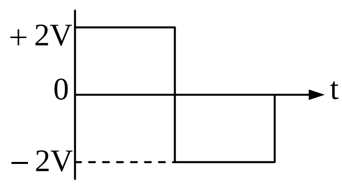
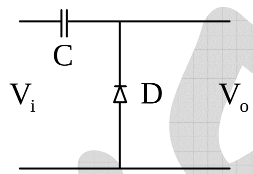
Solid State Physics, Devices and Electronics

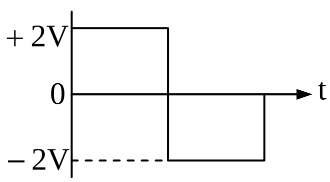
OBJECTIVE QUESTIONS

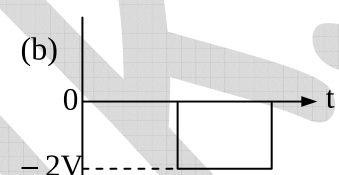
IIT-JAM-2005

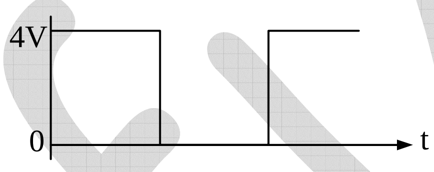
Q1. A circuit and the signal applied at its input terminals (V_i) are shown in figure below. Which one of the options correctly describes the output waveform (V_0). (Assume all the devices used are ideal).

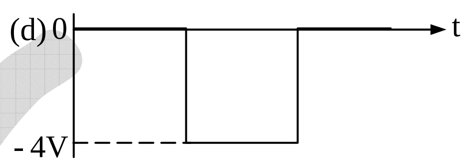




(a)


(b)


(c)


(d)


Ans. : (c)

Solution: Its clamper circuit in which peak to peak remains fixed and voltage level will shift in the direction of diode current.

Q2. The susceptibility of a diamagnetic material is

(a) positive and proportional to temperature

(b) negative and inversely proportional to temperature

(c) negative and independent of temperature

(d) positive and inversely proportional to temperature

Ans. : (b)

Q3. Which of the following statements is correct for $NaCl$ crystal structure?

(a) It is simple cubic lattice with one atom basis

(b) It is a face-centered cubic lattice with one atom basis

(c) It is a simple cubic lattice with two atom basis

(d) It is a face-centered cubic lattice with two atom basis

Ans. : (d)

IIT-JAM-2006

Q4. In a crystalline solid, the energy band structure (E-k relation) for an electron of mass m is given by $E = \frac{\hbar^2 k(2k-3)}{2m}$. The effective mass of the electron in the crystal is

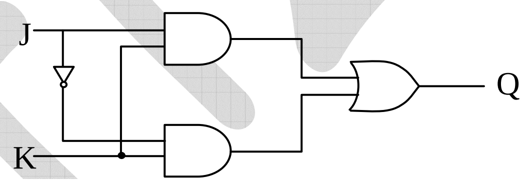
(a) m (b) $\frac{2}{3}m$ (c) $\frac{m}{2}$ (d) $2m$

Ans. : (c)

Solution: The expression of effective mass of electron in solid is $m^* = \frac{\hbar^2}{d^2E/dk^2}$

$$\frac{dE}{dk} = \frac{\hbar^2}{2m}(4k-3) \Rightarrow \frac{d^2E}{dk^2} = \frac{\hbar^2}{2m}(4) = \frac{2\hbar^2}{m} \Rightarrow m^* = \frac{m}{2}$$

Q5. The truth table for the given circuit is



(a)

J	K	Q
0	0	1
0	1	0
1	0	1
1	1	0

(b)

J	K	Q
0	0	1
0	1	0
1	0	0
1	1	1

(c)

J	K	Q
0	0	0
0	1	1
1	0	0
1	1	1

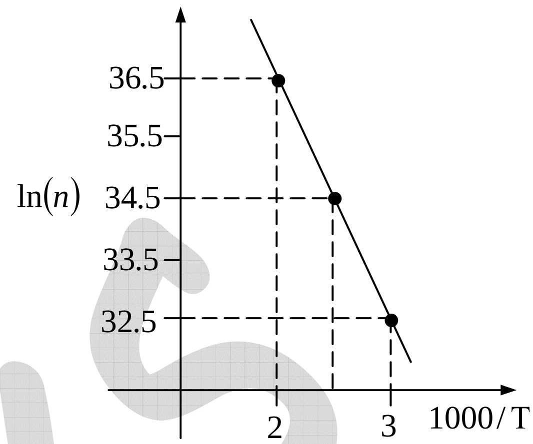
(d)

J	K	Q
0	0	0
0	1	1
1	0	1
1	1	0

Ans. : (c)

Solution: $Q = J.K + \overline{J}.\text{K} = \text{K}$

Q6. In an intrinsic semiconductor, the free carrier concentration n (in cm^{-3}) varies with temperature T (in Kelvin) as shown in the figure below. The band gap of the semiconductor is (use Boltzmann constant $k_B = 8.625\times10^{-5} eVK^{-1}$)



(a) $1.44\,eV$

(b) $0.72\,eV$

(c) $1.38\,eV$

(d) $0.69\,eV$

Ans. : (d)

Solution: Since $n_i = n = \sqrt{N_c N_v}\exp\left(-\frac{E_g}{2kT}\right) \Rightarrow \frac{n_1}{n_2} = \exp\left[\frac{E_g}{2k}\left(\frac{1}{T_2}-\frac{1}{T_1}\right)\right]$

$$\Rightarrow E_g = 2k\ln\left(\frac{n_1}{n_2}\right)\Big/\left(\frac{1}{T_2}-\frac{1}{T_1}\right) = 2\times8.625\times10^{-5}(36.5-32.5)/(0.003-0.0002)$$

$$\Rightarrow E_g = 2\times8.625\times10^{-5}\times4/1\times10^{-3} = 0.69eV$$

IIT-JAM-2007

Q7. Fermi energy of a certain metal M_1 is $5eV$. A second metal M_2 has an electron which is 6% higher than that of M_1. Assuming that the free electron theory is valid for both the metals, the Fermi energy of M_2 is closet to

(a) $5.6\,eV$ (b) $5.2\,eV$ (c) $4.8\,eV$ (d) $4.4\,eV$

Ans. : (b)

Solution: The expression of Fermi energy is $E_F = \frac{\hbar^2}{2m}\left(3\pi^2 n\right)^{2/3}$

Let us consider that n_1, E_{F_1} is the concentration of electron and Fermi energy in metal M_1 and n_2, E_{F_2} is in metal M_2.

Given, $n_2 = n_1 + 0.06n_1 = 1.06n_1$

$$\frac{E_{F_2}}{E_{F_1}} = \frac{\left(\frac{\hbar^2}{2m}\left(3\pi^2 n_2\right)^{2/3}\right)}{\left(\frac{\hbar^2}{2m}\left(3\pi^2 n_1\right)^{2/3}\right)} = \frac{\left(n_2\right)^{2/3}}{\left(n_1\right)^{2/3}} = \frac{\left(1.06n_1\right)^{2/3}}{\left(n_1\right)^{2/3}} = \left(1.06\right)^{2/3} = 1.0396$$

$$E_{F_2} = 1.0396 \times E_{F_1} = 1.0396 \times 5eV = 5.2\,eV$$

Q8.

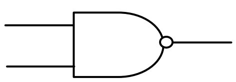


Fig. (i)

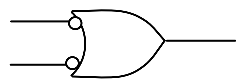


Fig. (ii)

Figure (i) and (ii) represent respectively,

(a) NOR, NOR
(b) NOR, NAND
(c) NAND, NAND
(d) OR, NAND

Ans. : (c)

IIT-JAM-2008

Q9. The ratio of the second-neighbour distance to the nearest-neighbour distance in an *fcc* lattice is

(a) $2\sqrt{2}$
(b) 2
(c) $\sqrt{3}$
(d) $\sqrt{2}$

Ans. : (d)

Solution: In FCC lattice the first nearest is at distance $= \sqrt{2}a/2 = a/\sqrt{2}$

Whereas the second nearest at distance of $= a$

The ratio of the second-neighbour distance to the nearest-neighbour distance is

$$\frac{a}{a/\sqrt{2}} = \sqrt{2}$$

Q10. Consider a doped semiconductor having the electron and the hole mobilities μ_n and μ_p, respectively. Its intrinsic carrier density is n_i. The hole concentration p for which the conductivity is minimum at a given temperature is

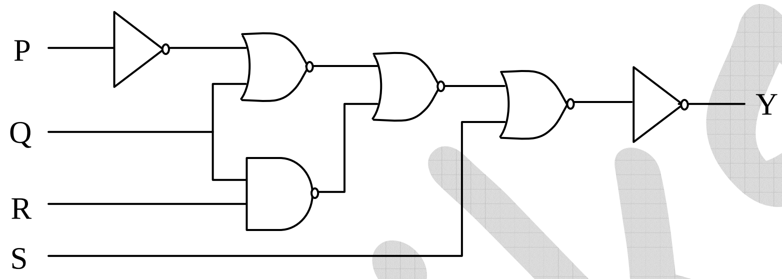
(a) $n_i\sqrt{\frac{\mu_n}{\mu_p}}$
(b) $n_i\sqrt{\frac{\mu_p}{\mu_n}}$
(c) $n_i\frac{\mu_p}{\mu_n}$
(d) $n_i\frac{\mu_n}{\mu_p}$

Ans. : (a)

Solution: Conductivity $\sigma = e\left(n\mu_n + p\mu_p\right) = e\left(\frac{n_i^2}{p}\mu_n + p\mu_p\right)$

For minimum conductivity, $\frac{d\sigma}{dp} = 0 \Rightarrow p = n_i\sqrt{\mu_n / \mu_p}$

Q11. The logic expression for the output Y of the following circuit is



(a) $\overline{\overline{\overline{P}+Q}+\overline{QR}}+S$

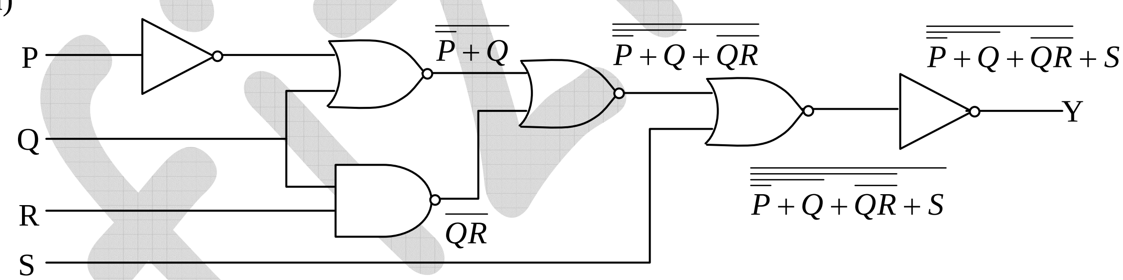
(b) $\overline{\overline{\overline{P}+Q}+\overline{QR}+S}$

(c) $\overline{\overline{P}+Q+\overline{QR}}+S$

(d) $\overline{\overline{\overline{P}+Q}+\overline{QR}}+\overline{S}$

Ans. : (a)

Solution:



IIT-JAM-2009

Q12. Monochromatic X -rays of wavelength $1\overset{0}{\mathrm{A}}$ are incident on a simple cubic crystal. The first order Bragg reflection from (311) plane occurs at angle of 30^0 from the plane. The lattice parameter of the crystal in $\overset{0}{\mathrm{A}}$ is

(a) 1 (b) $\sqrt{3}$ (c) $\sqrt{\frac{11}{2}}$ (d) $\sqrt{11}$

Ans. : (d)

Solution: Expression of Bragg´s law is $2d\sin\theta = n\lambda$,

where, d is the inter-planar spacing defined for cubic lattice of lattice constant a in term of Miller indices $(h\,k\,l)$ as $d = \frac{a}{\sqrt{h^2+k^2+l^2}}$

The lattice parameter a is

$$a = \frac{\lambda}{2\times\sin\theta}\sqrt{h^2+k^2+l^2} = \frac{1}{2\times\sin 30^0}\sqrt{3^2+1^2+1^2} = \frac{1}{2\times 1/2}\times\sqrt{11} = \sqrt{11}$$

Q13. Which one of the following is an INCORRECT Boolean expression?

(a) $\bar{P}Q + PQ = Q$ (b) $(P+\bar{Q})(P+Q) = P$

(c) $P(P+Q) = Q$ (d) $(\bar{P}\bar{Q}\bar{R} + \bar{P}\bar{Q}R + P\bar{Q}\bar{R} + P\bar{Q}R) = \bar{Q}$

Ans. : (c)

Solution: (a) $\bar{P}Q + PQ = (\bar{P}+P)Q = 1.Q = Q$

(b) $(P+\bar{Q})(P+Q) = P + Q\bar{Q} = P$

(c) $P(P+Q) = P + PQ = P(1+Q) = P$

(d) $(\bar{P}\bar{Q}\bar{R} + \bar{P}\bar{Q}R + P\bar{Q}\bar{R} + P\bar{Q}R) = \bar{P}\bar{Q}(\bar{R}+R) + P\bar{Q}(\bar{R}+R) = \bar{P}\bar{Q} + P\bar{Q} = (\bar{P}+P)\bar{Q} = \bar{Q}$

Q14. A battery with a constant *emf* ε and internal resistance r_i provides power to an external circuit with a load resistance made up by combining resistance R_L and $2R_L$ in parallel. For what value of R_L will the power delivered to the load be maximum?

(a) $R_L = \frac{r_i}{4}$ (b) $R_L = \frac{r_i}{2}$ (c) $R_L = \frac{2}{3}r_i$ (d) $R_L = \frac{3}{2}r_i$

Ans. : (d)

Solution: Since R_L and $2R_L$ are in parallel so load $R = \frac{R_L \times 2R_L}{R_L + 2R_L} = \frac{2}{3}R_L$.

Power through load $P = I^2 R = \left(\frac{\varepsilon}{r_i + R}\right)^2 R$

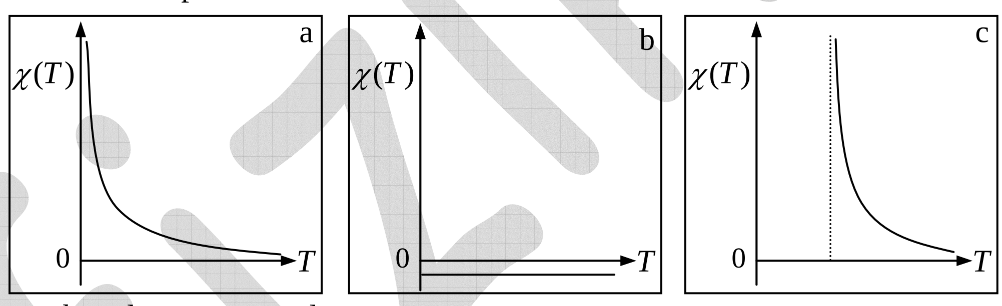
For maximum power through load

$$\frac{dP}{dR} = 0 \Rightarrow \frac{(r_i + R)^2 \varepsilon^2 - \varepsilon^2 R \times 2(r_i + R)}{(r_i + R)^4} = 0 \Rightarrow (r_i + R) - 2R = 0 \Rightarrow R = r_i$$

Thus $R = r_i \Rightarrow \frac{2}{3}R_L = r_i \Rightarrow R_L = \frac{3}{2}r_i$

IIT-JAM-2010

Q15. The following are the plots of the temperature dependence of the magnetic susceptibility for three different samples.



The plots a, b and c correspond to

(a) ferromagnet, paramagnet and diamagnet, respectively

(b) paramagnet, diamagnet and ferromagnet, respectively

(c) ferromagnet, diamagnet and paramagnet, respectively

(d) diamagnet, paramagnet and ferromagnet, respectively

Ans. : (b)

Q16. The value of θ at which the first-order peak in X-ray ($\lambda = 1.53\overset{0}{\text{A}}$) diffraction corresponding to (111) plane of a simple cubic structure with the lattice constant, $\alpha = 2.65\overset{0}{\text{A}}$, is approximately

(a) 15^0 (b) 30^0 (c) 45^0 (d) 60^0

Ans. : (b)

Solution: Expression of Bragg´s law is, $2d\sin\theta = n\lambda$

where, d is the inter-planar spacing defined for cubic lattice of lattice constant a in term of Miller indices *(h k l)* as $d = \dfrac{a}{\sqrt{h^2+k^2+l^2}}$

$$\sin\theta = \frac{\lambda}{2d} = \frac{\lambda}{2a}\sqrt{h^2+k^2+l^2} = \frac{1.53}{2\times 2.65}\times\sqrt{3} = \frac{1}{2} \Rightarrow \theta = \sin^{-1}\left(\frac{1}{2}\right) = 30^0$$

Q17. Consider the following truth table

The logic expression for F is

(a) $AB+BC+CA$

(b) $\overline{A}B+A\overline{C}+\overline{B}C$

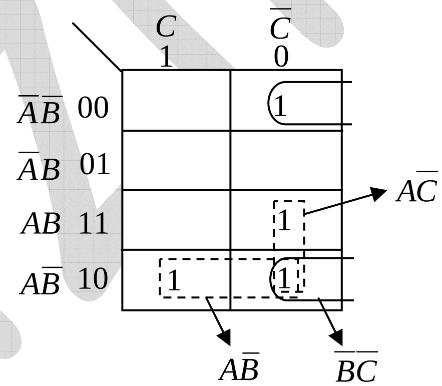
(c) $\overline{C}\,\overline{A}\,\overline{B}+A\overline{B}$

(d) $\overline{C}\left(A+\overline{B}\right)+A\overline{B}$

A	B	C	F
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

Ans. : (d)

Solution: $F = A\overline{B}+\overline{C}\left(A+\overline{B}\right)$



IIT-JAM-2011

Q18. An X - ray diffraction (XRD) experiment is carried out on a crystalline solid having FCC structure at room temperature. The solid undergoes a phase transformation on cooling to $-20^0 C$ and shows orthorhombic structure with small decrease in its unit cell lengths as compared to the FCC unit cell lengths. As a result the (311) line of the XRD pattern corresponding to the FCC system

(a) will split into a doublet

(b) will split into a triplet

(c) will remain unchanged

(d) will split into two separate doublets

Ans. : (b)

Solution: In FCC the inter-planar spacing is defined as $d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$

whereas in Orthorhombic the inter-planar spacing is $d = \frac{1}{\sqrt{\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}}}$

For (311), numbers XRD peaks in FCC is derived from Bragg's law as

$$\sin\theta = \frac{\lambda}{2d} = \frac{\lambda}{2a}\sqrt{h^2 + k^2 + l^2} = \frac{\lambda}{2a}\sqrt{3^2 + 1^2 + 1^2} = \frac{\lambda}{2a}\sqrt{11}$$

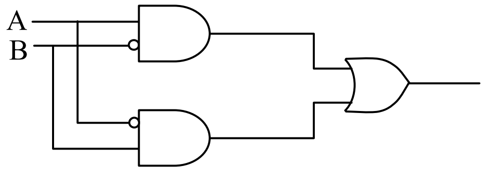
Thus only one peak appears in FCC.

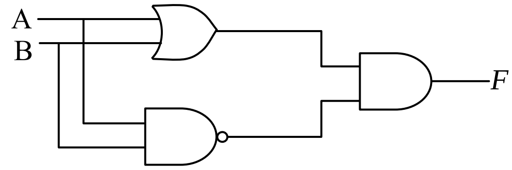
In Orthorhombic, $\sin\theta = \frac{\lambda}{2d} = \frac{\lambda}{2\sqrt{\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}}}$

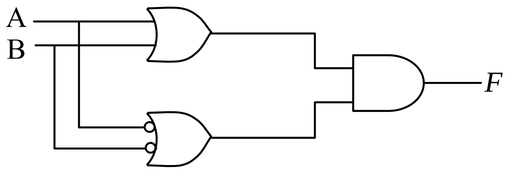
For (311), there will be three peaks corresponding to

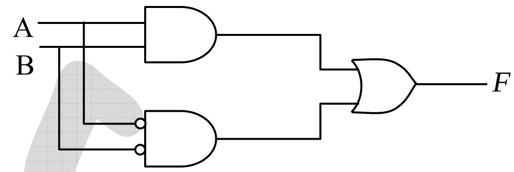
$$\theta_1 = \sin^{-1}\left(\frac{\lambda}{2\sqrt{\frac{3^2}{a^2} + \frac{1^2}{b^2} + \frac{1^2}{c^2}}}\right), \theta_2 = \sin^{-1}\left(\frac{\lambda}{2\sqrt{\frac{1^2}{a^2} + \frac{3^2}{b^2} + \frac{1^2}{c^2}}}\right) \text{ and } \theta_3 = \sin^{-1}\left(\frac{\lambda}{2\sqrt{\frac{1^2}{a^2} + \frac{1^2}{b^2} + \frac{3^2}{c^2}}}\right)$$

Q19. Which of the following circuit does not satisfy the Boolean expression $A\overline{B}+\overline{A}B=F$

(a) 

(b) 

(c) 

(d) 

Ans. : (d)

Solution: (a) $F=A\overline{B}+\overline{A}B$

(b) $F=(A+B).\overline{AB}=(A+B).(\overline{A}+\overline{B})=A\overline{B}+\overline{A}B$

(c) $F=(A+B).(\overline{A}+\overline{B})=A\overline{B}+\overline{A}B$

(d) $F=AB+\overline{A}\,\overline{B}$

<u>IIT-JAM-2012</u>

Q20. An X-ray beam of wavelength $1.54\overset{0}{\mathrm{A}}$ is diffracted from the (110) planes of a solid with a cubic lattice of lattice constant $3.08\overset{0}{\mathrm{A}}$. The first-order Bragg diffraction occurs at

(a) $\sin^{-1}\left(\frac{1}{4}\right)$ (b) $\sin^{-1}\left(\frac{1}{2\sqrt{2}}\right)$ (c) $\sin^{-1}\left(\frac{1}{2}\right)$ (d) $\sin^{-1}\left(\frac{1}{\sqrt{2}}\right)$

Ans. : (b)

Solution: Expression of Bragg´s law is $2d\sin\theta=n\lambda$

where, d is the inter-planar spacing defined for cubic lattice of lattice constant a in term of Miller indices $(h\,k\,l)$ as $d=\frac{a}{\sqrt{h^2+k^2+l^2}}$

$$\sin\theta=\frac{\lambda}{2d}=\frac{\lambda}{2a}\sqrt{h^2+k^2+l^2}=\frac{1.54}{2\times 3.08}\times\sqrt{2}=\frac{1}{2\sqrt{2}}\Rightarrow\theta=\sin^{-1}\left(\frac{1}{2\sqrt{2}}\right)$$

Q21. The Boolean expression $P+\bar{P}Q$, where P and Q are the inputs to a circuit, represents the following logic gate

(a) AND (b) NAND (c) NOT (d) OR

Ans. : (d)

Solution:

P	Q	$\bar{P}Q$	$P+\bar{P}Q$
0	0	0	0
0	1	1	1
1	0	0	1
1	1	0	1

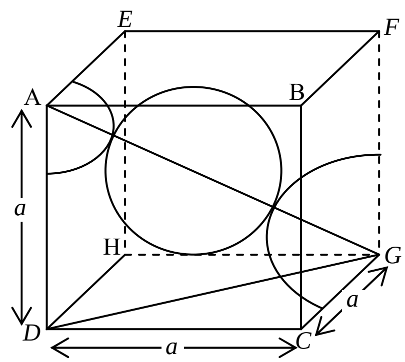
IIT-JAM-2013

Q22. The fraction of volume unoccupied in the unit cell of the body centered cubic lattice is

(a) $\frac{8-\sqrt{3}\pi}{8}$ (b) $\frac{\sqrt{3}\pi}{8}$ (c) $\frac{6-\sqrt{2}\pi}{6}$ (d) $\frac{\pi}{3\sqrt{2}}$

Ans. : (a)

Solution: The effective number of atoms in bcc structure is



$$n_{eff}=\frac{1}{8}n_c+\frac{1}{2}n_f+n_i=\frac{1}{8}\times 8+\frac{1}{2}\times 0+1=2$$

The radius of atom and lattice constant are related as

$$r=\frac{a\sqrt{3}}{4}$$

The volume occupide by the atoms in unit cell is

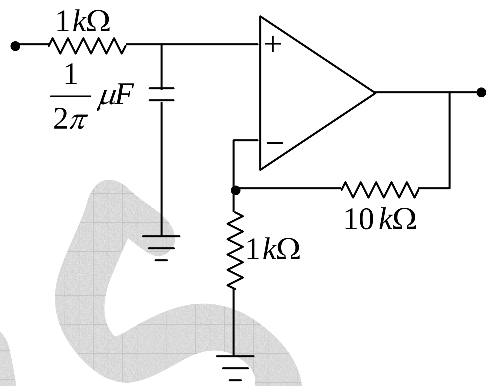
$$2\times\frac{4\pi}{3}\left(\frac{a\sqrt{3}}{4}\right)^3=\frac{\pi\sqrt{3}}{8}a^3$$

Thus amount of volume unoccupied in the unit cell is

$$=\text{volume of unit cell}-\text{filled volume}=a^3-\frac{\pi\sqrt{3}}{8}a^3=\left(\frac{8-\pi\sqrt{3}}{8}\right)a^3$$

Thus, the fraction of volume unoccupied in the unit cell of the body centered cubic lattice is $\left(\frac{8-\pi\sqrt{3}}{8}\right)$

Q23. For an ideal op-amp circuit given below, the dc gain and the cut off frequency respectively are



(a) 1 and $1kHz$

(b) 1 and $100\,Hz$

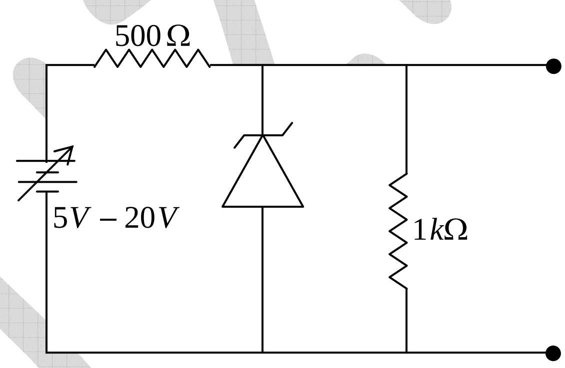
(c) 11 and $1kHz$

(d) 11 and $100\,Hz$

Ans. : (b)

Solution: DC Gain $=1+\frac{10}{1}=11$ and $f_H=\frac{1}{2\pi RC}=\frac{1}{2\pi\times 1\times\frac{1}{2\pi}}=1kHz$

Q24. A variable power supply $5V-20V$ is connected to a Zener diode specified by a breakdown voltage of $10V$ (see figure). The ratio of the maximum power to the minimum power dissipated across the load resistor is



Ans. : 9.02

Solution: When $V=5V$ $\Rightarrow$ open circuit voltage $V_i=\frac{1000}{1500}\times 5=3.33<V_Z=10V$

$\Rightarrow V_L=V_i=3.33V \Rightarrow P_{L,\min}=\frac{V_i^2}{R_L}$.

When $V=20V$ $\Rightarrow$ open circuit voltage $V_i=\frac{1000}{1500}\times 20=13.33>V_Z=10V$

$\Rightarrow V_L=V_z=10V \Rightarrow P_{L,\max}=\frac{V_Z^2}{R_L} \Rightarrow \frac{P_{L,\max}}{P_{L,\min}}=\frac{V_Z^2}{V_i^2}=\left(\frac{10}{3.33}\right)^2=9.02$

IIT-JAM-2014

Q25. Octal equivalent of decimal number $(478)_{10}$ is

(a) 736_8 (b) 673_8 (c) 637_8 (d) 367_8

Ans. : (a)

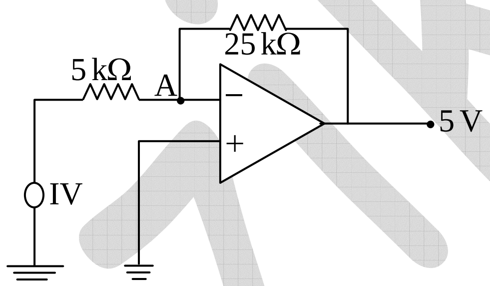
Solution: $736_8 = 7\times 8^2 + 3\times 8^1 + 6\times 8^0 = 448 + 24 + 6 = 478_{10}$

$673_8 = 6\times 8^2 + 7\times 8^1 + 3\times 8^0 = 384 + 56 + 3 = 443_{10}$

$637_8 = 6\times 8^2 + 3\times 8^1 + 7\times 8^0 = 384 + 24 + 7 = 415_{10}$

$367_8 = 3\times 8^2 + 6\times 8^1 + 7\times 8^0 = 192 + 48 + 7 = 247_{10}$

Q26. In an ideal operational amplifier depicted below, the potential at node A is



(a) $1V$ (b) $0V$ (c) $5V$ (d) $25V$

Ans. : (b)

Solution: Node A is virtually grounded.

Q27. To operate a *npn* transistor in active region, its emitter-base and collector- base junction respectively, should be

(a) forward biased and reversed biased (b) forward biased and forward biased

(c) reversed biased and forward biased (d) reversed biased and reversed biased

Ans. : (a)

Solution: In active region: emitter-base junction is F.B.

: collector-base junction is R.B.

Q28. Diamond lattice can be considered as a combination of two fcc lattice displaced along the body diagonal by one quarter of its length. There are eight atoms per unit cell. The packing fraction of the diamond structure is

(a) 0.48 (b) 0.74 (c) 0.34 (d) 0.68

Ans. : (c)

Solution: $P\cdot F=\dfrac{n_{eff}\times\dfrac{4\pi}{3}r^3}{V}$

Where, $n_{eff}=8, V=a^3$ and $\dfrac{\sqrt{3}a}{4}=2r\Rightarrow a=\dfrac{8r}{\sqrt{3}}$

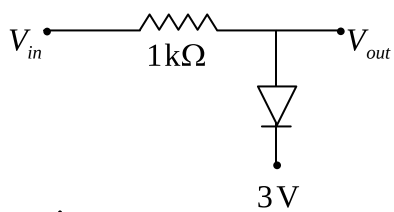
$\therefore P\cdot F=\dfrac{8\times\dfrac{4\pi}{3}r^3}{\left(\dfrac{8r}{\sqrt{3}}\right)^3}=\dfrac{\sqrt{3}\pi}{16}=0.34$.

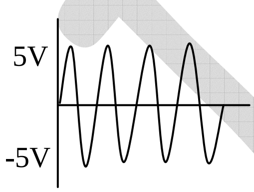
Q29. Thermal neutrons (energy $=300$, $k_B=0.025\,eV$) are sometimes used for structural determination of materials. The typical lattice spacing of a material for which these can be used is

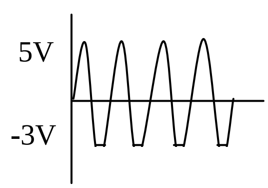
(a) $0.01\,nm$ (b) $0.05\,nm$ (c) $0.1\,nm$ (d) $0.15\,nm$

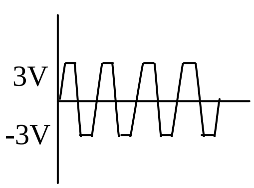
Ans. : (c)

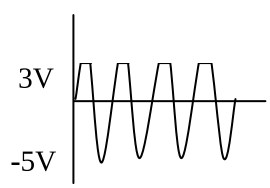
Q30. A sine wave of $5V$ amplitude is applied at the input of the circuit shown in the figure. Which of the following waveforms represents the output most closely?



(a)


(b)


(c)


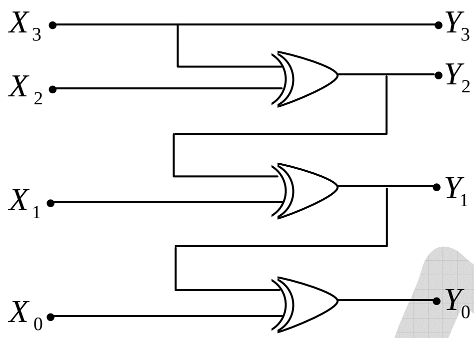
(d)


Ans. : (d)

Solution: If $V_{in}<3\,V$, diode is OFF and $V_0=V_{in}$.

If $V_{in}>3\,V$, diode is ON and $V_0=3\,V$.

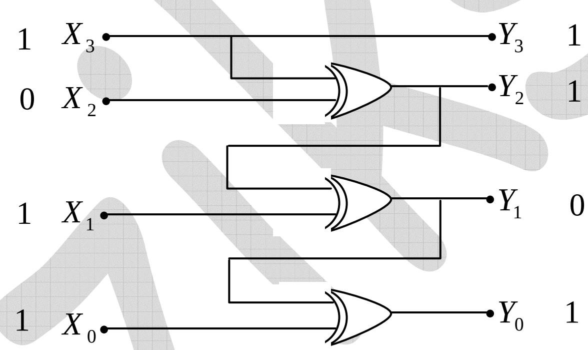
Q31. 1011 binary input have been applied at $X_3X_2X_1X_0$ input in the shown logic circuit made of XOR gates. The binary output $Y_3Y_2Y_1Y_0$ of the circuit will be



(a) 1101 (b) 1010 (c) 1111 (d) 0101

Ans. : (a)

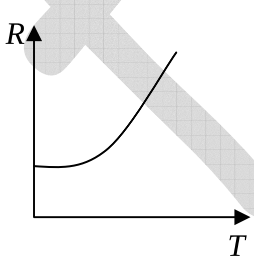
Solution:



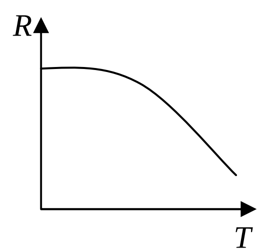
IIT-JAM-2015

Q32. Temperature dependence of resistivity of a metal can be described by

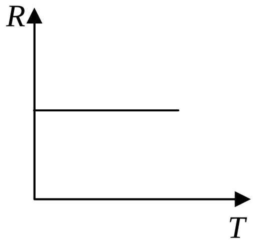
(a)



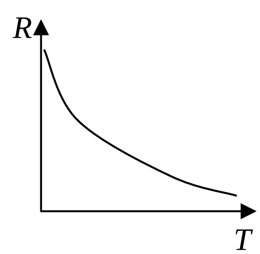
(b)



(c)



(d)



Ans. : (a)

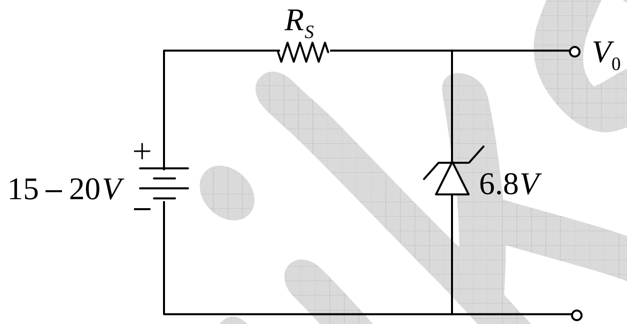
Solution: Electrical resistivity of metal varies as

$$\rho \propto T^5 \qquad (\text{For } T << \theta_D)$$

$$\rho \propto T \qquad (\text{For } T >> \theta_D)$$

where θ_D is the Debye temperature. Thus, correct answer is option (a)

Q33. A Zener regulator has an input voltage in the range $15V - 20V$ and a load current in the range of $5\ mA - 20\ mA$. If the Zener voltage is $6.8V$, the value of the series resistor should be

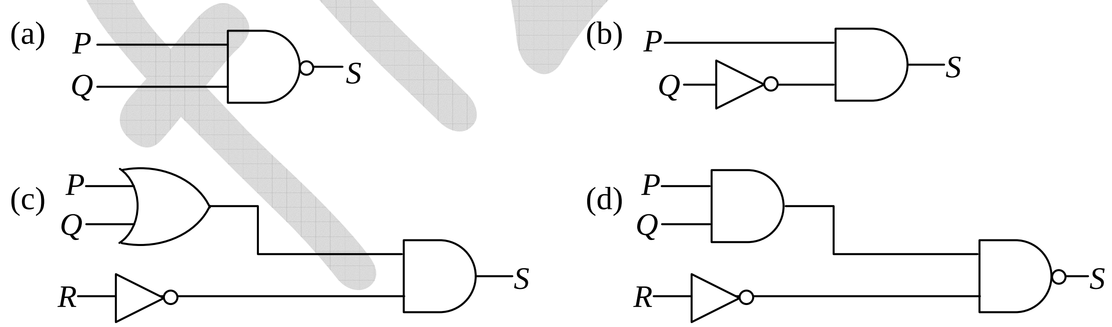


(a) 390 Ω (b) 420 Ω (c) 440 Ω (d) 460 Ω

Ans. : Some data is missing. (No answer is possible)

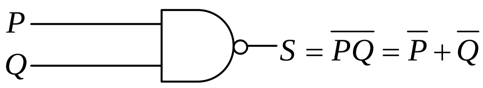
Q34. Which of the following circuits represent the Boolean expression

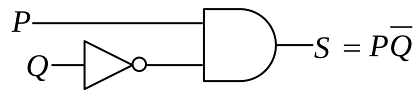
$$S = \overline{\overline{P + QR} + \overline{\overline{Q}P}}$$

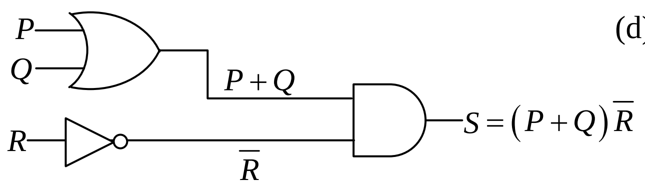


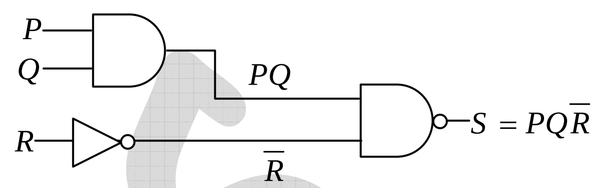
Ans. : (b)

Solution: $S=\overline{\overline{P+QR}+\overline{\overline{Q}P}}=\left(\overline{\overline{P+QR}}\right)\left(\overline{\overline{\overline{Q}P}}\right)=(P+QR)\left(\overline{Q}P\right)=P\overline{Q}$

(a) 

(b) 

(c) 

(d) 

Q35. Miller indicates of a plane in cubic structure that contains all the directions $[100]$, $[011]$ and $[111]$ are

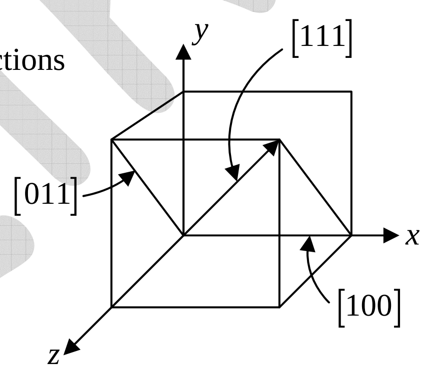
(a) (011) (b) (101) (c) (100) (d) (110)

Ans. : (a)

Solution: The name of the plane containing all the directions

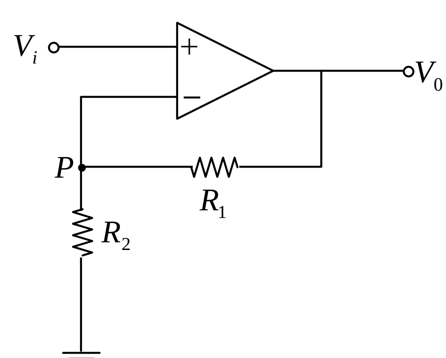
$[100]$, $[011]$ & $[111]$ is $(0\overline{1}1)$ or $(01\overline{1})$

The best suitable answer is option (a)



SECTION–B: MSQ

Q36. In an ideal Op-Amp circuit shown below $R_1=3k\Omega$, $R_2=1k\Omega$ and $V_i=0.5\sin\omega t$ (in Volt). Which of the following statements are true?



(a) The current through R_1 = The current through R_2

(b) The potential at P is $V_0\dfrac{R_2}{R_1}$

(c) The amplitude of V_0 is $2V$

(d) The output voltage V_0 is in phase with V_i

Ans. : (a), (c) and (d)

Solution: Voltage at P is $V_P = \dfrac{V_0 R_2}{R_1 + R_2}$.

Current through R_1 is $I_1 = \dfrac{V_o - V_P}{R_1} = \dfrac{V_o - \dfrac{V_0 R_2}{R_1 + R_2}}{R_1} = \dfrac{V_0 R_1}{R_1 \left(R_1 + R_2\right)} = \dfrac{V_0}{\left(R_1 + R_2\right)}$

and Current through R_2 is $I_2 = \dfrac{V_P}{R_2} = \dfrac{V_0}{\left(R_1 + R_2\right)}$.

Thus $I_1 = I_2$. Option (a) is true

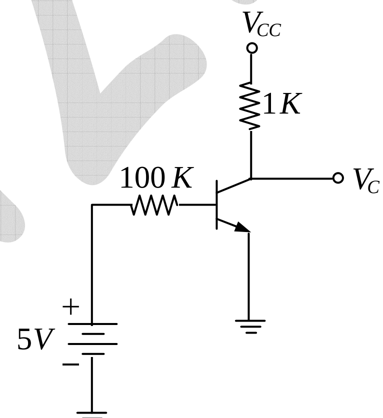
The potential at P is $V_P = \dfrac{V_0 R_2}{R_1 + R_2}$. Option (b) is not true.

$V_0 = \left(1 + \dfrac{R_2}{R_1}\right) V_i = \left(1 + \dfrac{3}{1}\right) 0.5 \sin \omega t = 2 \sin \omega t \Rightarrow V_m = 2V$. Option (c) is true

Option (d) is true

SECTION–C: NAT (Numerical Answer Type)

Q37. In the given circuit $V_{CC} = 10V$ and $\beta = 100$ for $n - p - n$ transistor. The collector voltage V_C (in volts) is............



Ans. : 5.7

Solution: $I_B = \dfrac{5 - 0.7}{100 \times 10^3} = 4.3 \times 10^{-5} A \Rightarrow I_C = \beta I_B = 4.3\ mA$

$\Rightarrow V_C = V_{CC} - I_C R_C = 10 - 4.3 = 5.7\ V$

Q38. A diode at room temperature $\left(kT = 0.025 eV\right)$ with a current of $1\mu A$ has a forward bias voltage $V_F = 0.4V$. For $V_F = 0.5V$, the value of the diode current (in μA) is.............

Ans. : 54.5

Solution: $I = I_0\left(e^{V/V_T} - 1\right) \Rightarrow \frac{I_2}{I_1} = \frac{\left(e^{V_2/V_T} - 1\right)}{\left(e^{V_1/V_T} - 1\right)} = \frac{\left(e^{0.5/0.025} - 1\right)}{\left(e^{0.4/0.025} - 1\right)} = \frac{\left(e^{20} - 1\right)}{\left(e^{16} - 1\right)} = 54.5 \Rightarrow I_2 = 54.5\,\mu A$

Q39. GaAs has a diamond structure. The number of Ga-As bonds per atom which have to be broken to fracture the crystal in the (001) plane is……….

Ans. : 4

Solution: Diamond structure has tetrahedral bond. To fracture the diamond structure along $(0\;0\;1)$ plane, four bonds need to be broken.

IIT-JAM-2016

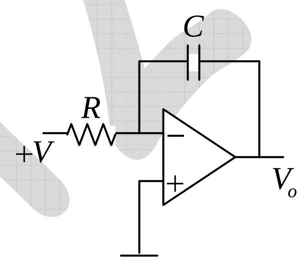
Q40. The solution of the Boolean equation $Y = \overline{A+B} + \overline{AB}$ is

(a) 1 (b) $\overline{AB}$ (c) $\overline{A}\,\overline{B}$ (d) $\overline{A} + \overline{B}$

Ans. : (b) and (d) both are correct

Solution: $Y = \overline{A+B} + \overline{AB} = \overline{A}.\overline{B} + \overline{A} + \overline{B} = \overline{A}\left(1+\overline{B}\right) + \overline{B} = \overline{A} + \overline{B}$ or $\overline{AB}$

Q41. If a constant voltage $+V$ is applied to the input of the following OPAMP circuit for a time t, then the output voltage V_0 will approach



(a) $+V$ exponentially (b) $-V$ exponentially

(c) $+V$ linearly (d) $-V$ linearly

Ans. : (d)

Solution: $\because\; I_R = I_C \Rightarrow \frac{V-0}{R} = C\frac{d\left(0-V_0\right)}{dt} \Rightarrow \frac{dV_0}{dt} = -\frac{V}{RC} \Rightarrow V_0 = -\frac{V}{RC}t + c$

SECTION–B: MSQ

Q42. A pn junction was formed with a heavily doped $\left(10^{18}\ cm^{-3}\right)$ p-region and lightly doped $\left(10^{14}\ cm^{-3}\right)$ n-region. Which of the following statement (s) is (are) correct?

(a) The width of the depletion layer will be more in the n-side of the junction

(b) The width of the depletion layer will be more in the p-side of the junction

(c) The width of the depletion layer will be same on the both side of the junction

(d) If the pn junction is reverse biased, then the width of the depletion region increase

Ans. : (a), (d)

Solution: Since p-region is heavily doped and n-region is lightly doped, on n-side width of depletion layer will be more and on p-side width of the depletion layer will be less.

SECTION–C: NAT (Numerical Answer Type)

Q43. The addition of two binary numbers 1000.01 and 0001.11 in binary representation is…………

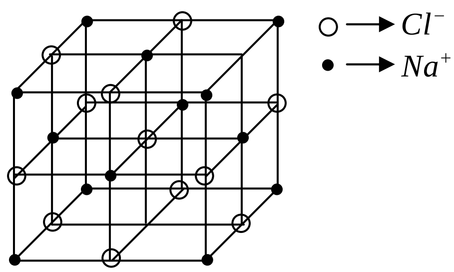
Ans. : 1010

Solution:

$$\begin{array}{r} 1000.01 \\ 0001.11 \\ \hline 1001.00 \\ \hline \end{array}$$

Q44. The number of second-nearest neighbor ions to a Na^+ ion in $NaCl$ crystal is__________.

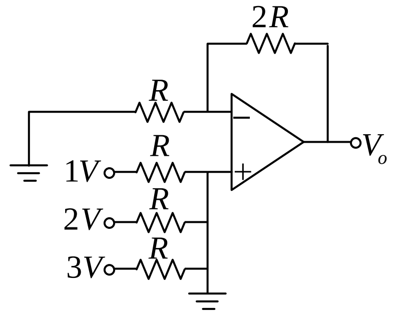
Ans. : 12



Solution: The 2^{nd} nearest neighbour is at distance $=\dfrac{\sqrt{2}a}{2}=\dfrac{a}{\sqrt{2}}$

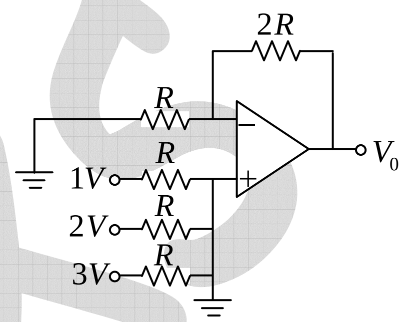
The number of 2^{nd} nearest neighbour $=\dfrac{3\times 8}{2}=12$

Q45. The output voltage V_0 of the OPAMP circuit given below is…………….. V



Ans. : 6

Solution: $V_0 = \left(1+\dfrac{2R}{R}\right)V_1 = 3V_1$

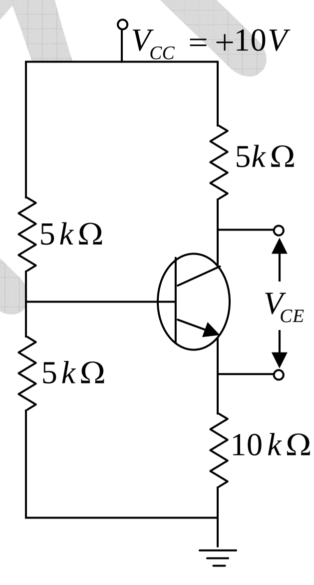


Where, $V_1 = \dfrac{R/2}{R+R/2}\times 1 + \dfrac{R/2}{R+R/2}\times 2 + \dfrac{R/2}{R+R/2}\times 3$

$V_1 = \dfrac{1}{3}\times 1 + \dfrac{1}{3}\times 2 + \dfrac{1}{3}\times 3 = 2V \Rightarrow V_0 = 6\ V$

Q46. In the circuit given below, the collector to emitter voltage V_{CE} is…………… V .

(Neglect V_{BE} , take $\beta = 100$)



Ans. : 2.5

Solution: $V_B = \dfrac{5}{5+5}\times 10 = 5\ V \Rightarrow V_E = V_B - V_{BE} \approx 5\ V \Rightarrow I_E = \dfrac{V_E}{R_E} = \dfrac{5}{10} = 0.5\ mA$

$V_{CE} = V_{CC} - I_C\left(R_C + R_E\right) = 10 - 0.5\left(5+10\right) = 2.5\ V$

Q47. X-ray diffraction of a cubic crystal gives an intensity maximum for Bragg angle 20^0 corresponding to the (110) plane. The lattice parameter of the crystal is………….. nm.

(Consider wavelength of $X - ray = 0.15\ nm$)

Ans. : 0.31

Solution: According to Bragg's law $2d\sin\theta = n\lambda$

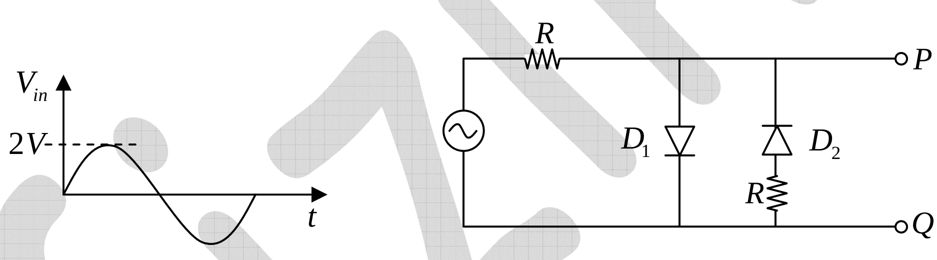
For $n = 1$, $2d\sin\theta = \lambda \Rightarrow d = \dfrac{\lambda}{2\sin\theta} = \dfrac{0.5\times10^{-9}}{2\times\sin 20^0} \Rightarrow d = \dfrac{0.15\times10^{-9}}{2\times0.342} = 0.219\,nm$

Now, $d = \dfrac{a}{\sqrt{h^2+k^2+l^2}} = \dfrac{a}{\sqrt{2}}$

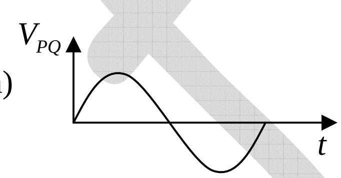
$\therefore\ a = \sqrt{2}\,d = 0.31nm \Rightarrow a = 0.31nm$

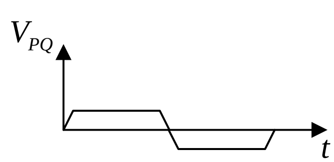
IIT-JAM 2017

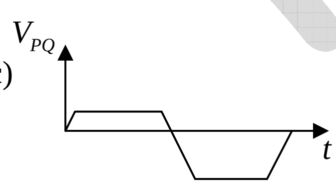
Q48. Consider the following circuit with two identical Si diodes. The input ac voltage waveform has the peak voltage $V_P = 2V$, as shown

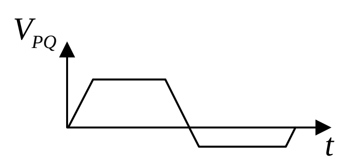


The voltage waveform across PQ will be represented by:

(a)


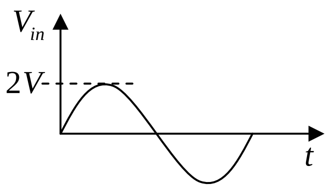
(b)


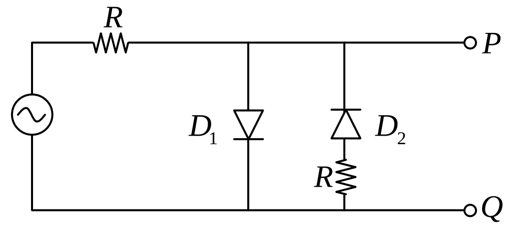
(c)


(d)


Ans. : (c)

Solution:





During positive half cycle D_1 is ON, when input is more than $0.7V$ and D_1 is OFF when input is less than $0.7V$.

During negative half cycle D_1 is ON, when input is more negative than $-(0.7+IR)$ and D_1 is OFF when input is less negative than $-(0.7+IR)$.

Q49. If the Boolean function $Z = PQ + PQR + PQRS + PQRST + PQRSTU$, then $\overline{Z}$ is

(a) $\overline{P}\,\overline{Q}+\overline{R}\left(\overline{S}+\overline{T+U}\right)$ (b) $\overline{P}\,\overline{Q}$

(c) $\overline{P}+\overline{Q}$ (d) $\overline{P}+\overline{Q}+\overline{R}+\overline{S}+\overline{T}+\overline{U}$

Ans. : (c)

Solution: $Z = PQ + PQR + PQRS + PQRST + PQRSTU$

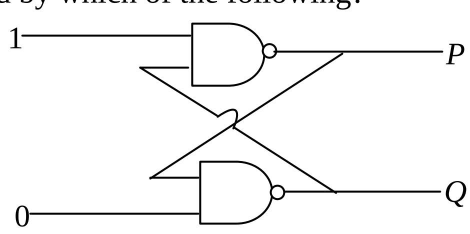
$= PQ + PQR + PQRS + PQRST(1+U) = PQ + PQR + PQRS + PQRST$

$= PQ + PQR + PQRS(1+T) = PQ + PQR + PQRS$

$= PQ + PQR(1+S) = PQ + PQR = PQ(1+R) = PQ$

$\Rightarrow \overline{Z} = \overline{PQ} = \overline{P} + \overline{Q}$

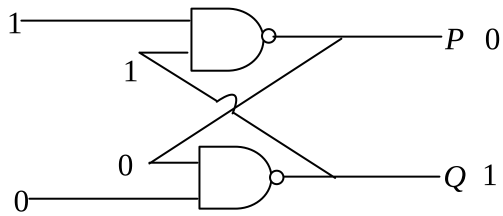
Q50. Shown in the figure is a combination of logic gates. The output values at P and Q are correctly represented by which of the following?



(a) 0 0 (b) 1 1 (c) 0 1 (d) 1 0

Ans. : (c)

Solution:



Q51. A plane in a cubic lattice makes intercepts of $a, \frac{a}{2}$ and $\frac{2a}{3}$ with the three crystallographic axes, respectively. The Miller indices for this plane are:

(a) (243) (b) (342) (c) (634) (d) (123)

Ans. : (a)

Solution: Intercepts: $a, \quad \frac{a}{2}, \quad \frac{2a}{3}$

Divide by a: $1, \quad \frac{1}{2}, \quad \frac{2}{3}$

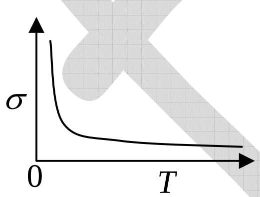
Reciprocal: $1, \quad 2, \quad \frac{3}{2}$

LCM: $2, \quad 4, \quad 3$

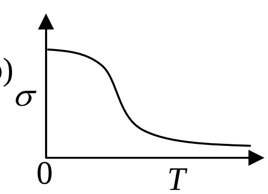
Miller Indices $= (2 \quad 4 \quad 3)$

Q52. Which one of the following schematic curves best represents the variation of conductivity σ of a metal with temperature T?

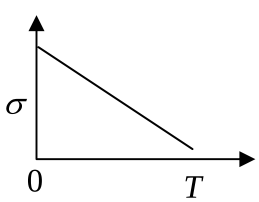
(a)



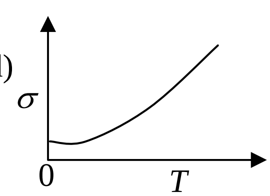
(b)



(c)



(d)

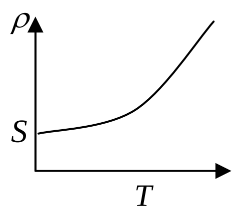


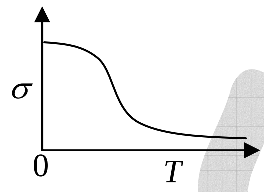
Ans. : (b)

Solution: Resistivity of metal is $\rho = \rho_0 + \rho_{ph}$, where ρ_0 is temperature independent

And, $\rho_{ph} \propto T^5$ when $T << \theta_D$ and $\rho_{ph} \propto T$ when $T >> \theta_D$

The conductivity is defined as $\sigma \propto \dfrac{1}{\rho}$

$\therefore$ 



Thus correct option is (b)

Q53. KCl has the $NaCl$ type structure which is fcc with two-atom basis, one at $(0,0,0)$ and the other at $(1/2,1/2,1/2)$. Assume that the atomic form factors of K^+ and Cl^- are identical. In an X - ray diffraction experiment on KCl, which of the following (hkl) peaks will be observed?

(a) (100) (b) (110) (c) (111) (d) (200)

Ans. : (d)

Solution In KCl the reflection from (111) layer containing K^+ ions is exactly out of phase with the reflection from the Cl^- close packed layers. The net effect is that the two reflections cancel and (111) is absent. This mean the first reflection is from (200)

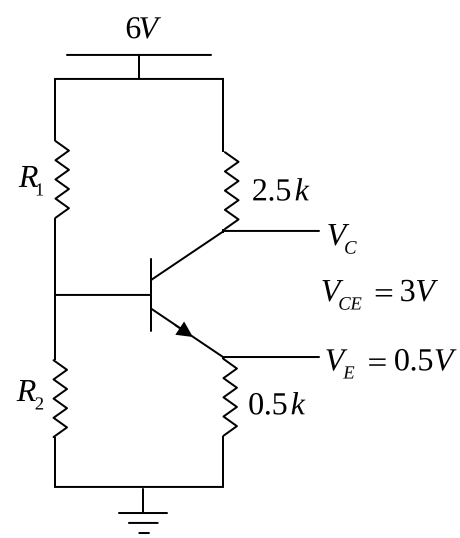
Q54. An $n-p-n$ transistor is connected in a circuit as shown in the figure. If $I_C = 1mA,\ \beta = 50, V_{BE} = 0.7V$ and the current through R_2 is $10I_B$ where, I_B is the base current. Then the ratio R_1/R_2 is:

(a) 0.375

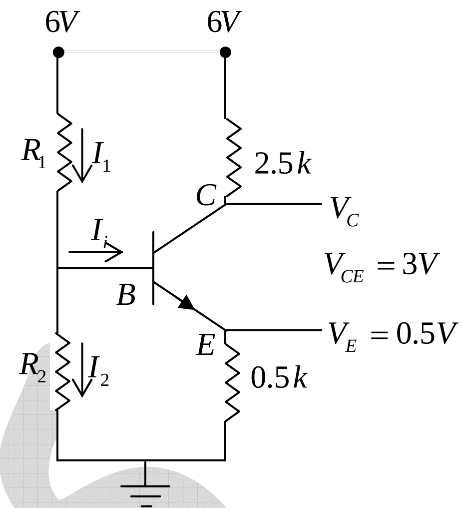
(b) 0.25

(c) 0.5

(d) 0.275



Ans. : (b)



Solution: $I_1 = I_i + I_2 \approx I_2 = 10I_B$, $I_C = 1mA,\ \beta = 50, V_{BE} = 0.7V$

$$V_B = I_2R_2 = V_{BE} + I_ER_E = 0.7 + 0.5 = 1.2\ V$$

$$\Rightarrow R_2 = \frac{1.2\ V}{I_2} = \frac{1.2\ V}{10I_B} = \frac{1.2\ V}{10\times(1/50)} = 6\ k\Omega$$

$$\because V_B = \frac{V_{CC}R_2}{R_1 + R_2} \Rightarrow 1.2 = \frac{6\times 6}{R_1 + 6} \Rightarrow R_1 = 24\ k\Omega$$

$$\Rightarrow \frac{R_2}{R_1} = \frac{6}{24} = 0.25$$

Q55. An intrinsic semiconductor of band gap $1.25 eV$ has an electron concentration $10^{10}\ cm^{-3}$ at $300 K$. Assume that its band gap is independent of temperature and that the electron concentration depends only exponentially on the temperature. If the electron concentration at $200 K$ is $Y\times 10^N\ cm^{-3}\ (1 < Y < 10; N = \text{integer})$, then the value of N is…………

Ans. : 4

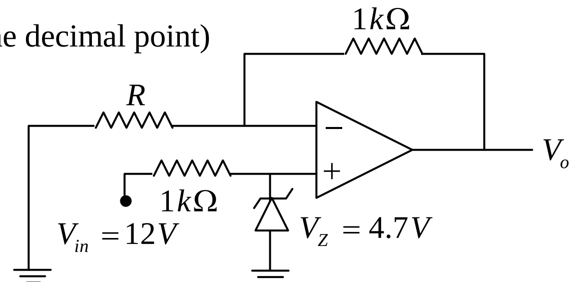
Solution: $n_i = \sqrt{N_cN_v}e^{-E_g/2kT} \Rightarrow \dfrac{n_{i1}}{n_{i2}} = \dfrac{e^{-E_g/2kT_1}}{e^{-E_g/2kT_2}} \Rightarrow \dfrac{10^{10}\ cm^{-3}}{n_{i2}} = \exp\left[-\dfrac{E_g}{2k}\left(\dfrac{1}{300} - \dfrac{1}{200}\right)\right]$

$$\Rightarrow n_{i2} = 10^{10}\times\exp\left[\frac{E_g}{2k}\left(\frac{1}{300} - \frac{1}{200}\right)\right] = 10^{10}\times\exp\left[\frac{1.25\times1.6\times10^{-19}}{2\times1.38\times10^{-23}\times100}\left(-\frac{1}{6}\right)\right] = 10^{10}\times5.7\times10^{-6}$$

$$\Rightarrow n_{i2} = 5.7\times10^4\ cm^{-3} \Rightarrow N = 4$$

Q56. An OPAMP is connected in a circuit with a Zener diode as shown in the figure. The value of resistance R in $k\Omega$ for obtaining a regulated output $V_0 = 9V$ is…………..

(Specify your answer to two digits after the decimal point)



Ans. : 1.09

Solution: $V_0 = \left(1 + \dfrac{1}{R}\right)\times 4.7 = 9V \Rightarrow R = 1.09k\Omega$

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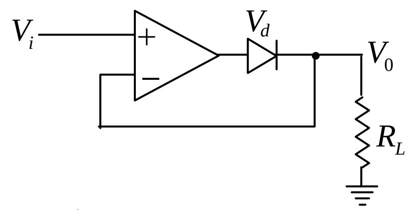
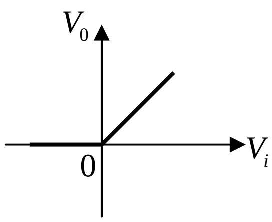
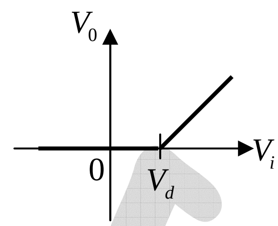
Q57. Which one of the following graphs shows the correct variation of V_0 with V_i? Here, V_d is the voltage drop across the diode and the OP-Amp is assumed to be ideal.



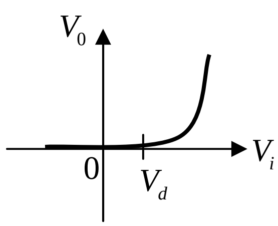
(a)



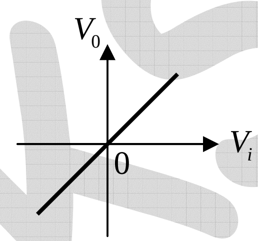
(b)



(c)



(d)



Ans. : (a)

Solution: During positive half cycle it behaves as voltage follower i.e. $v_0 = v_i$, during negative half cycle $v_0 = 0$.

Q58. The Boolean expression $\left(\overline{AB}\right)\left(\bar{A}+B\right)\left(A+\bar{B}\right)$ can be simplified to

(a) $A+B$ (b) $\bar{A}B$ (c) $\overline{A+B}$ (d) AB

Ans.: (c)

Solution: $Y=\left(\overline{AB}\right)\left(\bar{A}B\right)\left(A+\bar{B}\right)=\left(\overline{AB}\right)\left(\bar{A}\bar{B}+AB\right)$

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

Q59. In a pn junction, dopant concentration on the p-side is higher than that on the n-side. Which of the following statements is (are) correct, when the junction is unbiased?

(a) The width of the depletion layer is larger on the n-side.

(b) At thermal equilibrium the Fermi energy is higher on the p-side.

(c) In the depletion region, number of negative charges per unit area on the p-side is equal to number of positive charges per unit area on the n-side

(d) The value of the built-in potential barrier depends on the dopant concentration.

Ans. : (a), (c) and (d)

Q60. Which of the combinations of crystal structure and their coordination number is (are) correct?

(a) body centered cubic -8 (b) face centred cubic -6

(c) diamond -4 (d) hexagonal closed packed -12

Ans. : (a), (c), (d)

Solution: Co-ordination number in different crystal structure are

(i) Body central cubic -8

(ii) Face central cubic -12

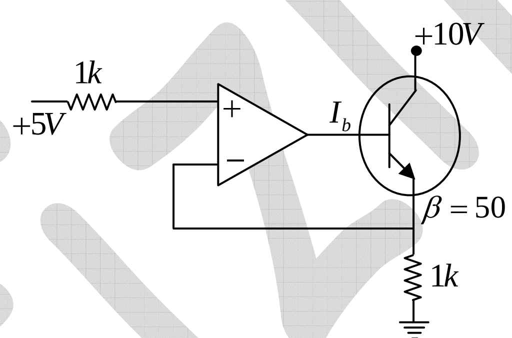
(iii) Diamond -4

(iv) Hexagonal closed packed -12

Q61. For the given circuit, value of the base current (I_b) of the npn transistor will be ____mA.

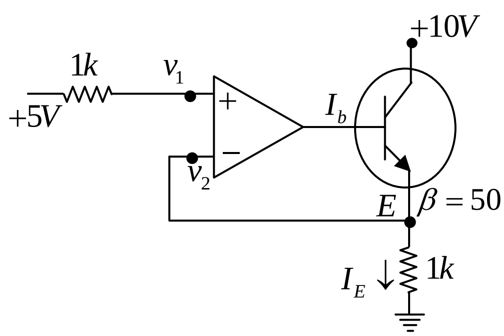
(β is the current gain and assume Op-Amp as ideal.)

(Specific your answer in mA upto two digits after the decimal point.)



Ans. : 0.1

Solution: $v_2 = 5V = V_E$



$$I_E = \frac{5}{1} = 5\,mA$$

$$\beta I_B = 5\,mA \Rightarrow I_B = \frac{5}{50}\,mA = 0.1\,mA$$

Q62. The lattice constant of unit cell of $NaCl$ crystal is $0.563\,nm$. X-rays of wavelength $0.141\,nm$ are diffracted by this crystal. The angle at which the first order maximum occurs is _______degrees.

Ans. : 12.5

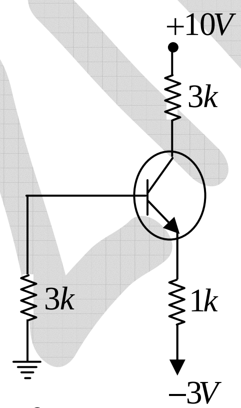
Solution: $2d\sin\theta=\lambda$

$$\theta=\sin^{-1}\left(\frac{\lambda}{2d}\right)=\sin^{-1}\left(\frac{\sqrt{3}\lambda}{2a}\right)$$

$$=\sin^{-1}\left(\frac{\sqrt{3}\times 0.141}{2\times 0.563}\right)=\sin^{-1}(0.217)=12.53^{0}$$

Q63. For the following circuit, the collector voltage with respect to ground will be _________ V. (Emitter diode voltage is $0.7V$ and β_{DC} of the transistor is large)

(Specify your answer in volts upto one digit after the decimal point).



Ans. : 3.1

Solution: $V_{BE}=0.7V$ and $\beta_{dc}\to$ large so $I_B\approx 0$

From input section;

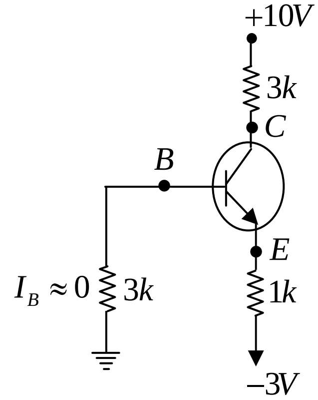
$0+0.7+I_E\times 1-3=0$

$\Rightarrow I_E=2.3\,mA$

From output section;

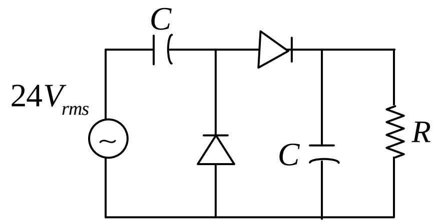
$-10+3\times 2.3+V_C=0$

$\Rightarrow V_C=10-6.9=3.1V$



Q64. In the following circuit, the time constant RC is much greater than the period of the input signal. Assume diode as ideal and resistance R to be large. The dc output voltage across resistance R will be ____________ V.

(Specify your answer in volts upto one digit after the decimal point)



Ans. : 68

Solution: It's a voltage doubler circuit

$$V_R = 2V_m = 2\left(\sqrt{2}\,V_{rms}\right) = 2\left(\sqrt{2}\times 24\right)$$

$$\Rightarrow V_R \approx 68\ V$$

Q65. For a metal, the electron density is $6.4\times10^{28}\,m^{-3}$. The Fermi energy is __________ eV.

($h = 6.626\times10^{-34}\ J\ s,\ m_e = 9.11\times10^{-31}\,kg,\ 1\ eV = 1.6\times10^{-19}\ J$)

(Specify your answer in electron volts (eV) upto one digit after the decimal point)

Ans. : 5.84

Solution: $E_F = \dfrac{\hbar^2}{2m}\left(3\pi^2 n\right)^{2/3} = \dfrac{\left(1.05\times10^{-34}\right)^2}{2\times9.11\times10^{-31}}\left(3\pi^2\times6.4\times10^{28}\right)^{2/3}$

$$= 6.1\times10^{-39}\left(1.53\times10^{20}\right) = 9.34\times10^{-19}\ J$$

$$= \frac{9.34\times10^{-19}}{1.6\times10^{-19}}\,eV = 5.84eV.$$