Physics of Solids + Assignment - Complete Course.

Question-1 :-

a). The given radiation is Cu-Kα with $\lambda = 1.5406$ Å.

Using the Formula:-

$$\boxed{2d\sin\theta = n\lambda}$$

here we need d spacing and we know θ and λ, putting n = 1 for first order diffraction.

$$\boxed{d = \frac{n\lambda}{2\sin\theta}}$$

Lamda(λ)	2θ	d-spacings.
1.5406 Å	22.88	3.8837.
1.5406 Å	32.54	2.7494.
1.5406 Å	40.10	2.2468.
1.5406 Å	46.60	1.9474.
1.5406 Å	52.48	1.7422.
1.5406 Å	57.92	1.5908.
1.5406 Å	67.94	1.3785.
1.5406 Å	72.68	1.2999.
1.5406 Å	77.30	1.2333.

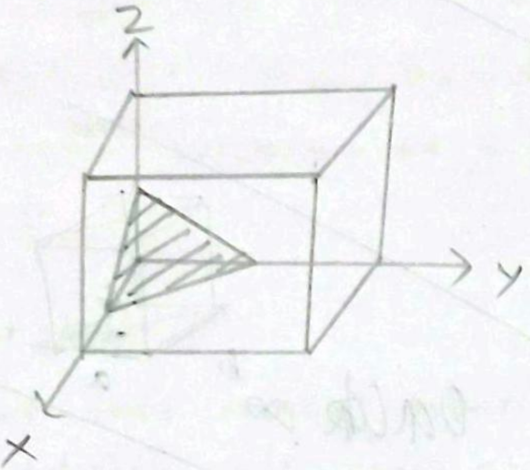
b). For this part, we need to calculate theta of peaks for radiation Fe Kα with λ = 1.93604 Å.

We'll use the same formula with λ for Fe Kα and d spacings calculated in previous part.

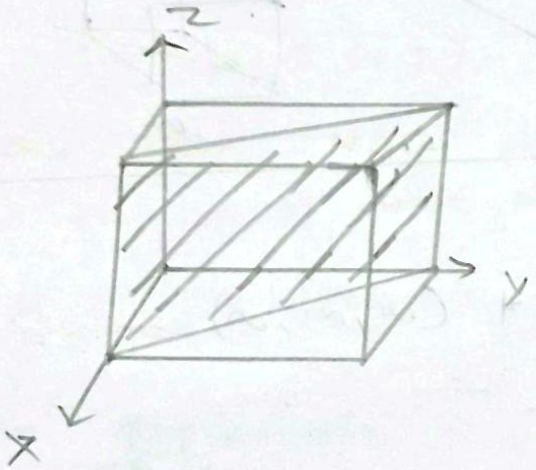
d-spacings.	λ'	$2\theta'$.
3.8837	1.93604	28.866.
2.7494	1.93604	41.2287.
2.2468	1.93604	51.0417.
1.9474	1.93604	59.6131.
1.7422	1.93604	67.5066.
1.5908	1.93604	74.9597.
1.3785	1.93604	89.2044
1.2999	1.93604	96.2628
1.2333	1.93604	103.417

Question-2 :-

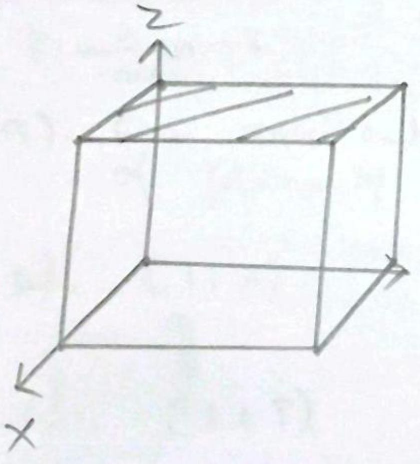
a). ~~(2,2,2)~~. (2 2 2)



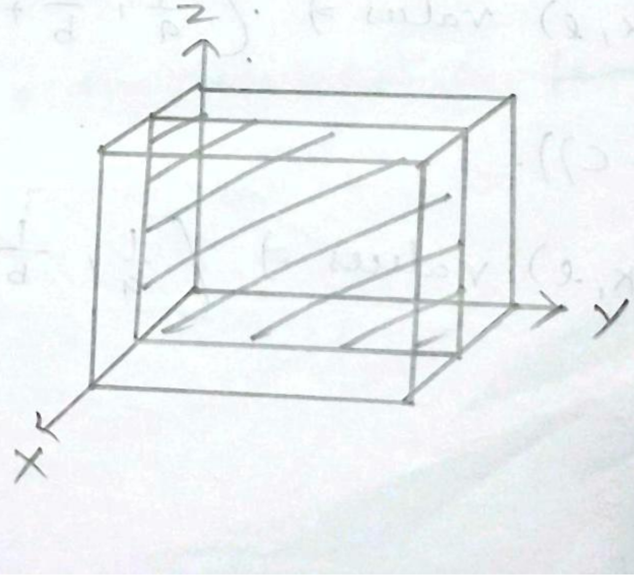
b). ~~(1,1,0)~~. (1 1 0).



(c) (0 0 1).



(d). (2 0 0).



Question - 3

a). For non-cubic lattice, the planes belong to family of planes of {0 0 1}

b). (1 1 0)

c). (1 1 $\bar{1}$).

Question-4 :-

Part-a)).

If a single coin given rise to two outcomes or Eigenstates, then considering the coins are distinguishable the total outcomes or Eigenstates will be $2 \times 2 \times 2$

$\Rightarrow 8$.

Part-b)).

If we toss three coins, the outcomes would be (considering all coins are distinguishable).

(TTT), (HHH), (HTT), (H,HT), (THH), (TTH), (HTH), (THT).

~~Since coins~~ Now we consider coins as indistinguishable so the no. of ~~diff~~ different outcomes will be:-

(TTT), (HHH), (THH), (H,TT).

So degenerate states $\Rightarrow 8-4 = 4$ ans.

Question-5 :-

Width of 1-D potential width ⇒ 0.3 nm.

Since the electron is confined in 1-D potential well :-

Total Energy = KE + $\cancel{PE}^{0}$.

KE = E

$$E \Rightarrow \frac{n^2 h^2}{8 m L^2} \quad \left(\text{For ground state } n = 1 \right)$$

$$KE = \frac{(6.6 \times 10^{-34})^2}{8 \times 9.1 \times 10^{-31} \times (0.3)^2 \times (10^{-9})^2}$$

$$= \frac{43.56 \times \cancel{10^{-68}} \;\; 10^{-19}.}{6.552 \times \cancel{10^{-49}}}$$

$$= 6.64 \times 10^{-19}. \Rightarrow \boxed{4.15 \text{ eV.}}$$

Calculating Energy difference:--

$$\Delta E = (\varepsilon_3 - \varepsilon_1) = 9\varepsilon_1 - \varepsilon_1 = 8\varepsilon_1.$$

$$\Rightarrow 8(4.15)$$

$$\Rightarrow 33.2\,eV.$$

Since $\varepsilon = h\nu$.

$$\nu = \frac{\varepsilon}{h} \Rightarrow \frac{33.2}{4.13 \times 10^{-15}} \Rightarrow \boxed{8.03 \times 10^{15}\, s^{-1}} \text{ ans.}$$

-: Question-6 :-

a). Fermi-Dirac distribution:-

$$f(\varepsilon) = \frac{1}{1 + e^{(\varepsilon - E_F)/KT}}$$

here $\varepsilon = 8eV$, $E_F = 7eV$.

$\varepsilon - \varepsilon_f = 1eV = 1.6 \times 10^{-19} J$

$$F(\varepsilon) = \frac{1}{1 + e^{\frac{1.6\times10^{-19}}{1.38\times10^{-23} \times 298K}}}$$

(Taking $k = 1.38 \times 10^{-23} m^2 kg\, s^{-2} K^{-1}$ and $T = 298 K$).

$$= \frac{1}{1 + e^{38.9}}$$

$$= \frac{1}{e^{38.9}} \Rightarrow \boxed{1.27 \times 10^{-17}}$$ ans.

b). Putting $f(\varepsilon) = 0.3$

$$0.3 = \frac{1}{1 + e^{\frac{1.6 \times 10^{-19}}{1.38 \times 10^{-23} \times T}}}.$$

Solving this, we get

$$\boxed{T \approx 13640.235 \text{ K}}$$ ans.

:: Question - 7 :-

BCC basis Vectors :-

$$a_1 = \frac{1}{2} a (\vec{x} + \vec{y} - \vec{z}).$$

$$a_2 = \frac{1}{2} a (-\vec{x} + \vec{y} + \vec{z})$$

$$a_3 = \frac{1}{2} a (\vec{x} - \vec{y} + \vec{z}).$$

Vectors in reciprocal Lattice :-

$$b_1 = \frac{2\pi (a_2 \times a_3)}{a_1 \cdot (a_2 \times a_3)}$$

$$\vec{a_2} \times \vec{a_3} = \frac{a^2}{4} \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -1 & 1 & +1 \\ 1 & -1 & 1 \end{vmatrix}$$

$$\vec{b_1} = (\vec{x} + \vec{y}) \times K$$

where K is a scaling factor $\left(K = \frac{2\pi}{\bar{a}}\right)$.

similarly $b_2 = \dfrac{2\pi (a_3 \times a_1)}{a_1 \cdot (a_2 \times a_3)} = K \times (\vec{z} + \vec{y})$.

$$b_3 = \frac{2\pi (a_1 \times a_2)}{a_1 \cdot (a_2 \times a_3)} = K \times (\vec{z} + \vec{x}).$$

~~where~~ hence we get latice (inverse) vectors as

$K \cdot (\bar{x} + \bar{y})$, $K \cdot (\bar{z} + \bar{y})$, $K \cdot (\bar{z} + \bar{x})$

we get Inverse Latice vectors as

$$\frac{2\pi}{\bar{a}}(\bar{x}+\bar{y}), \quad \frac{2\pi}{\bar{a}}(\bar{y}+\bar{z}), \quad \frac{2\pi}{a}(\bar{z}+\bar{x}).$$

which are Latice vectors of FCC.

hence inverse Lattice of BCC is FCC.

Question - 8 :-

Group velocity of a wave packet :-

$$V_g = \frac{d\omega}{dK}$$

Since we know :-

$$E = \hbar\omega$$

$$\frac{dE}{dK} = \hbar \times \frac{d\omega}{dK}$$

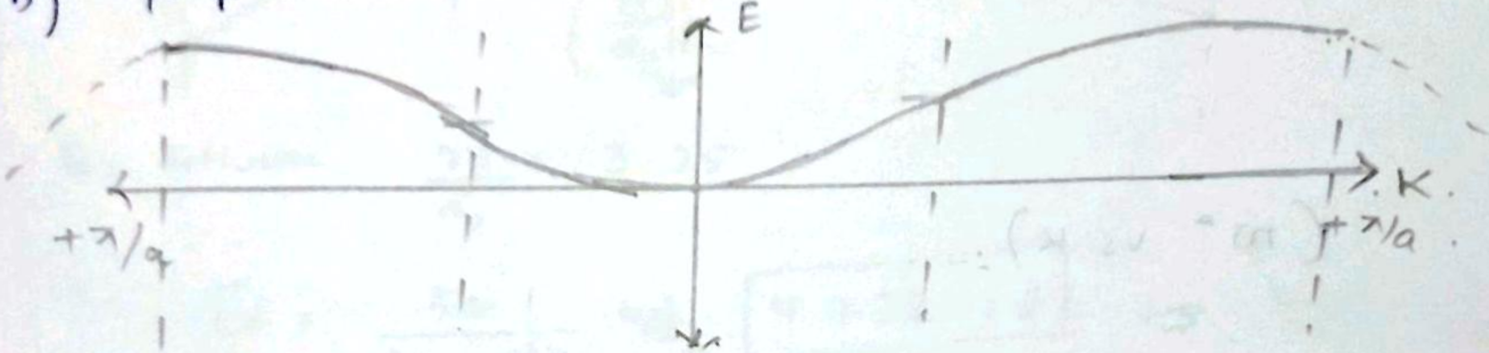
$$V_g = \frac{1}{\hbar}\left(\frac{dE}{dK}\right)$$

$$a = \frac{dV_g}{dt}$$

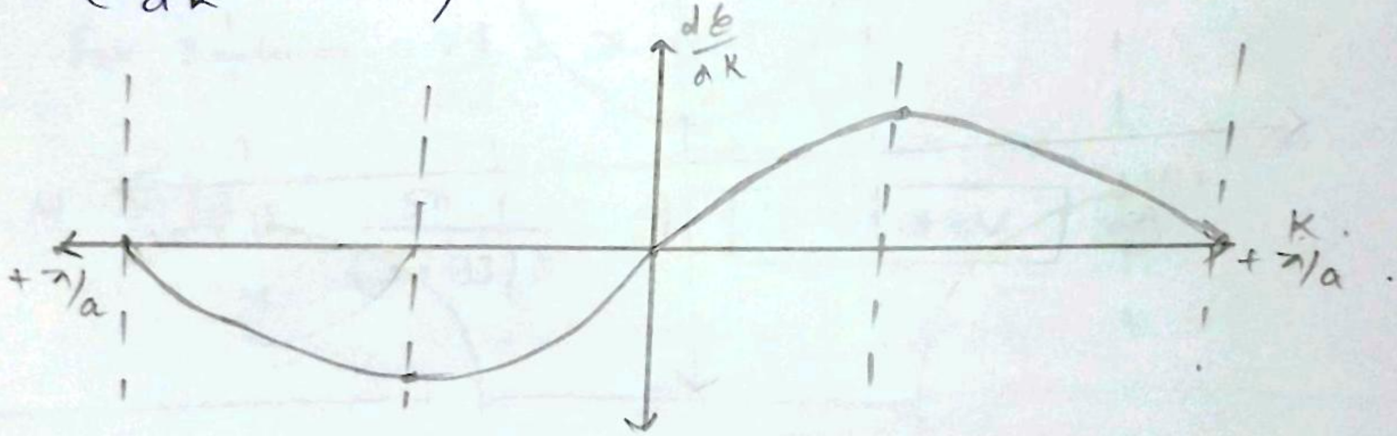
$$F = \frac{\hbar^2}{d^2\varepsilon/dK^2} \cdot \frac{dv}{dt}.$$

$$\boxed{\frac{1}{m^*} = \frac{1}{\hbar^2}\frac{d^2\varepsilon}{dK^2}}.$$

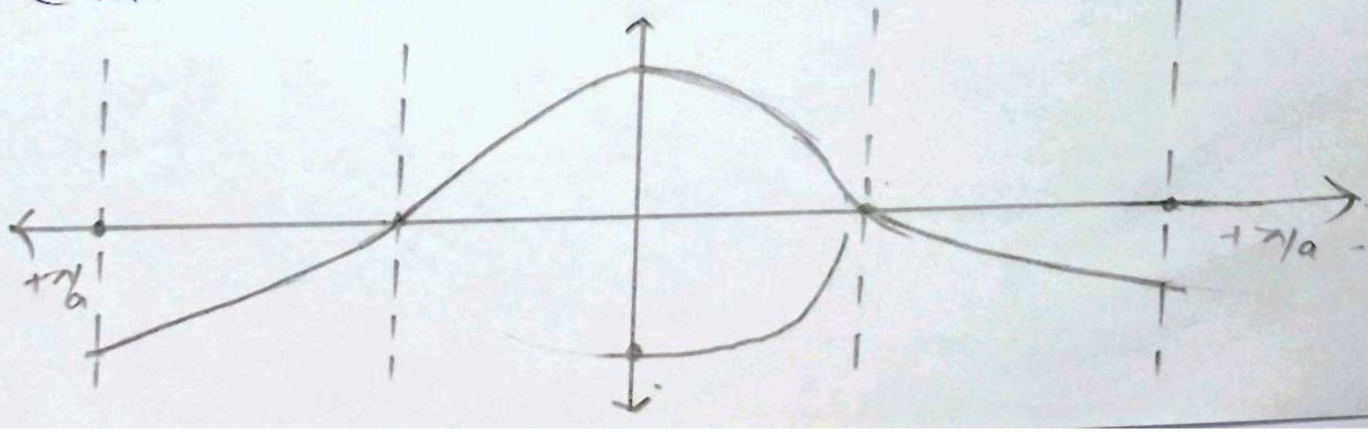
b) Graphs:- (ε vs K).



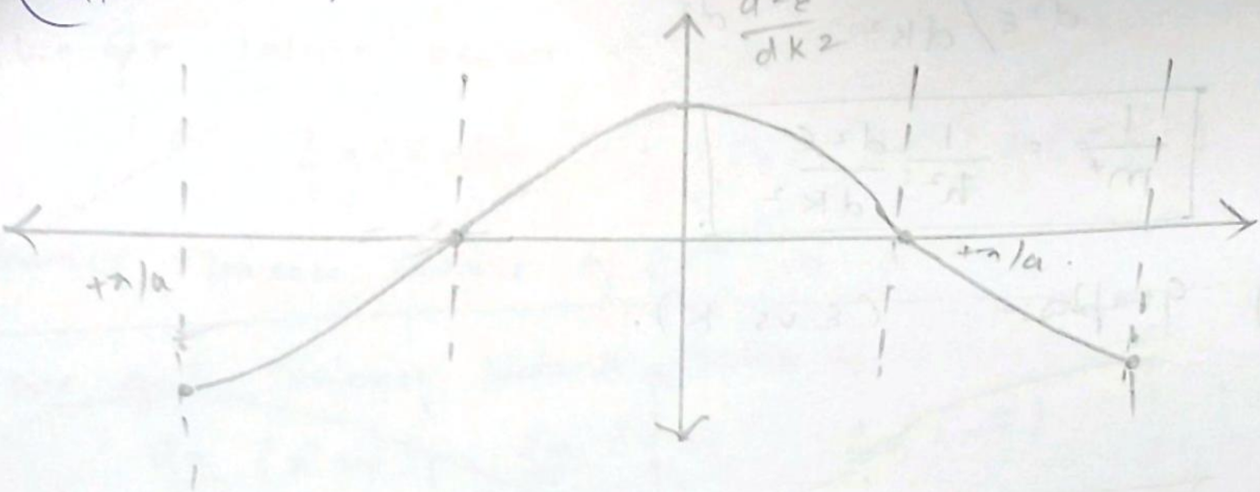
$\left(\frac{d\varepsilon}{dK} \text{ vs } K\right)$.



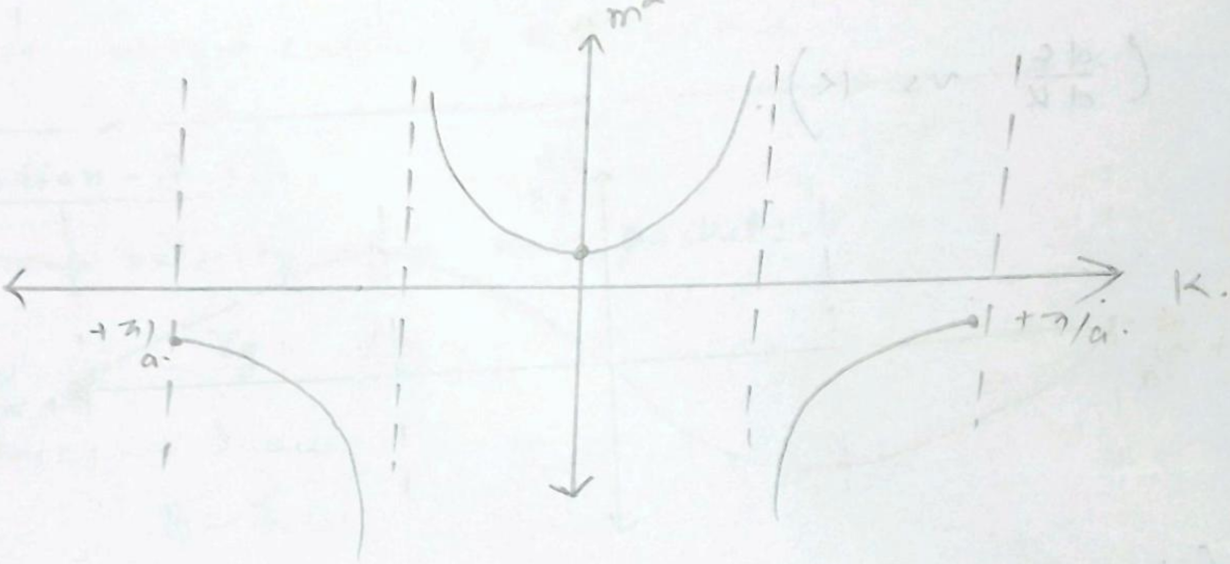
$\left(\frac{d^2\varepsilon}{dK^2} \text{ vs } K\right)$.



$\left(\frac{d^2\varepsilon}{dK^2} \text{ vs } K\right)$.



$(m^* \text{ vs } K)$:-



Question - 20 :-

For Lithium :-

~~Given rs~~

We'll use the formula :-

$$E_F = \frac{50.1\,eV}{\left(\frac{r_s}{a_0}\right)^2}$$

For lithium $\frac{r_s}{a_0} = 3.25$

$$E_F = \frac{50.1}{(3.25)^2} \Rightarrow \boxed{4.732\ eV}$$ ans.

For Sodium $\frac{r_s}{a_0} = 3.93$

$$E_F = \frac{50.1}{(3.93)^2} \Rightarrow \boxed{3.243\ eV}$$ ans.

Question-9 :-

Formula for Effective mass:-

$$\frac{1}{m^*} = \frac{1}{\hbar^2}\frac{d^2E}{dk^2}.$$

The Positive value of effective corresponds to acceleration in direction of Force applied, but ~~force~~ when effective mass is negative, the acceleration is in opposite direction of the Force applied. The opposition experienced is due to the interaction of electron with lattice. The resistance ~~applied~~ given by lattice exceeds Force applied near Brillouin zone, so this negative interaction is only ~~so~~ referred to as negative mass.