DEPARTMENT OF PHYSICS

KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

COURSE No. Ph.1111 (IEM)

PROBLEM SHEET, SESSION: 2018-2019

1. Sketch the [111], [110], [211], [112], [332], [103] & [101] planes in a simple cubic cell.

2. The lattice constant of a cubic lattice is $4A^0$. Calculate the spacing between (211), (111), (001), (110), (123) and (234).

3. Calculate the number of atoms per unit cell for a fcc lattice of copper crystal. Given a = $3.8A^0$, atomic weight of copper = 63.5 and density of copper = 8.9.

4. (a) For a cubic (fcc) crystal, lattice constant

$$a = \left[\frac{4M}{\rho N}\right]^{1/3}$$

, where M is the gm molecular weight of molecules a lattice points, ρ is the density of crystal and N is Avogadro's number.

(b) A substance has fcc lattice, molecular weight 60.2 and density $6250 Kg/m^3$. Calculate its lattice constant 'a'.

5. A KCl crystal which has fcc lattice structure has a density of $1.97\times10^3 Kg/m^3$. Its molecular weight is 74.5. Find the distance between adjacent atoms.

6. In a unit cell of sc structure, find the angle between the normal to pair of planes whose Miller indices are (i) [111] & [101] (ii) [112] & [011] (iii) [212] & [101] and (iv) [110] & [211].

7. The orthorhombic crystal has axial units in the ratio of 0.424:1:0.367. Find the Miller indices of crystal face whose intercepts are in the ratio 0.212:1:0.183.

8. The primitives of a crystal are $1.24A^0$, $1.82A^0$ and $2A^0$ along whose Miller indices [211] cut intercepts $1.2A^0$ along X-axis. What will be the lengths of intercept along Y- & Z-axes?

9. Calculate the packing fraction in crystals for (i) sc (ii) bcc & (iii) fcc structures, treating the atoms as spherical.

10. Show that spacing d of plane [hkl] in a simple cubic lattice of side a is $d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$.

11. The interplanar spacing d_{111} in a FCC metal is 0.25nm. Calculate its lattice constant and atomic radius.

12. How many atoms per mm^2 surface area are there in (i) [110] plane (ii) [111] and (iii) [211] plane for copper which has fcc structure and a lattice constant 'a' = 3.5×10^{-10}m.

13. A certain orthorhombic crystals has axial units a:b:c of 0.424:1:0.367. Find the Miller indices of crystal faces whose intercepts are:

    a. 0.212:1:0.183

    b. 0.848:1:0.732

    c. 0.424:∞:0.123

14. Calculate the maximum phonon frequency generated by scattering of visible light of wavelength λ = 4800A^0. Given that velocity of sound in medium is 4.8×10^5cm/sec and refractive index is 1.5.

15. Compare the frequencies of sound waves of wavelength $\lambda = 10^{-7}$cm for (i) a homogeneous line (ii) acoustic waves on a linear lattice containing two identical atoms per primitive cell of inter-atomic spacing 2.5A^0 and (iii) light waves of the same wavelength, given that $v_0 = 10^5\ cm/_{sec}$.

16. Calculate the conductivity of germanium. Given mobilities of electrons and holes in a simple of germanium at room temperature are $0.56 m^2V^{-1}s^{-1}$ and $0.19 m^2V^{-1}s^{-1}$ respectively. Assuming that electron and hole densities are each equal to 3.62×10^{19} per m^3. If a potential difference of 2 volts is applied across the germanium plate of thickness 0.2mm and area 1 cm^2, calculate the current produced in the plate.

17. Assuming that each atom of copper contributes one free electron, calculate the drift velocity of free electrons in the copper conductor of cross-sectional area 10^{-4} m^2 carrying a current of 200mA.

18. The intrinsic carrier density of Ge at 27^0C is $2.5\times10^{17}m^{-2}$. Calculate its intrinsic resistivity, if the electron and hole mobilities are $0.35m^2V^{-1}s^{-1}$.

19. A small current of 1.1mA exists in a copper wire of diameter 2.1mm. Compute drift velocity.

20. Compute free electrons per unit volume n and electron mobility μ for copper if its atomic weight is $63.54kg.kmol^{-1}$, density $8960kg\text{-}m^{-3}$; velocity (rms), $1.6\times10^6ms^{-1}$; and electrical conductivity 6.5×10^7, $(\Omega\text{-}m)^{-1}$.

21. (i) Calculate Einstein temperature given Einstein frequency as 9.5×10^{11} Hz. (ii) Calculate the frequency of Einstein oscillator for θ_E = 248K. Given $k_B = 1.38\times 10^{-23}JK^{-1}$ and $h = 6.63\times10^{-34}J\text{-}s$.

22. The Debye temperature of carbon (diamond structure) is 1840K. Calculate the specific heat per kmole for diamond at 25K. Also compute the highest lattice frequency involved in the Debye theory.

23. Show that average kinetic energy of a free electron at 0K is $\frac{3}{5}E_f$ where E_f is Fermi energy and average speed is $\frac{3}{4}v_f$ where v_f is the velocity at Fermi surface.

24. Consider silver in the metallic state with one free electron per atom. Calculate the Fermi energy. Given density of silver is $10.5gm\text{-}cm^{-3}$ and atomic weight 108.

25. Aluminum metal crystallizes in fcc structure. If each contributes single electron as free electron and the lattice constant a is $4A^0$, calculate treating conduction electrons as free electron Fermi gas (i) Fermi energy (E_f) and Fermi vector (k_f) (ii) Total kinetic energy of free electron gas per unit volume at 0K. [$\hbar = 1.054\times10^{-27}\,erg-\sec$, Electron rest mass = 9.11×10^{-28}gm.

26. Copper has a mass density ρ_m = $8.9gm/cm^3$ and an electrical resistivity ρ = 1.66×10^{-8} ohm-m at room temperature. Calculate (i) The Fermi energy (E_f) (ii)

the concentration of the conduction electrons (iii) The mean free time τ (iv) The Fermi velocity v_f and (v) The mean free path λ_f at Fermi level.

27. The inter collision time in copper 2.6×10^{-14}s. Calculate its thermal conductivity at 310K.

28. A copper wire of length 0.5m and diameter 0.3mm has a resistance 0.11Ω at 20^0C. If the thermal conductivity of copper at 20^0C is $390 Wm^{-1}K^{-1}$, calculate Lorentz number. Compare this value with the value predicted by classical free electron theory.

29. The relaxation time of conduction electron in copper is 2.5×10^{-14}s. Find the thermal conductivity of copper at 0^0C. Assume density of electrons to be $8.5\times10^{28} \,/_{m^3}$.

30. Calculate the inter collision time at room temperature and drift velocity in a field of $100Vm^{-1}$ in sodium, whose conductivity is $2.16\times10^{7}\Omega^{-1}m^{-1}$.

31. The density of states function for electrons in a metal is given by Z(E)dE = $13.6E^{1/2}dE$. Calculate the Fermi level at a room temperature a few degrees above absolute zero for sodium which has 2.3×10^{28}electrons per cubic meter.

32. Show that if the mean free path is independent of the velocity, the electrical conductivity of Maxwell-Boltzmann free electron gas may expressed by the relation $\sigma = \dfrac{4ne^2\lambda}{3\sqrt{2\pi KTm}}$. When λ and τ are independent of velocity, the Maxwell-Boltzmann distributrion gives average value of τ as $\bar{\tau} = \dfrac{\lambda\langle v\rangle}{\langle v^2\rangle}$.

33. Electrical resistivities of copper and nickel at room temperature are 1.65×10^{-3} and $14\times10^{-8}\Omega$-m respectively. If wave mechanical treatment of Wiedemann-Franz law applies to these materials, find the electronic contribution to the thermal conductivities of these materials.

34. Find the mobility of electrons in copper assuming that each atom contributes one free electron for conduction. For Cu, resistivity = 1.7×10^{-6}ohm-cm, density = $8.9\times$gm/cm^3, atomic weight = 63.5 and Avogadro's number = 6.02×10^{23}/gm-mole.

35. Find the Hall coefficient and electron mobility for germanium if for a given sample [length 1cm, breadth 4mm and thickness 1mm] a current of 5milliampere flown from a 1.5volts supply develops a Hall voltage 20millivolts across the specimen in a magnetic field of 0.45wb/m^3.

36. A copper strip 2.25cm wide and 1.15mm thick is placed in a magnetic field with B = 1.75wb/m^2 perpendicular to the strip. If a current of 220mA. Is set up in the strip, what Hall potential difference appears across the strip?

37. Find the Hall coefficient and electron mobility for germanium if for a given sample [length 1cm, breadth 3mm and thickness 1mm] a current of 4.2mA flown from a 1.5volts supply develops a Hall voltage 20mV across the specimen in a magnetic field of 0.45wb/m^3.

38. A semiconductor slice is 2mm thick and carries a current of 0.22A, when a magnetic field of flux density 0.52 Wb-m^{-2} is applied. If the Hall voltage developed is 8.2mV, find the charges per m^{-3}. Given: the charge of electron = 1.6×10^{-19}C.

39. In case of a metal strip of thickness 1mm, when a magnetic field of 1 Tesla is applied, a current of 12 A flows through the strip. Determine the magnetic flux density, if a Hall voltage of 0.65μV is developed. Given: the number of electrons = 10^{29}m^{-3} and electronic charge = 1.6×10^{-19}C.

40. A LASER beam has a wavelength of 8.6×10^{-7}m and aperture 5.4×10^{-3}m. The LASER beam is sent to moon is 4×10^5Km from the earth. Calculate (i) the angular spread of the beam & (ii) the axial spread when it reaches the moon.

41. The coherence length for sodium light is 2.9×10^{-2}m. The wavelength of sodium light is 5896A^0. Calculate (i) the number of oscillation corresponding to the coherence length and (ii) the coherence time.

42. A LASER beam $\lambda = 5890$A^0 on earth is focused by a lens (or mirror) of diameter 2m on the crater on the moon. The distance of the moon is 4×10^8m. How big is the spot on the moon? Neglect the effect of earth's atmospheres.

43. A LASER beam has a power of 75mW. It has an aperture of 5×10^{-3}m and it emits light of wavelength 6000A^0. The beam is focused with a lens of focal length 0.16m. Calculate the area and the intensity of the image.

44. The coherence length for the red cadmium line of wavelength 6.4×10^{-7}m is 30cm. Calculate (i) the number of oscillations corresponding to the coherence length and (ii) the coherence time.

45. A LASER beam has a power of 60mW. It has an aperture of 5×0^{-3}m and it emits light of wavelength 7200A°. The beam is focused with a lens of focal length 0.1m. Calculate the area and the intensity of the image.

46. A 8Kw LASER emits light of 650nm wavelength. Calculate the number of photons emitted by the laser every second

47. Find the increase in the relative population of lasing levels of He-Ne LASER when temperature is increased from 300K to 1000K. Given the Boltzmann constant is 1.38×10^{-23}JK^{-1}.

48. Line width of a commercial LASER is 22 kHz. Find its coherence time as well as coherence length.

49. A beam has a power of 0.25 watt and has an aperture of 1mm. It emits light of wavelength 6000 $A°$. If it is focused by a lens of F.L. 80cm. Calculate the area and intensity of the image.

50. The coherence length of sodium D_2 line is 2.5cm. Deduce the (i) coherence time, (ii) spectral width of line and (iii) purity factor, Given $\lambda = 5890$ $A°$.