ii) LED.

4. Write the truth table for a two input AND gate.

5. At what temperature does a semiconductor behave as an insulator?

6. Write two uses of logic gates in daily life.

7. If L and C are the inductance and capacitance of the tank circuit of an oscillator, what will be the frequency of oscillation?

8. Semiconductors do not support strong current *i.e.,* a semiconductor is damaged when strong current passes through it. Why?

9. Draw I–V characteristic of a solar cell.

10. What is the phase difference between input and output waveform in the common emitter transistor amplifier?

11. What type of feedback is required in an oscillator? Why?

12. What is the direction of diffusion current in a junction diode?

13. Draw a circuit diagram showing the biasing of a photodiode.

14. Name the semiconductor device that can be used to regulate an unregulated dc power supply.

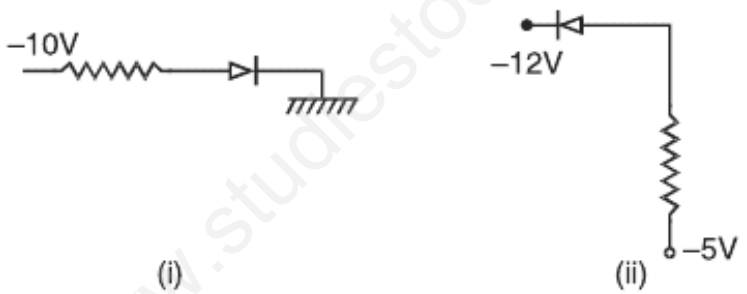
15. Name the p.n. junction diode which emits spontaneous radiation when forward biased.

16. Name any one semiconductor used to make LED.

17. What is meant by 'regulation' as applied to a power supply?

18. A semiconductor device is connected in a series circuit with a battery and a resistance. A current is found to pass through the circuit. When polarity of the battery is reversed, the current drops to almost zero. Name the semiconductor device.

19. In the following diagram write which of the diode is forward biased and which is reverse biased?



20. How does the energy gap in a semiconductor vary, when doped, with a pentavalent impurity?

21. What is the order of energy gap in a conductor, semiconductor and insulator.

22. The ratio of the number of free electrons to holes n_e/n_h for two different materials *A* and *B* are 1 and < 1 respecti vely. Na me the type o f semiconductor to which *A* and *B* belong.

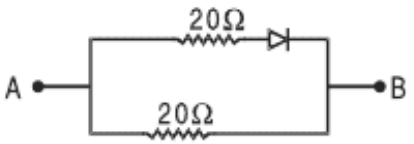
SHORT ANSWER QUESTIONS (2 Marks)

1. If the frequency of the input signal is f. What will be the frequency of the pulsating output signal in case of:

   (i) half wave rectifier? (ii) full wave rectifier?

2. Find the equivalent resistance of the network shown in figure between point A and B when the p-n junction diode is ideal and :

   (i) A is at higher potential (ii) B is at higher potential

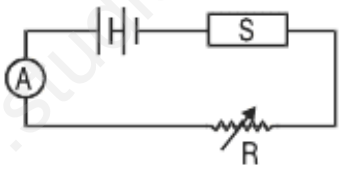


3. Potential barrier of p.n. junction cannot be measured by connecting a sensitive voltmeter across its terminals. Why?

4. Diode is a non linear device. Explain it with the help of a graph.

5. A *n*-type semiconductor has a large number of free electrons but still it is electrically neutral. Explain.

6. The diagram shows a piece of pure semiconductor S in series with a variable resistor R and a source of constant voltage V. Would you increase or decrease the value of R to keep the reading of ammeter A constant, when semiconductor S is heated? Give reason.



7, What is the field ionisation in zener diode? Write its order of magnitude.

8. Power gain of a transistor is high. Does it mean the power is generated by the transistor itself? Explain.

9. What is the role of feedback in an oscillator circuit?

10. Why is a photo diode used in reverse bias?

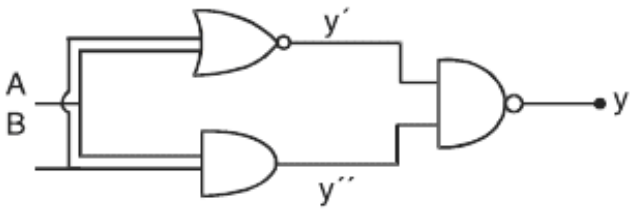
11. Give four advantages of LED over incandescent lamp.

12. Explain the amplifying action of a transistor.

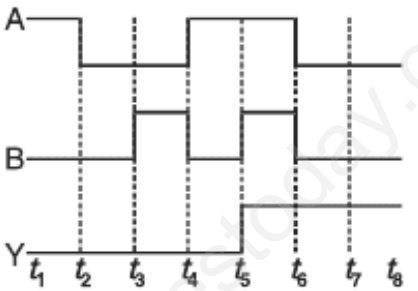
13. Draw a labelled circuit diagram of *n-p-n* transistor amplifier in CE–configuration.

14. The output of a 2 input AND gates fed as input to a NOT gate. Write the truth table for the final output of the combination. Name this new logic gate formed.

15. Write the truth table for the combination of gates shown.



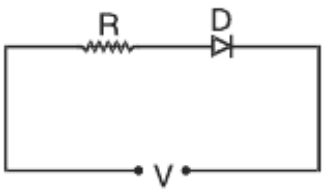
16. The following figure shows the input waveform 'A' and 'B' and output wave form Y of a gate. Write its truth table and identify the gate.



17. In the given circuit, D is an ideal diode. What is the voltage across R. When the applied voltage V makes the diode.

    (a) Forward bias?

    (b) Reverse bias?

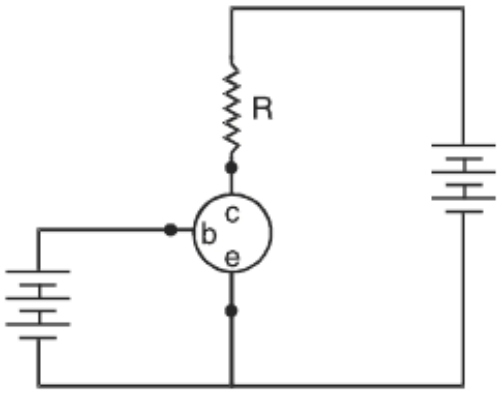


18. A transistor is a current operated device. Explain.

19. Given here is a circuit diagram of a transistor as a NOT gate. Here the transistor has been represented by a circle with the emitter (e), base (b) and collector (c) terminals marked clearly. Carefully look at the polarity of the voltages applied and answer the following question.

    (a) What is the type of transistor *pnp* or *npn*?

    (b) Is the transistor in saturation or cutoff?



20. Why is photodiode used in reverse bias? Give one use of a photodiode.

21. Which special type of diode can act as a voltage regulator? Give the symbol of this diode and draw the general shape of its V-I characteristics.

22. In the working of a transistor as an amplifier mitter base junction is forward biased, while the collector base junction is reverse biased, why.

23. In a transistor, base is slightly doped and is a thin layer, why?

24. Show the donor energy level in energy band diagram of *n*-type semiconductor.

25. Show the acceptor energy level in energy band diagram of *n*-type semiconductor.

26. What is the value of knee voltage in

    (a) Ge junction diode.

    (b) Si junction diode.

27. Which of the input and output circuits of a transistor has a higher resistance and why?

28. Draw the transfer characteristic for a transistor, indicating cut off region, active region and saturation region.

SHORT ANSWER QUESTIONS (3 Marks)

1. What is depletion region in *p-n* junction diode. Explain its formation with the help of a suitable diagram.

2. Explain the working of *npn* transistor as an amplifier and find an expression for its voltage gain.

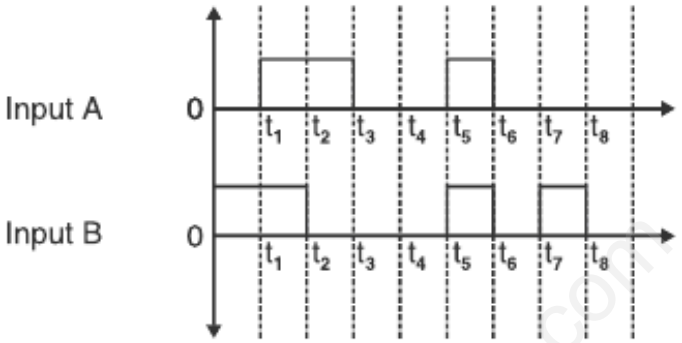
3. What is rectification? With the help of a labelled circuit diagram explain half wave rectification using a junction diode.
4. Explain the working of a transistor as a switch with the help of a suitable circuit diagram.
5. Using block diagram show the feedback in an oscillator.
6. With the help of a circuit diagram explain the V–I graph of a *p-n* junction in forward and reverse biasing.
7. With the help of a circuit diagram, explain the input and output characteristic of a transistor in common emitter configuration.
8. What is *p-n* junction? How is *p-n* junction made? How is potential barrier developed in a *p-n* junction?
9. What is a transistor? Draw symbols of *npn* and *pnp* transistor. Explain action of transistor.
10. Give three differences between forward bias and reverse bias.
11. What is integrated circuit? Give two advantages of integrated circuit over conventional electronic circuit.
12. Write three differences between *n*-type semiconductor and *p*-type semiconductor.
13. Construct AND gate using NAND gate and give its truth table.
14. Construct NOT gate using NAND gate and give its truth table.

LONG ANSWER QUESTIONS (5 Marks)

1. How does a transistor work as an oscillator? Explain its working with suitable circuit diagram. Write the expression for frequency of output.
2. What is the function of base region of a transistor? Why is this region made thin and lightly doped? Draw a circuit diagram to study the input and output characteristics of *npn* transistor in a common emitter configuration. Show these characteristics graphically.
3. What is *p-n* junction diode? Define the term dynamic resistance for the junction. With the help of labelled diagram, explain the working of *p-n* junction as a full wave rectifier.
4. What are logic gates? Why are they so called? Draw the logic symbol and write truth table for AND, OR and NOT gate.

5. Describe (i) NAND gate (ii) NOR gate and

6. Two signals *A*, *B* as given below are applied as input to (i) AND (ii) NOR and (iii) NAND gates. Draw the output waveform in each case.



NUMERICALS

1. In a *p-n* junction, width of depletion region is 300 nm and electric field of 7×10^5 V/m exists in it.

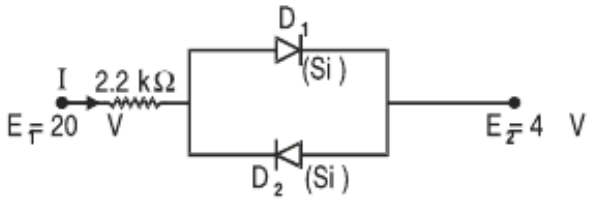
   (i) Find the height of potential barrier.

   (ii) What should be the minimum kinetic energy of a conduction electron which can diffuse from the *n*-side to the *p*-side?

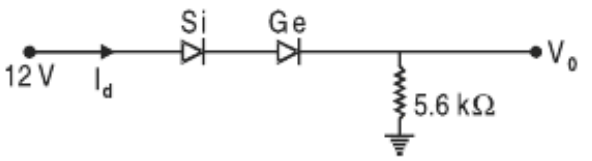
2. In an *npn* transistor circuit, the collector current is 10mA. If 90% of the electrons emitted reach the collector, find the base current and emitter current.

3. An LED is constructed from a *p-n* junction of a certain semiconducting material whose energy gap is 1.9eV. What is the wavelength of light emitted by this LED?

4. Determine the current I for the network. (Barrier voltage for Si diode is 0.7 volt).



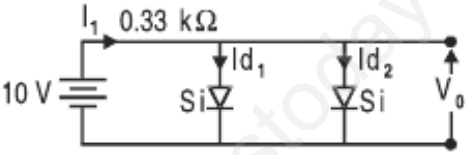
5. Determine V_0 and I_d for the network.



6. A *p-n* junction is fabricated from a semiconductor with a band gap of 2.8 eV. Can it detect a wavelength of 600 nm? Justify your answer.

7. Determine V_0, I_{dl} and I_{d2} for the given network. Where D_1 and D_2 are made of silicon.

$$\left(I_{d1} = I_{d2} = \frac{I_1}{2} = 14.09\ mA \right)$$



8. Two amplifies with voltage gain 10 and 20 are connected in series. Calculate the output voltage for an input signal of 0.01 volt. [**Ans.** : 2 volt]

9. A transistor has a current gain of 30. If the collector resistance is 6kW and input resistance 1kΩ. Calculate the voltage gain. [**Ans.** : 180]

10. If the current gain of a CE – Amplifier is 98 and collector current I_c = 4mA, determine the base current. [**Ans.** : I_b = 0.040mA]

11. Pure Si at 300 K has equal electron (n_e) and hole (n_h) concentration of 1.5 × $10^{16}/m^3$. Doping by indium increases n_h to 4.5 × $10^{22}/m^3$. Calculate n_e in the doped silicon. [**Ans.** : 5× 10^9 m^{-3}]

12. The solar radiation spectrum shows that maximum solar intensity is near to energy hv = 1.5 eV. Answer the following :

    (i) Why are *Si* and *GaAs* are preferred materials for solar cells.

    (ii) Why *Cd S* or *CdSe* (*Eg* ~ 2.4 *eV*) are not preferred.

    (iii) Why we do not use materials like *PbS* (*Eg* ~ 0.4 *eV*).

    Ans.

    (i) For photo-excitation, *hv* > *Eg*. *Si* has *Eg*. ~ 1.1 *eV* and for *GaAs*, *Eg*. ~ 1.53 *eV*.

GaAs is better than *Si* because of its relatively higher absorption coefficient.

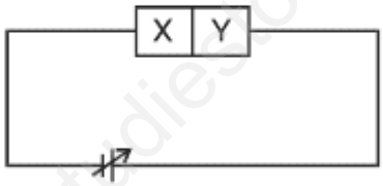
(ii) If we choose *CdS* or *CdSe*, we can use only the high energy component of the solar energy for photo-conversion and a significant part of energy will be of no use.

(iii) The condition $h\nu > Eg.$ is satisfied, but if we use *Pbs*, most of solar radiation will be absorbed on the top-layer of solar cell and will not reach in or near depletion region.

HOTS

SHORT ANSWER QUESTIONS (2 Marks)

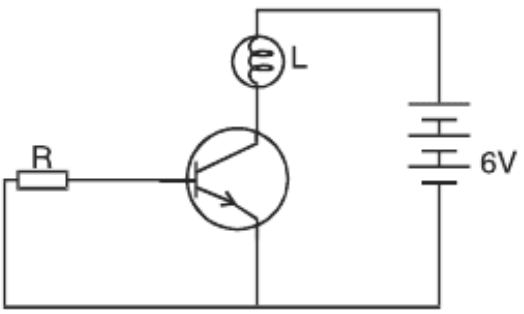
1. Two semiconductor materials X and Y shown in the given figure, are made by doping germanium crystal with indium and arsenic respectively. The two are joined end to end and connected to a battery as shown.



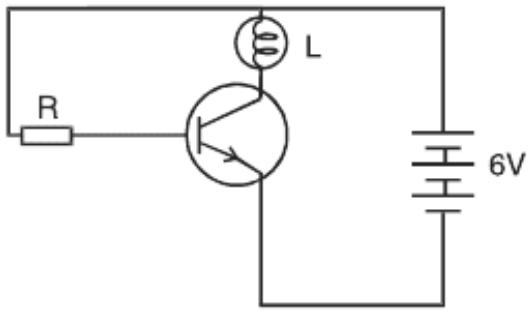
(i) Will the junction be forward biased or reversed biased?

(ii) Sketch a V–I graph for this arrangement.

2. In only one of the circuits given below the lamp L lights. Which circuits is it? Give reason for your answer.

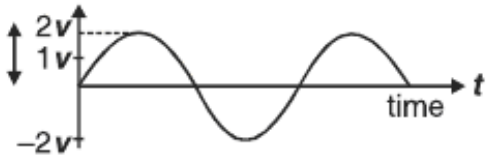


(a)



(b)

3. Following voltage waveform is fed into half wave rectifier that uses a silicon diode with a threshold voltage of 0.7V. Draw the output voltage. waveform.



4. Why are Si and GaAs are preferred materials for solar cell.

ANSWERS

VERY SHORT ANSWER QUESTIONS (I Mark)

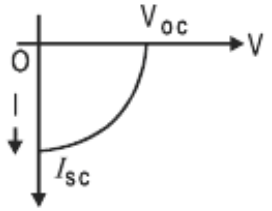
1. $n_e = n_h$.

2. (i) zero (ii) Infinite

7. Frequency of A.C. $f = \frac{1}{2\pi\sqrt{LC}}$.

8. Because bonds break up, crystal breakdown takes place and crystal becomes useless.

9. I – V characteristic of solar cell :



10. Phase difference between input and output waveform is π or 108°.

11. Positive feedback.

12. Direction of diffusion current is from P to N in a semiconductor junction diode.

15. Light emitting diode.

16. GaAs, GaP.

17. Constant power supply.

20. The energy gap decreases.

21. Conductor – no energy gap

Semi conductor – < 3 *eV*

Insulator – > 3 *eV*.

22. $n_e/n_h = 1 \Rightarrow n_e = n_n \therefore$ intrinsic semiconductor.

$n_e/n_n < 1 \Rightarrow n_e = n_n \therefore$ *p*-type extrinsic semiconductor.

SHORT ANSWER QUESTIONS (2 Marks)

1. Frequency of output in half wave Rectifier is *f* and in full have rectifier is 2*f*.

2. Equivalent resistance is

(i) 10Ω (ii) 20Ω

3. Because there is no free charge carrier in depletion region.

6. On heating S, resistance of semiconductors S is decreased so to compensate the value of resistance in the circuit R is increased.

10. In this case diode is sensitive and it gives very large amount of current in this situation.

15.

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

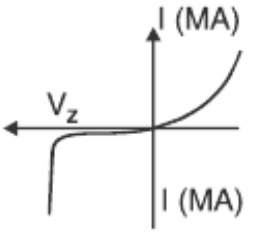
17. (a) V. (b) Zero

18. Change in I_c is related to I_b and not to the base voltage change (δV_{be}).

19. (a) *npn* (ii) saturation

21. Zever diode

(i) Reverse Bias



(ii) Iosmard Bias

22. To make transistor to act as an amplifier.

24. N.C.E.R.T. pg. 477

25. N.C.E.R.T. pg. 477

26. Ge ~ 0.2V

Si ~ 0.7 V.

27. Output circuit is reverse biased, which has large resistance.

NUMERICALS

1. (i) $V = Ed = 7 \times 10^5 \times 300 \times 10^{-9} = 0.21\,V$

(ii) Kinetic energy = eV = 0.21 eV

2. Emitter current $I_e = \frac{10}{90} \times 100 = 11.11\,mA$

Base current $I_b = I_e - I_c = 11.11mA$

4. $$I = \frac{E_1 - E_2 - V_d}{R} = \frac{20 - 4 - 0.7}{2.2 \times 10^3} = 6.95m\ A$$

5. $$V_0 = E - V_{si} - V_{Ge} = 12 - 0.7 - 1.1 = 12 - 1.8 = 10.2\ V$$

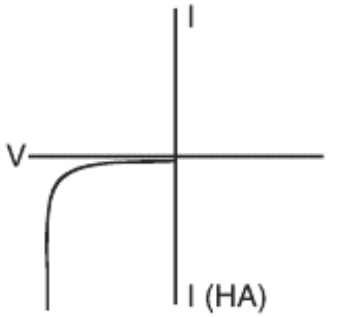
$$I_d = \frac{V_0}{R} = \frac{10.2}{5.6 \times 10^3} = 1.82\ mA.$$

ANSWERS OF HOTS

2 MARK QUESTIONS

1. (i) Reverse bias

(ii)



2. (b)

3. Output waveform is :