Kuldeep Singh

SOLID STATE PHYSICS

CONTENTS

SOLID STATE PHYSICS

Assignment & Previous Years' Question

Leve-1

LEVEL-1

7

8.

9.

CAREER ENDEAVOUR
Best Institute for IIT-JAM, NET & GATE

CSIR-UGC-NET/JRF|GATE-PHYSICS

SOLID STATE PHYSICS

Assignment-1

1. The packing fraction of a simple cubic lattice is approximately:
(a) 0.74 (b) 0.68 (c) 0.52 (d) 0.34

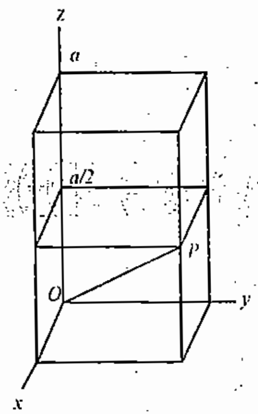
2. Given that r is the radius of the atoms and a is the lattice constant of a solid having a cubic structure, which one of the following relations is true for a body centred cubic structure?
(a) $a = 2r$ (b) $a = 2r\sqrt{2}$ (c) $a = 2r\sqrt{3}$ (d) $a = 4r/\sqrt{3}$

3. What is the second nearest-neighbour distance in a face centred cubic lattice whose conventional unit cell parameter is a?
(a) $a/\sqrt{2}$ (b) a/2 (c) a (d) $\sqrt{2}/a$

4. The C/a ratio for an ideal hexagonal closed packed structure is:
(a) $\frac{2}{\sqrt{3}}$ (b) $\sqrt{8}$ (c) $\sqrt{5}$ (d) $\sqrt{\frac{8}{3}}$

5. For a closed packed BCC structure of hard spheres, the lattice constant a is related to the sphere radius R as:
(a) $a = 4R/\sqrt{3}$ (b) $a = 4R\sqrt{3}$ (c) $a = 4R\sqrt{2}$ (d) $a = 2R\sqrt{2}$

6. In crystallographic notation the vector $\overline{OP}$ in the cubic cell shown in the figure is:



(a) [2 2 1] (b) [1 2 2] (c) [1 2 1] (d) [1 1 2]

7. The de-Broglie wavelength λ for an electron of energy 150 eV is:
(a) 10^{-8} m (b) 10^{-10} m (c) 10^{-12} m (d) 10^{-14} m

8. Which is loose packed structure?
(a) Body centred cubic structure (b) Hexagonal close-packed structure
(c) Face-centred cubic structure (d) None of these

9. The value of a primitive unit cell defined by axes $(\hat{k}+\hat{i})$Å, $(\hat{i}+\hat{j})$Å, $(\hat{j}+\hat{k})$Å, is
(a) 1Å^3 (b) 3Å^3 (c) 2Å^3 (d) 4Å^3

10. The Miller indices of a plane passing through the points $3\hat{a}$, $4\hat{b}$ and $5\hat{c}$, where $\hat{a}$, $\hat{b}$ and $\hat{c}$, are lattice vectors are

(a) (12, 15, 20) (b) (20, 15, 12) (c) (5, 4, 3) (d) (3, 4, 5)

11. A simple cubic crystal with lattice parameter a_c undergoes transition into a tetragonal structure with lattice parameter $a_t = b_t = \sqrt{2}\, a_c$ and $c_t = 2a_c$, below a certain temperature. The ratio of the interplanar spacings of (101) planes for the cubic and the tetragonal structure is

(a) $\sqrt{\frac{1}{6}}$ (b) $\frac{1}{6}$ (c) $\sqrt{\frac{3}{8}}$ (d) $\frac{3}{8}$

12. The inter-planar spacing for (110) plane of a monoatomic FCC crystal of lattice constant 2Å is

(a) $1/\sqrt{2}$ Å (b) 2Å (c) $\sqrt{2}$ Å (d) $\sqrt{3}$ Å

13. Which one of the following diffraction techniques has most surface sensitivity?

(a) X-ray (b) Electron (b) Neutron (d) Optical

14. By using X-ray diffraction one cannot obtain

(a) crystal structure (b) type of bonding (c) residual stress (d) grain size178.

15. A flat surface is covered with non-overlapping disks of same size. What is the largest fraction of the area that can be covered?

(a) $\frac{3}{\pi}$ (b) $\frac{5\pi}{6}$ (c) $\frac{6}{7}$ (d) $\frac{\pi}{2\sqrt{3}}$

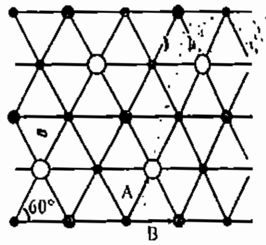
16. A metal suffers a structural phase transition from face-centred cubic (FCC) to the simple cubic (SC) structure. It is observed that this phase transition does not involve any change of volume. The nearest neighbour distances d_{fc} and d_{sc} for the FCC and the SC structures respectively are in the ratio (d_{fc}/d_{sc}) [Given $2^{1/3} = 1.26$]

(a) 1.029 (b) 1.122 (c) 1.374 (d) 1.130

17. Consider the crystal structure of sodium chloride which is modeled as a set of touching spheres. Each sodium atom has a radius r_1 and each chlorine atom has a radius r_2. The centres of the spheres form a simple cubic lattice. The packing fraction of this system is

(a) $\pi\left[\left(\frac{r_1}{r_1+r_2}\right)^3+\left(\frac{r_2}{r_1+r_2}\right)^3\right]$ (b) $\frac{2\pi}{3}\frac{r_1^3+r_2^3}{(r_1+r_2)^3}$ (c) $\frac{r_1^3+r_2^3}{(r_1+r_2)^3}$ (d) $\pi\frac{r_1^3+r_2^3}{2(r_1+r_2)^3}$

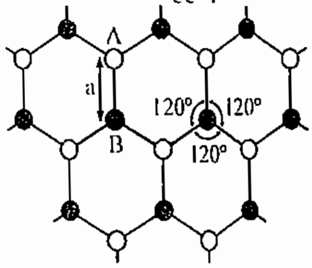
18. What is the area of the irreducible Brillouin zone of the crystal structure as given in the figure ?



$|A| = |B| = A$

(a) $\frac{2\pi^2}{\sqrt{3}A^2}$ (b) $\frac{\sqrt{3}\pi^2}{2A^2}$ (c) $\frac{2\pi^2}{A^2}$ (d) $\frac{\pi^2}{\sqrt{3}A^2}$ [JEST 2015]

19. For a 2-dimensional honeycomb lattice as shown in the figure, the first Bragg spot occurs for the grazing angle θ_1, while sweeping the angle from 0°. The next Bragg spot is obtained at θ_2 given by,



(a) $\sin^{-1}(3\sin\theta_1)$ (b) $\sin^{-1}\left(\frac{3}{2}\sin\theta_1\right)$ (c) $\sin^{-1}\left(\frac{\sqrt{3}}{2}\sin\theta_1\right)$ (d) $\sin^{-1}\left(\sqrt{3}\sin\theta_1\right)$

20. In a simple cubic lattice of lattice constant 0.287 nm, the number of atoms per mm² along the 111 plane is **[TIFR 2016]**

(a) 2.11×10^{13} (b) 1.73×10^{13} (c) 1.29×10^{13} (d) 1.21×10^{13} (d) none of these

21. The crystal structure of diamond is:

(a) fcc with two atom basis of (000) and $\frac{a}{4}(\hat{i}+\hat{j}+\hat{k})$.

(b) simple cubic with two atom basis of (000) and $\frac{a}{2}(\hat{i}+\hat{j}+\hat{k})$

(c) fcc with two atoms basis of (000) and $\frac{a}{2}(\hat{i}+\hat{j}+\hat{k})$

(d) bcc with one atom basis

22. Which of the following crystals cannot be represented by interpenetrating lattices:
(a) Sodium (b) Sodium chloride
(c) Cesium chloride (d) Diamond

23. For an NaCl crystal, the cell-edge a = 0.542 nm. The smallest angle at which Bragg reflection can occur corresponds to a set of planes whose indices are
(a) 100 (b) 110 (c) 111 (d) 200

24. Consider the atomic packing factor (APF) of the following crystal structures:
P. Simple Cubic Q. Body Centred Cubic
R. Face Centred Cubic S. Diamond
T. Hexagonal Close Packed
Which two of the above structures have equal APF?
(a) P and Q (b) S and T (c) R and S (d) R and T

25. A metal with body centered cubic (bcc) structure shows the first (i.e. smallest angle) diffraction peak at Bragg angle of $\theta = 30°$. The wavelength of X-ray used is 2.1 Å. The volume of the PRIMITIVE unit cell of the metal is:

(a) 26.2 (Å)³ (b) 13.1 (Å)³ (c) 9.3 (Å)³ (d) 4.6 (Å)³.

26. Consider X-ray diffraction from a crystal with a face-centered-cubic (fcc) lattice. The lattice. The lattice plane for which there is NO diffraction peak is:
(a) (2, 1, 2) (b) (1, 1, 1) (c) (2, 0, 0) (d) (3, 1, 1)

27. The $\theta - 2\theta$ X-ray powder diffraction pattern of ionic crystals KCl and KBr both of which form fcc structure will have:
(a) same number of diffraction lines with equal intensities
(b) pattern of KBr will have more lines
(c) Pattern of KCl will have more lines
(d) number of lines will be same but their intensities will be different

Statement for Linked Answer Q.28 and Q.29.

The powder diffraction pattern of a body centred cubic crystal is recorded by using Cuk_{α} X-rays of wavelength 1.54Å.

28. If the (002) planes diffract at 60°, then lattice parameter is:
(a) 2.67 Å (b) 3.08 Å (c) 3.56 Å (d) 5.34 Å

29. Assuming the atomic mass of the constituent atoms to be 50.94 amu, then density of the crystal in units of kg m^{-3} is:
(a) 3.75×10^3 (b) 4.45×10^3 (c) 5.79×10^3 (d) 8.89×10^3

30. In a powder differaction pattern recorded from a face-centred cubic sample using x-rays, the first peak appears at 30°. The second peak will appear at:
(a) 32.8° (b) 33.7° (c) 34.8° (d) 35.3°

Statement for Linked Answer Q. 31 and Q. 32.
Lead has atomic weight of 207.2 amu and density of 11.35 gm cm^{-3}.

31. Number of atoms per cm^3 for lead is:
(a) 1.1×10^{25} (b) 3.3×10^{22} (c) 1.1×10^{22} (d) 3.3×10^{25}

32. If the energy of vacancy formation in lead is 0.55 eV/atom, the number of vacancies cm^3 at 500K is:
(a) 3.2×10^{16} (b) 3.2×10^{19} (c) 9.5×10^{19} (d) 9.5×10^{16}

Statement for Linked Answer Q. 33 and Q. 34:
The primitive translatin vectors of the face centered cubic (fcc) lattice are

$$\hat{a}_1 = \frac{a}{2}(\hat{j}+\hat{k});\ \hat{a}_2 = \frac{a}{2}(\hat{i}+\hat{k});\ a_3 = \frac{a}{2}(\hat{i}+\hat{j})$$

33. The primitive translation vectos of the fcc reciprocal lattice are

(a) $\hat{b}_1 = \left(\frac{2\pi}{a}\right)(-\hat{i}+\hat{j}+\hat{k});\ \hat{b}_2 = \left(\frac{2\pi}{a}\right)(\hat{i}-\hat{j}+\hat{k});\ \hat{b}_3 = \left(\frac{2\pi}{a}\right)(\hat{i}+\hat{j}-\hat{k})$

(b) $\hat{b}_1 = \left(\frac{\pi}{a}\right)(-\hat{i}+\hat{j}+\hat{k});\ \hat{b}_2 = \left(\frac{\pi}{a}\right)(\hat{i}-\hat{j}+\hat{k});\ \hat{b}_3 = \left(\frac{\pi}{a}\right)(\hat{i}+\hat{j}-\hat{k})$

(c) $\hat{b}_1 = \left(\frac{\pi}{2a}\right)(-\hat{i}+\hat{j}+\hat{k});\ \hat{b}_2 = \left(\frac{\pi}{2a}\right)(\hat{i}-\hat{j}+\hat{k});\ \hat{b}_3 = \left(\frac{\pi}{2a}\right)(\hat{i}+\hat{j}-\hat{k})$

(d) $\hat{b}_1 = \left(\frac{3\pi}{a}\right)(-\hat{i}+\hat{j}+\hat{k});\ \hat{b}_2 = \left(\frac{3\pi}{a}\right)(\hat{i}-\hat{j}+\hat{k});\ \hat{b}_3 = \left(\frac{3\pi}{a}\right)(\hat{i}+\hat{j}-\hat{k})$

34. The volume of the primitive cell of the fcc reciprocal lattice is:
(a) $4\left(\frac{2\pi}{a}\right)^3$ (b) $4\left(\frac{\pi}{a}\right)^3$ (c) $4\left(\frac{\pi}{2a}\right)^3$ (d) $4\left(\frac{3\pi}{a}\right)^3$

35. A narrow beam of X-rays with wavelength 1.5Å is reflected from an ionic crystal with an fcc lattice structure with a density of 3.32 g cm^{-3}. The molecular weight is 108 AMU (1 AMU= 1.66×10^{-24} g).

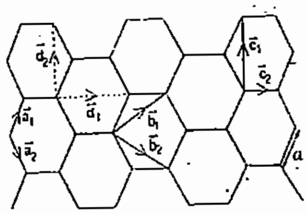
A. The lattice constant is:

(a) 6.00Å (b) 4.56Å (c) 4.00Å (d) 2.56Å

B. The sine of the angle corresponding to (111) reflection is:

(a) $\sqrt{3}/4$ (b) $\sqrt{3}/8$ (c) $1/4$ (d) $1/8$

36. The two dimensional lattice of graphene is an arrangement of Carbon atoms forming a honeycomb lattice of lattice spacing a, as shown below. The carbon atoms occupy the vertices.



A. The Wigner-Seitz cell has an area of

(a) $2a^2$ (b) $\frac{\sqrt{3}}{2}a^2$ (c) $6\sqrt{3}\,a^2$ (d) $\frac{3\sqrt{3}}{2}a^2$

B. The Bravais lattice for this array is a

(a) Rectangular lattice with basis vectors $\vec{d}_1$ and $\vec{d}_2$

(b) Rectangular lattice with basis vectors $\vec{c}_1$ and $\vec{c}_2$

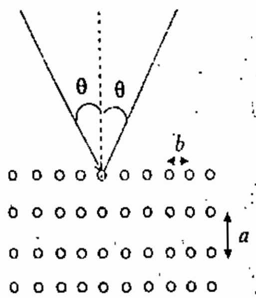
(c) Hexagonal lattice with basis vectors $\vec{a}_1$ and $\vec{a}_2$

(d) Hexagonal lattice with basis vectors $\vec{b}_1$ and $\vec{b}_2$.

37. The co-ordination number of Na^+ and Cl^- in the rock salt structure is respectively

(a) 8 and 6 (b) 6 and 8 (c) 6 and 6 (d) 4 and 4

38. A monochromatic beam of X-ray with wavelength λ is incident at an angle θ on a crystal with lattice spacing a and b as sketched in the figure below:



A condition for there to a maximum in the diffracted X-ray intensity is

(a) $2\sqrt{a^2+b^2}\sin\theta=\lambda$ (b) $2b\cos\theta=\lambda$ (c) $2a\cos\theta=\lambda$ (d) $(a+b)\sin\theta=\lambda$

39. Metallic Copper is known to from cubic crystals and the lattice constant is measured from X-ray diffraction studies to be about 0.36nm. If the specific gravity of Copper is 8.96 and its atomic weight is 63.5, one can conclude that

(a) the crystals are of simple cubic type (b) the crystals are of b.c.c. type

(c) the crystals are of f.c.c. type (d) the crystals are a mixture of f.c.c. and b.c.c. types.

40. The experimental method used most frequently for detecting magnetic structure of solids is

(a) electron diffraction (b) neutron diffraction

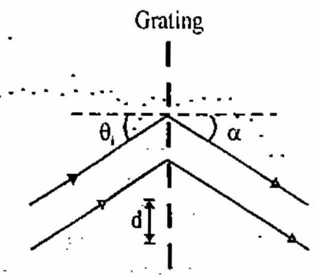
(c) x-ray diffraction (d) photo-emission spectroscopy

41. The most suitable experimental method for studying the dispersion relation of phonons is
(a) X-ray diffraction (b) elastic scattering of neutorns
(c) inelastic scattering of thermal neutrons (d) photo-electron emission.

42. A beam of x-rays is incident on a BCC crystal. If the difference between the incident and the scattered wave vectors is $\vec{K} = h\hat{x} + k\hat{y} + \ell\hat{z}$ where $\hat{x}, \hat{y}, \hat{z}$ are the unit vectors of the associate cubic lattice, the necessary condition for the scattered beam to given a Laue maximum is
(a) h + k + l = even (b) h = k = l (c) h, k, l are all distinct (d) h + k + l = odd

43. the second order maximum in the diffraction of X-rays of 0.20 nanometer wavelength from a simple cubic crystal is found to occur at an angle of thirty degrees with respect to the crystal plane. The distance between the lattice planes is
(a) 1 Angstrom (b) 2 Angstroms (c) 4 Angstroms (d) 8 Angstroms

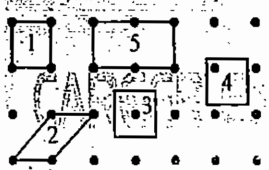
44. A parallel beam of light of wavelength λ is incident on a transmission grating with groove spacing d, at an angle θ_i, as shown in the figure on the left. The plane of incidence is normal to the grooves. After diffraction, the transmitted beam is seen to be at an angle α relative to the normal. Which of the following conditions must be satisfied for this to happen?



(a) $d(\sin\theta_i - \sin\alpha) = n\lambda$ (b) $2d\sin(\theta_i - \alpha) = n\lambda$
(c) $d(\sin\theta_i + \sin\alpha) = n\lambda$ (d) $2d(\alpha + \theta_i) = n\lambda$

45. KCl has the NaCl type structure which is fcc with two-atom basis, one at (0, 0, 0) and the other at $\left(\frac{1}{2}, \frac{1}{2}, \frac{1}{2}\right)$. Assume that the atomic form factors of K^+ and Cl^- are identical. In an x-ray diffraction experiment on KCl, which of the following $(h\,k\,l)$ peaks will be observed?
(a) (1 0 0) (b) (1 1 0) (c) (1 1 1) (d) (2 0 0)

46. For the given unit cells of a two dimensional square lattice, which option lists all the primitive cells ?



[GATE 2018]

(a) 1 and 2 (b) 1, 2 and 3 (c) 1, 2, 3 and 4 (d) 1, 2, 3, 4 and 5

47. Which of the combinations of crystal structure and their coordination number is(are) correct?
(a) body centered cubic – 8 (b) tape centered cubic – 6
(c) diamond – 4 (d) hexagonal closed packed – 12

48. The lattice consatant of unit cell of NaCl crystal is 0.563 nm. X-rays of wavelength 0.1[illegible]1 nm are diffracted by this crystal. The angle at which the first order maximum occurs is __________ degrees. (Specify your answer in degrees upto two digits after the decimal point)

49. A crystal of MnO has NaCl structure. It has a paramagnetic to anti-ferromagnetic transition at 120 K. Below 120 K, the spins within a single [111] plane are parallel but the spins in adjacent [111] planes are anti-parallel. If neutron scattering is used to determine the lattice constants, respectively, d and d', below and above the transition temperature of MnO then [NET Dec. 2017]

(a) $d = \frac{d'}{2}$ (b) $d = \frac{d'}{\sqrt{2}}$ (c) $d = 2d'$ (d) $d = \sqrt{2}d'$

50. Sodium Chloride (NaCl) crystal is a face centred cubic lattice, with a basis consisting of Na^+ and Cl^- ions separated by half the body diagonal of a unit cube. Which of the planes corresponding to the Miller indices given below will not give rise to Bragg reflection of X-rays? [NET June 2018]

(a) (2 2 0) (b) (2 4 2) (c) (2 2 1) (d) (3 1 1)

51. Hard discs of radius R are arranged in a two-dimensional triangular lattice. What is the fractional area occupied by the discs in the closests possible packing? [NET June 2018]

(a) $\frac{\pi\sqrt{3}}{6}$ (b) $\frac{\pi}{3\sqrt{2}}$ (c) $\frac{\pi\sqrt{2}}{5}$ (d) $\frac{2\pi}{7}$

CSIR-UGC-NET/JRF|GATE-PHYSICS

SOLID STATE PHYSICS

Assignment-2

1. Atoms, which can be assumed to be hard spheres of radius R, are arranged in an fcc lattice with lattice constant a, such that each atom touches its nearest neighbours. Take the center of one of the atoms as the origin. Another atom of radius r (assumed to be hard sphere) is to be accommodated at a position $(0, a/2, 0)$ without distorting the lattice. The maximum value of r/R is ________. (Give your answer upto two decimal places). [GATE 2016]

2. Consider a regular arrangement of identical spheres in a face-centred cubic (fcc) structure in which the centres of the respective spheres are located at each of the eight corners and the centres of the six surfaces of a unit cube. The fraction of each cubic unit cell occupied by the spheres in the close-pack configuration is
(a) 0.50 (b) 0.62 (c) 0.74 (d) 0.88

3. The number of different Bravais lattices possible in two dimension is:
(a) 2 (B) 3 (c) 5 (d) 6 [JEST 2016]

4. Which of the following statements is correct for NaCl crystal structure?
(a) It is a 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.

5. The value of θ at which the first-order peak in X-ray $(\lambda = 1.53\,\text{Å})$ diffraction corresponding to (111) plane of a simple cubic structure with the lattice constant, a = 2.65 Å, is approximately
(a) 15° (b) 30° (c) 45° (d) 60°

6. The number of second-nearest neighbor ions to a Na^+ ion in NaCl crystal is ________

7. The ratio of the second-neighbour distance to the nearest-neighbour distance to the nearest-neighbour distance in an fcc lattice is
(a) $2\sqrt{2}$ (b) 2 (c) $\sqrt{3}$ (d) $\sqrt{2}$

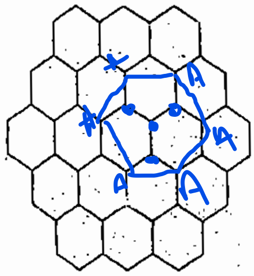
8. An X-ray beam of wavelength 1.54Å is diffracted from the (110) planes of a solid with a cubic lattice of lattice constant 3.08Å. The first-order Bragg diffraction occurs at
(a) $\sin^{-1}\left(\frac{1}{4}\right)$ (b) $\sin^{-1}\left(\frac{1}{2\sqrt{2}}\right)$ (c) $\sin^{-1}\left(\frac{1}{2}\right)$ (d) $\sin^{-1}\left(\frac{1}{\sqrt{2}}\right)$

9. 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) $\frac{\pi}{3\sqrt{2}}$

10. Diamond lattice can be considered as a combination of two fcc lattices 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

11. In a single layer of graphite, called graphene, the carbon atoms from a hexagonal lattice (see figure). How many carbon atoms are there in a unit cell of the lattice?

Imp



(a) one (b) two (c) three (d) six

12. An X-ray machine operates at a potential of 5000 V. What is the minimum possible value of wavelength present in the radiations?

(a) 0.0124 nm (b) 0.0245 nm (c) 0.124 nm (d) 0.248 nm

13. Helium atoms at low temperatures make a perfect closed pack structure of hexagonal lattice with parameters a = 0.36 nm and c = 0.59 nm. The density of the crystal is approximately

(a) 2000 kg/m³ (b) 100 kg/m³ (c) 123 kg/m³ (d) 200 kg/m³

14. Monochromatic X rays of wavelength 1Å are incident on a simple cubic crystal. The first order Brag reflection from (311) plane occurs at an angle of 30° from the plane. The lattice parameter of the crystal in Å is:

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

15. The second order maximum in the diffraction of X-rays of 0.20 nanometer wavelength from a simple cubic crystal is found to occur at an angle of thirty degrees with respect to the crystal plane. The distance between the lattice planes is

(a) 1 Angstrom (b) 2 Angstroms (c) 4 Angstroms (d) 8 Angstroms

16. A lattice is characterized by the following primitive vectors (in angstroms):

$\vec{a} = 2(\hat{i}+\hat{j}),\ \vec{b} = 2(\hat{j}+\hat{k}),\ \vec{c} = 2(\hat{k}+\hat{i})$. The reciprocal lattice corresponding to the above is:

(a) body centered cubic lattice with cube edge $\pi \text{Å}^{-1}$

(b) body centered cubic lattice with cube edge $2\pi \text{Å}^{-1}$

(c) face centered cubic lattice with cube edge $\pi \text{Å}^{-1}$

(d) face centered cubic lattice with cube edge $2\pi \text{Å}^{-1}$

17. Neutrons moving with speed 10^3 m/s are used for the determination of crystal structure. If the Bragg angle for the first order diffraction is 30°, the interplanarspacing of the crystal is ________ Å.

(Given: $m_n = 1.675\times10^{-27}\,kg,\ h = 6.626\times10^{-34}\ J.s$)

18. If $\vec{k}$ is the wavefactor of incident light ($|\vec{k}| = 2\pi/\lambda$, λ is the wavelength of light) and $\vec{G}$ is a reciprocal lattice vector, then the Bragg's law can be written as: **[JEST 2016]**

(a) $\vec{k}+\vec{G}=0$ (b) $2\vec{k}\cdot\vec{G}+G^2=0$ (c) $2\vec{k}\cdot\vec{G}+k^2=0$ (d) $\vec{k}\cdot\vec{G}=0$

19. The structure factor of a single cell of identical atoms of form factor f is given by

$Shkl = f\sum_{1}\exp\left(-i2\pi\left(x_j h + y_j k + z_j l\right)\right)$ where (x_j, y_j, z_j) is the coordinate of an atom, and hkl are the Miller indices. Which one of the following statement is correct for the diffraction peaks of body centered cubic (BCC) and face centered cubic (FCC) lattices?

(a) BCC : (200); (110); (222)
FCC : (111); (311); (400)

(b) BCC : (210); (110); (222)
FCC : (111); (311); (400)

(c) BCC : (200); (110); (222)

(d) BCC : (200); (210); (222)

FCC : (111); (211); (400)   FCC : (111); (211); (400)

20. Which one of the following axes of rotational symmetry is NOT permissible in single crystals?
(a) two fold axis (b) three-fold axis (d) four-fold axis (d) five-fold axis

Common Data for Q. 21 and Q. 22.

A crystal belongs to a face centered cubic lattice with four atoms in the unit cell. The size of the crystal is 1 cm and its unit cell dimension is 1 nm. f is the scattering factor of the atom.

21. The number of atoms in the crystal is:
(a) 2×10^{21} (b) 4×10^{21} (c) 2×10^{23} (d) 4×10^{24}

22. The structure factors for (0 1 0) and (2 0 0) reflections respectively are:
(a) 2 f and zero (b) zero and 4 f (c) 2 f and 2 f (d) zero and zero

23. The total number of Na^+ and Cl^- ions per unit cell of NaCl is, **[JEST 2015]**
(a) 2 (b) 4 (c) 6 (d) 8

24. Which of the following bonds has more directional:
(a) Ionic bonds (b) Covalent (c) Metalic (d) Vander Waals

25. If there are n-atoms in the primitive cell, the phonon dispersion relation had optical branches:-
(a) 3n – 3 (b) 3n – 2 (c) 3n – 1 (d) none

26. In a cubic crystal, atoms of mass M_1 lie on one set of planes and atoms of mass M_2 lie on planes interleaved between those of the first set. If C is the force constant between nearest neighbour planes, the frequency of lattice vibrations for the optical phonon branch with wavevector k = 0 is:

(a) $\sqrt{2C\left(\frac{1}{M_1}+\frac{1}{M_2}\right)}$ (b) $\sqrt{C\left(\frac{1}{M_1}+\frac{1}{M_2}\right)}$ (c) $\sqrt{C\left(\frac{1}{M_1}+\frac{1}{2M_2}\right)}$ (d) 0

27. At low temperature the specific heat of insulating crystals varies as:
(a) AT^3 (b) $BT + CT^3$
(c) D exp (E/T) (d) will not change with temperature

28. A cubic cell consists of two atoms of masses m_1 and m_2 ($m_1 > m_2$) with m_1 and m_2 atoms situated on alternate planes. Assuming only nearest neighbour interactions, the center of mass of the two atoms:
(a) moves with the atoms in the optical mode and remains fixed in the acoustic mode
(b) remains fixed in the optical mode and moves with the atoms in the acoustic mode
(c) remains fixed in both optical and acoustic modes
(d) moves with the atoms in both optical and acoustic modes

29. A linear diatomic lattice of lattice constant a with masses M and m (M > m) are coupled by a force constant C. The dispersion relation is given by:

$$\omega_{\pm}^2 = C\left(\frac{M+m}{Mm}\right) \pm \left[C^2\left(\frac{M+m}{M}\right)^2 - \frac{4C^2}{Mm}\sin^2\frac{ka}{2}\right]^{1/2}$$

Which one of the following statements is incorrect?
(a) The atoms vibrating in transverse mode correspond to the optical branch
(b) The maximum frequency of the acoustic branch depends on the mass of the lighter atom.
(c) The dispersion of frequency in the optical branch is smaller than that in the acoustic branch.
(d) No normal modes exist in the acoustic branch for any frequency greater than the maximum frequency at $k = \frac{\pi}{a}$.

30. The solid phase of an element follows van der Waals bonding with iner-atomic potential $V(r) = -\frac{P}{r^6} + \frac{Q}{r^{12}}$, where P and Q are constants. The bond length can be expressed as

(a) $\left(\frac{2Q}{P}\right)^{1/6}$ (b) $\left(\frac{Q}{P}\right)^{-6}$ (c) $\left(\frac{P}{2Q}\right)^{-6}$ (d) $\left(\frac{P}{Q}\right)^{-6}$

31. At the equilibrium spacing of a diatomic molecule, the resultant force is
(a) zero (b) minimum (c) maximum (d) unity

32. The potential energy in the above said spacing is
(a) zero (b) minimum (c) maximum (d) unity

33. Which of the interatomic bonds are directional?
(a) covalent (b) metallic (c) ionic (d) van der Waals Imp

34. The number of phonon branch in graphite, with four atoms in the primitive cell, is
(a) 8, out of which two are acoustic, the rest optical
(b) 9, out of which three are acoustic, the rest optical
(c) 12, out of which three are acoustic, the rest optical
(d) 12, out of which two are acoustic, the rest optical

35. The excitation of a three-dimensional solid are bosonic in nature with their frequency ω and wave-number k are related by $\omega \propto k^2$ in the large wavelength limit. If the chemical potential is zero, the behaviour of the specific heat of the system at low temperature is proportional to
(a) $T^{1/2}$ (b) T (c) $T^{3/2}$ (d) T^3

36. The nature of the interaction that gives rise to the van der Waals force in a molecular crystal is
(a) dipolar (b) nuclear (c) magnetic (d) quadrupolar

37. The specific heat of a normal metal at low temperatures is dominated by the contribution of
(a) conduction electrons (b) acoustic phonons
(c) core electrons (d) optical phonons

38. According to the Debye model, the internal energy of a solid a at temperature T close to absolute zero varies as
(a) T^2 (b) T^4 (c) T^3 (d) T

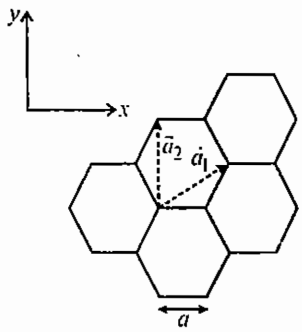
39. In the continuum model of an elastic solid, the frequency of sound waves
(a) is constant in some directions and proportional to the wave-vector in other directions
(b) is proportional to the square of the wave-vector
(c) is a constant independent of the wave-vector
(d) is proportional to the wave-vector in all directions.

40. The number of acoustic phonon branches in a three-dimensional crystal with 3 atoms per primitive cell is
(a) 6 (b) 9 (c) 3 (d) 12

41. Suppose the frequency of phonons in a one-dimensional chain of atoms is proportional to the wavevector. If n is the number density of atoms and c is the speed of the phonons, then the Debye frequency is
(a) $2\pi cn$ (b) $\sqrt{2}\pi cn$ (c) $\sqrt{3}\pi cn$ (d) $\frac{\pi cn}{2}$ **[NET June 2016]**

42. The free energy difference between the superconducting and the normal states of a material is given by $\Delta F = F_S - F_N = \alpha|\psi|^2 + \frac{\beta}{2}|\psi|^4$, where ψ is an order parameter and α and β are constants such that $\alpha > 0$ in the normal and $\alpha < 0$ in the superconducting state, while $\beta > 0$ always. The minimum value of ΔF in the superconducting state is
(a) $-\alpha^2/\beta$ (b) $-\alpha^2/2\beta$ (c) $-3\alpha^2/2\beta$ (d) $-5\alpha^2/2\beta$

43. Consider a hexagonal lattice with basis vectors as shown in the figure below. [NET Dec. 2016]



If the lattice spacing is $a = 1$, the reciprocal lattice vectors are

(a) $\left(\frac{4\pi}{3}, 0\right), \left(-\frac{2\pi}{3}, \frac{2\pi}{\sqrt{3}}\right)$

(b) $\left(\frac{4\pi}{3}, 0\right), \left(\frac{2\pi}{3}, \frac{2\pi}{\sqrt{3}}\right)$

(c) $\left(0, \frac{4\pi}{\sqrt{3}}\right), \left(\pi, \frac{2\pi}{\sqrt{3}}\right)$

(d) $\left(\frac{2\pi}{3}, \frac{2\pi}{\sqrt{3}}\right), \left(-2\pi, \frac{2\pi}{\sqrt{3}}\right)$

CSIR-UGC-NET/JRF|GATE-PHYSICS

SOLID STATE PHYSICS

Assignment-3

1. Which one of the following CANNOT be explained by considering a harmonic approximation for the lattice vibrations in solids?

(a) Debye's T^3 law (b) Dulong petit's law
(c) Optical baranches in lattices (d) Thermal expansion

Common data for Q. 2 and Q. 3

The dispersion relation for a one dimensional monatomic crystal with lattice spacing a, which interacts via nearest neighbour harmonic potential is given by $\omega = A\left|\sin\frac{Ka}{2}\right|$, where A is a constant of a appropriate unit.

2. The group velocity at the boundary of the first Brillouin zone is

(a) 0 (b) 1 (c) $\sqrt{\frac{Aa^2}{2}}$ (d) $\frac{1}{2}\sqrt{\frac{Aa^2}{2}}$

3. The force constant between the nearest neighbour of the lattice is (M is the mass of the atom)

(a) $\frac{MA^2}{4}$ (b) $\frac{MA^2}{2}$ (c) MA^2 (d) $2MA^2$

4. The Dulong Petit law fails near room temperature (300 K) for many light elements (such as boron and beryilium) because their Debye temperature is

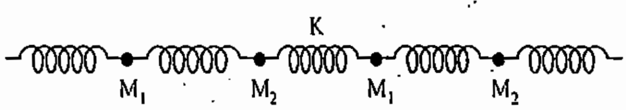
(a) $\gg 300$ K (b) ~ 300 K (c) $\ll 300$ K (d) 0 K

5. The dispersion relation of phonons in a solid is given by $\omega^2(k) = \omega_0^2(3 - \cos k_x a - \cos k_y a - \cos k_z a)$

The velocity of the phonons at large wavelenght is

(a) $\omega_0 a/\sqrt{3}$ (b) $\omega_0 a$ (c) $\sqrt{3}\omega_0 a$ (d) $\omega_0 a/\sqrt{2}$

6. The phonon dispersion for the following one-dimensional diatomic lattice with masses M_1 and M_2 (as shown in the figure)



is given by

$$\omega^2(q) = K\left(\frac{1}{M_1}+\frac{1}{M_2}\right)\left[1 \pm \sqrt{1-\frac{4M_1M_2}{(M_1+M_2)^2}\sin^2\left(\frac{qa}{2}\right)}\right]$$

where a is the lattice parameter and K is spring constant. The velocity of sound is

(a) $\sqrt{\frac{K(M_1+M_2)}{2M_1M_2}}a$ (b) $\sqrt{\frac{K}{2(M_1+M_2)}}a$ (c) $\sqrt{\frac{K(M_1+M_2)}{M_1M_2}}a$ (d) $\sqrt{\frac{KM_1M_1}{2(M_1+M_2)^3}}a$

7. Using the frequency-dependent Drude formula, what is the effective kinetic inductance of a metallic wire that is to be used as a transmission line? [In the following, the electron mass is m, density of electrons is n, and the length and cross-sectional area of the wire are ℓ and A respectively]

(a) $mA/(ne^2\ell)$ (b) zero (c) $m\ell/(ne^2A)$ (d) $m\sqrt{A}/(ne^2\ell^2)$

8. A typical semiconductor such as Ge is formed by what kind of bonds?
(a) Covalent (b) Ionic (c) van der Waals (d) Metallic

9. The lattice specific heat C of a crystalline solid can be obtained using the Dulong Petit model, Einstein model and Debye model. At low temperature $\hbar\omega >> K_BT$, which one of the following statements is true (a and A are constants)

(a) Dulong Petit: $C \propto \exp\left(\frac{-a}{T}\right)$; Einstein:C=.constant, Debye:$C \propto \left(\frac{T}{A}\right)^3$

(b) Dulong Petit:C = .constant; Einstein:$C \propto \left(\frac{T}{A}\right)^3$; Debye:$C \propto \exp\left(\frac{-a}{T}\right)$

(c) Dulong Petit:C = .constant; Einstein:$C \propto \frac{e^{-a/T}}{T^2}$;Debye:$C \propto \left(\frac{T}{A}\right)^3$

(d) Dulong Petit:$C \propto \left(\frac{T}{A}\right)^3$; Einstein:$C \propto \frac{e^{-a/T}}{T^2}$;Debye:C=.constant

10. A uniform linear monoatomic chain is modeled by a spring-mass system of masses m separated by nearest neighbor distance a and spring constant $m\omega_0^2$. The dispersion relation for this system is

(a) $\omega(k) = 2\omega_0\left(1-\cos\left(\frac{ka}{2}\right)\right)$ (b) $\omega(k) = 2\omega_0\sin^2\left(\frac{ka}{2}\right)$

(c) $\omega(k) = 2\omega_0\sin\left(\frac{ka}{2}\right)$ (d) $\omega(k) = 2\omega_0\tan\left(\frac{ka}{2}\right)$

11. At low temperature the specific heat of insulating crystals varies as
(a) AT^3 (b) $BT + CT^3$
(c) D exp (E/T) (d) will not change with temperature.

12. Consider two crystalline solids, one of which has a simple cubic structure, and the other has a tetragonal structure. The effective spring constant between atoms in the c-direction is half the effective spring constant between atoms in the a and b directions. At low temperatures, the behaviour of the lattice contribution to the specific heat will depend as a function of temperature T as

(a) T^2 for the tetragonal solid, but as T^3 for the simple cubic solid

(b) T for the tetragonal solid and as T^3 for the simple cubic solid

(c) T for both solids (d) T^3 for both solids

13. A one-dimensional linear chain of atoms contains two types of atoms of masses m_1 and m_2 (where $m_2>m_1$), arranged alternately. The distance between successive atoms is the same. Assume that the harmonic approximation is valid. At the first Brillouin zone boundary, which of the following statements is correct?

(a) The atoms of mass m_2 are at rest in the optical mode, while they vibrate in the acoustical mode.

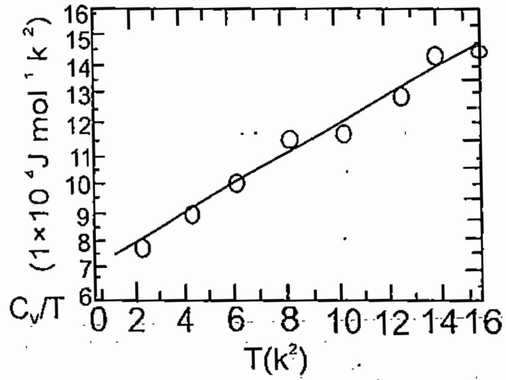
(b) The atoms of mass m_1 are at rest in the optical mode, while they vibrate in the acoustical mode.

(c) Both types of atoms vibrate with equal amplitudes in the optical as well as in the acoustical modes.

(d) Both types of atoms vibrate, but with unequal, non-zero amplitudes in the optical as well as in the acoustical modes. **[GATE 2016]**

14. The dispersion relation for phonons in a one dimensional monatomic Bravais lattice with lattice spacing a and consisting of ions of masses M is given by, $\omega(k)=\sqrt{\frac{2C}{M}\left[1-\cos(ka)\right]}$, where ω is the frequency of oscillation, k is the wavevector and C is the spring constant. For the long wavelength modes $(\lambda >> a)$, the ratio of the phase velocity to the group velocity is __________ **[GATE 2015]**

15. The ratio of the specific heat capacity and temperature, C_v/T, of Cu is plotted as a function of T^2, the square of the absolute temperature, in the graph below:



The values of γ and β (the coefficients corresponding to the electronic and the vibrational components of the specific heat) are, approximately

(a) $\gamma=7.0\times10^{-4}\,\text{Jmol}^{-1}\text{K}^{-2}$ and $\beta=5.0\times10^{-5}\,\text{Jmol}^{-1}\text{k}^{-4}$

(b) $\gamma=5.0\times10^{-5}\,\text{J mol}^{-1}\text{k}^{-2}$ and $\beta=7.0\times10^{-4}\,\text{J mol}^{-1}\text{k}^{-4}$

(c) $\gamma=1.4\times10^{-3}\,\text{J mol}^{-1}\text{k}^{-2}$ and $\beta=7.0\times10^{-4}\,\text{J mol}^{-1}\text{k}^{-4}$

(d) $\gamma=5.0\times10^{-4}\,\text{J mol}^{-1}\text{k}^{-2}$ and $\beta=7.0\times10^{-5}\,\text{J mol}^{-1}\text{k}^{-4}$

16. The Fermi energies of two metals X and Y are 5eV and 7eV and their Debye temperatures are 170 K and 340 K, respectively. The molar specific heats of these metals at constant volume at low temperatures can be written as $(C_V)_X=\gamma_X T+A_X T^3$ and $(C_V)_Y=\gamma_Y T+A_Y T^3$, where γ and A are constants. Assuming that the thermal effective mass of the electrons in the two metals are same, which of the following is correct?

(a) $\frac{\gamma_X}{\gamma_Y}=\frac{7}{5}, \frac{A_X}{A_Y}=8$ (b) $\frac{\gamma_X}{\gamma_Y}=\frac{7}{5}, \frac{A_X}{A_Y}=\frac{1}{8}$ **[GATE 2016]**

(c) $\frac{\gamma_X}{\gamma_Y}=\frac{5}{7}, \frac{A_X}{A_Y}=\frac{1}{8}$ (d) $\frac{\gamma_X}{\gamma_Y}=\frac{5}{7}, \frac{A_X}{A_Y}=8$

17. The binding energy per molecule of NaCl (lattice parameter is 0.563 nm) is 7.95 eV. The repulsive term of the potential is of the form $\frac{K}{r^9}$, where K is a constant. The value of Madelung constant is __________ (upto three decimal places). **[GATE 2015]**

(Electron charge $e=-1.6\times10^{-19}C$; $\varepsilon_0=8.854\times10^{-12}\,C^2N^{-1}m^{-2}$).

18. The origin of van der Waals interaction of molecular crystals is:
(a) nuclear (b) magnetic (c) ionic (d) fluctuating dipolar

19. Consider the Fermi-Dirac distribution function f(E) at room temprature (300 K) where E refers to energy. If E_F is the Fermi energy, which of the following is true?
(a) f(E) is a step function
(b) f(EF) has a value of 1/2
(c) States with $E<E_F$ are filled completely
(d) f(E) is large and tends to infinity as E decreases much below E_F

20. Consider the energy E in the first Brillouin zone as a function of the magnitude of the wave vector k for a crystal of lattice constant a. Then
(a) the slope of E versus k is proportional to the group velocity
(b) the slope of E versus k has its maximum value at $|k| = \pi/a$
(c) the plot of E versus k will be parabolic in the interval $(-\pi/a) < k < (\pi/a)$
(d) the slope of E versus k is non-zero for all k the interval $(-\pi/a) < k (\pi/a)$

Statement for Linked Answer Q. 21 and Q. 22.

The atomic density of a solid is $5.85\times10^{28}\ m^{-3}$. Its electrical resistivity is $1.6\times10^{-8}\ \Omega$ m. Assume that electrical conduction is described by the Drude model (classical theory), and that each atom contributes one conduction electron.

21. The drift mobility (in $m^2 V^{-1}s^{-1}$) of the conduction electrons is:
(a) 6.67×10^{-3} (b) 6.67×10^{-6} (c) 7.63×10^{-3} (d) 7.63×10^{-6}

22. The relaxation time (mean free time), in seconds, of the conduction electrons is:
(a) 3.98×10^{-15} (b) 3.79×10^{-14} (c) 2.84×10^{-12} (d) 2.64×10^{-11}

23. Metallic monovalent sodium crystallizes in body centered cubic structure. If the length of the unit cell is 4×10^{-8} cm, the concentration of conduction electrons in metallic sodium is:
(a) $6.022 \times 10^{23}\ cm^{-3}$ (b) $3.125 \times 10^{22}\ cm^{-3}$ (c) $2.562 \times 10^{21}\ cm^{-3}$ (d) $1.250 \times 10^{20}\ cm^{-3}$

24. The kinetic energy of a free electron at a corner of the first Brillouin zone of a two dimensional square lattice is larger than that of an electron at the mid-point of a side of the zone by a factor b. The value of b is:
(a) $b = \sqrt{2}$ (b) b = 2 (c) b = 4 (d) b = 8

25. The valence electrons do not directly determine the following property of a metal.
(a) Electrical conductivity (b) Thermal conductivity
(c) Shear modulus (d) metallic lustre.

26. For a two-dimensional free electron gas, the electronic density n, and the Fermi energy E_F, are related by

(a) $n = \dfrac{(2mE_F)^{3/2}}{3\pi^2\hbar^3}$ (b) $n = \dfrac{mE_F}{\pi\hbar^2}$ (c) $n = \dfrac{mE_F}{2\pi\hbar^2}$ (d) $n = \dfrac{2^{3/2}(mE_F)^{1/2}}{\pi\hbar}$

27. The resistivity of metals:
(a) Always varies as T^5
(b) is independent of temperature
(c) increases liniearly with temperature at room temperature and above
(d) attains a constant value as temperature tends to absolute zero

28. For a Fermi gas of N particles in three dimensions at T = 0 K, the Fermi energy, E_F..

(a) $N^{2/3}$ (b) $N^{3/2}$ (c) N^3 (d) N^2

29. For an energy state E of a photon gas, the density of states is proportional to:

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

30. Density of states of free electrons in a solid moving with an energy 0.1 eV is given by 2.15×10^{21} eV^{-1} cm^{-3}. The density of states in eV^{-1} cm^{-3}) for electrons moving with an energy of 0.4 eV will be:

(a) 1.07×10^{21} (b) 1.52×10^{21} (c) 3.04×10^{21} (d) 4.30×10^{21}

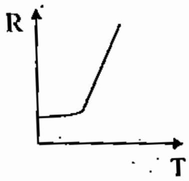
31. Which one of the following statements is NOT correct about the Brillouin zones (BZ) of a square lattices with constant a?

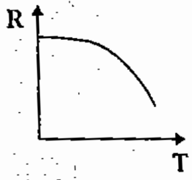
(a) The first BZ is a square of size 2p/a in k_x–k_y plane
(b) The areas of the first BZ and third BZ are the same
(c) The k-points are equidistant in k_x as well as in k_y directions
(d) The area of the second BZ is twice that of the first BZ

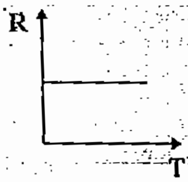
32. An electron confined within a thin layer of semiconductor may be treated as a free particle inside an infinitely deep one-dimensional potential well. If the difference in energies between the first and the second energy levels is δE, then the thickness of the layer is: **[JEST 2016]**

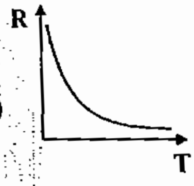
(a) $\sqrt{\frac{3\hbar^2\pi^2}{2m\delta E}}$ (b) $\sqrt{\frac{2\hbar^2\pi^2}{3m\delta E}}$ (c) $\sqrt{\frac{\hbar^2\pi^2}{2m\delta E}}$ (d) $\sqrt{\frac{\hbar^2\pi^2}{m\delta E}}$

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

(a) 

(b) 

(c) 

(d) 

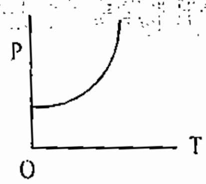
34. A copper wire is 1 metre long and has a uniform cross-section of 0.1 mm^2. The resistance of the wire at room temperature is 0.171 ohm. What is the resistivity of the material?

(a) $1.71\times10^{-6}\ \Omega.m$ (b) $1.71\times10^{-7}\ \Omega.m$ (c) $1.71\times10^{-8}\ \Omega.m$ (d) $1.71\times10^{-9}\ \Omega.m$

35. As the Fermi energy of silver is 8.8×10^{-19} joule, the velocity of the fastest electron in the silver at 0 K. (Given: Rest mass of electron = 9.1×10^{-31} kg) is:

(a) $3.33\times10^5\ m/s$ (b) $4.40\times10^7\ m/s$ (c) $1.39\times10^6\ m/s$ (d) $3\times10^8\ m/s$

36. The temperature dependence of the electrical resistivity ρ of a material is shown in the plot below. This material is a



(a) insulator (b) semiconductor (c) normal metal (d) superconductor

37. For Li metal, the resistivity at 77K is $1.01\ \mu\Omega-cm$ and that at 273K is $8.57\ \mu\Omega-cm$. The ratio of the mean collision times, $\frac{\tau_{77}}{\tau_{273}}$ is approximately,

(a) 3 (b) 1/9 (c) 9 (d) 1/3

38. The real part of the ac conductivity of a metal at a large frequency $\omega(\omega\tau >> 1, \tau =$ mean collision time).

(a) increases as ω (b) decreases $\frac{1}{\omega^2}$.
(c) becomes independent of ω (d) varies as $\sqrt{\omega}$.

39. For an ideal Fermi gas in three dimensions, the electron velocity V_F at he Fermi surface is related to electron concentration n as,

(a) $V_F \propto n^{2/3}$ (b) $V_F \propto n$ (c) $V_F \propto n^{1/2}$ (d) $V_F \propto n^{1/3}$

40. The radius of the Fermi sphere of free electrons in a monovalent metal with an fcc structure, in which the volume of the unit cell is a^3, is

(a) $\left(\frac{12\pi^2}{a^3}\right)^{1/3}$ (b) $\left(\frac{3\pi^2}{a^3}\right)^{1/3}$ (c) $\left(\frac{\pi^2}{a^3}\right)^{1/3}$ (d) $\frac{1}{a}$

41. The fraction of electrons excited across the energy gap of 0.7 eV in Ge, at room temperature is

(a) 0 (b) 1.4×10^{-6} (c) 1.6×10^{-8} (d) 1.03×10^{-12}

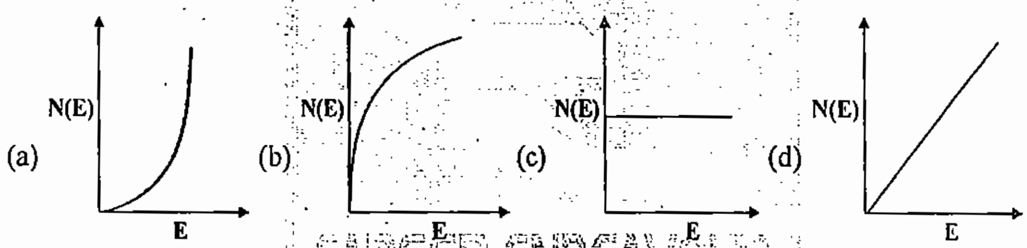
42. What is the value of potential energy V, in a free electron gas theory of metals?

(a) A constant (b) Infinite
(c) It varies with the distance (d) zero

43. Which of the following statement best explains why the specific heat of electrons in metals is much smaller than that expected in a non-interacting (free) electron gas model?

(a) The mass of electron is much smaller than that of the ions in the crystal.
(b) The Pauli exclusion principle restricts the number of electrons which can absorb thermal energy
(c) Electron spin can take only two different values.
(d) Electrons in a metal cannot be modelled as non-interacting.

44. For a free electron gas in two dimensions, the variation of the density of states, N(E) as a function of energy E, is the best represented by



45. The energy dependence of the density of states for a two dimensional non-relativistic electron gas is given by, $g(E) = CE^n$, where C is constant. The value of n is ________ [GATE 2015]

46. Given that the Fermi energy of gold is 5.54 eV, the number density of electrons is ________ $\times10^{28}$ m^{-3} (upto one decimal places) [GATE 2015]
(Mass of electron = 9.11×10^{-31} kg; h = 6.626×10^{-34} J.s; 1 eV = 1.6×10^{-19} J)

47. A thin metal film of dimension 2 mm × 2 mm contains 4×10^{12} electrons. The magnitude of the Fermi wavevector of the system, in the free electron approximation, is [NET Dec. 2015]

(a) $2\sqrt{\pi}\times10^7\text{cm}^{-1}$ (b) $\sqrt{2\pi}\times10^7\text{cm}^{-1}$ (c) $\sqrt{\pi}\times10^7\text{cm}^{-1}$ (d) $2\pi\times10^7\text{cm}^{-1}$

48. The potential in a divalent solid at a particular temperature is represented by a one-dimensional periodic model. The solid should behave electrically as:

(a) semiconductor (b) a conductor
(c) an insulator (d) a superconductor

49. A metal has free-electron density $n = 10^{29}$ m^{-3}. Which of the following wavelengths will excite plasma oscillations?

(a) 0.033 μm (b) 0.330 μm (c) 3.300 μm (d) 33.000 μm

50. In a one-dimensional Kroning Penny model, the total number of possible wave functions is equal to:
(a) twice the number of unit cells
(b) number of unit cells
(c) half the number of unit cells
(d) independent of the number of unit cells

51. In a crystal of N primitive cells, each cell contains two monovalent atoms. The highest occupied energy band of the crystal is:
(a) one-fourth filled (b) one-third filled (c) half filled (d) completely filled

52. The Bloch theore states that within a crystal, the wavefunction, $\psi(\vec{r})$, of an electron has the form

(a) $\psi(\vec{r}) = u(\vec{r})e^{i\vec{k}.\vec{r}}$ where $u(\vec{r})$ is an arbitrary function and $\vec{k}$ is an arbitrary vector.

(b) $\psi(\vec{r}) = u(\vec{r})e^{i\vec{G}.\vec{r}}$ where $u(\vec{r})$ is an arbitrary function and $\vec{G}$ is a reciprocal lattice vector.

(c) $\psi(\vec{r}) = u(\vec{r})e^{i\vec{G}.\vec{r}}$ where $u(\vec{r}) = u(\vec{r}+\vec{\Lambda}), \vec{\Lambda}$ is a lattice vector and $\vec{G}$ is a reciprocal lattice vector.

(d) $\psi(\vec{r}) = u(\vec{r})e^{i\vec{k}.\vec{r}}$ where $u(\vec{r}) = u(\vec{r}+\vec{\Lambda}), \vec{\Lambda}$ is a lattice vector and $\vec{k}$ is an arbitrary vector.

53. The lattice specific heat C of a crystalline solid can be obtained using the Dulong Petit model. Einstein modle and Debye model. At low tesmperature hw >> k_BT, which one of the following statements is true (a and A are constants)

(a) Dulong Petit : $C \propto \exp\left(\frac{-a}{T}\right)$; Einstein: C = constant; Debye : $C \propto \left(\frac{T}{A}\right)^3$

(b) Dulong Petit : C = constant; Einstein $C \propto \left(\frac{T}{A}\right)^3$ Debye : $C \propto \left(\frac{-a}{T}\right)$

(c) Dulong Petit : C = constant; Einstein $C \propto \frac{e^{-a/T}}{T^2}$ Debye : $C \propto \left(\frac{T}{A}\right)^3$

(d) Dulong Petit : $C \propto \left(\frac{T}{A}\right)^3$ Einstein $C \propto \frac{e^{-a/T}}{T^2}$ Debye : C = constant

Common data Q. 54 and Q.55:

The tight binding energy dispersion (E–k) relation for electrons in a one-dimensional array of atoms having lattice constant a and total length L is:

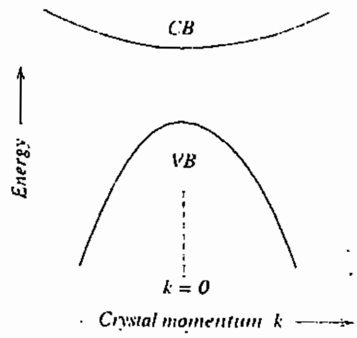
$$E = E_0 - \beta - 2\gamma\cos(ka)$$

Where E_0, β and γ are constants and k is the wave-vector.

54. The density of states of electrons (including spin degeneracy) in the band is given by
(a) $\frac{L}{\pi\gamma a\sin(ka)}$ (b) $\frac{L}{2\pi\gamma a\sin(ka)}$ (c) $\frac{L}{2\pi\gamma a\cos(ka)}$ (d) $\frac{L}{\pi\gamma a\cos(ka)}$

55. The effective mass of electrons in the band is given by
(a) $\frac{\hbar^2}{\gamma a^2\cos(ka)}$ (b) $\frac{\hbar^2}{2\gamma a^2\cos(ka)}$ (c) $\frac{\hbar^2}{\gamma a^2\sin(ka)}$ (d) $\frac{\hbar^2}{2\gamma a^2\cos(ka)}$

56. Suppose the energy band of a certain pure crystalline solid is as shown in the figure below, where the energy (E) varies with crystal momentum (k) as $E \propto k^2$



At finte temperatures the bottom of the conduction band (CB) is partially filled with electrons (e) and the top of the valence band (VB) is partially filled holes (h). If an electric fields is applied to this solid, both e and h will start moving. If the time between collisions is the same for both e and h, then

(a) e and h will move with the same speed in opposite directions
(b) h will on an average achieve higher speed than e
(c) e will on an average achieve higher speed than h
(d) e and h will recombine and after a while there will be no flow of charges.

57. In a period potential given by $V(\vec{r}) = V(\vec{r}+\vec{R})$, where $\vec{R}$ is the lattice vector, the eigenstates of the Hamiltonian $H = \frac{-\hbar^2}{2m}\nabla^2 + V(\vec{r})$ are $\psi_k(\vec{r}) = e^{i\vec{k}.\vec{r}}u_{\vec{k}}(\vec{r})$, where

(a) $u_{\vec{k}}(\vec{r}) = e^{i\vec{k}.\vec{R}}(\vec{k} \neq \vec{k}')$
(b) $u_{\vec{k}}(\vec{r}) = e^{i\vec{k}.\vec{R}} u_{\vec{k}}\left(\vec{r}+\frac{\vec{R}}{3}\right)$
(c) $u_{\vec{k}}(\vec{r}) = u_{\vec{k}}\left(\vec{r}+\frac{\vec{R}}{2}\right)$
(d) $u_{\vec{k}}(\vec{r}) = u_{\vec{k}}(\vec{r}+\vec{R})$

58. The Fermi level in an intrinsic semiconductor at zero temperature lies
(a) in the conduction band
(b) at the top of the valence band
(c) at the bottom of the conduction band
(d) in the energy gap between the valence and the conduction bands

59. In a band structure calculation, the dispersion relation for electrons is found to be

$$\varepsilon_k = \beta\left(\cos k_x a + \cos k_y a + \cos k_z a\right)$$

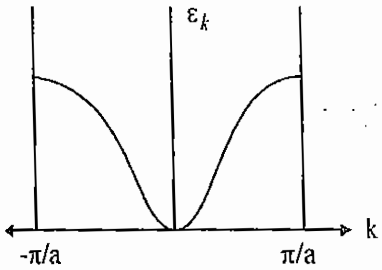
where β is a constant and a is the lattice constant. The effective mass at the boundary of the first Brillouin zene is

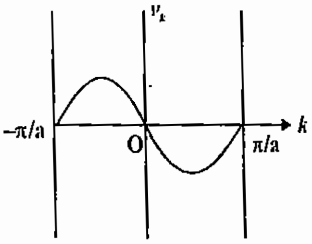
(a) $\frac{2\hbar^2}{5\beta a^2}$ (b) $\frac{4\hbar^2}{5\beta a^2}$ (c) $\frac{\hbar^2}{2\beta a^2}$ (d) $\frac{\hbar^2}{3\beta a^2}$ (e) none of these

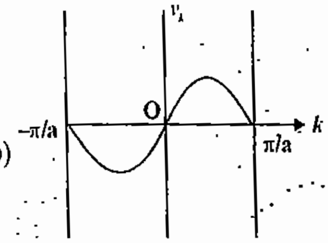
60. Which one of the following diffraction peaks will be absent in a powder diffraction pattern for BCC-crystalline powder such as Fe

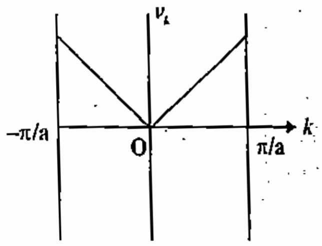
(a) (110) (b) (111) (c) (200) (d) (211)

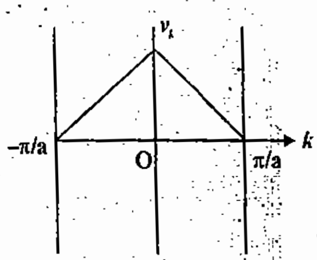
61. The energy, ε_k for band electrons as a function of the wave vector, k in the first Brillouin zone $\left(-\frac{\pi}{a} \le k \le \frac{\pi}{a}\right)$ of a one dimensional monatomic lattice is shown as (a is latticec constant)



(a)


(b)


(c)


(d)


62. Consider an electron in a b.c.c. lattice with lattice constant a. A single particle wavefunction that satisfies the Bloch theorem will have the form $f(\bar{r})\exp(i\bar{k}.\bar{r})$, with $f(\bar{r})$ being

(a) $1+\cos\left[\frac{2\pi}{a}(x+y-z)\right]+\cos\left[\frac{2\pi}{a}(-x+y+z)\right]+\cos\left[\frac{2\pi}{a}(x-y+z)\right]$

(b) $1+\cos\left[\frac{2\pi}{a}(x+y)\right]+\cos\left[\frac{2\pi}{a}(y+z)\right]+\cos\left[\frac{2\pi}{a}(z+x)\right]$

(c) $1+\cos\left[\frac{\pi}{a}(x+y)\right]+\cos\left[\frac{\pi}{a}(y+z)\right]+\cos\left[\frac{\pi}{a}(z+x)\right]$

(d) $1+\cos\left[\frac{\pi}{a}(x+y-z)\right]+\cos\left[\frac{\pi}{a}(-x+y+z)\right]+\cos\left[\frac{\pi}{a}(x-y+z)\right]$

63. The dispersion relation for electrons in an f.c.c. crystal is given, in the tight binding approximation by

$$\varepsilon(k) = -4\varepsilon_0\left[\cos\frac{k_x a}{2}\cos\frac{k_y a}{2}+\cos\frac{k_y a}{2}\cos\frac{k_z a}{2}+\cos\frac{k_z a}{2}\cos\frac{k_x a}{2}\right]$$

where 'a' is the lattice constant and ε_0 is a constant with the dimension of energy. The x-component of the velocity of the electrons at $\left(\frac{\pi}{a},0,0\right)$ is

(a) $-\frac{2\varepsilon_0 a}{\hbar}$ (b) $\frac{2\varepsilon_0 a}{\hbar}$ (c) $-\frac{4\varepsilon_0 a}{\hbar}$ (d) $\frac{4\varepsilon_0 a}{\hbar}$

64. Which of the following is the best technique for measuring the effective mass of an electron in a semiconductor?
(a) Resistivity measurements (b) X-rays diffraction experiment
(b) Cyclotron resonance (d) Millikan's oil drop experiment

65. In the basic band structure theory of crystalline solids, which of the following leads to energy gaps in the allowed electronic energy values ?
(a) Electron spin (b) Bragg reflection
(c) Electron-electron interacion (d) Electron-phonon interaction

66. The material inside a box is either a metal or a semiconductor. If $R (= 1\ \Omega)$ is the resistance of the material, which of the following experiments CANNOT distinguish whether it is a metal or a semiconductor ?
(a) Measurement of R using power supplies of different frequencies.
(b) Measurement of absorption spectrum in the energy range $0.1 - 2$ eV.
(c) Measurement of R at different temperatures.
(d) Measurement of R in the presence of different magnetic fields.

67. Given that tight binding dispersion relation $E(k) = E_0 + A\sin^2\left(\frac{ka}{2}\right)$, where E_0 and A are constant and a is the lattice parameter. What is the group velocity of an electron at the second Brillouin zone boundary?
(a) 0 (b) $\frac{a}{h}$ (c) $\frac{2a}{h}$ (d) $\frac{a}{2h}$ **[JEST 2015]**

68. The dispersion relation for electrons in the conduction band of a n-type semiconductor has the form $E(k) = ak^2 + b$ where a and b are constant. It was observed that the cyclotron resonance frequency of such electrons is $\omega_0 = 1.8\times10^{11}$ rad s^{-1}, when placed in a magnetic field $B = 0.1$ W m^{-2}. It follows that the constant a must be about **[TIFR 2016]**
(a) 10^{-36} (b) 10^{-28} (c) 10^{-32} (d) 10^{-38}

69. The dispersion relation of electrons in a 3-dimensional lattice in the tight binding approximation is given by,
$\varepsilon_k = \alpha\cos k_x a + \beta\cos k_y a + \gamma\cos k_z a$ where a is the lattice constant and α, β, γ are constants with dimension of energy. The effective mass tensor at the corner of the first Brillouin zone $\left(\frac{\pi}{a}, \frac{\pi}{a}, \frac{\pi}{a}\right)$ is

(a) $\frac{\hbar^2}{a^2}\begin{pmatrix} -\frac{1}{\alpha} & 0 & 0 \\ 0 & -\frac{1}{\beta} & 0 \\ 0 & 0 & \frac{1}{\gamma} \end{pmatrix}$ (b) $\frac{\hbar^2}{a^2}\begin{pmatrix} -\frac{1}{\alpha} & 0 & 0 \\ 0 & -\frac{1}{\beta} & 0 \\ 0 & 0 & -\frac{1}{\gamma} \end{pmatrix}$ **[NET Dec. 2015]**

(c) $\frac{\hbar^2}{a^2}\begin{pmatrix} \frac{1}{\alpha} & 0 & 0 \\ 0 & \frac{1}{\beta} & 0 \\ 0 & 0 & \frac{1}{\gamma} \end{pmatrix}$ (d) $\frac{\hbar^2}{a^2}\begin{pmatrix} \frac{1}{\alpha} & 0 & 0 \\ 0 & \frac{1}{\beta} & 0 \\ 0 & 0 & -\frac{1}{\gamma} \end{pmatrix}$

70. For an electron moving through a one-dimensional periodic lattice of periodicity a, which of the following corresponds to an energy eigenfunction consistent with Bloch's theorem? **[NET Dec. 2015]**

(a) $\psi(x) = A\exp\left(i\left[\frac{\pi x}{a} + \cos\left(\frac{\pi x}{2a}\right)\right]\right)$ (b) $\psi(x) = A\exp\left(i\left[\frac{\pi x}{a} + \cos\left(\frac{2\pi x}{a}\right)\right]\right)$

(c) $\psi(x) = A\exp\left(i\left[\frac{2\pi x}{a} + i\cosh\left(\frac{2\pi x}{a}\right)\right]\right)$ (d) $\psi(x) = A\exp\left(i\left[\frac{\pi x}{2a} + i\left|\frac{\pi x}{2a}\right|\right]\right)$

71. Consider electrons in graphene, which is a planar monatomic layer of carbon atoms. If the dispersion relation of the electrons is taken to be $\varepsilon(k) = ck$ (where c is constant) over the entire k-space, then the Fermi energy ε_F depends on the number density of electrons ρ as **[NET June 2016]**

(a) $\varepsilon_F \propto \rho^{1/2}$ (b) $\varepsilon_F \propto \rho$ (c) $\varepsilon_F \propto \rho^{2/3}$ (d) $\varepsilon_F \propto \rho^{1/3}$

72. The band energy of an electron in a crystal for a particular k-direction has the form $\varepsilon(k) = A - B\cos 2ka$, where A and B are positive constants and $0 < ka < \pi$. The electron has a hole-like behaviour over the following range of k: **[NET June 2016]**

(a) $\frac{\pi}{4} < ka < \frac{3\pi}{4}$ (b) $\frac{\pi}{2} < ka < \pi$ (c) $0 < ka < \frac{\pi}{4}$ (d) $\frac{\pi}{2} < ka < \frac{3\pi}{4}$

73. The low-energy electronic excitations in a two-dimensional sheet of graphene is given by $E(\vec{k}) = \hbar v k$, where v is the velocity of the excitations. The density of states is proportional to **[NET June 2015]**

(a) E (b) $E^{3/2}$ (c) $E^{1/2}$ (d) E^2

74. Consider a metal which obeys the Sommerfeld model exactly. If E_F is the Fermi energy of the metal at $T = 0$K and R_H is its Hall coefficient, which of the following statements is correct? **[GATE 2016]**

(a) $R_H \propto E_F^{3/2}$ (b) $R_H \propto E_F^{2/3}$

(c) $R_H \propto E_F^{-3/2}$ (d) R_H is independent of E_F

75. Consider a one-dimensional chain of atoms with lattice constant a. The energy of an electron with wave-vector k is $\varepsilon(k) = \mu - \gamma\cos(ka)$, where μ and γ are constants. If an electric field E is applied in the positive x-direction, the time dependent velocity of an electron is **[NET Dec. 2016]**
(in the following B is the constant)

(a) proportional to $\cos\left(B - \frac{eE}{\hbar}at\right)$ (b) proportional to E

(c) independent of E (d) proportional to $\sin\left(B - \frac{eE}{\hbar}at\right)$

76. The electrons in graphene can be thought of as a two-dimensional gas with a linear energy-momentum relation $E = |\vec{p}|v$, where $\vec{p} = (p_x, p_y)$ and v is a constant. If ρ is the number of electrons per unit area, the energy per unit area is proportional to **[NET Dec. 2016]**

(a) $\rho^{3/2}$ (b) ρ (c) $\rho^{1/3}$ (d) ρ^2

77. Consider a 2-D sqaure lattice. The ratio of the kinetic energy of a free electron at a corner of the first Brillouin zone (E_c) to that of an electron at the midpoint of a side face of the same zone (E_m) is $E_c/E_m =$

(a) 1/2 (b) 2 (c) $\sqrt{2}$ (d) 1 **[TIFR 2017]**

78. In two dimensions two metals A and B, have the number density of free electrons in the ratio $n_A : n_B = 1:2$. The ratio of their Fermi energies is **[TIFR 2017]**

(a) 2 : 3 (b) 1 : 2 (c) 1 : 4 (d) 1 : 8

79. Electrons in a metal are scattered by both impurities and phonons. The impurity scattering time is 8×10^{-12} s and the phonon scattering time is 2×10^{-12} s. Taking the density of electrons to be 3×10^{14} m^{-3}, find the conductivity of the metal in units of A V^{-1} m^{-1}. [Assume that the effective mass of the electrons is the same as that of a free electron]. **[TIFR 2017]**

80. The atomic mass and mass density of Sodium are 23 and 0.968 g cm^{-3}, respectively. The number density of valence electrons is ______ $\times 10^{22}\ cm^{-3}$. (Up to two decimal places.) [GATE 2017]
(Avogadro number, $N_A = 6.022 \times 10^{23}$).

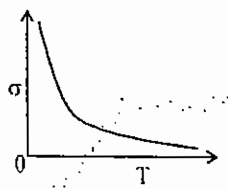
81. Consider a one-dimensional lattice with a weak periodic potential $U(x) = U_0 \cos\left(\frac{2\pi x}{a}\right)$. The gap at the edge of the Brillouin zone $\left(k = \frac{\pi}{a}\right)$ is: [GATE 2017]

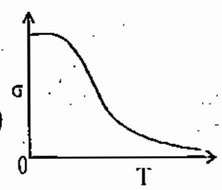
(a) U_0 (b) $\frac{U_0}{2}$ (c) $2U_0$ (d) $\frac{U_0}{4}$

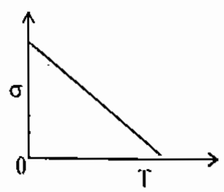
82. The energy gap and lattice constant of an indirect band gap semiconductor are 1.875 eV; 0.52 nm, respectively. For simplicity take the dielectric constant of the material to be unity. When it is excited by broadband radiation, an electron initially in the valence band at $k = 0$ makes a transition to the conduction band. The wavevector of the electron in the conduction band, in terms of the wavevector k_{max} at the edge of the Brillouin zone, after the transition is closest to [NET June 2017]
(a) $k_{max}/10$ (b) $k_{max}/100$ (c) $k_{max}/1000$ (d) 0

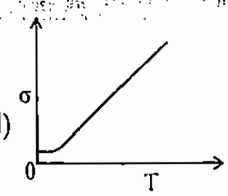
83. The electrical conductivity of copper is approximately 95% of the electrical conductivity of silver, while the electron density in silver is approximately 70% of the electron density in copper. In Drude's model, the approximate ratio τ_{Cu}/τ_{Ag} of the mean collision time in copper (τ_{Cu}) to the mean collision time in silver (τ_{Ag}) is
(a) 0.44 (b) 1.50 (c) 0.33 (d) 0.66 [NET June 2017]

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

(a)


(b)


(c)


(d)


85. A white dwarf star has volume V and contains N electrons so that the density of electrons is $n = \frac{N}{V}$. Taking the temperature of the star to be 0 K, the average energy per electron in the star is $\epsilon_0 = \frac{3\hbar^2}{10m}(3\pi^2 n)^{2/3}$, where m is the mass of the electron. The electronic pressure in the star is

(a) $n\epsilon_0$ (b) $2n\epsilon_0$ (c) $\frac{1}{3}n\epsilon_0$ (d) $\frac{2}{3}n\epsilon_0$

86. If X is the dimensionality of a free electron gas, the energy (E) dependence of density of states is given by $E^{\frac{1}{2}X-Y}$, where Y is ________ . [GATE 2018]

87. The energy dispersion for electron in one dimensional lattice with lattice parameter a is given by

$$E(k) = E_0 - \frac{1}{2}W\cos ka,$$

where W and E_0 are constants. The effective mass of the electron near the bottom of the band is

(a) $\frac{2\hbar^2}{Wa^2}$ (b) $\frac{\hbar^2}{Wa^2}$ (c) $\frac{\hbar^2}{2Wa^2}$ (d) $\frac{\hbar^2}{4Wa^2}$ [GATE 2018]

88. For a metal, the electron density is 6.4×10^{28} m^{-3}. The Fermi energy is ____________ eV.

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

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

89. A metallic nanowire of length l is approximated as a one-dimensional lattice of N atoms with lattice spacing a. If the dispersion of electrons in the lattice is given as $E(k) = E_0 - 2t\cos ka$, where E_0 and t are constants, then the density of states inside the nanowire depends on E as [NET Dec. 2017]

(a) $N^3\sqrt{\frac{t^2}{E-E_0}}$ (b) $\sqrt{\left(\frac{E-E_0}{2t}\right)^2-1}$ (c) $N^3\sqrt{\frac{E-E_0}{t^2}}$ (d) $\frac{N}{\sqrt{(2t)^2-(E-E_0)^2}}$

90. The dispersion relation for the electrons in the conduction band of a semiconductor is given by $E = E_0 + \alpha k^2$, where α and E_0 are constants. If ω_c is the cyclotron resonance frequency of the conduction band electrons in a magnetic field B, the value of α is [NET June 2018]

(a) $\frac{\hbar^2\omega_c}{4eB}$ (b) $\frac{2\hbar^2\omega_c}{eB}$ (c) $\frac{\hbar^2\omega_c}{eB}$ (d) $\frac{\hbar^2\omega_c}{2eB}$

CAREER ENDEAVOUR
Best Institute for NET, GATE & IIT-JAM

CSIR-UGC-NET/JRF|GATE-PHYSICS

SOLID STATE PHYSICS

Assignment-4

1. The effective mass of an electron in a semiconductor can be:
(a) negative near the bottom of the band (b) a scalar quantity with a small magnitude
(c) zero at the center of the band (d) negative near the top of the band

2. The effective mass of an electron in a semiconductor
(a) can never be positive (b) can never be negative
(c) can be positive or negative (d) depends on its spin

3. An n-type semiconductor has an electron concentration of $3\times10^{20}\ m^{-3}$. If the electron drift velocity is $100\ ms^{-1}$ in an electric field of $200\ Vm^{-1}$, the conductivity (in $W^{-1}m^{-1}$) of this material is:
(a) 24 (b) 36 (c) 48 (d) 96

4. Which one of the following is NOT a correct statement about semiconductors?
(a) The electrons and holes have different mobilities in a semiconductor
(b) In an n-type semiconductor, the Fermi level lies closer to the conduction band edge
(c) Silicon is a direct band gap semiconductor.
(d) Silicon has diamond structure

5. Compared to a p-n junction with $N_A = N_D = 10^{14}/cm^3$, which one of the following statement is TRUE for a p-n junction with $N_A = N_D = 10^{20}/cm^3$?
(a) Reverse breakdown voltage is lower and depletion capacitance is lower.
(b) Reverse breakdown voltage is higher and depletion capacitance is lower.
(c) Reverse breakdown voltage is lower and depletion capacitance is higher.
(d) Reverse breakdown voltage is higher and depletion capacitance is higher.

6. Silicon is doped with boron to a concentration of 4×10^{17} atoms/cm³. Assume the intrinsic carrier concentration of silicon to be $1.5\times10^{10}/cm^3$ and the value of kT/q to be 25 mV at 300 K. Compared to un-doped silicon, the Fermi level of doped silicon:
(a) Goes down by 0.13 eVs (b) Goes up by 0.13 eV
(c) Goes down by 0.427 eV (d) Goes up by 0.427 eV

7. The electron and hole concentrations in an intrinsic semiconductor are n_i per cm³ at 300K. Now, if acceptor impurities are introduced with a concentration of N_A per cm³ (where $N_A >> n_i$), the electron concentration per cm³ at 300 K will be:
(a) n_i (b) $n_i + N_A$ (c) $N_A - n_i$ (d) $\frac{n_i^2}{N_A}$

8. In a p^+n junction diode under reverse bias, the magnitude of electric field is maximum at:
(a) The edge of the depletion region on the p-side (b) The edge of the depletion region on the n-side
(c) The p^+n junction (d) The centre of the depletion region on the n-side.

9. A P^+–N junction has a built-in potential of 0.8 V. The depletion layer width at a reverse bias of 1.2 V is 2 μm. For a reverse bias of 7.2 V, the depletion layer width will be:
(a) 4 μm (b) 4.9 μm (c) 8 μm (d) 12 μm

10. A silicon PN junction diode under reverse bias has depletion region of width 10 μm. The relative permitivity of Silicon. $\varepsilon_r = 11.7$ and the permitivity of free space $\varepsilon_o = 8.85 \times 10^{-12}\ F/m$. The depletion capacitance of the diode per square metter is:
(a) 100 μF (b) 10 μF (c) 1 μF (d) 20 μF

11. In an abrupt p-n junction, the doping concentrations on the p-side and n-side are $N_A = 9\times10^{16}/cm^3$ and $N_D = 1\times10^{16}/cm^3$ respectively. The p-n junction is reverse biased and the total depletion width is 3 μm. The depletion width on the p-side is:
(a) 2.7 μm (b) 0.3 μm (c) 2.25 μm (d) 0.75 μm

12. N-type silicon bar 0.1 cm long and 100 μm^2 in cross-sectional area has a majority carrier concentration of $5\times10^{20}/cm^3$ and the carrier mobility is 0.13 m^2/V-s at 300 K. If the charge of an electron is 1.6×10^{-19} coulomb, then the resistance of the bar is:
(a) 10^6 ohm (b) 10^4 ohm (c) 10^{-1} ohm (d) 10^{-4} ohm

13. A long specimen of p-type semiconductor material:
(a) Is positively charged (b) Is electrically neutral
(c) Has an electric field directed along its length (d) Acts as a dipole

14. In a P-type silicon sample, the hole concentration is $2.25\times10^{15}/cm^3$. If the intrinsic carrier concentration is $1.5\times10^{10}/cm^3$, the electron concentartion is:
(a) Zero (b) $10^{10}/cm^3$ (c) $10^5/cm^3$ (d) $1.5\times10^{25}/cm^3$

15. An infra-red LED is usually fabricated from:
(a) Ge (b) Si (c) Ga As (d) Ga As P

16. Which of the following statements is/are true for a good conductor of electricity?
1. Its conductivity decreases with increasing temperature.
2. Number of free electrons is around $10^{28} m^{-3}$.
3. Its conductivity decreases with addition of impurities.
4. It is a good conductor of heat also.
(a) 1, 2, 3 and 4 (b) 1 only (c) 2 and 3 only (d) 3 and 4 only

17. Consider the following statements:
The conductivity of a metal has negative temperature coefficient since:
1. The electron concentration increases with temperature.
2. The electron mobility decreases with temperature.
3. The electron-lattice scattering rate increases with temperature.
Which of the above statements is/are correct?
(a) 1 only (b) 1 and 2 (c) 2 and 3 (d) 3 only

18. Consider the following:
1. Si 2. Ge 3. GaAs 4. In P
Which of the above semiconductors should be used for making highly efficient photodiodes?
(a) 1 and 4 only (b) 3 and 4 only (c) 1, 3 and 4 (d) 2, 3 and 4.

19. In a materials, the Fermi level is located between the centre of the forbidden band and the conduction band. Then what is that material?
(a) A p-type semiconductor (b) An n-type semiconductor
(c) An intrinsic semicondutor (d) An insulator.

20. An intrinsic semiconductor with energy gap 1 eV has a carrier cocentration N at temperature 200 K. Another intrinsic semiconductor has the same value of carrier concentration N at temperature 600K. What is the energy gap value for the second semiconductor?
(a) (1/3) eV (b) (3/2) eV (c) 3 eV (d) 9 eV

21. Consider the following statements:
n-type of silicon can be
1. Formed by adding impurity of phosphorus
2. Formed by adding impurity of arsenic
3. Formed by adding impurity of boron.
4. Formed by adding impurity of aluminium.
Which of the statements given above are correct?
(a) 1 and 3 only (b) 3 and 4 only (c) 1 and 2 only (d) 1, 2, 3 and 4.

22. In a step-graded p-n junction diode, what is the ratio of depletion-region penetration depths into p and n regions (if the ratio of acceptor to donor impurity atoms densities is 1:2)?
(a) 2:1 (b) 4:1 (c) 1:2 (d) 1:4

23. Match **List-I** with **List-II** and select the corret answer using the code given below the lists:

List-I(Item)	**List-II(Position)**
A. Donor energy band	1. At the middle of the forbidden energy gap.
B. Fermi level of p-type semiconductor at room temperature	2. Close to the conduction band.
C. Acceptor energy band	3. Very close to the valance band.
D. Fermi level in intrinsic semiconductor	4. Close to the valence band.

	A	B	C	D
(a)	4	3	2	1
(b)	2	1	4	3
(c)	4	1	2	3
(d)	2	3	4	1

24. The depletion layer in a p-n junction is made of which of the following?
(a) Ionized donors in p-side and ionized acceptors in n-side.
(b) Ionized acceptors in p-side and ionized donors in n-side.
(c) Accumulated holes in p-side and accumulated electrons in n-side.
(d) Accumulated electrons in p-side and accumulated holes in n-side.

25. Match the **List-I(Current)** with **List-II** (Variation) and select the correct answer using the code given below the lists:

List-I (Current)	**List-II (Variation)**
A. Hole deffusion current	1. n.E
B. Electron drift current	2. p.E
C. Hole drift current	3. $-dp/dx$
D. Electron diffusion current	4. dn/dx

(a) A-2, B-1, C-3, D-4 (b) A-3, B-4, C-2, D-1
(c) A-2, B-4, C-3, D-1 (d) A-3, B-1, C-2, D-4

26. A thin resistive film having length (l), width (w) and thickness (t) is used as a resistor (R_1) for conducting current in the direction of l. If the film is connected to serve as a resistor (R_2) for conducting current in the direction of w, then what is the value of R_1/R_2.
(a) l/w (b) w/l (c) l^2/w^2 (d) w^2/l^2.

27. **Match List-I (Type of Material)** with **List-II (Type of Bonding)** and the select the correct answer using the codes given below the lists:

List-I (Typed of Material)	**List-II (Type of Bonding)**
A. Elemental semiconductor	1. Ionic
B. Hydrogen molecule	2. Covalent
C. Copper	3. Van der Waals'
D. AgI	4. Metallic.

Codes:
(a) A-3 B-2 C-1 D-4 (b) A-2 B-3 C-1 D-4
(c) A-2 B-3 C-4 D-1 (d) A-3 B-4 C-2 D-1

28. Depletion capacitance in a diode depends on:
1. Applied junction voltage.
2. Junction built-in potential
3. Current through junction
4. Doping profile across the junction

Select the correct answer using the codes given below:
(a) 1 and 2 (b) 1 and 3 (c) 1, 2 and 4 (d) 2, 3 and 4

29. The depletion layer across a p^+-n junction lies
(a) mostly in the p region
(b) mostly in the n region
(c) equally in both p^+ and n regions
(d) Entirely in the p^+ region.

30. Match **List-I (Crystal type)** with **List-II (Name of the solid)** and select the correct answer using the codes given below the Lists:

List-I	**List-II**
A. Ionic	1. Solid argon
B. Covalent	2. Copper
C. Metallic	3. Silicon
D. Van der Waal's	4. Sodium chloride

Codes:
(a) A-3 B-4 C-2 D-1
(b) A-4 B-3 C-1 D-2
(c) A-3 B-4 C-1 D-2
(d) A-4 B-3 C-2 D-1

31. At very high temperatures, the extrinsic semiconductors become intrinsic because
(a) Of drive-in diffusion of dopants and carries
(b) Band to band transition dominates over impurity ionization.
(c) Impurity ionization dominates over band to band transition.
(d) Band to band transition is balanced by impurity ionization

32. The increasing temperature, the electrical conductivity would:
(a) Increase in metals as well as in intrinsic semiconductor
(b) Increase in metals but decrease in intrinsic semiconductor
(c) Decrease in metals but increase in intrinsic semiconductor
(d) Decrease in metals as well as in intrinsic semiconductors.

33. The minority carrier life-time and diffusion constant in a semiconducting material are respectively 100 microsecond and 100 cm^2/s. The diffusion length of the carriers is:
(a) 0.1 cm (b) 0.01 cm (c) 0.0141 cm (d) 1 cm

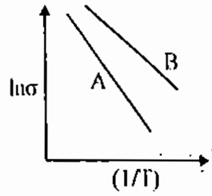
34. The band gap at 300°K of diamond cubic crystals of C, Si, Ge and Sn is 5.5, 1.2, 0.67 and 0.1 eV respectively. Identify the crystal which will have the highest electrical condictivity at 300 K
(a) Ge (b) Sn (c) C (d) Si

35. The effective density of states at the conduction band edge of Ge is 1.04×10^{19} cm^{-3} at room temeprature 300 K). Ge has an optical bandgap of 0.66 eV. The intrinsic carrier concentration (in cm^{-3}) in Ge at room temperature (300 K) is approximately:
(a) 3×10^{10} (b) 3×10^{13} (c) 3×10^{16} (d) 6×10^{16}

36. An extrinsic semiconductor sample of cross-section A and length L is doped in such a way that the doping concentration varies as $N_D(x) = N_0 \exp\left(-\frac{x}{L}\right)$, where N_0 is a constant. Assume that the mobility m of the majority carriers remains constant. The resistance R of the sample is given by:

(a) $R = \frac{L}{A\mu e N_0}\left[\exp(1.0) - 1\right]$
(b) $R = \frac{L}{\mu e N_0}\left[\exp(1.0) - 1\right]$
(c) $R = \frac{L}{A\mu e N_0}\left[\exp(-1.0) - 1\right]$
(d) $R = \frac{L}{A\mu e N_0}$

37. The temperature dependence of the electrical conductivity σ of two intrinsic semi-conductors A and B is shown in the figure. If E_A and E_B are the band gaps of A and B respectively, which one of the following is TRUE?



(a) $E_A > E_B$

(b) $E_A < E_B$

(c) $E_A = E_B$

(d) E_A and E_B both depend on temperature.

38. An intrinsic semiconductor with mass of a hole m_h and mass of an electron m_C is at a finite temperature T. If the top of the valence band enegy is E_V and the bottom of the conduction band energy is E_C, the Fermi energy of the semiconductor is:

(a) $E_F = \left(\frac{E_V + E_C}{2}\right) - \frac{3}{4}k_B T \ln\left(\frac{m_h}{m_e}\right)$ (b) $E_F = \left(\frac{k_B T}{2}\right) + \frac{3}{4}(E_V + E_C)\ln\left(\frac{m_h}{m_e}\right)$

(c) $E_F = \left(\frac{E_V + E_C}{2}\right) + \frac{3}{4}k_B T \ln\left(\frac{m_h}{m_e}\right)$ (d) $E_F = \left(\frac{k_B T}{2}\right) - \frac{3}{4}(E_V + E_C)\ln\left(\frac{m_h}{m_e}\right)$

39. A silicon sample A is doped with 10^{18} atoms/cm³ of Boron. Another sample B of identical dimensions is doped with 10^{18} atoms/cm³ of Phosphorus. The ratio of electron to hole mobility is 3. The ratio of conductivity of the sample A to B is:
(a) 3 (b) 1/3 (c) 2/3 (d) 3/2

40. The intrinsic carrier density at 300 K is $1.5\times10^{10}/cm^3$, in silicon. For n-type silicon doped to 2.25×10^{15} atoms$/cm^3$, the equilibrium electron and hole densities are:
(a) $n = 1.5\times10^{15}/cm^3,\ p = 1.5\times10^{10}/cm^3$ (b) $n = 1.5\times10^{10}/cm^3,\ p = 2.25\times10^{15}/cm^3$
(c) $n = 2.25\times10^{15}/cm^3,\ p = 1.0\times10^{5}/cm^3$ (d) $n = 1.5\times10^{10}/cm^3,\ p = 1.5\times10^{10}/cm^3$

41. A silicon sample is uniformly doped with 10^{16} phosphorous atoms/cm³ and 2×10^{16} boron atoms/cm³. If all the dopants are fully ionized, the material is:
(a) n-type with carrier concentration of $10^{16}/cm^3$
(b) p-type with carrier concentration of $10^{16}/cm^3$
(c) p-type with carrier concentration of $2\times10^{16}/cm^3$
(d) T_2 will get damaged and T_1 will be safe.

42. In a uniformly doped abrupt p-n junction, the doping level of n-side is four (4) times the doping level of the p-side. The ratio of the depletion layer widths is:
(a) 0.25 (b) 0.5 (c) 1.0 (d) 2.0

43. The doping concentration on the n-side of a p-n junction diode is enhanced. Which one of the following will get affected?
(a) Width of the depletion region on n-side.
(b) Width of the depletion region on p-side.
(c) Width of the depletion region on both sides.
(d) No change in width of depletion regions

44. Which one of the following expressions may be used to correctly describe the temperature(T) variation of the intrinsic carrier density (n_i) of a semiconductor?

(a) $n_i(T) = (A/T)\exp(-E_g/kT^2)$ (b) $n_i(T) = A(E_g/kT)^{10}$

(c) $n_i(T) = A\exp(-E_g/2kT)$ (d) $n_i(T) = AT^{3/2}\exp(-E_g/2kT)$

45. An intrinsic semiconductor (intrinsic electron density = $10^{16}\ m^{-3}$) is doped with donors to a level of $10^{22}\ m^{-3}$. What is the hole density assuming all donors to the ionized?
(a) $10^{7}\ m^{-3}$ (b) $10^{8}\ m^{-3}$ (c) $10^{10}\ m^{-3}$ (d) $10^{6}\ m^{-3}$.

46. Consider the following statements in respect of graphite:
1. It has the three coplanar covalent bonds.
2. It has good electrical and thermal conductivity.
3. Sheets of graphite are held together by van der waals interaction.
Which of the statements given above are correct?
(a) 1, 2 and 3 (b) 1 and 2 (c) 2 and 3 (d) 1 and 3

47. A conductor carries a current of 4A and if magnitude of charge of an electron $e = 1.6\times10^{-19}$ coulomb, then th number of electrons which flow past the cross section per second is:
(a) 2.5×10^{19} (b) 1.6×10^{19} (c) 6.04×10^{19} (d) 0.4×10^{19}

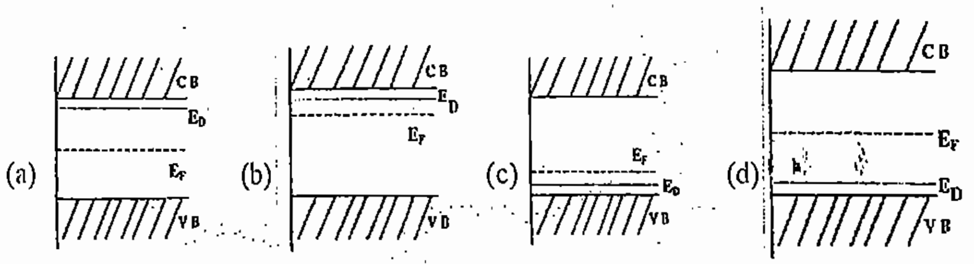
48. Which of the following elements act as donor impurities?
1. Gold 2. Phosphorus 3. Boron 4. Antiomony
5. Arsenic 6. Indium.
Select the corrent answer using the codes given below:
(a) 1, 2 and 3 (b) 1, , 4 and 5 (c) 3, 4, 5 and 6 (d) 2, 4 and 5

49. The conductivity of an intrinsic semicoductor is (symbols have the usual meanings) where e is electron charge
(a) Generally less than that of a doped semiconductor.
(b) Given by $\sigma_i = en_i(\mu_n - \mu_p)$
(c) Given by $\sigma_i = en_i(\mu_n + \mu_p)$ (d) Given by $\sigma_i = n_i(\mu_n + \mu_p)$

50. In an intrinsic semiconductor, as the temperature increases the conductivity σ, electron concentration n, and mobility μ vary as follows:
(a) σ decreases, n increases and μ decreases (b) σ decreases, n is unaffected and μ decreases
(c) σ increases, n increases and μ decreases (d) σ increases, n increases and μ is unaffected

51. A Ge semiconductor is doped with acceptor impurity concentration of 10^{15} atoms/cm^3. For the given hole mobility of $1800\ cm^2/V-s$, the resistivity of this material is:
(a) $0.288\ \Omega$ cm (b) $0.694\ \Omega$ cm (c) $3.472\ \Omega$ cm (d) $6.944\ \Omega$ cm

52. Identify the CORRECT energy band diagram for silicon doped with Arsenic. Here CB, VB, E_D and E_F conduction band, valence band, impurity level and Fermi level, respectively.



53. For a intrinsic semiconductor, m_e^* and m_h^* are respectively the effective masses of electrons and holes near the corresponding band edges. At a finite temperature, the position of hte Fermi level
(a) Depends on m_e^* but not on m_h^* (b) Depends on m_h^* but not on m_e^*
(c) Depends on m_e^* and m_h^* (d) depends neither on m_e^* nor on m_h^*

54. An n-type semiconductor is
(a) positively charged (b) negatively charged
(c) electrically neutral (d) positively or negatively charged

55. A sample of Si has electron and hole mobilities of 0.13 and 0.05 m^2/V-s respectively at 300K. It is doped with P and Al with doping densities of $1.5 \times 10^{21}/m^3$ and $2.5 \times 10^{21}/m^3$ respectively. The conductivity of the doped Si sample at 300K is

(a) $8\Omega^{-1}m^{-1}$ (b) $32\Omega^{-1}m^{-1}$ (c) $20.8\Omega^{-1}m^{-1}$ (d) $83.2\Omega^{-1}m^{-1}$

56. The donor concentration in a sample of n-type silicon is increased by a factor of 100. The shift in the position of the Fermi level at 300K, assuming the sample to be non degenerate is _______ meV.

$(k_BT = 25meV$ at 300K$)$

57. An electron makes a transition from the valence band to the conduction band in an indirect band gap semiconductor. Which of the following is NOT true ?
(a) The energy of the electron increases (b) A phonon is involved in the process
(c) A photon is absorbed in the process (d) There is no momentum change in the electron

58. A beam of X-ray of intensity I_0 is incident normally on a metal sheet of thickness 2 mm. The intensity of the transmtted beam is $0.025I_0$. The linear absorption coefficient of the metal sheet (in m^{-1}) is _______________ (upto one decimal places) **[GATE 2015]**

59. The band gap of an intrinsic semiconductor is $E_g = 0.72$ eV and $m_h^* = 6m_e^*$. At 300K, the Fermi level with respect to the edge of the valence band (in eV) is at _________ (upto three decimal places) $k_B = 1.38\times10^{-23}JK^{-1}$ **[GATE 2015]**

60. The concentration of electrons, n and holes, p for an intrinsic semiconductor at a temperature T can be expressed as $n = p = AT^{3/2}\exp\left(-\frac{E_g}{2k_BT}\right)$, where E_g is the band gap and A is a constant. If the mobility of both types of carries is proportional to $T^{-3/2}$, then the log of the conductivity is a linear function of T^{-1} with slope

(a) $\frac{E_g}{(2k_B)}$ (b) $\frac{E_g}{k_B}$ (c) $\frac{-E_g}{(2k_B)}$ (d) $\frac{-E_g}{k_B}$ **[NET June 2015]**

61. The majority carriers in n-type semiconductor have an average drift velocity V in a direction perpendicular to a uniform magnetic field B. The electric field E induced due to Hall effects acts in the direction:
(a) V×B (b) B×V (c) along V (d) opposite to V

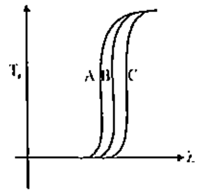
62. The longest wavelength that can be absorbed by silicon, which has the band-gap of 1.12 eV, is $1.1\,\mu m$. If the longest wavelength that can be absorbed by another material is 0.87 μm, then the bandgap of this material is:
(a) 1.416 eV (b) 0.886 eV (c) 0.854 eV (d) 0.706 eV

63. A particular green LED emits light of wavelength 5490 Å. The energy bandgap of the semiconductor material used there is (Planck's constant = 6.626×10^{-34} J-s):
(a) 2.26 eV (b) 1.98 eV (c) 1.17 eV (d) 0.74 eV

64. An infra-red LED is usually fabricated from:
(a) Ge (b) Si (c) Ga As (d) Ga As P

65. Consider the following statements for a photo conducting material:
1. Its dark conductivity is small.
2. With the absorption of radiation, equal numbers of electrons and of holes are produced.
Which of the statements given above is/are correct?
(a) 1 only (b) 2 only (c) Both 1 and 2 (d) Neither 1 nor 2.

66. Photovoltaic devices may be made from various semiconductors as optical materials for which the transmission coefficient (T_r) is shown in the figure given below as a function of photon wavelength.



Which one of the following is the correct sequence of A, B and C pertaining to Ge, Ga, As and Si, respectively?
(a) A–B–C (b) B–A–C (c) C–A–B (d) C–B–A

67. Photons of energy 1.53×10^{-19} Joule are incident on a photodiode which has a responsivity of 0.65 A/W. If the optical power level is 10 μW. What is the photo current generated?
(a) 64 nA (b) 1.5 μA (c) 2.1 μA (d) 6.5 μA

68. An LED made usig GaAs emits radiation in:
(a) Visile region (b) Ultraviolet region
(c) Infra red region (d) Microwave frequency region.

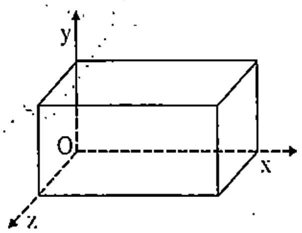
69. The light emitting diode (LED) emits light of a particular colour because
(a) It is fabricated from a fluorescent material.
(b) Transition between energy levels of the carriers takes place while crossing the p-n junction.
(c) Heat generated in the diode is converted into light.
(d) The band gap of the semi-conductor material used in fabrication of the diode is equal to the energy h_ν of the light photon.

70. Hall effect is observed in a specimen when it (metal or a semiconductor) is carrying current and is placed in a magnetic field. The resultant electric field inside the specimen will be in
(a) A direction normal to both current and magnetic field.
(b) The direction of current
(c) A direction antiparallel to magnetic field
(d) An arbitrary direction depending upon the conductivity of the specimen.

71. The wavelength of light emitted by a GaAs laser s 8670×10^{-10} m. Given Planck's constant = 6.626×10^{-34} Js, velocity of light = 2.998×10^{8} m/s and 1 eV = 1.602×10^{-19} J, the energy gap in GaAs is
(a) 0.18 eV (b) 0.7 eV (c) 1.43 eV (d) 2.39 eV

72. A doped Germanium crystal of length 2 cm, breadth 1 cm and width 1 cm, carries a current of 1 mA along its length parallel to +x axis. A magnetic field of 0.5 T is applied along +z axis. Hall voltage of 6 mV is measured with negative polarity at y = 0 plane. The sign and concentration of the majority charge carrier are, respectively [Given : $e = 1.6\times10^{-19}$ C]

(a) Positive and $5.2\times10^{19}\ m^{-3}$
(b) Negative and $5.2\times10^{19}\ m^{-3}$
(c) Positive and $10.4\times10^{19}\ m^{-3}$
(d) Negative and $10.4\times10^{19}\ m^{-3}$



73. An electron of wavevector $\vec{k}_e$, velocity $\vec{\upsilon}_e$ and effective mass m_e is removed from a filled energy band. The resulting hole has wavevevtor $\vec{k}_h$, velocity $\vec{\upsilon}_h$, and effective mass m_h. Which one of the following statements is correct?
(a) $\vec{k}_h = -\vec{k}_e;\ \vec{\upsilon}_h = \vec{\upsilon}_e;\ m_h = -m_e$ (b) $\vec{k}_h = \vec{k}_e;\ \vec{\upsilon}_h = \vec{\upsilon}_e;\ m_h = m_e$
(c) $\vec{k}_h = \vec{k}_e;\ \vec{\upsilon}_h = -\vec{\upsilon}_e;\ m_h = -m_e$ (d) $\vec{k}_h = -\vec{k}_e;\ \vec{\upsilon}_h = \vec{\upsilon}_e;\ m_h = m_e$

74. In an extrinsic semiconductor the Hall coefficient R_H.
(a) Increases with increase of temperature (b) Decreaes with increase of temperature
(c) Is independent of the change of temperature (d) Changes with the change of magnetic field.

75. Which of the following statements related to the Hall effect?
1. A potential difference is developed across a current-carrying metal strip when the strip is placed in a transverse magnetic field.
2. The Hall effect is very weak in metals but is large in semiconductors
3. The Hall effect is very weak in semiconductors but is large in metals.
4. It is applied in the measurement of the magnetic field intensity.
Select the correct answer using the code given below:
(a) 1, 2 and 3 (b) 2 and 4 (c) 1, 3 and 4 (d) 1, 2 and 4

76. Germanium and silicon photo-sensors have their maximum spectral response in the
(a) Infrared region (b) Ultraviolet region (c) Visible region (d) X-ray region

77. Measurement of Hall effect coefficient in a semiconductor provides information on the
(a) Sign and mass of charge carriers (b) Mass and concentration of charge carriers
(c) Sign of charge carriers alone (d) Sign and concentration of charge carriers.

78. Light of wavelength 660 nm and power of 1 mW is incident on a semiconductor photodiode with an absorbing layer of thickness of (ln 4) μm.
A. If the absorption coefficient at this wavelength is 10^4 cm^{-1} and if 1% power is lost on reflection at the surface, the power absorbed will be
(a) 750 μW (b) 675 μW (c) 250 μW (d) 225 μW

B. The generated photo-current for a quantum efficiency of unity will be
(a) 360 μA (b) 400 μA (c) 133 μA (d) 120 μA

79. The number density of electrons in the conduction band of a semiconductor at a given temperature is 2×10^{19} m^{-3}. Upon lightly doping this semiconductor with donor impurities, the number density of conduction electrons at the same temperature becomes 4×10^{20} m^{-3}. The ratio of majority to minority charge carrier concentration is ______________. **[GATE 2016]**

80. A *pn* junction was formed with a heavily doped (10^{18} cm^{-3}) *p*-region and lightly doped (10^{14} cm^{-3}) *n*-region. Which of the following statement(s) is(are) correct?
(a) the width of the depletion layer will be more in *n*-side of the junction
(b) the width of the depletion layer will be more in the *p*-side of the function
(c) the width of the depletion layer will be same on both sides of the junction.
(d) if the *pn* junction is reverse biased, then the width of the depletion region increases.

81. Consider a 20 μm diameter p-n junction fabricated in silicon. the donor density is 10^{16} per cm^3. The charge developed on the n-side is $1.6\times10^{-13} C$. Then the width (in μm) of the depletion region on the n-side of the p-n junction is ______________

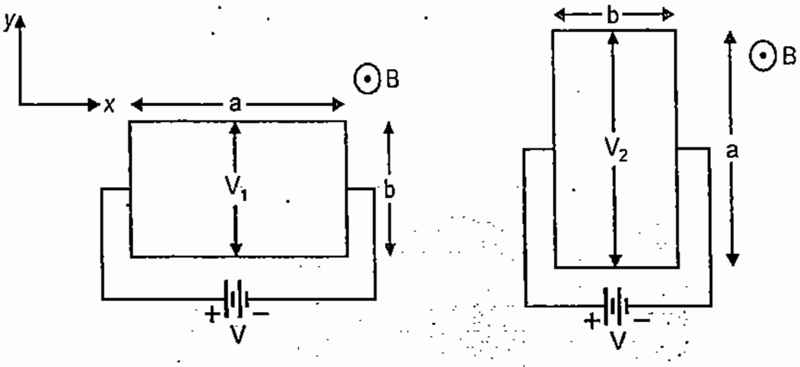
82. The active medium in a blue LED (Light Emitting Diode) is a $Ga_xIn_{1-x}N$ alloy. The band gaps of GaN and InN are 3.5 eV and 1.5 eV respectively. If the band gap of $Ga_xIn_{1-x}N$ varies approximately linearly with x, the value of x required for the emission of blue light of wavelength 400 nm is (take $hc \approx 1200$ eV-nm)
(a) 0.95 (b) 0.75 (c) 0.50 (d) 0.33 **[NET Dec. 2016]**

83. Let I_0 be the saturation current, η the ideality factor and v_F and v_R the forward and reverse potentials, respectively, for a diode. The ratio R_R/R_F of its reverse and forward resistances R_R and R_F respectively, varies as (In the following k_B is the Boltzmann constant, T is the absolute temperature and q is the charge).

[NET June 2017]

(a) $\frac{v_R}{v_F}\exp\left(\frac{qv_F}{\eta k_B T}\right)$ (b) $\frac{v_F}{v_R}\exp\left(\frac{qv_F}{\eta k_B T}\right)$ (c) $\frac{v_R}{v_F}\exp\left(-\frac{qv_F}{\eta k_B T}\right)$ (d) $\frac{v_F}{v_R}\exp\left(-\frac{qv_F}{\eta k_B T}\right)$

84. A thin rectangular conducting plate of length a and width b is placed in the xy-plane in two different orientations, as shown in the figures below. In both cases a magnetic field B is applied in the z-direction and a current flows in the x-direction due to the applied voltage V. **[NET Dec. 2016]**



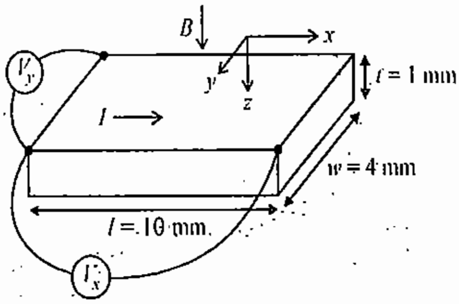
If the Hall voltage across the y-direction in the two cases satisfy $V_2 = 2V_1$, the ratio $a:b$ must be

(a) $1:2$ (b) $1:\sqrt{2}$ (c) $2:1$ (d) $\sqrt{2}:1$

85. An intrinsic semiconductor of band gap 1.25 eV has an electron concentration 10^{10} cm^{-3} at 300K. Assume that its band gap is independent of the temperature and that the electron concentration depends only exponentially on the temperature. If the electron concentration at 200K is

$Y \times 10^N$ cm^{-3} ($1 < Y < 10$, N = integer), then the value of N is ________

86. A p-doped semiconductor slab carries a current $I = 100$ mA in a magnetic field $B = 0.2$ T as shown. One measures $V_y = 0.25$ mV and $V_x = 2$ mV. The mobility of holes in the semiconductor is ________ m^{2}V^{-1}s^{-1} (up to two decimal places). **[GATE 2018]**



87. A Germanium diode is operated at a temperature of 27 degree C. The diode terminal voltage is 0.3 V when the forward current is 10 mA. What is the forward current (in mA) if the terminal voltage is 0.4 V?

(a) 477.3 (b) 577.3 (c) 47.73 (d) 57.73 **[JEST 2018]**

88. In a pn junction, dopant concentration on the p-side is higher than that on the n-side. Which of the following statement(s) 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

89. Consider a two-dimensional material of length l and width w subjected to a constant magnetic field B applied perpendicular to it. The number of charge carriers per unit area may be expressed as

$$n = \frac{k|q|B}{(2\pi\hbar)},$$

where k is a positive real number and q is the carrier charge. Then the Hall resistivity ρ_{xy} is

(a) $\frac{2\pi\hbar k}{q^2}\sqrt{\frac{l}{w}}$ (b) $\frac{2\pi\hbar}{kq^2}\sqrt{\frac{w}{l}}$ (c) $\frac{2\pi\hbar}{kq^2}$ (d) $\frac{2\pi\hbar k}{q^2}$ **[NET Dec. 2017]**

CSIR-UGC-NET/JRF|GATE-PHYSICS

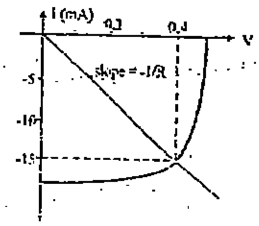
SOLID STATE PHYSICS

Assignment-5

1. Monochromatic light of wavelength 660 nm and intensity 100 mW/cm^2 falls on a solar cell of area 30 cm^2. The conversion efficiency of the solar cell is 10%. If each coverted photon results in an electron-hole pair, what is the maximum circuit current supplied by the solar cell? (Take $h = 6.6\times10^{-34}\,J-s$, $c = 3\times10^8\,m/s$ and $e = 1.6\times10^{-19}\,C$).
(a) 160 mA (b) 320 mA (c) 1600 mA (d) 3200 mA

2. In the Hall effect the sign of the Hall voltage depends upon the carrier concentration (n,p) and mobility (μ_n, μ_p) of electrons and holes, respectively. The Hall voltage in intrinsic and n-type semiconductors is negative because
(a) $n\mu_n > p\mu_p$ (b) $n > p, \mu_n < \mu_p$ (c) $n > p, \mu_n = \mu_p$ (d) $n = p, \mu_n > \mu_p$

3. The I-V characteristics of a solar cell of dimension 1 cm × 1 cm illuminated with light of intensity 600 Wm^{-2} are shown in the figure. If the cell is used to drive a load R (see the load line in the figure) the efficiency of the solar cell is:

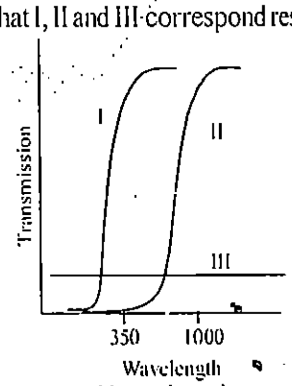


(a) 1% (b) 5% (c) 20% (d) 10%

4. In an experiment to measure the Hall co-efficient of a particular sample, the generated Hall voltage was found to be too small to measure. To improve the measurement, you would
(a) Increase the magnetic field (b) Increase the temperature of the sample
(c) Use a longer and thinner sample (d) Use a shorter and thicker sample.

5. An LED operates at 1.5 V and 5 mA in forward bias. Assuming an 80% external efficiency of the LED, how many photons are emitted per second?
(a) 5.0×10^{16} (b) 1.5×10^{16} (c) 0.8×10^{16} (d) 2.5×10^{16}

6. The experimentally measured transmission spectra of metal, insulator and semiconductor thin films are shown in the figure. It can be inferred that I, II and III correspond respectively, to

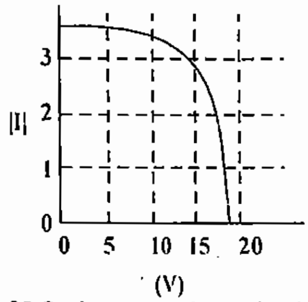


(a) insulator, semiconductor and metal (b) semiconductor, metal and insulator
(c) metal, semiconductor and insulator (d) insulator, metal and semiconductor

7. A magnetic field sensor based on the Hall effect is to be fabricated by implanting. As into a Si film of thickness 1 μm. The specifications require a magnetic field sensitivity of 500 mV/Tesla at an excitation current of 1 mA. The implanation dose is to be adjusted such that the average carrier density, after activation, is

(a) $1.25\times10^{26}\ m^{-3}$ (b) $1.25\times10^{22}\ m^{-3}$ (c) $4.1\times10^{21}\ m^{-3}$ (d) $4.1\times10^{20}\ m^{-3}$

8. The output characteristics of a solar panel at a certain level of irradiance is shown in the figure below.



If the solar cell is to power a load of 5 Ω, the power drawn by the load is:
(a) 97 W (b) 73 W (c) 50 W (d) 45 W

9. If the gap between ground state and excited state energy levels of electrons in an atom is 1eV. Estimate the wavelength of the light the atom will absorb? The value of the Planck's constant is 6.6×10^{-34} Js.

(a) 1 mm (b) 1.24 μm (c) 1.24 angstrom (d) 1cm

10. The difference between the electron and hole of a semiconductor laser is 1.5 eV and the band gap of the semiconductor is 1.43 eV. The upper and lower frequency limits of the laser will be respectively

(a) 3.3×10^{14} and 9.9×10^{13} Hz (b) 3.7×10^{14} and 3.5×10^{14} Hz
(c) 6.28×10^{14} and 3.1×10^{14} Hz (d) 1.16×10^{15} and 8.97×10^{14} Hz

11. The power density of sunlight incident on a solar cell is 100 mW/cm². Its short circuit current density is 30 mA/cm² and the open circuit voltage is 0.7V. If the fill factor of the solar cell decreases from 0.8 to 0.5 then the percentage efficiency will decrease from

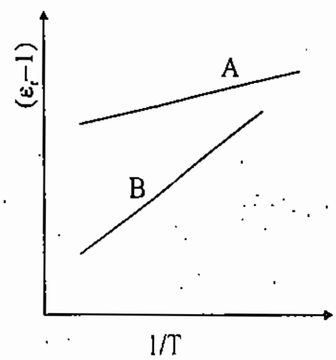
(a) 42.0 to 26.2 (b) 24.0 to 16.8 (c) 21.0 to 10.5 (d) 16.8 to 10.5

12. In a Hall effect experiment, the Hall voltage for an intrinsic semiconductor is negative. This is because (symbols carry usual meaning). **[GATE 2015]**

(A) $n \approx p$ (B) $n > p$ (C) $\mu_e > \mu_h$ (D) $m_e^* > m_h^*$

(a) A (b) B (c) C (d) D

13. Two dielectric materials A and B exhibit both ionic and orientational polarizabilities. The variation of the dielectric constant $c(=e_r-1)$ with temperature T is shown in the figure, where e_r is the relative dielectric constant. It can be inferred from the figure that:



(a) A is more polar and it has a smaller value of ionic polarizability than that of B
(b) A is more polar and it has a higher value of ionic polarizability than that of B
(c) B is more polar and it has a higher value of ionic polarizability than that of A
(d) B is more polar and it has a smaller value of ionic polarizability than that of A

14. If the static dielectric constant of NaCl crystal is 5.6 and its optical refractive index is 1.5, the ratio of its electric polarizability to its total polarizability is:
(a) 0.5 (b) 0.7 (c) 0.8 (d) 0.9

15. The dielectric constant of a material at optical frequencies is mainly due to
(a) Ionic polarizability. (b) Electronic polarizability
(c) Dipolar polarizability (d) Ionic and dipolar polarizability.

16. Magnetic long range order is typically exhibited by:
(a) noble metals (b) alkali metals
(c) inert gas solids (d) transition metals

17. Which one of the following is TRUE for a semiconductor p–n junction with no external bias?
(a) The total charge in the junction is not conserved
(b) The p side of the junction is positively charged
(c) The p side of the junction is negatively charged
(d) No charge develops anywhere in the junction

18. Which one of the following is the first order phase transition?
(a) Vaporization of a liquid at its boiling point
(b) Ferromagnetic to paramagnetic
(c) Normal liquid He to superfluid He
(d) Superconducting to normal state

19. Identify which one is a first order phase transition?
(a) A liquid to gas transition at its critical temperature.
(b) A liquid to gas transition close to its triple point.
(c) A paramagnetic to ferromagnetic transition in the absence of a magnetic field.
(d) A metal to superconductor transition in the absence of a magnetic field.

20. A second order phase transition is one in which:
(a) the plot of entropy as a function of temeprature shows a discontinuity
(b) the plot of specific heat as a function of temperature shows a discontinuity
(c) the plot of volume as a function of pressure shows a discontinuity
(d) the plot of comprehensibility as a function of temperature is continuous

21. A ferromagnetic material has a Curie temperature 100 K. Then:
(a) its succeptibility is double when it is cooled from 300 K to 200 K
(b) all the atomic magnets in it get oriented in the same direction above 100 K
(c) the plot of inverse susceptibility versus temperature is linear with a slope T_C
(d) the plot if its succeptibility versus temperature is linear with an intercept T_C

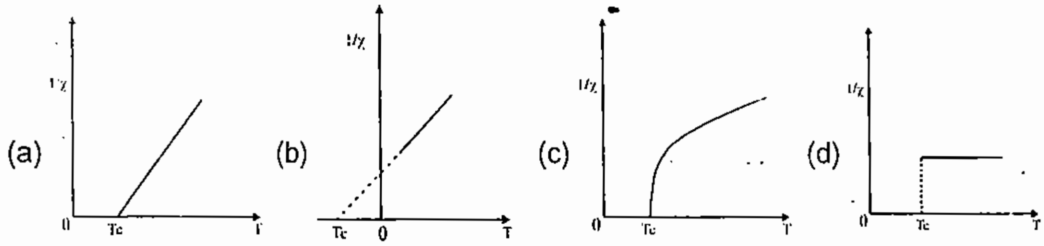
22. The energy of a ferromagnet as a function of magnetization M is given by:
$$F(M) = F_0 + 2(T - T_C)M^2 + M^4,\ F_0 > 0$$
The number of minima in the function F(M) for $T > T_C$ is:
(a) 0 (b) 1 (c) 3 (d) 4

23. When liquid oxygen is poured down close to a strong bar magnet, the oxygen stream is:
(a) repliecd towards the lower field because it is diamagnetic
(b) attracted towards the higher field because it is diamagnetic
(c) repelled towards the lower field becaue it is paramagnetic
(d) attracted towards the higher field because it is paramagnetic

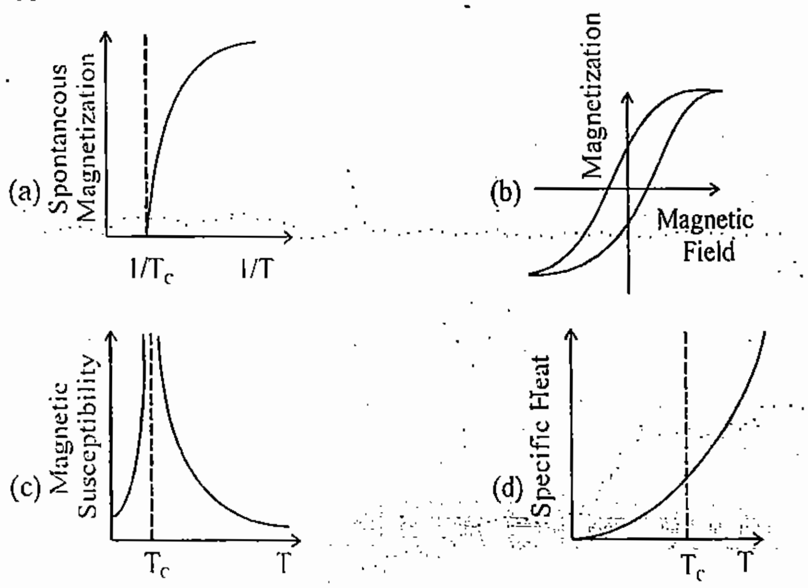
24. A ferromagnetic mixture of iron and copper having 75% atoms of Fe exhibits a saturation magnetization of $1.3 \times 10^6\ A\,m^{-1}$. Assume that the total number of atoms per unit volume is $8 \times 10^{28}\ m^{-3}$. The magnetic moment of an iron atom, in terms of the Bohr Magneton, is:

(a) 1.7 (b) 2.3 (c) 2.9 (d) 3.8

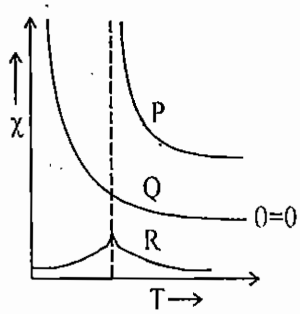
25. The plot of inverse magnetic susceptibility $\frac{1}{\chi}$ versus temperature T of an antiferromagnetic sample corresponds to:



26. In an experiment involving a ferromagnetic medium, the following observations were made. Which one of the plots does NOT correctly represented the property of the medium? (T_C is the Curie temperature)



27. The dependence of the magnetic susceptibility (χ) of a material with temperature (T) can be represented by $\chi \propto \frac{1}{T-\theta}$, where θ is the Curie-Weiss temperature. The plot of magnetic susceptibility versus temperature is sketched in the figure, as curves P, Q and R with curve Q having $\theta = 0$. Which one of the following statements is correct?



(a) Curve R represents a paramagnet and Q a ferromagnet.
(b) Curve Q represents a ferromagnet and P an anterromagnet.
(c) Curve R represents an antiferromagnet and Q a paramagnet.
(d) Curve R represents an antiferromagnet and Q a ferromanget.

28. The temperature (T) dependence of magnetic susceptibility (χ) of a ferromagnetic substance with a Curie temperature (T_c) is given by

(a) $\frac{C}{T-T_c}$, for $T < T_c$
(b) $\frac{C}{T-T_c}$, for $T > T_c$
(c) $\frac{C}{T+T_c}$, for $T > T_c$
(d) $\frac{C}{T+T_c}$, for all temperature.

29. Assume that the free energy of a magnetic system has an expansion in the order parameter M of the form $F(M,T) = a(T-T_C)M^2 + bM^4 + cM^6$, with a, b and c > 0. As the temperature is lowered below T_C, the system undergoes a phase transition. The behaviour of the order parameter just below the transition, where $(T-T_C)$ is very small, is best described by

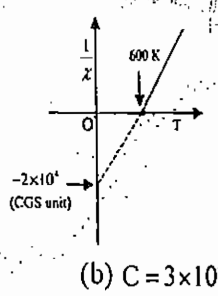
(a) $M \propto (T_C - T)^{-1/2}$ (b) $M \propto (T_C - T)^{1/2}$ (c) $M \propto (T_C - T)$ (d) $M \propto (T_C - T)^3$

30. The magnetization M of a system in equilibrium at temperature T is given by the equation $M = \tanh\left(M/T\right)$, where all quantities are in dimensionless units. This system will show

(a) a first order phase transition at $T = 1$
(b) a second order phase transition at T=1
(c) no phase transition at any T
(d) a second order phase transition at $T = 1/2$.

31. The (Pauli) paramagnetic susceptibility of a metal at a low temperature T is
(a) proportional to T
(b) independent of T
(c) proportional T^2
(d) proportional to T

32. Inverse susceptibility $(1/\chi)$ as a function of temperature, T for a material undergoing paramagnetic to ferromagnetic transition is given in the figure, where O is the origin. the values of the Curie constant, C and the Weiss molecular field constant, λ, in CGS units, are

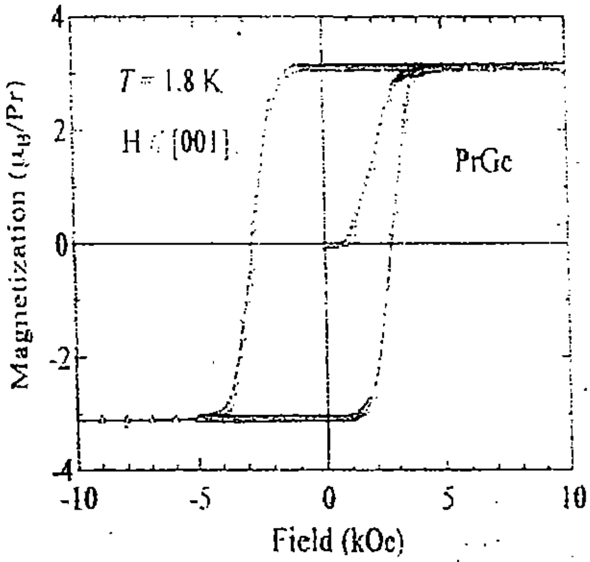


(a) $C = 5\times10^{-5}, \lambda = 3\times10^{-2}$
(b) $C = 3\times10^{-2}, \lambda = 5\times10^{-5}$
(c) $C = 3\times10^{-2}, \lambda = 2\times10^{-4}$
(d) $C = 2\times10^{4}, \lambda = 3\times10^{-2}$

33. The magnetization M of a ferromagnet, as a function of the temperature T and the magnetic field H, is described by the equation $M = \tanh\left(\frac{T_C}{T}M + \frac{H}{T}\right)$. In these units, the zero-field magnetic susceptibility in terms of $M(0) = M(H=0)$ is given by

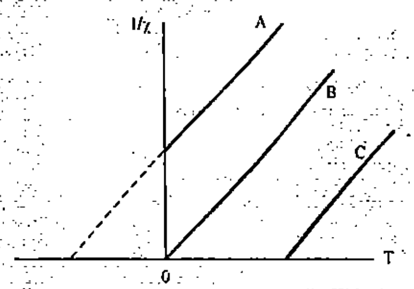
(a) $\frac{1-M^2(0)}{T-T_c(1-M^2(0))}$ (b) $\frac{1-M^2(0)}{T-T_c}$ (c) $\frac{1-M^2(0)}{T+T_c}$ (d) $\frac{1-M^2(0)}{T}$

34. The Curie temperature of a single crystal of PrGe is known to be 41 K. The magnetization data of this sample is measured at 1.8K for the magnetic field applied parallel to the [001] direction is shown in the figure on the left. At a temperature of 38 K, the hysteresis loop in the figure will



(a) Have the same width (b) decrease in width
(c) increase in width (d) shrink to a line.

35. The magnetic susceptibility χ of three samples A, B and C, is measured as a function of their absolute temperature T, leading to teh graphs shown below.



From these graphs, the magnetic nature of the samples can be inferred to be

(a) A:anti-ferromagnet B: paramagnet C: ferromagnet
(b) A:diamagnet B: paramagnet C: anti-ferromagnet
(c) A:paramagnet B: anti-ferromagnet C: ferromagnet
(d) A:anti-ferromagnet B: diamagnet C: paramagnet.

36. The physical phenomenon that cannot be used for memory storage applications is

(a) large variation in magnetoresistance as a function of applied magnetic field
(b) variation in magnetization of a ferromagnet as a function of applied magnetic field
(c) variation in polarization of a ferroelectric as a function of applied electric field
(d) variation in resistance of a metal as a function of applied electric field

37. For Nickel, the number density is 8×10^{23} atoms/cm^3 and electronic configuration is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$. The value of the saturation magnetization of Nickel in its ferromagnetic states is ________ $\times 10^9$ A/m.

(Given the value of Bohr magneton $\mu_B = 9.21\times10^{-21}\ Am^2$)

38. A solid material is found to have a temperature independent magnetic susceptibility, $\chi = C$. Which of the following statements is correct? **[GATE 2016]**

(a) If C is positive, the material is a diamagnet

(b) If C is positive, the material is a ferromagnet

(c) If C is negative, the material could be a type I superconductor

(d) If C is positive, the material could be a type I superconductor

39. In the Meissner state the magnetic susceptibility of a super conductor in S.I. units is:

(a) $-\frac{1}{4\pi}$ (b) $\frac{1}{4\pi}$ (c) -1 (d) $-\frac{1}{\mu_o}$

40. Which one of the following statements about superconductors is NOT true?

(a) A type I superconductor is completely diamagnetic

(b) All type II superconductor exhibits Meissner effect upto second critical magnetic field (H_{C_2}).

(c) A type II superconductor exhibits zero reistance upto the second critical magnetic field

(d) Both type I and type II superconductors exhibit sharp fall in resistance at the superconducting transition temperature.

41. A solid superconductor is placed in an external magnetic field and then cooled below its criticalk temperature. The superconductor.

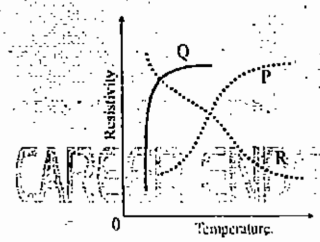
(a) retains its magnetic flux becuase the surface current supports it.

(b) expels out its magnetic flux because it behaves like a paramagnetic material.

(c) expels out its magnetic flux because it behaves like an anti-ferromagnetic material

(d) expels out its magnetic flux because the surface current induces a field in the direction opposite to the applied magnetic field.

42. Variation of electrical resistivity r with temperature T of three solids is sketched (on different scales) in the figure, as curves P, Q and R.



Which of the following statements describes the variations most appropriately?

(a) P is for a superconductor and R for a semiconductor

(b) Q is for a superconductor and P for a conductor

(c) Q is for a superconductor and R for a conductor

(d) R is for a superconductor, and P for a conductor

43. The critical magnetic field for a solid in superconducting state.

(a) Does not depend upon temperature

(b) Increases if the temperature

(c) Increases if the temperature decreases

(d) Does not depend on the transition temperature.

44. Which one of the following statements is NOT TRUE?

(a) Entropy decreases markedly on cooling a superconductor below the critical temperature, T_C.

(b) The electronic contribution to the heat capacity in the superconducting state has an exponential form with an argument proportional to T^{-1}, suggestive of an energy gap

(c) A type I superconductor is a perfect diamagnet.

(d) Critical temperature of superconductors does not vary with the isotopic mass.

45. A superconducting ring is cooled in the presence of a magnetic field below its critical temperature (T_c). The total magnetic flux that passes through the ring is:

(a) zero (b) $n\frac{h}{2e}$ (c) $\frac{nh}{4\pi e}$ (d) $\frac{ne^2}{hc}$

46. Experimental study shows that there exists an energy gap in a superconductor. Which one of the following statements is incorrect?

(a) The gap separates the lowest excited state in a superconductor from the ground state.
(b) The temperature dependence of electronic specific heat indicates the existence of an energy gap.
(c) The existence of an energy gap is accounted for in the BCS theory.
(d) The energy gap in supercondocturs is similar to the energy gap which occurs in insulators.

47. An external magnetic field of magnitude H is applied to a Type-I superconductor at a temperature below the transition ponit. Then which one of the following statements is NOT true for H less than the ciritical field H_c?

(a) the sample is diamagnetic
(b) it magnetization varies linearly with H
(c) the lines of magnetic induction are pushed out from the sample
(d) the sample exhibits mixed states of magnetization near H_c

48. The thermal conductivity of a given material reduces when it undergoes a transition from its normal state to the superconducting state. The reason is:

(a) The cooper pairs cannot transfer energy to the lattice.
(b) Upon the formation of cooper pairs, the lattice becomes less efficient in heat transfer.
(c) The electrons in the normal state lose their ability to transfer heat because of their coupling to the cooper pairs.
(d) The heat capacity increases on transition to the superconducting state leading to a reduction in thermal conductivity.

49. A flux quantum (fluxoid) is approximately equal to 2×10^{-7} gauss-cm^2. A type II superconductor is placed in a small magnetic field, which is then slowly increased till the field starts penetrating the superconductor. The strength of the field at this point is $\frac{2}{\pi}\times10^5$ gauss

A. The penetration depth of this superconductor is

(a) 100Å (b) 10Å (c) 1000Å (d) 314 Å

B. The applied field is further increased till superconductivity is completely destroyed. The strength of the field is now $\frac{8}{\pi}\times10^5$ gauss. The correlation length of the superconductor is:

(a) 20Å (b) 200Å (c) 628 Å (d) 2000Å

50. Let ξ and λ denote the coherence length and the penetration depth of a superconductor. For a type-I, superconductor

(a) $\xi<\lambda$ (b) $\xi>\lambda$ (c) $\xi=\lambda$ (d) $\lambda=0$

51. The magnetic susceptibility of a type I superconductor at a temperature T below the transition temperature T_c

(a) increases linearly from a negative value to zero as temperature increases from 0 to T_c
(b) decreases linearly from a positive value to zero as temperature increases from 0 to T_c
(c) is negative and constant at all T (d) is positive and constant at all T

52. The isotope effect in superconductors says that the critical temperature
(a) increases as the isotopic mass increases (b) decreases as the isotopic mass increases
(c) increases linearly with the isotopic mass (d) decreases linearly with the isotopic mass.

53. Considering the BCS theory of superconductors, which one of the following statements is NOT CORRECT? (h is the Planck's constant and e is the electronic charge)
(a) Presence of energy gap at temperatures below the critical temperature
(b) Different critical temperatures or isotopes
(c) Quantization of magnetic flux in superconducting ring in the unit of (h/e)
(d) Presence of Meissner effect

54. **Group-I** contains elementary excitations in solids. **Group-II** gives the associated fields with these excitations. MATCH the excitations with their associated field and select your answer as per codes given below.

Group-I	**Group-II**
(P) phonon	(i) photon + lattice vibration
(Q) plasmon	(ii) electron + elastic deformation
(R) polaron	(iii) collective electron oscillations
(S) polariton	(iv) elastic wave

Codes:
(a) (P–iv), (Q–iii), (R–i), (S–ii) (b) (P–iv), (Q–iii), (R–ii), (S–i)
(c) (P–i), (Q–iii), (R–ii), (S–iv) (d) (P–iii), (Q–iv), (R–ii), (S–i)

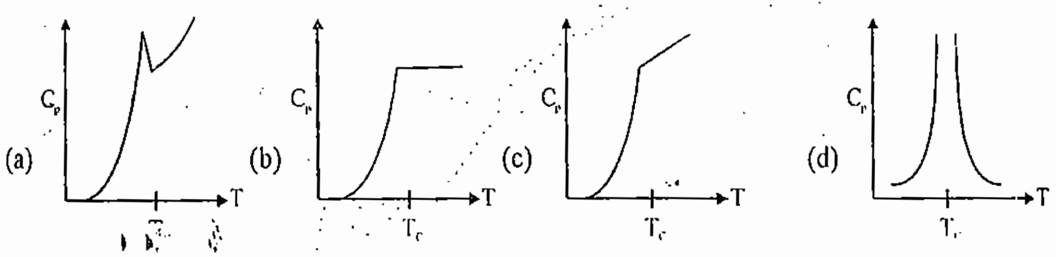
55. The order of magnitude of the energy gap of a typical superconductor is:
(a) 1 MeV (b) 1 KeV (c) 1 eV (d) 1 meV

56. The voltage required to produce 483.6 MHz through a Josephson junction is
(a) 1nV (b) 1 μV (c) 1mV (d) 1V

57. The transition temperature of a BCS superconductor with an average atomic mass of 199.5 is 4.185K. What is the transition temperature for an average atomic mass of 203.4?
(a) 4.185 (b) 4.145 (c) 4.226 (d) 4.105

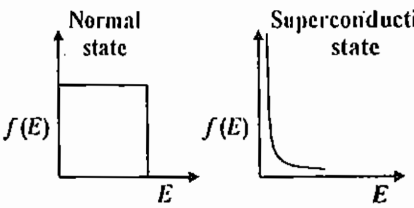
58. A solid sample has the property that, when cooled below a certain temperature, it expels any small applied magnetic field from within the material. Which of the following best describes this sample in the cooled state?
(a) Paramagnet (b) Diamagnet (c) Ferromagnet (d) Anti-ferromagnet

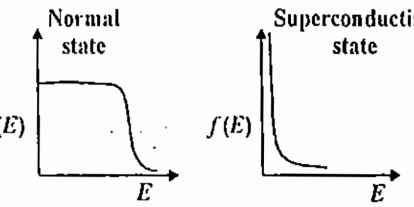
59. The plot of specific heat versus temperature across the superconducting transition temperature (T_C) is most appropriately represented by

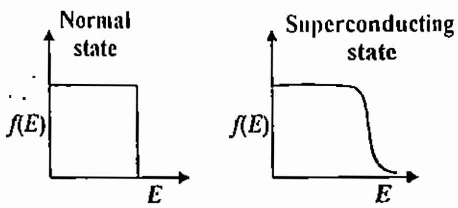


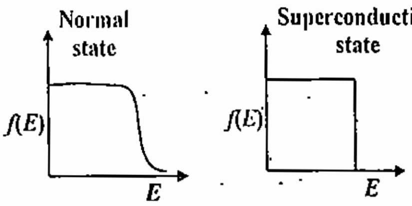
60. A superconducting ring carries a steady current in the presence of a magnetic field $\vec{B}$ normal to the plane of the ring. Identify the ***incorrect*** statement.
(a) The flux passing through the superconductor is quantized in units of hc/e
(b) The current and the magnetic field in the superconductor are time independent
(c) The current density $\vec{J}$ and $\vec{B}$ are related by the equation $\vec{\nabla} \times \vec{J} + \Lambda^2 \vec{B} = 0$, where Λ is a constant
(d) The superconductor shows an energy gap which is proportional to the transition temperature of the superconductor

61. Which one of the following represents the electron occupancy for a superconductor in its normal and superconducting states? **[GATE 2015]**

(a) 

(b) 

(c) 

(d) 

62. The critical magnetic fields of a super-conductor at temperatures 4 K and 8 K are 11 mA/m and 5.5 mA/m respectively. The transition temperature is approximately **[NET June 2015]**

(a) 8.4 K (b) 10.6 K (c) 12.9 K (d) 15.0 K

63. A DC voltage V is applied across a Josephson junction between two superconductors with a phase difference ϕ_0. If I_0 and k are constants that depend on the properties of the junction, the current flowing through it has the form

(a) $I_0 \sin\left(\frac{2eVt}{\hbar}+\phi_0\right)$ (b) $kV \sin\left(\frac{2eVt}{\hbar}+\phi_0\right)$ (c) $kV \sin\phi_0$ (d) $I_0 \sin\phi_0 + kV$

64. The high temperature magnetic susceptibility of solids having ions with magnetic moments can be described by

$$\chi \propto \frac{1}{T+\theta}$$

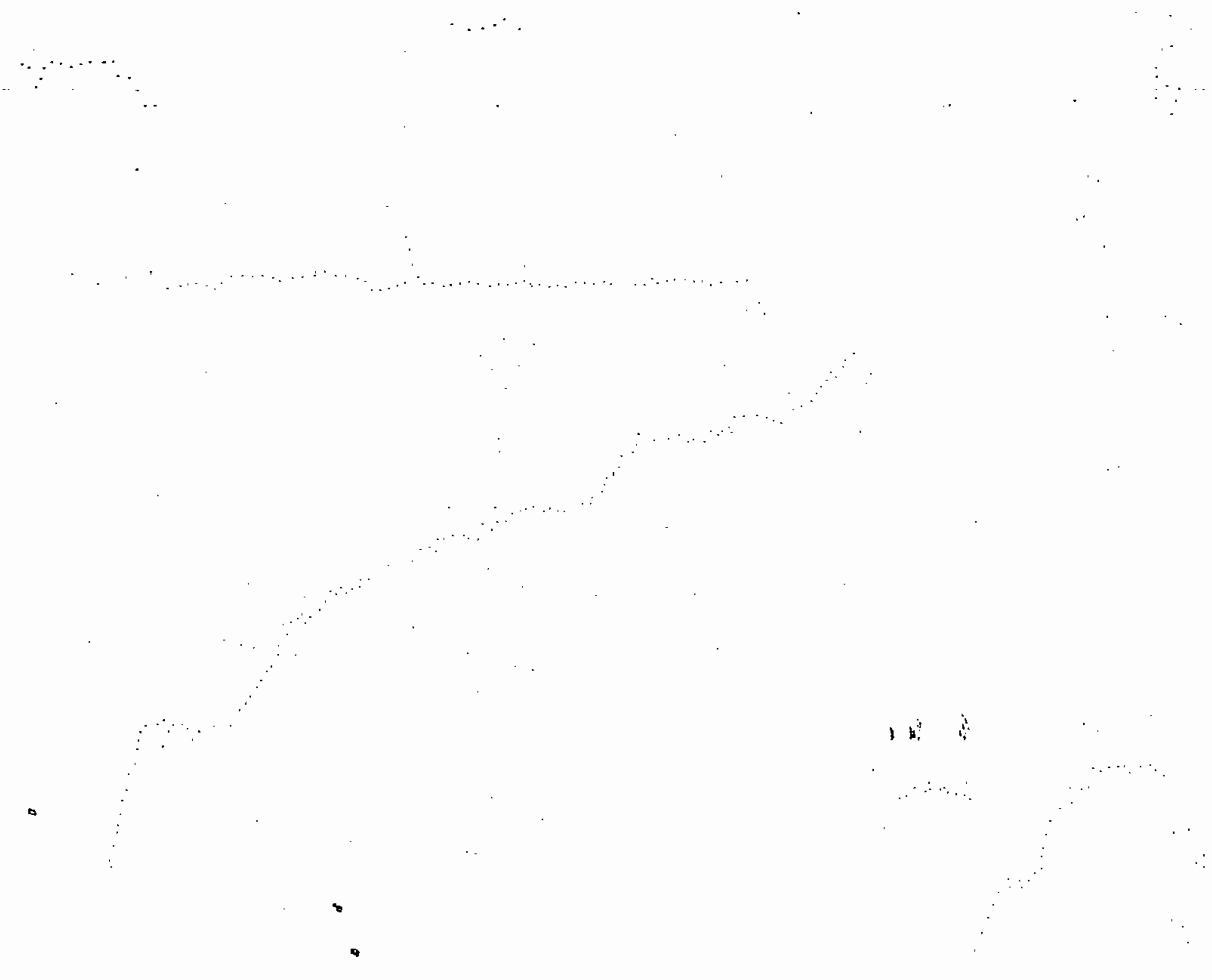
where T as absolute temperature and θ as constant. The three behaviors i.e., paramagnetic, ferromagnetic and anti-ferromagnetic are described, respectively, by **[GATE 2018]**

(a) $\theta < 0, \theta > 0, \theta = 0$ (b) $\theta > 0, \theta < 0, \theta = 0$

(c) $\theta = 0, \theta < 0, \theta > 0$ (d) $\theta = 0, \theta > 0, \theta < 0$

LEVEL-2

Solve Yourself



CSIR-UGC-NET/JRF|GATE-PHYSICS

SOLID STATE PHYSICS

LEVEL-2

1. The lattice parameters a, b, c of an orthorhombic crystal are related by $a = 2b = 3c$. In units of a, the interplanar separation between the (110) planes is ____________ (upto three decimal places) **[GATE 2015]**

2. The target of an X-ray tube is subjected to an excitation voltage V. The wavelength of the emitted X-rays is proportional to:

(a) $\frac{1}{\sqrt{V}}$ (b) $\sqrt{V}$ (c) $\frac{1}{V}$ (d) V

3. Silicon has diamond structure with unit-cell-edge a = 0.542 nm. The interatomic separation is:
(a) 0.122 nm (b) 0.234 nm (c) 0.383 nm (d) 0.542 nm.

4. The total number of Cl^- ions in a unit cell of NaCl crystal is
(a) 4 (b) 2. (c) 8 (d) 10

5. The basis vectors of a lattice are $2\hat{i}, \hat{i}+2\hat{j}$ and $\hat{k}$. The basis vectors of the reciprocal lattice are

(a) $\frac{2}{\pi}(\hat{i}+\hat{j}), \frac{2}{\pi}\hat{j}$ and $\frac{2}{\pi}\hat{k}$ (b) $\pi(2\hat{i}-\hat{j}), \pi\hat{j}$ and $4\pi\hat{k}$

(c) $\frac{\pi}{2}(2\hat{i}-\hat{j}), \pi\hat{j}$ and $2\pi\hat{k}$ (d) $2\pi\hat{i}, \pi(\hat{i}+2\hat{j})$, and $\pi\hat{k}$

6. A plane in a cubic lattice makes intercepts of a, $a/2$ and $2a/3$ with the three crystallographic axes, respectively. The Miller indices for this plane are
(a) (2 4 3) (b) (3 4 2) (c) (6 3 4) (d) (1 2 3)

7. X-ray diffraction of cubic crystal gives an intensity maximum for Bragg angle of 20° corresponding to the (110) plane. The lattice parameter of the crystal is ____________ nm.
(Consider wavelength of X-ray = 0.15 nm)

8. A lattice has the following primitive vectors (in Å): $\vec{a} = 2(\hat{j}+\hat{k}), \vec{b} = 2(\hat{k}+\hat{i}), \vec{c} = 2(\hat{i}+\hat{j})$. The reciprocal lattice corresponding to the above lattice is

(a) BCC lattice with cube edge of $\left(\frac{\pi}{2}\right)Å^{-1}$ (b) BCC lattice with cube edge of $(2\pi)Å^{-1}$

(c) FCC lattice with cube edge of $\left(\frac{\pi}{2}\right)Å^{-1}$ (d) FCC lattice with cube edge of $(2\pi)Å^{-1}$

(e) none of these

9. The primitive translation vectors of the body centered cubic lattice are $\vec{a} = \frac{a}{2}(\hat{x} + \hat{y} - \hat{z})$, $\vec{b} = \frac{a}{2}(\hat{x} + \hat{y} + \hat{z})$, and $\vec{c} = \frac{a}{2}(\hat{x} - \hat{y} + \hat{z})$. The primitive translation vectors $\vec{A}, \vec{B}$ and $\vec{C}$ of the reciprocal lattice are:

(a) $\vec{A} = \frac{2\pi}{a}(\hat{x} - \hat{y})$; $\vec{B} = \frac{2\pi}{a}(\hat{y} + \hat{z})$; $\vec{C} = \frac{2\pi}{a}(\hat{x} + \hat{z})$

(b) $\vec{A} = \frac{2\pi}{a}(\hat{x} + \hat{y})$; $\vec{B} = \frac{2\pi}{a}(\hat{y} - \hat{z})$; $\vec{C} = \frac{2\pi}{a}(\hat{x} + \hat{z})$

(c) $\vec{A} = \frac{2\pi}{a}(\hat{x} + \hat{y})$; $\vec{B} = \frac{2\pi}{a}(\hat{y} + \hat{z})$; $\vec{C} = \frac{2\pi}{a}(\hat{x} - \hat{z})$

(d) $\vec{A} = \frac{2\pi}{a}(\hat{x} + \hat{y})$; $\vec{B} = \frac{2\pi}{a}(\hat{y} + \hat{z})$; $\vec{C} = \frac{2\pi}{a}(\hat{x} + \hat{z})$

10. The total number of Cl^- ions in a unit cell of NaCl crystal is

(a) 4 (b) 2 (c) 8 (d) 10

11. The potencial of a diatomic molecule as a function of the distance r between the atoms is given by $V(r) = -\frac{a}{r^6} + \frac{b}{r^{12}}$. The value of the potential at equilibrium separation between the atoms is :

(a) $-4a^2/b$ (b) $-2a^2/b$ (c) $-a^2/2b$ (d) $-a^2/4b$

12. The real space primitive lattice vectors are $\vec{a}_1 = a\hat{x}$ and $\vec{a}_1 = \frac{a}{2}(\hat{x} + \sqrt{3}\hat{y})$. The reciprocal space unit vectors $\vec{b}_1$ and $\vec{b}_2$ for this lattice are, respectively **[GATE 2017]**

(a) $\frac{2\pi}{a}\left(\hat{x} - \frac{\hat{y}}{\sqrt{3}}\right)$ and $\frac{4\pi}{a\sqrt{3}}\hat{y}$ (b) $\frac{2\pi}{a}\left(\hat{x} + \frac{\hat{y}}{\sqrt{3}}\right)$ and $\frac{4\pi}{a\sqrt{3}}\hat{y}$

(c) $\frac{2\pi}{a\sqrt{3}}\hat{x}$ and $\frac{4\pi}{a}\left(\frac{\hat{x}}{\sqrt{3}} + \hat{y}\right)$ (d) $\frac{2\pi}{a\sqrt{3}}\hat{x}$ and $\frac{4\pi}{a}\left(\frac{\hat{x}}{\sqrt{3}} - \hat{y}\right)$

13. The total energy of an inert-gas crystal is given by $E(R) = \frac{0.5}{R^{12}} - \frac{1}{R^6}$ (in eV), where R is the inter-atomic spacing in Angstroms. The equilibrium separation between the atoms is ________ Angstrons. (up to two decimal places). **[GATE 2017]**

14. The total energy of an ionic solid is given by an expression $E = -\frac{\alpha e^2}{4\pi\varepsilon_0 r} + \frac{B}{r^9}$ where α is Madelung constant, r is the distance between the nearest neighbours in the crystal and B is a constant. If r_0 is the equilibrium separation between the nearest neighbours then the value of B is

(a) $\frac{\alpha e^2 r_0^8}{36\pi\epsilon_0}$ (b) $\frac{\alpha e^2 r_0^8}{4\pi\epsilon_0}$ (c) $\frac{2\alpha e^2 r_0^{10}}{9\pi\epsilon_0}$ (d) $\frac{\alpha e^2 r_0^{10}}{36\pi\epsilon_0}$

15. For a perfect free-electron gas in a metal, the magnitudes of phase velocity (v_p) and group velocity (v_g) are such that:

(a) $v_p = v_g$ (b) $v_p = \frac{1}{2}v_g$ (c) $v_p = \sqrt{2}v_g$ (d) $v_p = 2v_g$

16. In simple metals the phonon contribution to the electrical resistivity at temperature T is:
(a) directly proportional to T above Debye temperature and to T^3 below it.
(b) inversely proportional to T for all temperatures
(c) independent of T for all temperatures
(d) directly proportional to T above Debye temperature and to T^5 below it

17. Which one of the statements about density of states is not true?
(a) Variation in the energy dependence of density of states is dimension independent.
(b) Variation in the energy dependence of density of states in 3D follows $E^{1/2}$
(c) Variation in the energy dependence of density of states in 2D follows E^0
(d) Variation in the energy dependence of density of states in 1D follows $E^{-1/2}$

18. The energy of an electron in a band as a function of its wave vector **k** is given by

$E(k) = E_0 - B(\cos k_x a + \cos k_y a + \cos k_z a)$, where E_0, B and a are constants. The effective mass of the electron near the bottom of the band is

(a) $\frac{2\hbar^2}{3Ba^2}$ (b) $\frac{\hbar^2}{3Ba^2}$ (c) $\frac{\hbar^2}{2Ba^2}$ (d) $\frac{\hbar^2}{Ba^2}$

19. The energy vs. wave vector $(E-k)$ relationship near the bottom of a band for a solid can be approximated as $E = A(ka)^2 + B(ka)^4$, where the lattice constant $a = 2.1 Å$. The values of A and B are 6.3×10^{-19}J and 3.2×10^{-20}J, respectively. At the bottom of the conduction band, the ratio of the effective mass of the electron to the mass of free electron is ________. (Give your answer upto two decimal places) **[GATE 2016]**

(Take $\hbar = 1.05 \times 10^{-34}$ J-s, mass of free electron $= 9.1 \times 10^{-31}$kg).

20. Assume that the crystal structure of metallic copper (Cu) results in a density of atoms $\rho_{Cu} = 8.46 \times 10^{28}\ m^{-3}$. Each Cu atom in the crystal donates one electron to the conduction band, which leads, for the 3-D Fermi gas, to a density of states **[TIFR 2017]**

$$g(\varepsilon) = \frac{1}{2\pi^2}\left(\frac{2m^*}{\hbar^2}\right)^{3/2} \varepsilon^{1/2}$$

where m^* is the effective mass of the conduction electrons. In the low temperature limit (i.e. $T = 0\ K$), find the Fermi energy E_F, in units of eV. You may assume m^* to be equal to the free electron mass m_e.

21. Consider a 2-dimensional electron gas with a density of $10^{19}\ m^{-2}$. The Fermi energy of the system is _____ eV. (up to two decimal places). **[GATE 2017]**

$\left(m_e = 9.31 \times 10^{-31}\text{kg},\ h = 6.626 \times 10^{-34}\text{ Js},\ e = 1.602 \times 10^{-19}\text{C}\right)$

22. The ratio of the mobility to the diffusion coefficient in a semiconductor has the units:

(a) V^{-1} (b) $cm.V^{-1}$ (c) $V.cm^{-1}$ (d) $V.s$

23. The bandgap of silicon at room temperature is:

(a) 1.3 eV (b) 0.7 eV (c) 1.1 eV (d) 1.4 eV

24. The probability that an electron in a metal occupies the Fermi-level at any temperature (> 0 K):
(a) 0 (b) 1 (c) 0.5 (d) 1.0

25. Which one of the following is a trivalent material?
(a) Antimony (b) Phosphorus (c) Arsenic (d) Boron

26. The materials not having negative temperature coefficient of resistivity are
(a) Metals (b) Semiconductors (c) Insulators (d) None of the above.

27. The Ohm's law for conduction in metals is:
(a) $J = \sigma E$ (b) $J \propto \sigma E$ (c) $J = E/\sigma$ (d) $J \propto E/\sigma$

28. N-type silicon is obtained by doping silicon with:
(a) Germanium (b) Aluminium (c) Boron (d) Phosphorus

29. The band-gap of silicon at 300 K is:
(a) 1.36 eV (b) 1.10 eV (c) 0.80 eV (d) 6.67 eV

30. The drift velocity of electrons in silicon:
(a) Is proportional to the electric field for all values of electric field.
(b) Is independent of the electric field.
(c) Increases at low values of electric field and decreases at high values of electric field exhibiting negative differential resistance.
(d) Increases linearly with electric field at low values of electric field and gradually saturates at higher values of electric field.

31. The free electron density in a conductor is $(1/1.6)\times10^{22}$ cm^{-3}. The electron mobility is 10 cm^2/V s. What is the value of its resistivity?
(a) 10^{-4} Wm (b) 1.6×10^{-2} Wm (c) 10^{-4} Ωcm (d) 10^{-4} Ω cm^{-1}

32. The net charge of an n-type semiconductor is
(a) positive (b) zero (c) negative (d) dependent on the dopant density

33. When a pentavalent impurity is added to Si, it becomes
(a) an insulator (b) a conductor
(c) an intrinsic semiconductor (d) an *n*-type semiconductor

34. When a pure semiconductor is heated, its resistance
(a) increases (b) decreases linearly
(c) decreases exponentially (d) remains the same

35. Given that the band gap of cadmium sulphide is 2.5 eV, the maximum photon wavelength, for electron-hole pair generation will be
(a) 5400 μm (b) 540 μm (c) 5400Å (d) 540 Å

36. LED is a
(a) p-n diode (b) Thermistor (c) Gate (d) Transistor

37. As per Hall effect, if any specimen carrying a current I is placed in a transverse magnetic field B, then an electric field E is induced in the specimen in the direction.
(a) Parallel to I (b) Perpendicular to B and parallel to I
(c) Parallel to I and B (d) Perpendicular to both I and B.

38. Which one of the following is the correct relationship between the band gap of a material used in a photo detector and the energy of the incident photon?
(a) $E_g \geq hc/\lambda_g$ (b) $h\upsilon > E_g$ (c) $h\upsilon \geq E_g$ (d) $h\upsilon \leq E_g$

CAREER ENDEAVOUR

Best Institute for IIT-JAM, NET & GATE

CSIR-UGC-NET/JRF | GATE PHYSICS

SOLID STATE PHYSICS (LEVEL-1)

Assignment-1 : ANSWER KEY

1. (c)	2. (d)	3. (c)	4. (d)	5. (a)	6. (a)	7. (b)
8. (a)	9. (c)	10. (b)	11. (c)	12. (c)	13. (b)	14. (b)
15. (d)	16. (b)	17. (b)	18. (a)	19. (d)	20. ()	21. (a)
22. (a)	23. (c)	24. (d)	25. (b)	26. (a)	27. (b)	28. (b)
29. ()	30. ()	31. (b)	32. (d)	33. (a)	34. (a)	35_A(a)
35_B(b)	36_A (d)	36_B (d)	37. (c)	38. (c)	39. (c)	40. (b)
41. (c)	42. (a)	43. (c)	44. (c)	45. (d)	46. (c)	
47. (a), (c), (d)		48. (14.50)	49. (c)	50. (c)	51. (a)	

Assignment-2: ANSWER KEY

1. (0.41)	2. (c)	3. (c)	4. (d)	5. (b)	6. (12)	7. (d)
8. (b)	9. (b)	10. (c)	11. (d)	12. (d)	13. (d)	14. (d)
15. (c)	16. (a)	17. (3.96)	18. (b)	19. (a)	20. (d)	21. (b)
22. (b)	23. (d)	24. (b)	25. (a)	26. (a)	27. (a)	28. (b)
29. (b)	30. (a)	31. (a)	32. (b)	33. (a)	34. (a)	35. (c)
36. (a)	37. (a)	38. (b)	39. (d)	40. (a)	41. (a)	42. (b)
43. (a)						

Assignment-3: ANSWER KEY

1. (d)	2. (a)	3. (a)	4. (a)	5. (d)	6. (b)	7. (c)
8. (a)	9. (c)	10. (c)	11. (a)	12. (d)	13. (d)	14. (1)
15. (a)	16. (a)	17. (1.7)	18. (d)	19. (b)	20. (d)	21. (a)
22. (b)	23. (b)	24. (b)	25. (c)	26. (b)	27. (c)	28. (a)
29. (d)	30. (d)	31. (d)	32. (a)	33. (a)	34. (c)	35. (c)
36. (c)	37. (c)	38. (b)	39. (d)	40. (a)	41. ()	42. (d)
43. (b)	44. (d)	45. (0)	46. (5.9)	47. (a)	48. (c)	49. (a)
50. (b)	51. (d)	52. (d)	53. (c)	54. (b)	55. (b)	56. (b)
57. (d)	58. (d)	59. (c)	60. (b)	61. (b)	62. (b)	63. (d)
64. (b)	65. (b)	66. ()	67. (a)	68. (d)	69. (c)	70. (c)
71. (a)	72. (a & d)	73. (a)	74. (c)	75. (d)	76. (a)	77. (b)
78. (b)	79. (13.5×10^{-6})		80. (2.53)	81. (a)	82. (c)	83. (d)
84. (b)	85. (d)	86. (1)	87. (a)	88. (5.8)	89. (d)	90. (d)

Assignment-4: ANSWER KEY

1. (d)	2. (c)	3. (a)	4. (c)	5. (c)	6. (c)	7. (d)
8. (c)	9. (a)	10. (b)	11. (b)	12. (a)	13. (b)	14. (c)
15. (c)	16. (a)	17. (c)	18. (b)	19. (b)	20. (c)	21. (c)
22. (a)	23. (d)	24. (b)	25. (d)	26. (c)	27. (c)	28. (c)
29. (b)	30. (d)	31. (d)	32. (c)	33. (d)	34. (b)	35. (b)
36. (a)	37. (a)	38. (c)	39. (b)	40. (c)	41. (b)	42. (a)
43. (a)	44. (d)	45. (c)	46. (d)	47. (a)	48. (d)	49. (c)
50. (c)	51. (c)	52. (b)	53. (c)	54. (c)	55. (a)	
56. (115.15)	57. (d)	58. (1844.4)	59. (0.394)	60. (c)	61. (b)	62. (a)
63. (a)	64. (c)	65. (c)	66. (c)	67. (d)	68. (c)	69. (d)
70. (a)	71. (c)	72. (b)	73. (a)	74. (c)	75. (c)	76. (a)
77. (d)	78_A(a)	78_B(b)	79. (400)	80. (a)	81. (0.318)	82. (d)
83. (b)	84. (d)	85. (4)	86. (1.562)	87. ( )	88. (a,c,d)	89. (c)

Assignment-5: ANSWER KEY

1. (a)	2. (a)	3. (d)	4. (c)	5. (d)	6. (a)	7. (b)
8. (d)	9. (b)	10. (b)	11. (d)	12. (c)	13. (d)	14. (a)
15. (b)	16. (d)	17. (c)	18. (a)	19. (b)	20. (b)	21. (a)
22. (b)	23. (d)	24. (b)	25. (b)	26. (b)	27. (c)	28. (b)
29. (b)	30. (b)	31. (b)	32. (c)	33. (a)	34. (b)	35. (a)
36. (d)	37. (3.97)	38. (c)	39. (c)	40. (b)	41. (d)	42. (b)
43. (c)	44. (d)	45. (b)	46. (d)	47. (d)	48. (d)	49_A(a)
49_B(a)	50. (b)	51. (c)	52. (b)	53. (c)	54. (b)	55. (d)
56. (d)	57. (b)	58. (b)	59. (a)	60. (a)	61. (b)	62. (b)
63. (a)	64. (c)					

SOLID STATE PHYSICS (LEVEL-2)

1. (0.447)	2. (c)	3. (b)	4. (a)	5. (c)	6. (*)	7. (0.31)
8. (a)	9. (d)	10. (a)	11. (d)	12. ()	13. ( )	14. (a)
15. (b)	16. (a)	17. (a)	18. (d)	19. (0.21)	20. (6.87)	21. ( )
22. (a)	23. (c)	24. (c)	25. (d)	26. (a)	27. (a)	28. (d)
29. (b)	30. (d)	31. (c)	32. (b)	33. (d)	34. (c)	35. (d)
36. (a)	37. (d)	38. (c)				