Rubric End-Sem

Q.1

$$E_g = h\nu$$

$$\nu = c/\lambda$$

Thus $E_g = \frac{hc}{\lambda}$

$$\lambda = \frac{hc}{E_g} = \frac{1.243}{E_g} (\mu m)$$

a, for Si, $\lambda_c = \frac{1.243}{1.12} = 1.11 \mu m$ (IR region) (1)

b, for GaAs, $\lambda_c = \frac{1.243}{1.42} = 0.875 \mu m$ (near IR region) (1)

c, for GaP, $\lambda_c = \frac{1.243}{2.3} = 0.54 \mu m$ (green light) (1)

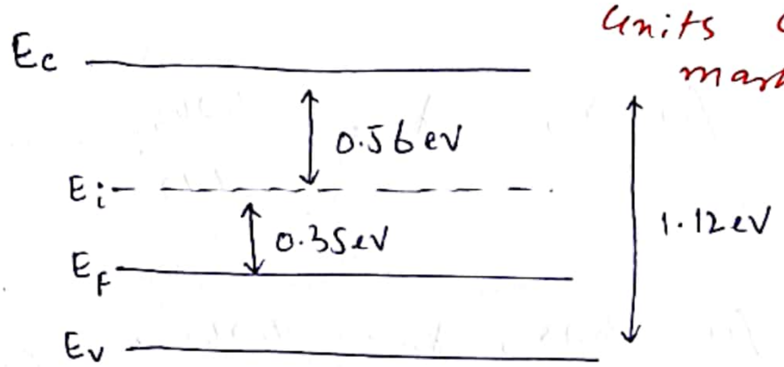
Thus out of these three materials, only GaP has the potential for visible light emitting application. (1)

Q.2 Since boron (trivalent) is a p-type dopant in Si, hence the material will be predominantly p-type & Since $N_A \gg n_i$, therefore $p_0 \simeq N_A = 10^{16}\ cm^{-3}$.

& $$n_0 = n_i^2/p_0 = \frac{(1.5\times10^{10})^2}{10^{16}} = \boxed{2.25\times10^{4}\ cm^{-3}}$$ 2 marks

Also $$E_i - E_F = kT\ln(p_0/n_i) = \boxed{0.35\ eV.}$$ 2 marks

Units carry marks as well.



Q.3 $$\mu = \frac{qt}{m_n^*}$$

$$\mu_1 = \frac{q t_1}{m_n^*}$$

$t_1 = 0.2\ ps$

$m_n^* = 0.5\ m_0$

1

$$\mu_1 = 7.033\times10^{-2}\ m^2/V\text{-}sec = \boxed{703.3\ cm^2/V\text{-}sec}$$

Similarly, with $t_2 = 0.3\,ps$

$$\boxed{\mu_2 = 1054.9\ cm^2/V\text{-}sec}$$ 1

Thus net (total or overall) mobility

$$\mu = (\mu_1^{-1} + \mu_2^{-1})^{-1} = \boxed{422\ cm^2/V\text{-}sec}$$ 1

b, Two scattering events having almost comparable relaxation times reduced the total mobility by almost half of what it would have been if only one such scattering mechanism was present 1

Q.4

a, As $\mu_e > \mu_p$

$\therefore$ $\boxed{D_e > D_p}$ 1 (As per Einstein Relation)

b, The numerical value of the equilibrium hole current density at $x=0$ will be zero. 1

Numerical value of the equilibrium hole diffusion current density at $x = 0$?

$$J_{p/diff} = -qD_p \frac{dp}{dx} = 1.6 \times 10^{-19} (0.026 \times 350) \frac{(4-1)\times 10^{17}}{10^{-4}}$$

where $D_p = \frac{KT}{q}\mu_p$

$$= \boxed{4.37 \times 10^3\ A/cm^2}$$ 0.5

Numerical Value of the equilibrium hole drift Current density at $x = 0$?

Since the equilibrium Current is Zero, the drift Current must be equal & opposite to the diffusion Current

$$J_{p|drift} = \boxed{-4.37 \times 10^{3}\ A/cm^2}$$ 0.5

Numerical value of the equilibrium electric field at $x=0$?

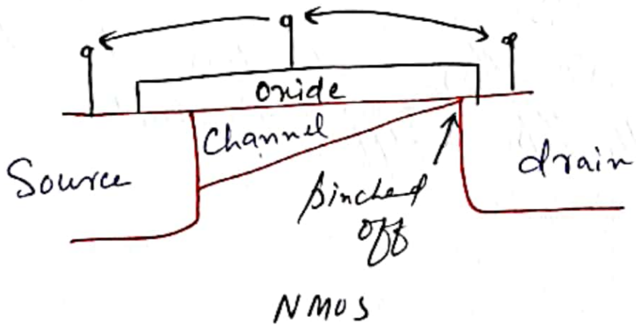
$$J_{p|drift} = p(0) q \mu_p E(0) = -4.37 \times 10^{3}$$

$$E(0) = \frac{4.37 \times 10^{3}}{(2.5 \times 10^{17})(1.6 \times 10^{-19}) 350}$$

$$\boxed{E(0) = -3.12 \times 10^{2}\ V/cm}$$ 1

Q.5 a, When $V_{GD} = V_T$, the Channel reaches threshold at the drain & the density of inversion Charge Vanishes at this point. This is the So-Called "pinch-off" Condition, which Leads to a Saturation of the drain Current Ids

(2)



explanation carries equal weightage

b, NMos is faster because of higher mobility of electrons.

(2)

Q.6 a. MOSFET transconductance is defined as the change in drain current with respect to the corresponding change in gate voltage or

$$\boxed{g_m = \frac{\partial I_D}{\partial V_{GS}}}$$

(1)

It is a key parameter because it determines Switching capability, gain etc.

(1)

called the pinch-off

b, Subthreshold Slope (SS) is the gate voltage swing needed to change I_D by an order of magnitude (mV/decade).

1

To clearly distinguish b/w the ON & OFF states in a logic operation, a few orders of magnitude is required which sets a minimum voltage requirement.

$$SS = (\ln 10)\left(\frac{KT}{q}\right)\left(\frac{C_{ox} + C_D}{C_{ox}}\right)$$

1

Limiting value of SS in MOSFET is $\boxed{60\,mV/decade}$ at room temperature.

Q.7

a,

$$E(x) = \frac{1}{q}\frac{dE_c}{dx} \qquad 1$$

$$\psi(x) = -\frac{E_c(x)}{q} \qquad 1$$

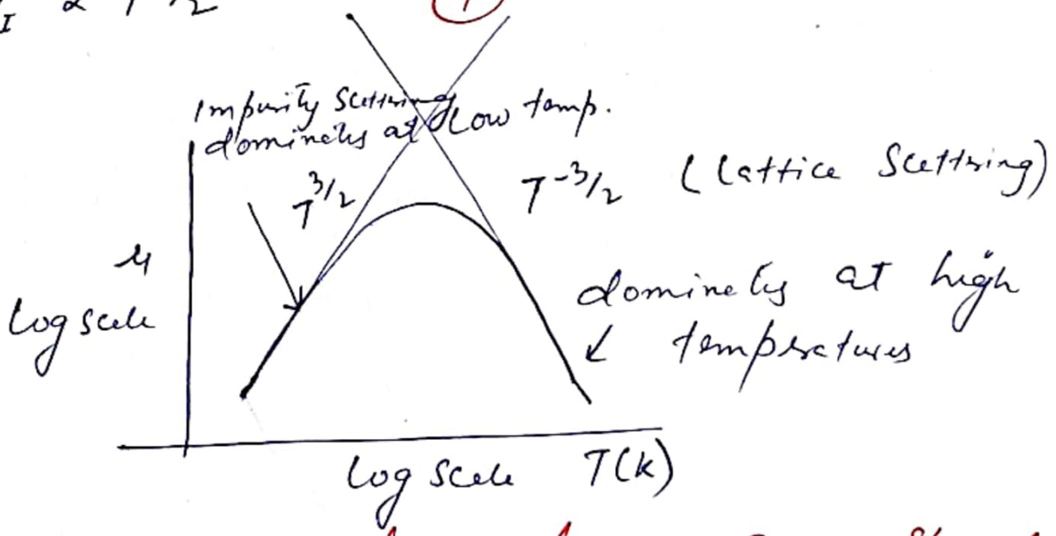
b,

For lattice Scattering

$$\mu_L \propto T^{-3/2} \qquad 1$$

for ionized Scattering

$$\mu_I \propto T^{3/2} \qquad 1$$



Those who have drawn graph should mention the Scale as well.

C, Fermi Level pinning refers to a phenomenon ~~[illegible]~~ where Fermi Level of a material remains fixed or 'pinned' at a particular energy Level, even when the material is brought into Contact with different material or interface.
The pinning occurs due to the presence of Localized States, defects, or impurities near the interface, which trap or hold the fermi Level at a Specific energy Level. 1

~~The~~ Due to Fermi Level pinning the threshold Voltage increases. 1