BPSC TEST

Date: 1 July, 2018

TEST 02 (OBJECTIVE SOLUTION)...

ANSWERS

1.	(b)	16.	(d)	31.	(c)	46.	(b)	61.	(b)
2.	(a)	17.	(c)	32.	(a)	47.	(c)	62.	(a)
3.	(d)	18.	(b)	33.	(c)	48.	(c)	63.	(d)
4.	(b)	19.	(c)	34.	(b)	49.	(d)	64.	(b)
5.	(a)	20.	(b)	35.	(b)	50.	(d)	65.	(b)
6.	(c)	21.	(d)	36.	(a)	51.	(d)	66.	(a)
7.	(b)	22.	(c)	37.	(a)	52.	(c)	67.	(d)
8.	(a)	23.	(d)	38.	(c)	53.	(a)	68.	(a)
9.	(a)	24.	(a)	39.	(c)	54.	(a)	69.	(d)
10.	(d)	25.	(c)	40.	(b)	55.	(d)	70.	(c)
11.	(c)	26.	(b)	41.	(d)	56.	(a)	71.	(b)
12.	(b)	27.	(b)	42.	(b)	57.	(d)	72.	(d)
13.	(b)	28.	(d)	43.	(b)	58.	(a)	73.	(d)
14.	(a)	29.	(c)	44.	(b)	59.	(b)	74.	(b)
15.	(b)	30.	(d)	45.	(c)	60.	(a)	75.	(c)

BPSC TEST-02 Solutions

Date: 1 July, 2018

1. **(b)**

- In a pure semiconductor the no of holes and electrons are equal and is given by

$$n = p = n_i$$

where n = no of electrons

p = no of holes

n_i = intrinsic carrier concentration

- If the temperature of semiconductor increases, the concentration of charge carriers (electrons and holes) is also increased. Hence the conductivity of a semiconductor is increased accordingly.
- The relation between temperature and concentration of charge carriers in pure semiconductor is given as

$$n_i^2 = A_0 T^3 e^{-E_{G0/KT}}$$

where T is the temperature in Kelvin scale.

2. **(a)**

In an extrinsic semiconductor,

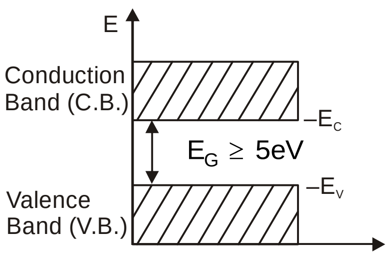
	Extrinsic Semicondcutor	
	p-type	n-type
Majority carrier concentration	$p_p = N_A$	$n_n = N_D$
Minority carrier concentration	$n_p = \frac{n_i^2}{N_A}$	$p_n = \frac{n_i^2}{N_D}$
Condutivity	$\sigma_p = q(p_p\mu_p + n_p\mu_n)$ $\simeq qp_p\mu_p$ $(\because p_p >> n_p)$ $\sigma_p \simeq qN_A\mu_p$	$\sigma_n = q(n_n\mu_n + p_n\mu_p)$ $\simeq qn_n\mu_n$ $(\because n_n >> p_n)$ $\sigma_n \simeq qN_D\mu_n$

Thus, conductivity of an extrinsic semiconductor significantly depends upon majority charge carrier, generated due to impurity doping.

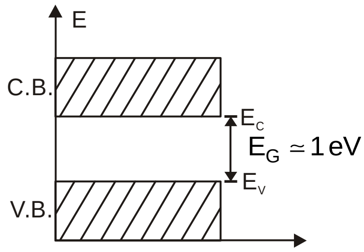
3. **(d)**

Energy Band Structure :

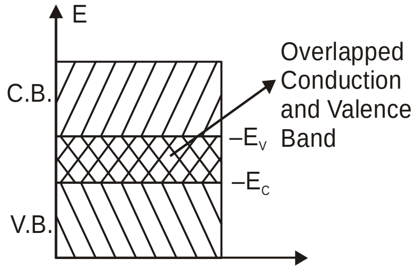
Insulators :



Semiconductors :



Metals :



4. **(b)**

Boron Aluminium, Gallium and Indium are Group-III elements. By doping Germanium with Group-III elements leads to formation of P-type Semiconductors. Also, Doped semiconductors are called extrinsic semiconductors.

5. **(a)**

Phosphorus, Arsenic and Antimony are Group V elements. Addition of Group V elements in Silicon increases the concentration of free electrons. Thus introduction of these impurities leads to the formation of n-type Silicon.

6. **(c)**

Drift velocity (v_d) is given by

$v_d = \mu E$, where

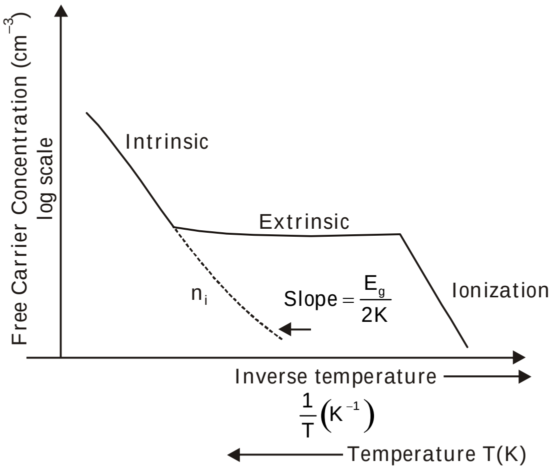
μ = mobility

E = Electric field

$\therefore \quad v_d \propto \mu$

- The amount of drift attained by the mobile charge carrier to move inside the semiconductor material is called mobility.
- Finite value of speed attained by the mobile charge carrier when it undergoes multiple inelastic collisions with the static atoms of the sample is called drift velocity.

7. (b)



At very high temperature, thermal breakdown of bonds takes place which results in equal increase of electrons and holes.

$$n = n_0 + \delta n \quad [\delta n = \delta p]$$

$$p = \frac{n_i^2}{n_0} + \delta p \quad \left(\because p_0 = \frac{n_i^2}{n_0}\right)$$

At very high temperature,

$$\delta n >> n_0$$

$$\delta p >> p_0$$

Alternate:

Effect of Temperature: When the temperature of an n-type semiconductor is raised, the number of electron-hole pairs due to thermal excitation from the valence band to the conduction band will increase. The number of electrons coming from the donor level will remain constant as all the donor atoms are already ionized. At a very high temperature the concentration of thermally generated free electrons from the valence band will be much larger than the concentration of free electrons contributed by the donors. At this situation the hole and the electron concentrations will be nearly equal and the semiconductor will behave like an intrinsic semiconductor. The same argument shows that a p-type semiconductor will also behave like an intrinsic semiconductor at a very high temeperature. The general result is that as the temperature of an extrinsic semiconductor increases, the semiconductor behaves as an intrinsic semiconductor.

8. (a)

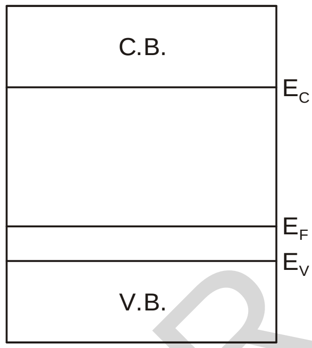


Fig. : Band Diagram of P-type semiconductor

From the figure we can observe that the Fermi level (E_F) in p-type semiconductor is closed to the valence band (E_V).

9. (a)

The covalent bond energy in germanium is about 7.4 eV.

10. (d)

A heavily doped semiconductor will behave as a metal due to which it exhibit a positive temperature coefficient of resistance.

11. (c)

$\frac{1}{\rho}$ is called Hall coefficient

i.e., $R_H = \frac{1}{\rho}$

Given that $\frac{1}{\rho}$ is found to be zero.

$$\frac{1}{\rho} = R_H = 0$$

$$\rho = \text{Charge density}$$

ρ is given by,

$$\rho = q.N$$

$$q = \text{Charge of material (constant)}$$

$$N = \text{Number of atoms/cm}^3$$

$$R_H = \frac{1}{q.N} = 0$$

$$N = \infty$$

As, we all know for metal, the number of atoms are infinite and $R_H = 0$.

12. (b)

Continuity equations in doped semi-conductor under low level injection.

$$\frac{\partial \rho_v}{\partial t} = \frac{P_o - P}{Z_p} - \frac{1}{q}\frac{\partial J_p}{\partial x}$$

or generally,

$$\bar{\nabla}.\bar{J} = -\frac{\partial \rho_v}{\partial t}$$

$\therefore$ It is based on law of conservation of charge.

13. (b)

A hole in a semiconductor has

(i) positive charge equal to the electron charge

(ii) an effective mass slightly greater than that of electron.

14. (a)

Medium doping : $1 : 10^6$ or $1 : 10^7$

Light doping : $1 : 10^{10}$ or $1 : 10^{11}$

High doping : $1 : 10^2$ or $1 : 10^3$

15. (b)

Assume semi-conductor to be intrinsic unless anything about doping is mentioned.

When temperature increases, generation of electron holes pairs and hence 'n' increases.

For intrinsic, only lattice scattering is present.

$$\therefore \quad \mu \propto \frac{1}{T}$$

So temperature increases,

μ decreases

$\bar{v}_d = \mu\bar{E}$ (decreases)

i.e. drift velocity decreases.

16. (d)

In intrinsic semiconductor, n = p (electron and hole concentrations are equal)

As temperature increases, more no. of new electron-hole pairs will be generated. Hence carrier density increases.

As temperature increases, conductivity of the intrinsic semiconductor increases.

17. (c)

In metals, as temperature increases, the amplitude of lattice vibration increases. This results into increase in interatomic collision. Hence mobility decreases and thus, resistivity decreases.

18. (b)

Arsenic being pentavalent atom has excess of electrons which, on donor level ionization donates all its excess electrons in the conduction band thereby producing an N-type semiconductor in which charge carriers are predominantly electrons and holes are present in minority.

19. (c)

Diffusion constant cannot be measured/determined using Hall effect. Quantities that can be measured using Hall effect are

(i) type of semiconductor.

(ii) mobility of charge carriers

(iii) carrier concentration

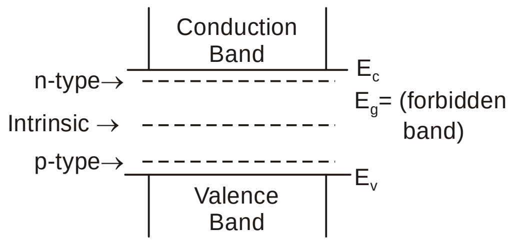
(iv) measure resistivity of material

To find diffusion constant, Haynes-Schockley method is used.

20. (b)

The fermi level is different for each material

- If the fermi level is at centre of the forbidden band then the material is called intrinsic semiconductor.
- If the fermi level is located between the centre of forbidden band, and the conduction band, then the material is n-type semiconductor.



- If fermi level is below the centre of forbidden band then the material is p-type semiconductor.

21. (d)

Drift velocity, $v_d = \mu E$

$$\therefore \quad \mu = \frac{v_d}{E}, \qquad ...(i)$$

where

μ = Mobility

E = Electric field

From equation (i) we can observe that mobility is given by drift velocity per unit field.

22. (c)

The intrinsic concentration is given as

$$n_i^2 = AT^3 e^{-(E_{GO}/KT)}$$

It is clear that intrinsic concentration (n_i)

(i) varies non-linearly with temperature (T).

(ii) increases exponentially with decrease of band gap energy (E_g).

23. (d)

Conductivity is given as

$$\sigma = \left(n\mu_n + p\mu_p\right)q$$

μ_n, μ_p = mobility of electron, hole

n, p = Concentration of electron, hole

q = charge of electron/hole.

Hence, conductivity is not proportional to surface states in the semiconductor.

24. (a)

We know that

$$v_d = \mu E$$

$$\Rightarrow \text{Mobility, } \mu = \frac{v_d}{E} = \frac{m/s}{V/m}$$

Thus, unit of μ is $\frac{m^2}{V-s}$ i.e. $m^2V^{-1}s^{-1}$.

25. (c)

We know Hall Co-efficient (R_H) = $\frac{V_H}{JBW}$

where J = current density

B = magnetic flux density

W = width of the semiconductor

V_H = hall voltage

$$\text{as} \uparrow (R_H) = \frac{1}{(B)\downarrow}$$

As Hall co-efficient has inverse relation with magnetic flux density. Hence the hall coefficient changes with change in magnetic field. Hall co-efficient is independent of change in temperature. Hence both options (c and d) are correct.

26. (b)

For large electric fields (> 10^3 V/cm), silicon (si), Germanium (Ge), Gallium arsenide (GaAs) and Iridium phosphide (IrP) does not follow Ohm's law.

27. (b)

At low temperatures, there are no charge carriers present in the extrinsic semiconductor (say n-type semiconductor).

As temperature is increased (upto 300 K), impurity ionization dominates and the no. of charge carriers (here, electrons) is equal to that of doping concentration (All the donor atoms are ionized).

When temperature is further increased (around 1000K), band-to-band transition dominates over impurity ionization and equal no. of electrons and holes are generated. In this case, electron and hole concentration is much greater than doping concentration. Thus, extrinsic semiconductor behaves as an intrinsic semiconductor.

28. (d)

Donor impurities are pentavalent atom which are

(i) Phosphorus (P)

(ii) Arsenic (As)

(iii) Antimony (Sb)

(iv) Bismuth (Bi)

However, Boron and Indium are Acceptor impurities as they are trivalent atoms.

29. (c)

Conductivity is given mathematically as

$$\sigma = nq\mu_n + pq\mu_p$$

For P-type semiconductor,

$$p >> n$$

$$\therefore \quad \sigma_P \approx pq\mu_p$$

30. (d)

At room temperature, intrinsic semiconductor will have equal number of electrons and holes. So, any kind of change in current will be attributed to both electrons and holes.

31. (c)

$$E = h\nu = \frac{hc}{\lambda}$$

As 'λ' (wavelength) decreases, energy of photon increases. Hence there will be higher velocity of electron corresponding to high energy.

32. (a)

The Hall Coefficient is given as

$$R_H = \frac{1}{\rho}, \quad \rho = \text{charge density}$$

$$\text{or} \quad R_H = \frac{\mu}{\sigma}$$

[$\therefore \sigma = \mu\rho$, where σ =conductivity, μ = mobility]

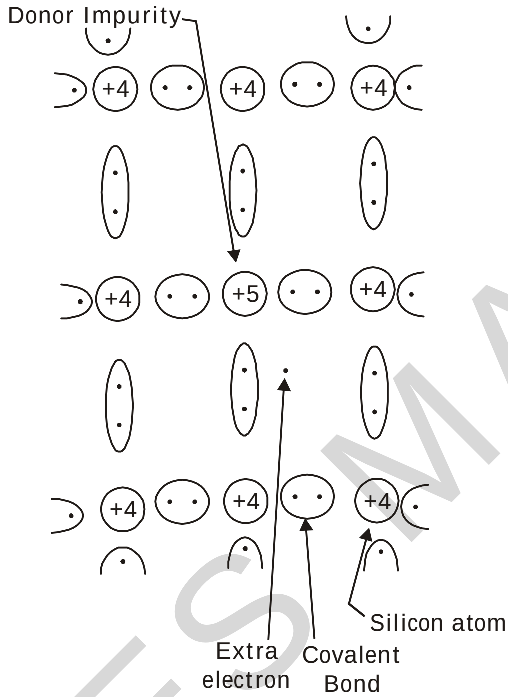
or $\frac{1}{\rho} = \frac{\mu}{\sigma}$

or $\mu = \sigma R_H$

This is used to determine mobility.

33. **(c)**

N-type semiconductor has excess of electrons in conduction band and it can be achieved by doping an intrinsic semiconductor with pentavalent atom such as phosphorus. Other pentavalent atom or donor impurities include As, Sb, Bi.



34. **(b)**

Gallium arsenide phosphide is used for manufacturing red, orange and yellow light emitting diodes.

35. **(b)**

In a semiconductor diode, cut in voltage is the voltage at which the current starts flowing is around 1% of the rated current which is very small.

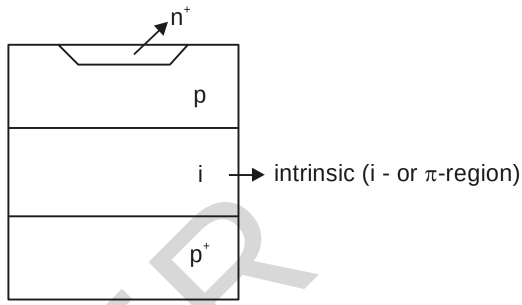
36. **(a)**

Necessary condition for photoelectric emission is that energy of the incident photon must be greater than the work function of the material i.e.

$$h\nu \geq e\phi$$

37. **(a)**

The basic structure of an Avalanche Photodiode is shown below:



Thus, $p^+ - i - p\ n^+$ is the basic structure of an Avalanche Photodiode.

38. **(c)**

- Built-in potential in a p-n junction is equal to the difference in the Fermi level of the two sides, expressed in volts.
- Built-in voltage (V_{bi}) is given by

$$V_{bi} = \frac{kT}{q} \ln\left(\frac{N_A N_D}{n_i^2}\right)$$

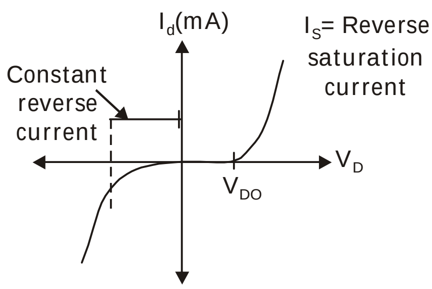
- Thus, Built-in potential increases with increase in the doping levels of the two sides.

Built-in potential also increases with increase in temperature.

39. **(c)**

Voltage characteristic of p-n diode

$$I_D = I_S\left(e^{V_D/\eta V_T} - 1\right)$$



- I_S (Reverse saturation current) proportional to area.
- The reverse saturation current is temeperature dependent.
- Reverse saturation current doubles for each 10°C rise in temperature.

So, by increasing the reverse bias voltage in p-n diode, the reverse current remains constant.

40. (b)

The efficiency of LED is $\eta = \frac{\phi_T}{P_{LED}}$

where $\phi_T = \left(\frac{h_e}{q_p e\lambda}\right)\left(\frac{2\pi}{a}\sum I(r_i)r_i + \pi\sum I(r_i)\right)$

hence $\eta \;\alpha$ current injected $I\ (r_i)$

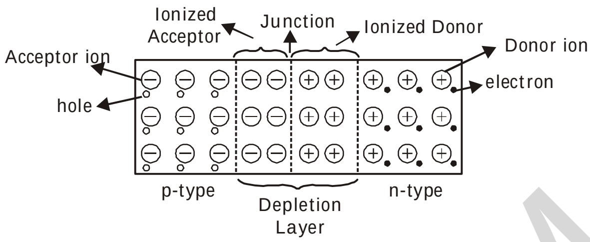
$\alpha\ \frac{1}{T}$ (inversely proportional to temperature)

41. (d)

Reverse saturation current is typically (1/1000) times its value in forward bias condition.

42. (b)

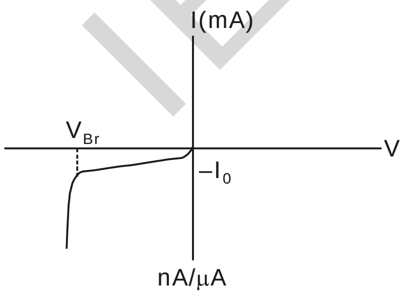
The schematic diagram of a p-n junction diode is shown below.



43. (b)

The reverse saturation current of a silicon diode is highly sensitive to temperature i.e. for every 10°C rise in temperature, reverse current doubles and for every 1°C rise in temperature, reverse saturation current increases by 7%. The mathematical relation is

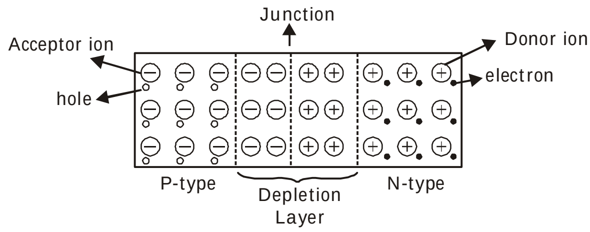
$$I(T_2) = \quad I(T_1).2^{T_2 - T_1/10}$$



But if we look at I-V characteristic of diode under reverse bias condition, for a wide range of voltage, reverse saturation current remains constant.

44. (b)

The schematic diagram of a p-n junction diode under open circuit condition is shown below.



Depletion region is depleted of charge carriers i.e. electrons or holes. It has positive ion (donor ion) on n-side and negative ion (acceptor ion) on p-side.

45. (c)

GaAs is a direct bandgap material and Gunn diode is generally made up of GaAs.

46. (b)

Width of depletion region $\propto \frac{1}{\text{doping level}}$

As p^+ is heavily doped as compared to 'n'. Hence depletion layer mostly lie in n-region.

47. (c)

The leakage current in an NPN transistor is due to the flow of holes from collector to base.

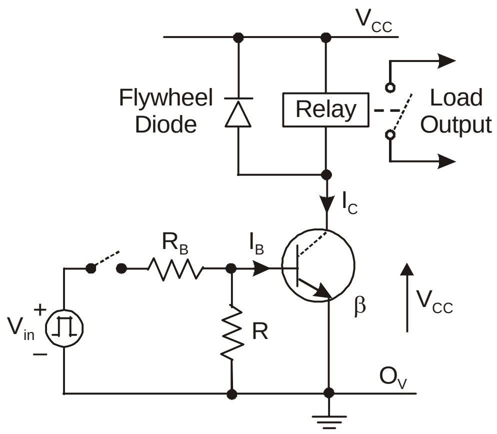
48. (c)

Due to reverse biased collector junction the depletion region width starts increasing. As the reverse bias is further increased the depletion region starts moving towards the base region as the base is least doped. This phenomenon of variation of base region is called early effect(or) base width modulation.

49. (d)

An example of an NPN Transistor as a switch being used to operate a relay is given below. With inductive loads such as relays or solenoids a flywheel diode is placed across the load to dissipate the back EMF generated by the inductive load when the transistor switches "OFF" and to protect the transistor from damage. If the load is of a very high current or voltage, such as motors, heaters etc., then the load current can be controlled via a suitable relay as shown.

Transistor Switching Circuit



50. (d)

BJT operates as a switch under cut off region (OFF) and saturation region (ON)

51. (d)

In n-p-n transistor, the electrons are the majority carriers. However in case of p-n-p transistor, holes (majority carriers) diffuse. Also the mobility of electrons is more than that of holes. Therefore n-p-n transistors are preferred over p-n-p transistors.

52. (c)

When transistor is saturated, then

$$I_{C,sat} < \beta I_B$$

or $$\beta > \left(\frac{I_{C,sat}}{I_B}\right)$$

And base potential becomes more than emitter and collector potentials. In this case, both EB and CB junction will be forward biased.

53. (a)

BJT operating in common collector configuration is also known as emitter follower whose characteristics are

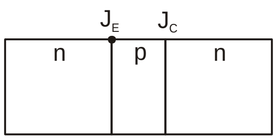
(i) high input impedance.

(ii) low output impedance.

(iii) unity voltage gain

(iv) high current gain

54. (a)



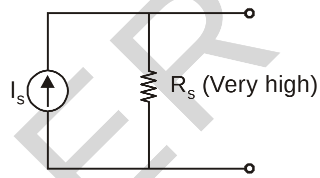
In a junction transistor the recombination of electron and holes occurs in base, emitter, collector region.

55. (d)

In npn transistor, in the Base region, the main stream of current is diffusion of electrons because electrons emit from emitter and some electrons diffuse in the base region. The minority current I_{nE} is electron diffusion current.

56. (a)

The internal resistance of a current source should be very high (ideally infinite) in order to avoid loading of source.



57. (d)

We know that

Rise in the junction temperature with respect to the ambient temperature,

$$\Delta T = T_j - T_A = \theta . P_D$$

ΔT = Change in temperature,

T_j = Junction temperature,

T_A = Ambient temperature,

θ = Thermal resistance,

P_D = Power dissipation

$$[\theta] = [\Delta T]/[P_D]$$

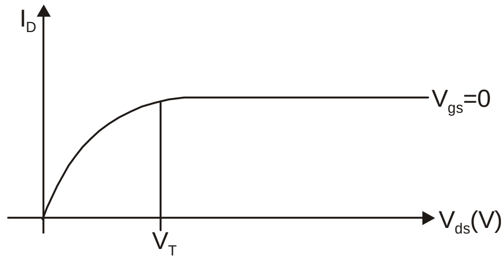
Thus,unit of thermal resistance is $°C/watt$.

58. (a)

FET possess a temperature coefficient at high current levels that prevents the thermal runaway phenomena that may occur in BJT. This is because, at all but very low drain currents, the temperature dependence is dominated by the negative temperature coefficient of the threshold voltage. This means that, as the temperature of the FET increases, the mobility of the charge carriers in the channel decreases.

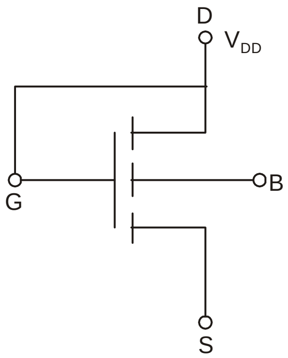
59. (b)

With the increase in drain to source voltage (by keeping V_{GS} constant) the drain current increases. It happens in the triode region. After a certain voltage called pinch off voltage, the drain current ceases to increease and remains constant even with the increase in V_{DS}. This region is called saturation region.



60. (a)

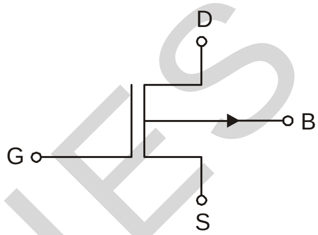
When gate is directly connected to drain, the enhancement type MOSFET is permanently ON. Hence, it acts like an active load.



61. (b)

Body effect refers to change in transistor threshold voltage (V_T) due to the voltage difference between source and the body. the change may be reduction (or) increase in threshold voltage.

62. (a)



It is a p-channel depletion type MOSFET.

63. (d)

In microprocessor, power dissipation requirement is very low. Hence CMOS is suitable. It also has good speed of operation.

64. (b)

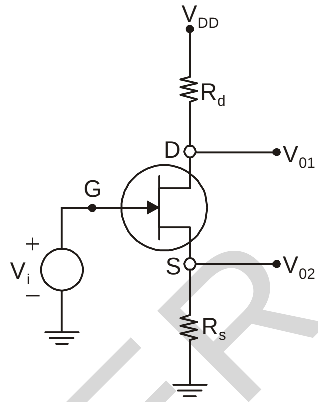
For an N-channel JFET to be operated as an amplifier, following conditions has to be fulfilled.

(i) $V_{GS} < 0$ i.e. Gate voltage has to be at negative potential as compared to source.

(ii) $V_{DS} > V_{th} > 0$ i.e. Drain to source voltage has to be positive with higher potential at drain end.

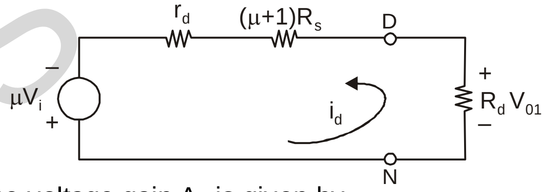
65. (b)

The generalized FET amplifier is shown below :



- If $V_{02} = 0$, then configuration is common source.
- $V_{01} = 0$, then configuration is common drain.

As per question, $V_{02} = 0$, then its equivalent circuit becomes



The voltage gain A_V is given by

$$A_V = \frac{-\mu R_d}{r_d + (\mu+1)R_s + R_d}$$

At $R_s = 0$

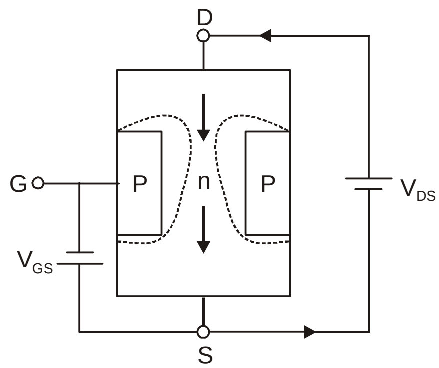
$$A_V = \frac{-\mu R_d}{r_d + R_d}$$

In general, $R_d >> r_d$

$$\therefore \quad A_V = \frac{-\mu R_d}{R_d} \approx -\mu$$

So, A_V depends on μ (amplification factor).

66. (a)



(n-channel JFET)

As V_{gs} is given more negative bias, the gate to source becomes more reverse biased, due to which depletion width increases. More the reverse bias more is depletion width and due to which channel width also changes.

67. **(d)**

CMOS is complementary MOS and it comprises of both PMOS and NMOS connected in series. It has low power dissipation as only one transistor will be ON at a time. Both transistors are never ON simultaneously.

68. **(a)**

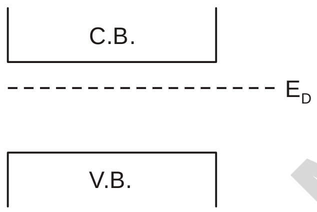
Hall coefficient,

$$R_H = \frac{1}{nq}$$

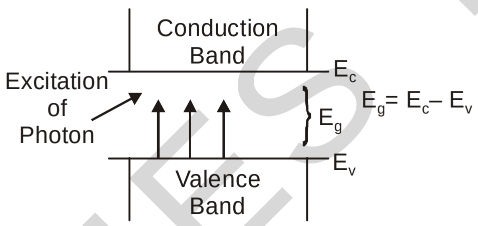
For metals, 'n' is very large. Hence $R_H \approx 0$.

69. **(d)**

When donor atoms are added to the semiconductor, then a new discrete energy level is introduced below conduction band. known as donor energy level.



70. **(c)**



In the figure, the gap between the valence band and conduction band is known as forbidden energy gap and it is shown by E_g.

So, for excitation of photon from valence band to conduction band the minimum energy required is forbidden gap energy.

71. (b)

- As per Planck's theory, when an electric current is passed through a gas, some of the electrons in the gas molecules move from their ground energy state to an excited state that is farther away from their nuclei. When the electrons return to the ground state, they emit energy of various wavelength which exhibits various energy states.
- Einstein's theory of relativity : Both space and time are relative (rather than absolute) which was said to hold true in a special case, the absence of a gravitational field.
- Schrodinger's equation : It is used in quantum mechanics to describe the behavior of a particle in a field of force i.e. it is used to describe wave like properties of matter.
- Pauli exclusion principle : No two electrons in an electronic system can have the same set of four quantum numbers n, l, m_c, m_s.

72. **(d)**

We know that Resistivity,

$$\rho = \frac{1}{nq\mu_n + pq\mu_p}$$

Assuming same type of impurity addition (say pentavalent impurity in both Ge and Si. Also

$N_{Ge} = N_{Si}$ (Given)

$$\rho = \frac{1}{Nq\mu_n}$$

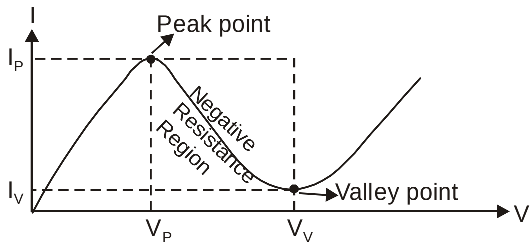
Since $\mu_{Ge} > \mu_{Si}$, $\rho_{Ge} < \rho_{Si}$

73. **(d)**

Tunnel diode is a low noise microwave device. Thus, Tunnel diode is used at microwave frequencies. It is used as a parametric amplifier and in design of microwave oscillators.

74. **(b)**

The V-I characteristic of tunnel diode is



A tunnel diode exhibits voltage controlled negative resistance between peak point and valley point, wherein the current decreases with increase in voltage.

75. **(c)**

From the relation

$$h\nu \geq E_g,$$

We deduce that minimum energy required by a photon for intrinsic excitation should be at least equal to the forbidden energy gap.