EC233
ELECTRONIC DEVICES 1

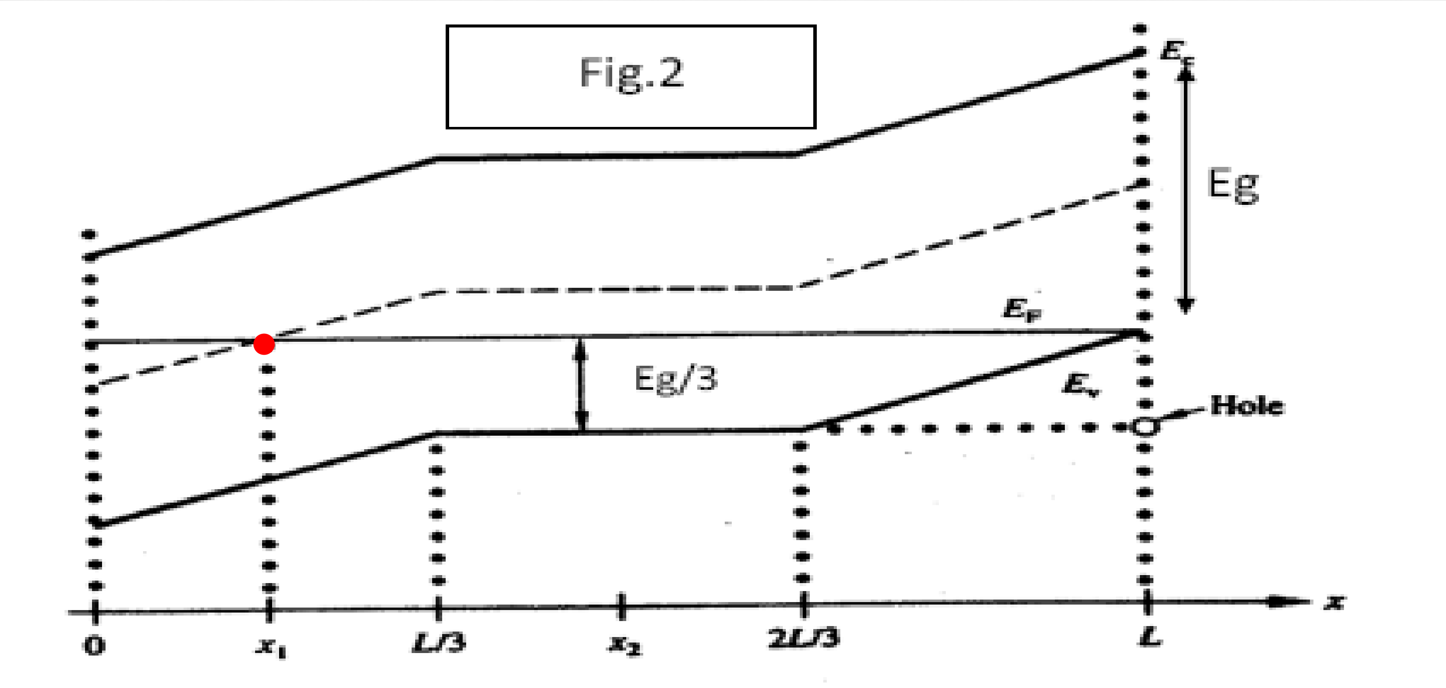
SHEET 5 SOLUTIONS

THERMAL EQUILIBRIUM

At thermal equilibrium:

No external effects
No change with time
No electric current
No change in the Fermi level with space (will be proved hereinafter)

PROBLEM 2

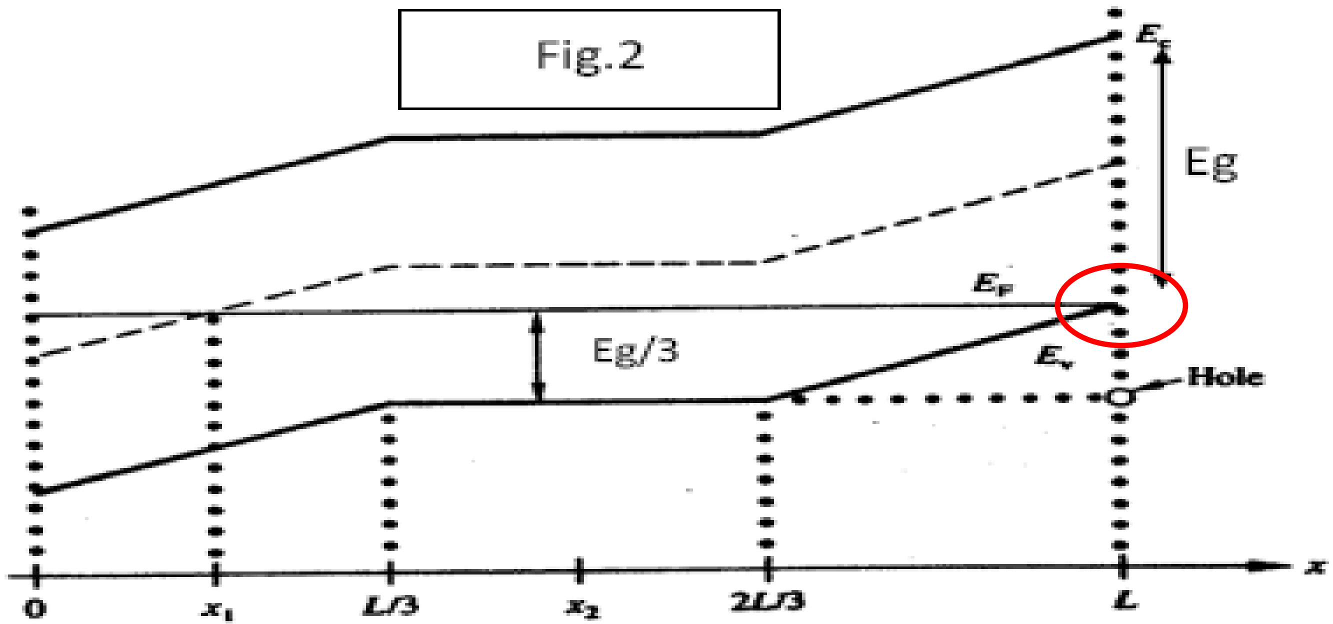


1. The semiconductor type at point x_1 is

(a) Extrinsic (b) Intrinsic (c) Degenerate

PROBLEM 2

Fig.2



2. The semiconductor is degenerate

(a) Near x = 0 (b) Nowhere (c) L/3< x < 2 L/3 (d) Near x = L

3. Do equilibrium conditions prevail? Justify.

(a) Yes (b) No (c) Can't be determined

From fig.2, E_f is invariant with Position.

PROBLEM 2

4. Draw the electric field distribution inside the semiconductor

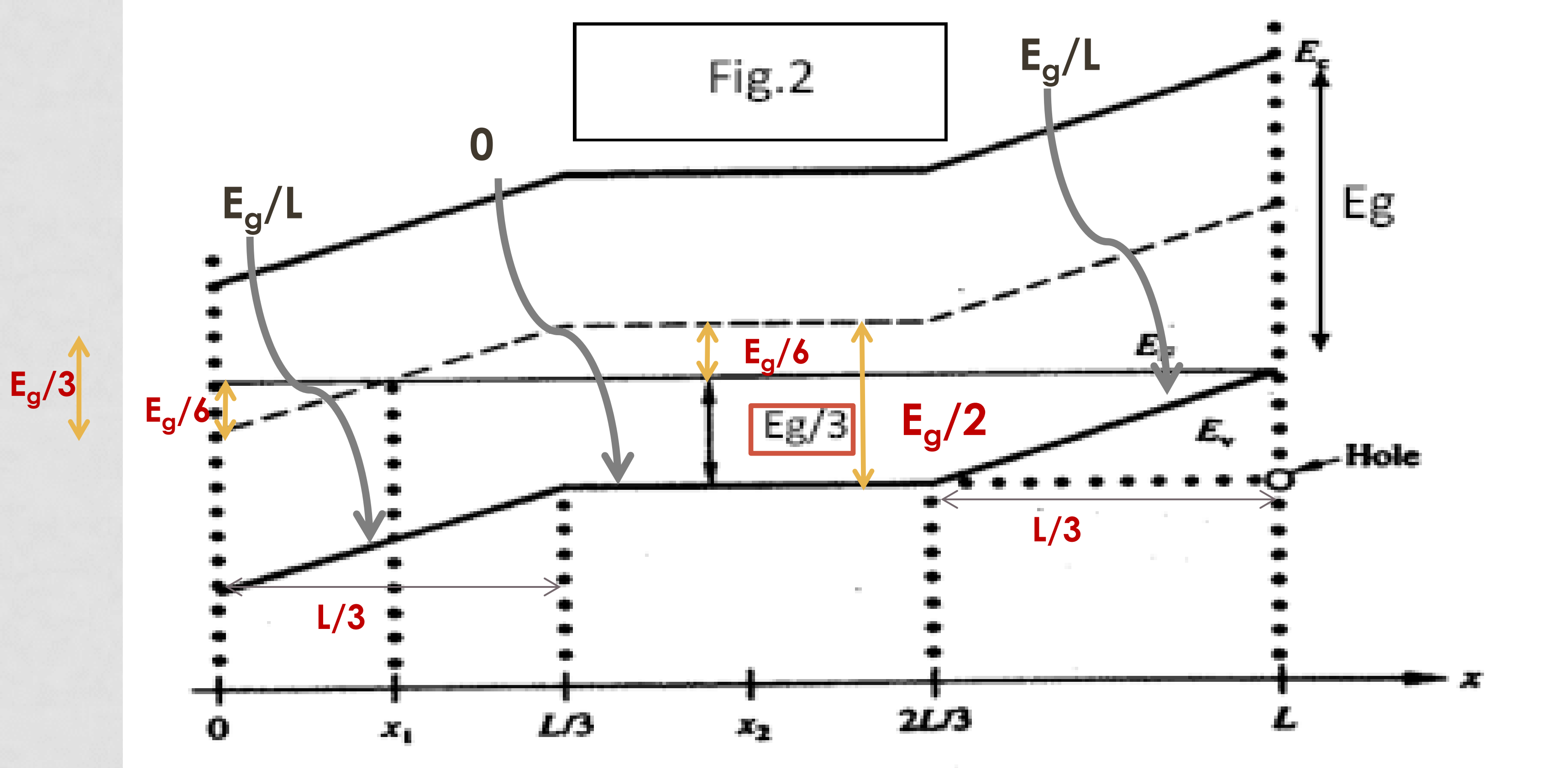
From Lec .5: $$\mathcal{E} = -\frac{dV}{dx} = \frac{1}{q}\frac{dE_c}{dx} = \frac{1}{q}\frac{dE_v}{dx} = \frac{1}{q}\frac{dE_i}{dx}$$

$$\boldsymbol{\varepsilon} = \frac{\mathbf{1}}{\boldsymbol{q}} \times \boldsymbol{Slope}(\boldsymbol{E}_{\boldsymbol{c}/\boldsymbol{v}/\boldsymbol{i}})$$

Get the slopes !!

PROBLEM 2

4. Draw the electric field distribution inside the semiconductor



PROBLEM 2

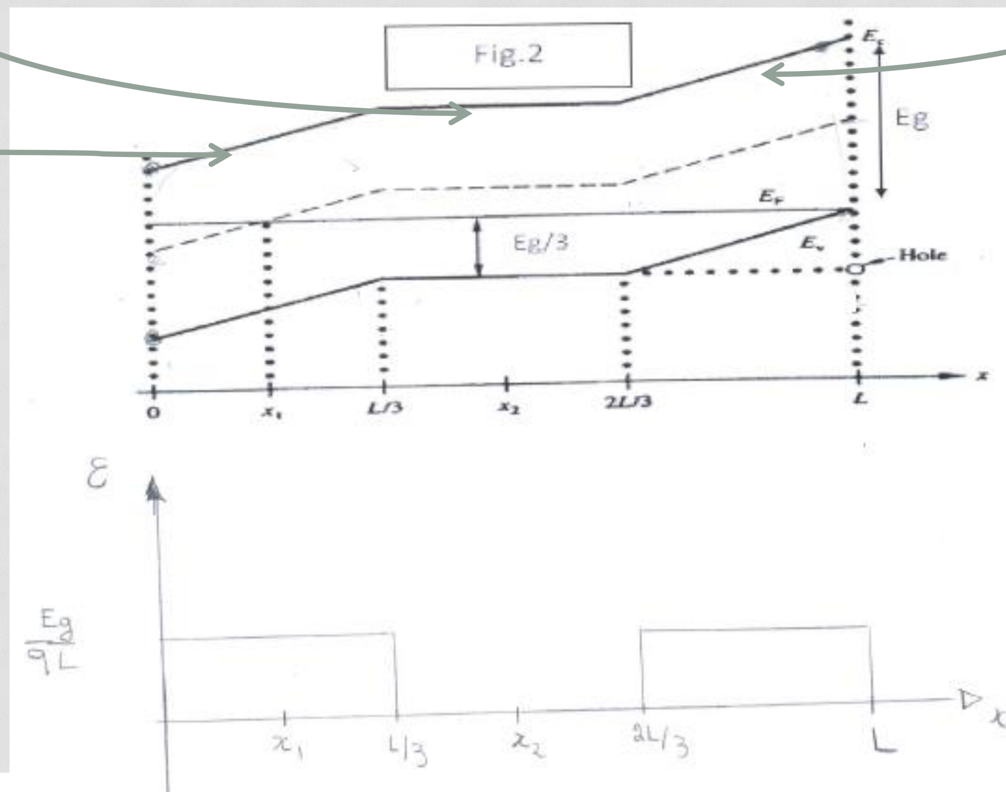
4. Draw the electric field distribution inside the semiconductor

$$\varepsilon = \frac{1}{q} \times Slope(E_{c/v/i})$$

0

E_g/L

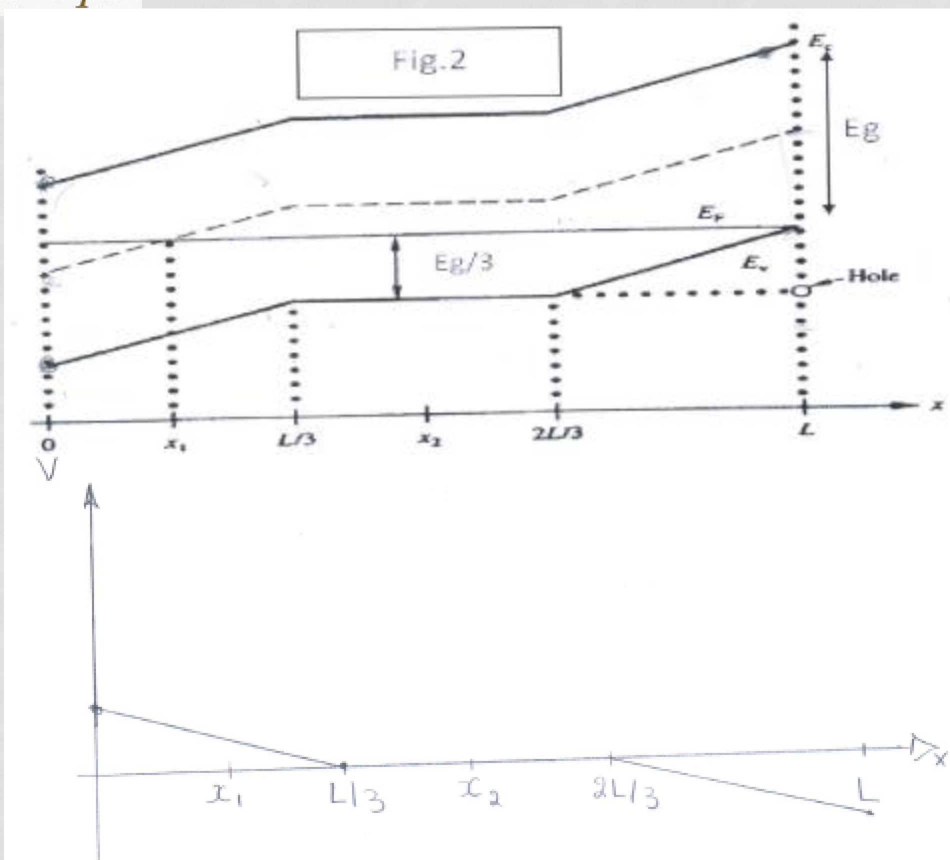
E_g/L



PROBLEM 2

5. Draw the electrostatic potential inside the semiconductor

From Lec .5: $E = -qV$



PROBLEM 2

6. The hole drift current density (Jpdrift) flowing at x = x_1 is:

(a) Zero (b) μ_p n_i E_g/L (c) 3μ_p n_i E_g/L (d) q$\mu_p$$N_D$ (kT/q)/L

$$J_{p,drift} = qp\mu_p\varepsilon = qp\mu_p\frac{E_g}{qL}$$

Since $n=p=n_i$

$$J_{p,drift}=qn_i\mu_p\frac{E_g}{qL}$$

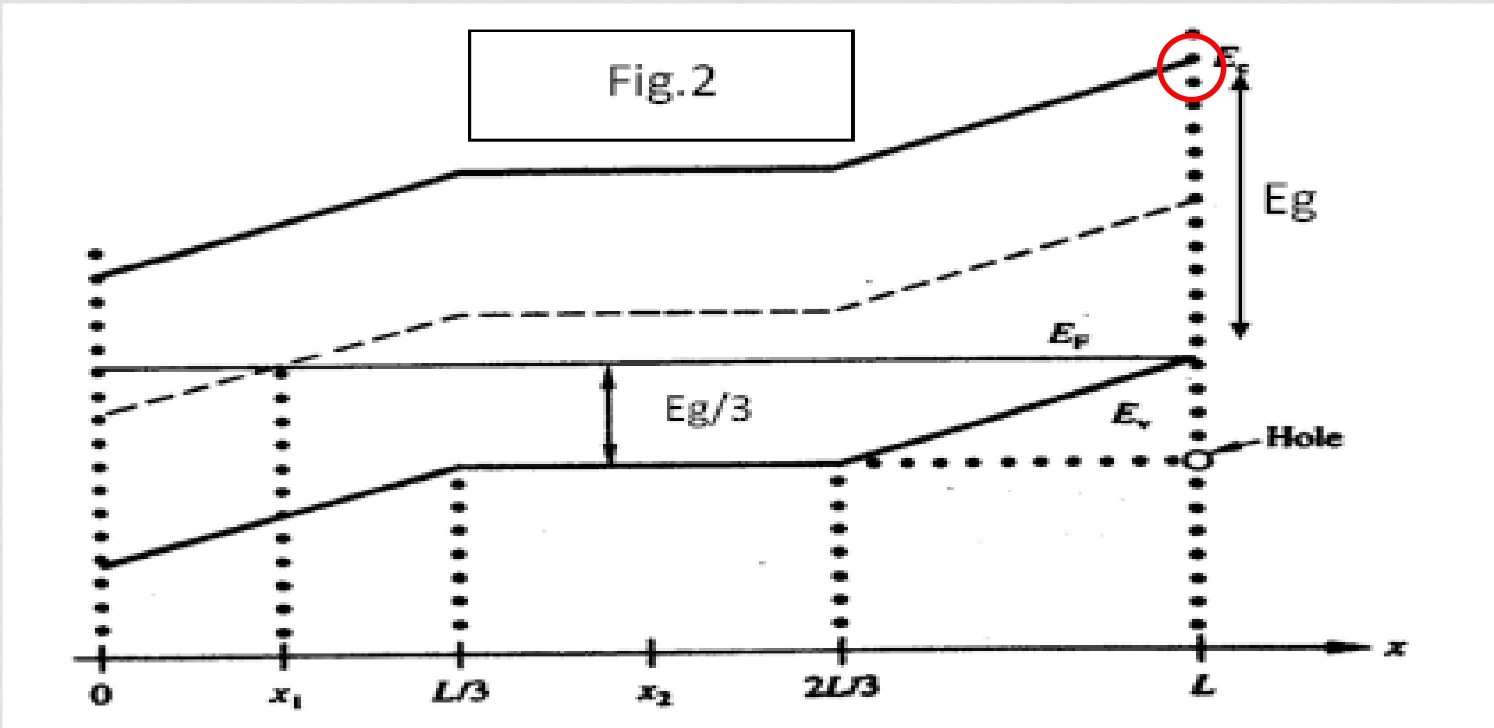
7. The electron current density (J_n) flowing at x = x_1 is:

(a) Zero (b) μ_n n_i E_g/L (c) 3μ_n n_i E_g/L (d) D_n [n(x_2) - n(0)]/L

$$J = J_p + J_n = 0\ (At\ Thermal\ Equilibrium)$$

$$J_n = J_{drift} + J_{diffusion} = 0$$

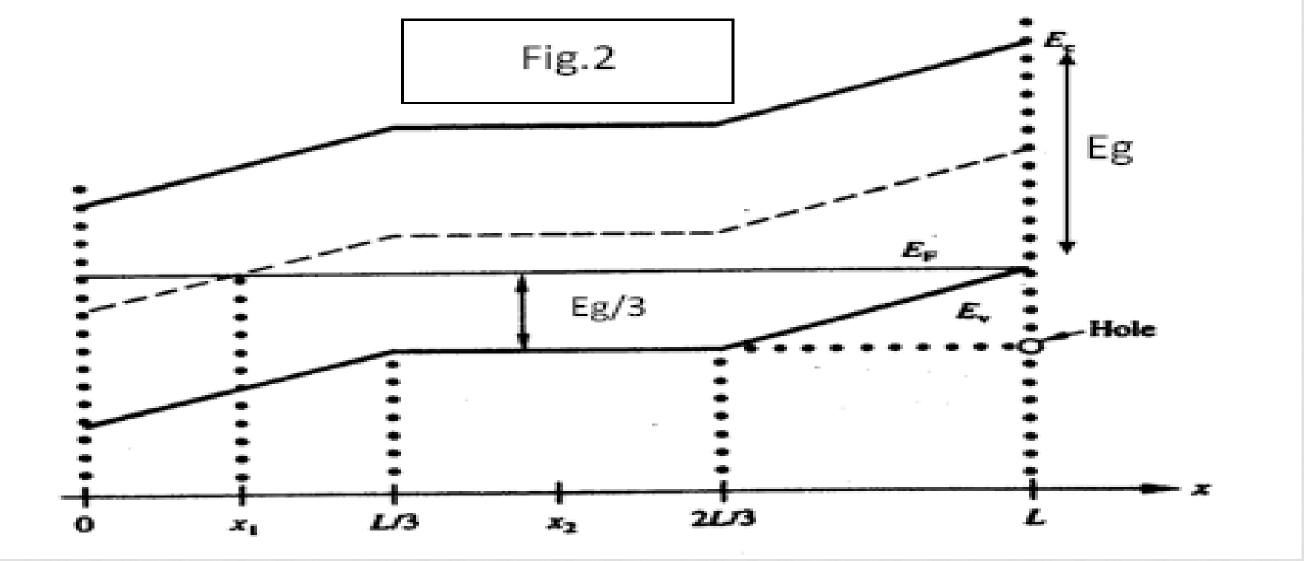
PROBLEM 2



8. The position of maximum potential energy for electrons is

(a) Near $x = 0$ (b) at $x= L/3$ (c) at $x= x_1$ (d) at $x = L$

PROBLEM 2



9. At $x = x_2$, p = ? (Hint: use n_i, E_g, k, T=300 °K)

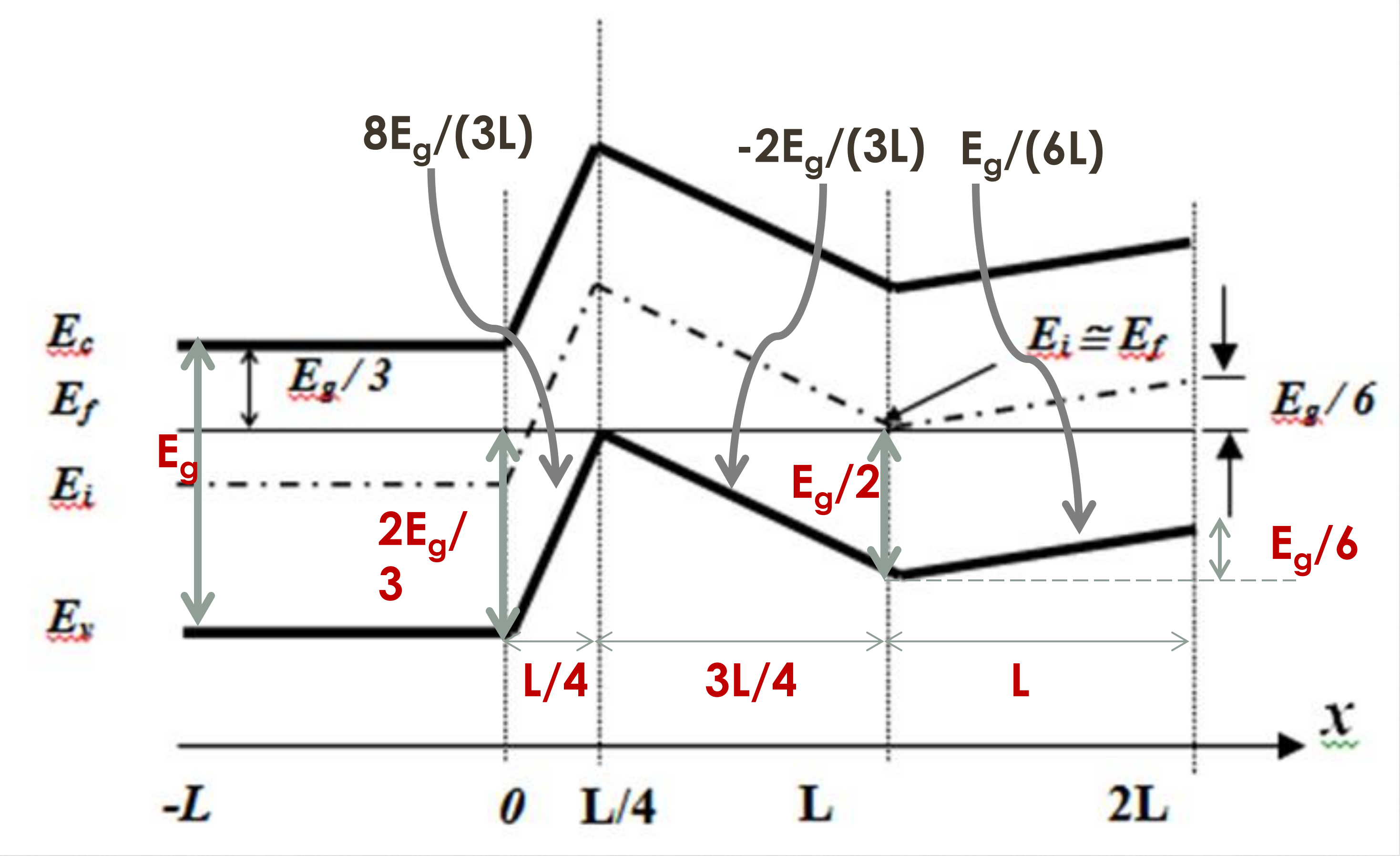
(a) $7.63 \times 10^6/cm^3$ (b) $1.31 \times 10^{13}/cm^3$ (c) $10^{10}/cm^3$ (d) $1.72 \times 10^{16}/cm^3$

At x=x2, $E_f<E_i$ hence p-type material

Recall $p = n_i \exp[(E_i - E_F)/kT]$

PROBLEM 3

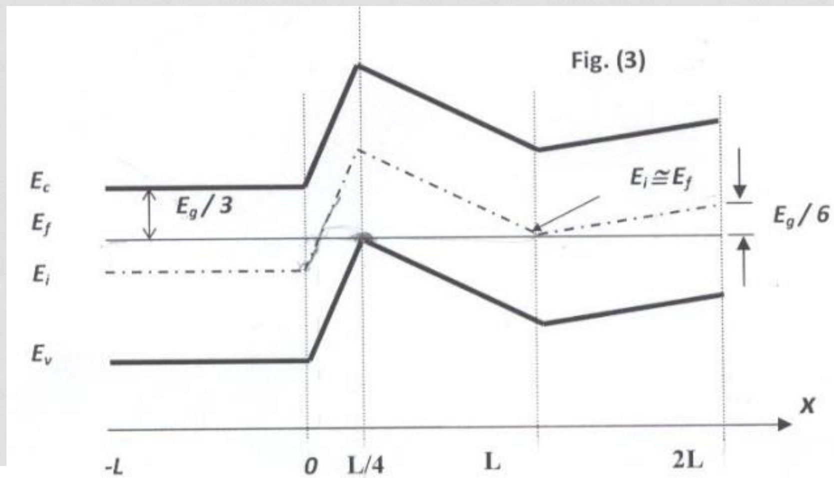
2. Plot the Electric Field inside the semiconductor as a function of x

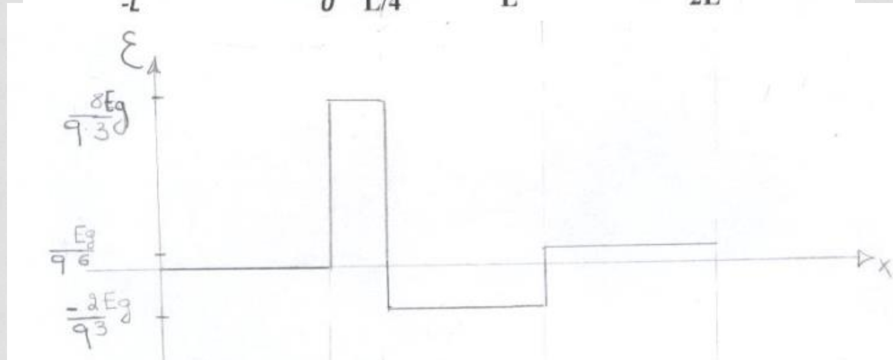


PROBLEM 3

2. Plot the Electric Field inside the semiconductor as a function of x

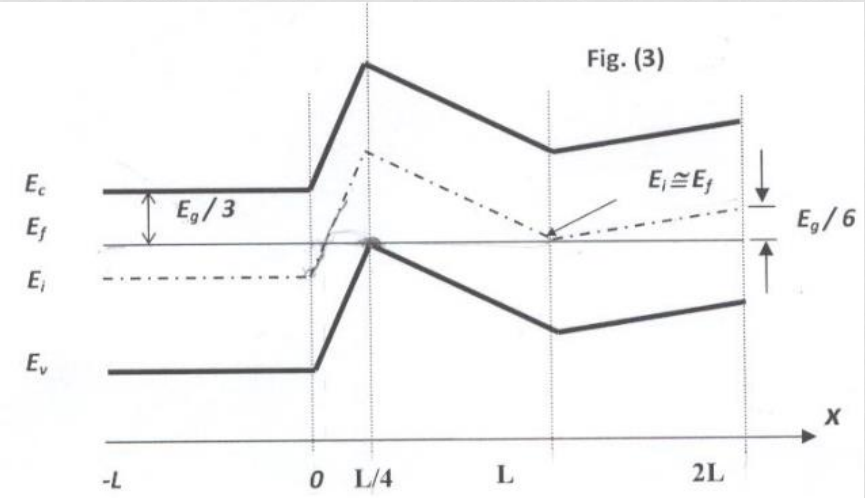
$$\boldsymbol{\varepsilon} = \frac{\mathbf{1}}{\boldsymbol{q}} \times \boldsymbol{Slope}(\boldsymbol{E}_{\boldsymbol{c/v/i}})$$

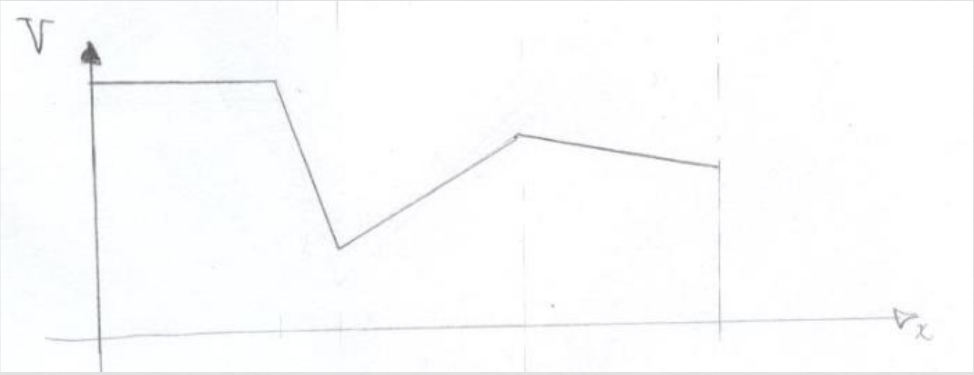




PROBLEM 3

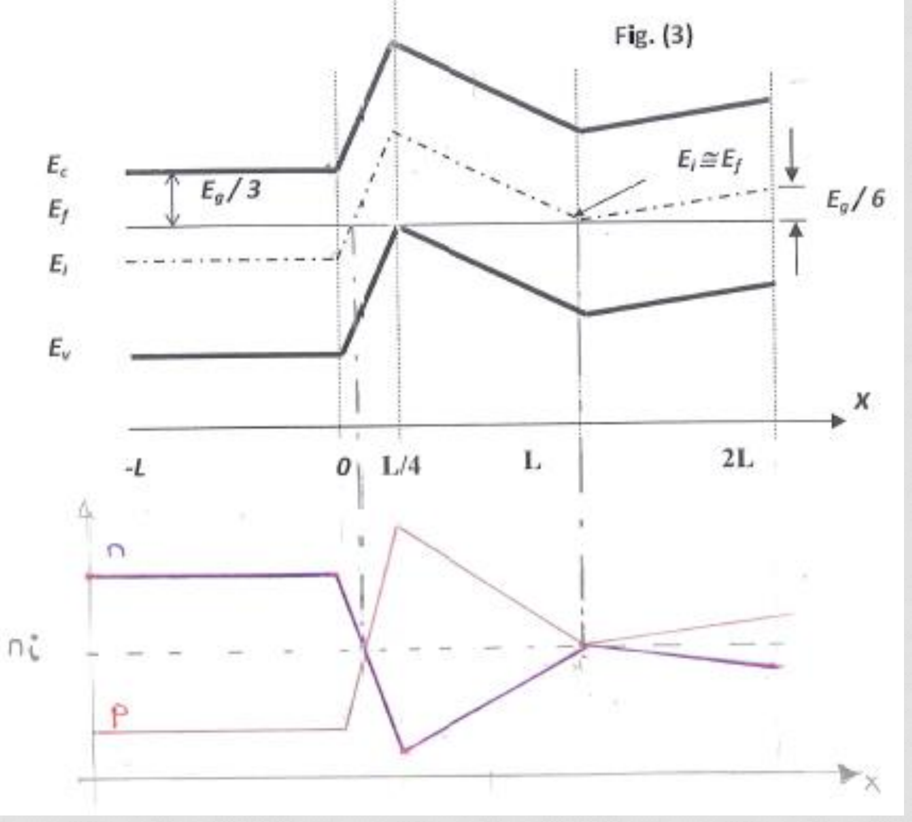
3. Sketch the electrostatic potential (V) inside the semiconductor as a function of x.





PROBLEM 3

1. Roughly sketch n and p versus x.



- Note: Rough Sketch of n and p over semi log (log-lin) scale.

PROBLEM 3

4. What is the direction of the electron diffusion current at x = L/2

Electron Diffusion is in the negative x direction.

Hence, Electron Diffusion **Current** is in Positive Current.

Note: Current Direction is opposite to electron flow.

5. Is the sample connected to external voltage source? Explain how you arrived at your answer.

No, E_f is invariant with position.