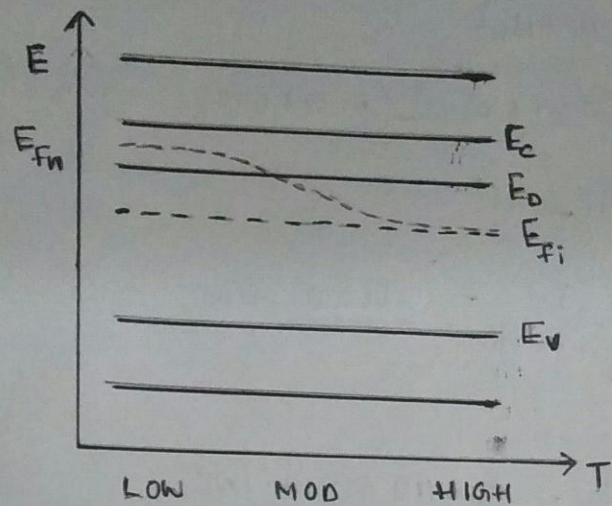
TAT-2

Solution Applied Physics-I 2017-2018

1 a)



— 2M

b) Fermi level: Fermi level provides a reference with which other energies can be compared in an energy band. It is denoted by E_f — 1M

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

where $f(E)$ is the probability that the energy level E is occupied by electrons.

$E_f \rightarrow$ Fermi level

$K \rightarrow$ Boltzman constant

$T \rightarrow$ Temperature in Kelvin. — 1M

Fermi level is defined as the highest filled energy level in any solid at absolute zero temperature.

c. $T = 300K$, $n_i = 2.5\times10^{19}/m^3$. $\mu_e = 0.39 m^2/V.s$, $\mu_h = 0.19 m^2/V.s$

$\sigma = n_i e(\mu_e + \mu_h)$ ——— ½M

$= 2.5\times10^{19} \times 1.6\times10^{-19} (0.39+0.19)$ ——— ½M

$= 2.32 (\Omega m)^{-1}$ ——— ½M

$\rho = \frac{1}{\sigma} = \frac{1}{2.32} = \underline{\underline{0.4310\ \Omega m}}$ ——— ½M

d. $\rho = 1.72\times10^{-8} \Omega m.$, $n_e = 10.41\times10^{28}/m^3.$

$\sigma = \frac{1}{\rho} = 58.14\times10^{6} (\Omega m)^{-1}$ ——— ½M

$\sigma = n_e \mu_e e$ ——— ½M

$\mu_e = \frac{\sigma}{n_e e} = \frac{58.14\times10^{6}}{10.41\times10^{28}\times1.6\times10^{-19}} = \underline{\underline{3.490\times10^{-3}\ m^2/V.s}}$ — 1m

e. When a rod of ferromagnetic material such as iron or nickel is kept in a magnetic field. parallel to its length, the rod suffers a change in its length. This change in length depends on the magnitude of the field and nature of material This phenomenon is known as magnetostriction effect. ——— 1M

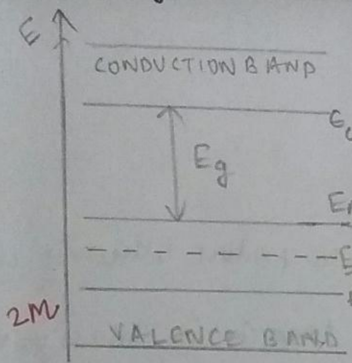
Limitations

a) It is not possible for avery higher frequencies.

any b) The frequency gets affected by temperature. } 1M

2 a) Effect of doping concentration on p-type semiconductor.

(i) Lightly doped



1. When the s.c is lightly doped the impurity atoms are 1M spaced far apart and donot interact with each other

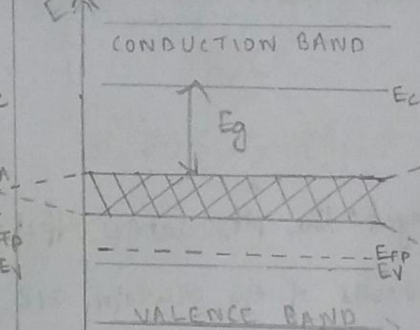
2. The acceptor level is 1M a discrete energy level.

3. The forbidden energy gap is very large.

4. The fermilevel lies 1M b/wn E_A & E_V

ie $E_{Fp} = \frac{E_A + E_V}{2}$

(ii) Moderately doped



1. In moderately doped s.c the concentration of impurity atoms are more and they interact with each other

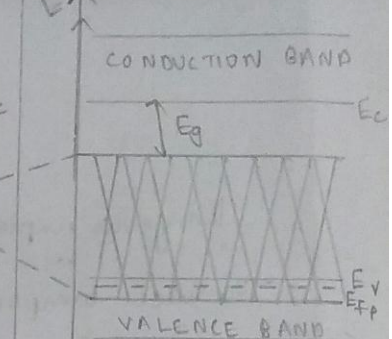
2. The acceptor level splits and forms a band

3. The forbidden gap is comparitively less

4. The fermi level lies close to the valence band

$E_{Fp} \approx E_V$

(iii) Heavily doped.



1. In heavily doped the concentration is very large and hence the interaction between impurity atoms is maximum

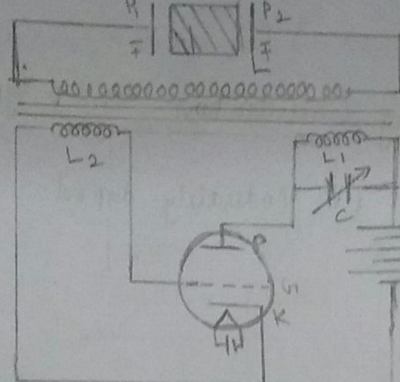
2. The acceptor band's width increases

3. The forbidden gap decreases.

4. The fermi level lies within the valence band.

b) Piezoelectric oscillator.

The principle: The working of piezoelectric oscillator is based on inverse piezoelectric oscillator. ——— 1M



——— 1M

Langevin employed the piezoelectric effect to produce ultrasonic waves. The basic components of the oscillator are tank circuit, triode valve amplifier and a feedback loop. The tank circuit consists of an inductor in parallel with a capacitor to produce the ac voltage. This ac voltage is fed to the triode valve which amplifies the signal. The output of the amplifier is then again fed back to the tank circuit through feedback circuit. The function of the feedback circuit is to maintain its output at constant amplitude. This enables high frequency ac voltage being applied to the crystal plate obtained from oscillatory circuit.

The tank circuit consists of the inductor L_1 and variable capacitor C. The frequency f' of the tank circuit is given by the relation $f' = \frac{1}{2\pi\sqrt{L_1 C}}$ ——— ½M

The frequency of the tank circuit can be adjusted by the variable capacitor C. When the circuit is switched on the battery charges the capacitor C which in turn discharges through the coil L_1, producing variable ac current through L_1. This ac current produces a variable magnetic field near coil L_1. Coil L is placed in the changing magnetic field of L_1. So the flux associated with coil L changes. With change in flux an emf is induced. So an emf is induced in coil L_1 consequently current will flow through it which will be ac current. As a result of this ac current, the polarity of the plates P_1 and P_2 become positive and negative during one half cycle and negative and positive during next half cycle, respectively. This sets up an inverse Piezoelectric effect in the quartz crystal, making it to expand and contract along the vertical axis with change in polarity of plates. Thus setting up mechanical vibrations in the crystal and in the surrounding air medium. This frequency of vibration is same as that of the tank circuit. The medium surrounding the crystal vibrates with the same frequency thus producing ultrasonic waves.

Now due to ac current in L a magnetic field is produced. The coil L which acts as a feedback circuit is placed in the magnetic field of L_2. So the flux associated with L_2

changes, inducing a current in it. This induced current is fed to the grid of the triode valve which will act as an amplifier in the circuit. The triode valve amplifies the input signal and the amplified output is again fed to tank circuit to sustain the oscillations.

The natural frequency of piezo-electric crystal is given by,

$$F = \frac{p}{2t}\sqrt{\frac{Y}{\rho}}$$ — 1m

where $p = 1, 2, 3 \ldots$ fundamental mode, first over tone, second over tone etc.

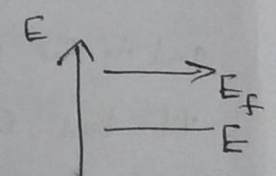
t = thickness of quartz crystal

Y = Young's modulus of quartz-crystal

ρ = density of quartz crystal.

When $p=1$, gives fundamental frequency given by

$$F = \frac{1}{2t}\sqrt{\frac{Y}{\rho}}$$ — 2m



3 (a) Data

$1 - F(E) = 0.01 = 1\% = \frac{1}{100}$

$E_F - E = 0.30 eV$

$E_F = 6.25 eV$

$K = 8.625 \times 10^{-5} eV/K.$

$T = ?$

Solution

$1 - F(E) = 0.01$

$F(E) = 0.99$ ——— 1M

By Fermi dirac distribution function

$$F(E) = \frac{1}{1+e^{(E-E_f)/KT}} \quad \text{——— 1M}$$

$$0.99 = \frac{1}{1+e^{-0.30/8.625\times10^{-5}\times T}}$$

$$\frac{1}{0.99} = 1+e^{\frac{-0.30}{8.625\times10^{-5}\times T}} \quad \text{——— 1M}$$

$$\frac{1}{0.99} - 1 = e^{-\frac{0.030}{8.625\times10^{-5}\times T}}$$

$$\ln\left[\frac{1}{0.99} - 1\right] = -\frac{0.30}{8.625\times10^{-5}\times T}$$

$$-4.595 = -\frac{0.30}{8.625\times10^{-5}\times T}$$

$$T = \frac{-0.30}{8.625\times10^{-5}\times -4.595}$$

$$T = \underline{\underline{756.966\,K}} \quad \text{——— 1M}$$

b) Data

$E_g = 1.2eV$ For intrinsic S.C, $T_1 = 600K$, $T_2 = 300K$

$$\frac{\sigma_{T_1}}{\sigma_{T_2}} = \frac{\sigma_1}{\sigma_2} = ?$$

Solution

$$f(E_c) = e^{-E_g/2KT}$$

At T_1

$$\frac{n_{c_1}}{n} = f(E_c) = e^{-E_g/2KT_1}$$

$$n_{c_1} = n e^{-E_g/2KT_1}$$

At T_2

$$n_{c_2} = n e^{-E_g/2KT_2}.$$

$$\frac{n_{c_1}}{n_{c_2}} = \frac{e^{-E_g/2KT_1}}{e^{-E_g/2KT_2}} \quad \text{----} \quad (1)$$

1M

The conductivity for intrinsic semiconductor

$$\sigma_1 = n_i e(\mu_e + \mu_h)$$

At T_1

$$\sigma_1 = n_{c_1} e(\mu_e + \mu_h)$$

At T_2 $\sigma_2 = n_{c_2} e(\mu_e + \mu_h)$

1M

Now $$\frac{\sigma_1}{\sigma_2} = \frac{n_{c_1}}{n_{c_2}} = \frac{e^{-\frac{E_g}{2KT_1}}}{e^{-E_g/2KT_2}} = e^{\frac{E_g}{2K}\left[\frac{1}{T_2} - \frac{1}{T_1}\right]}$$

$$= e^{\frac{1.2}{2 \times 8.625 \times 10^{-5}}\left[\frac{1}{300} - \frac{1}{600}\right]} =$$

2m

$\therefore$ $= 1.08 \times 10^5$