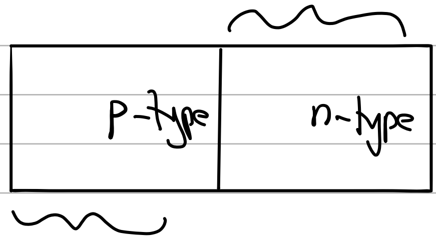
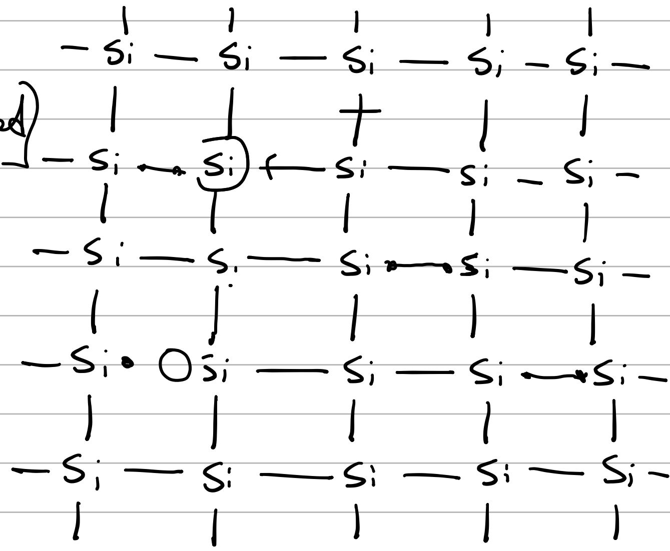
PN Junction Diode :



$Si(14) \rightarrow 1s^2\, 2s^2\, 2p^6\, \underbrace{3s^2\, 3p^2}_{\{4e^- \text{ needed}\}}$

intrinsic semiconductor :



$\boxed{2, 8, 18}$

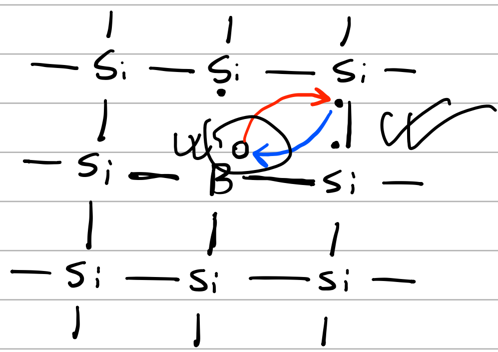
→ : hole movement

→ : electron movement

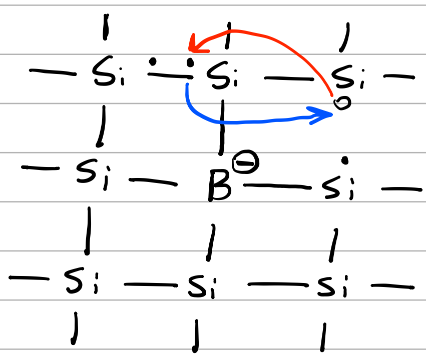
p-type : $B(5) \rightarrow 1s^2\, 2s^2\, \underbrace{2p^1}_{3e^-}$

→ extrinsically doped semiconductor with acceptor impurities

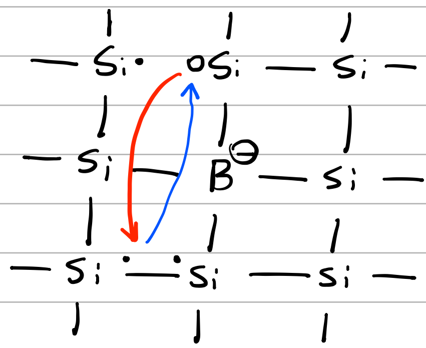
①



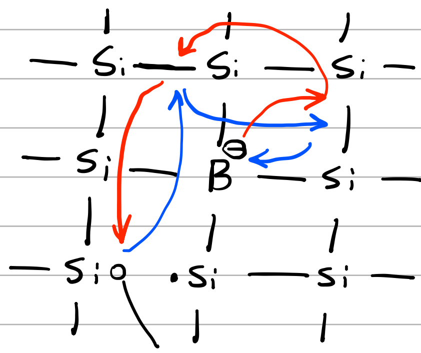
②



③



④



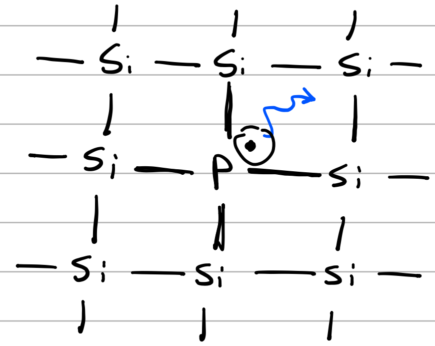
* hole movement reverse of electron movement.
* impurity charge uncovered, though irrelevant to current flow, atom immobile.

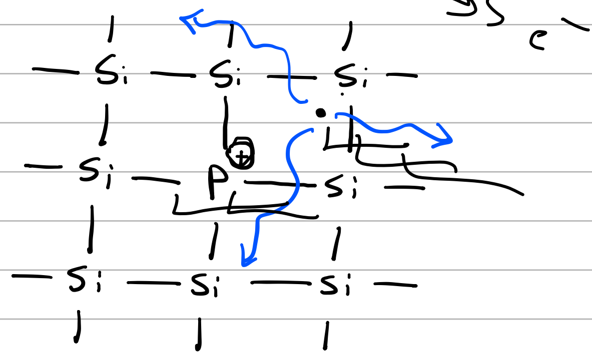
n-type:

→ extrinsically doped semiconductor with donor impurities

$P(15)$

$= 1s^2\, 2s^2\, 2p^6\, \underbrace{3s^2\, 3p^3}_{5e^-}$

① 

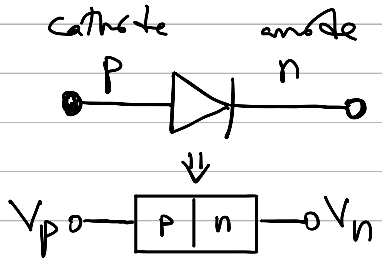
② 

→ extra electron freely moves, leaves uncovered positive charge in impurity atom.

$\boxed{n \times p = n_i^2} \rightarrow k\ \text{const.}$

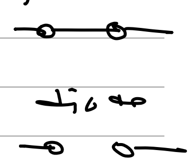
p-type:	n-type:
* majority carrier: holes (↑↑↑)	majority carrier: electrons (↑↑↑)
* minority carrier: electrons (↓↓↓)	minority carrier: holes (↓↓↓)

Circuit Symbol:



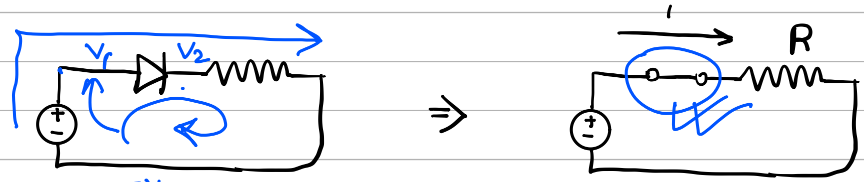
$V_p > V_n \rightarrow$ diode

$V_p < V_n \rightarrow$ diode

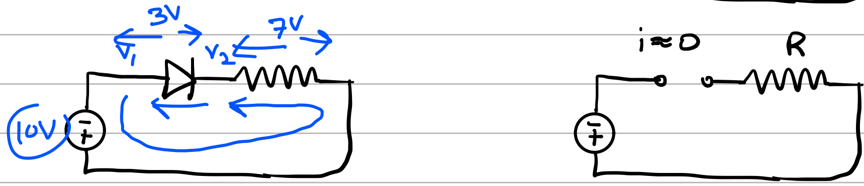


Most basic 'nonlinear' element!

+ve voltage:

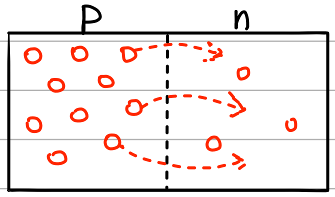


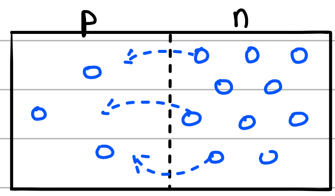
-ve voltage:



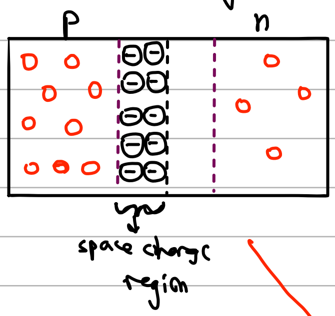
Acts like an electronic switch!

holes	electrons
→ diffusion of holes	→ diffusion of electrons

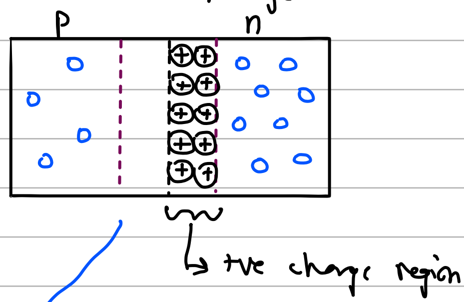


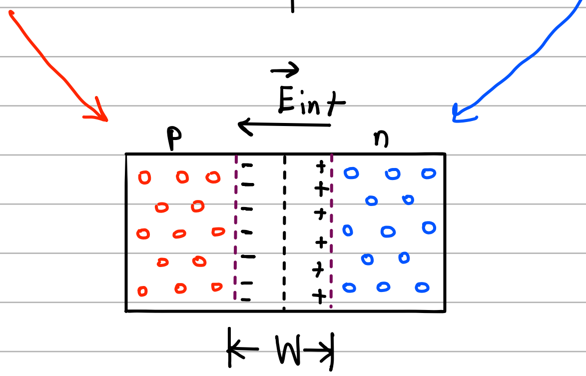


→ uncovered −ve charge of acceptors

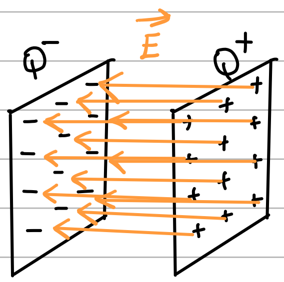


→ uncovered +ve charge of donors





* Almost like a parallel plate capacitor



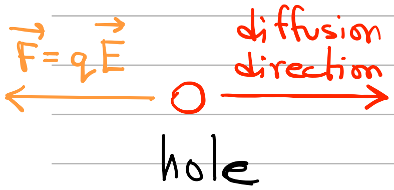
→ uniform electric field $\vec{E}$ between plates.

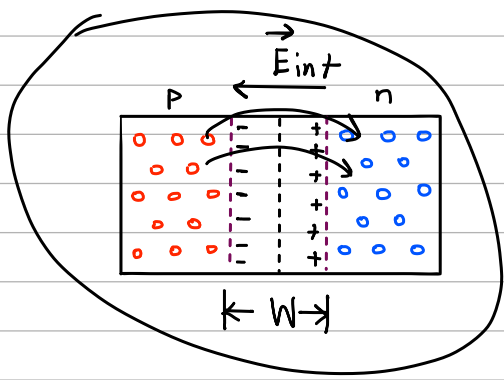
→ $\vec{E} = 0$ outside.

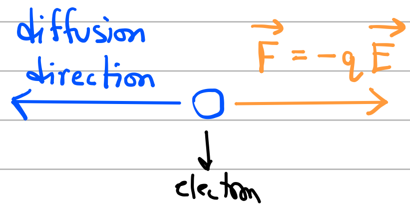
→ Space charge gradually increases with diffusion of holes and electrons.

→ At equilibrium, electrostatic force on carrier negates diffusion.

diffusing hole:

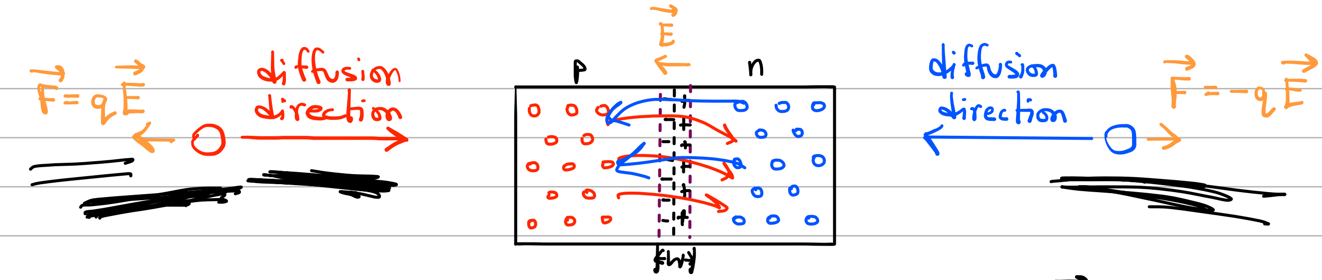






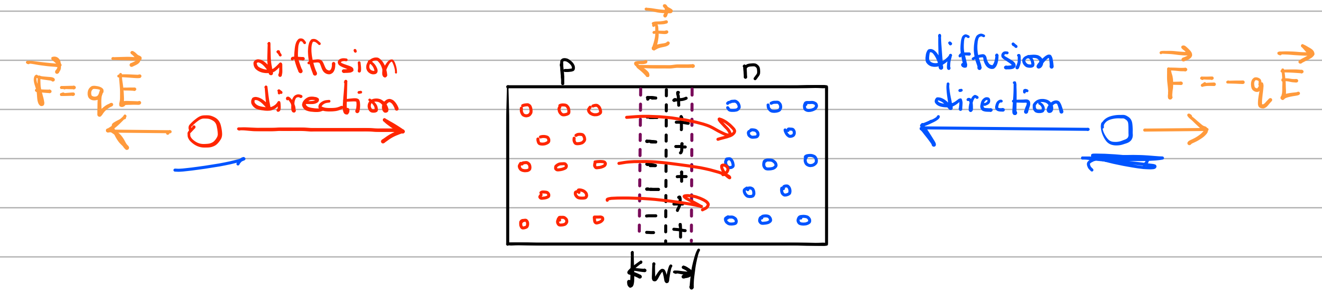
$q = 1.6 \times 10^{-19}$ C

1



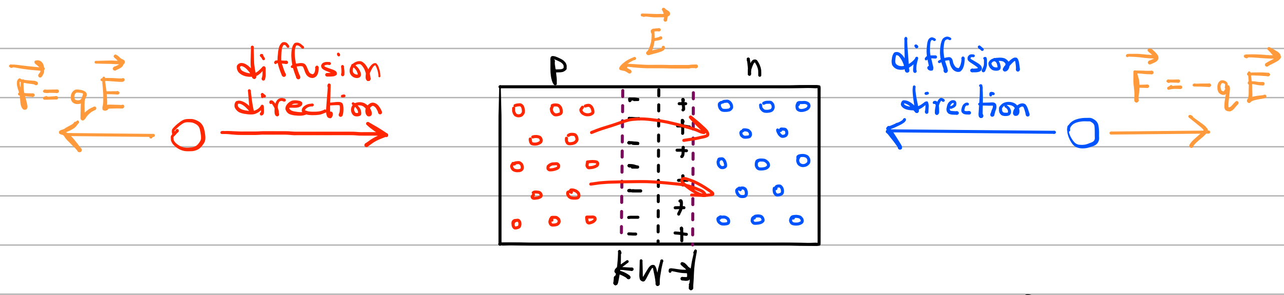
→ particles can diffuse. More charge uncovered. $\vec{E}$ increases.

2



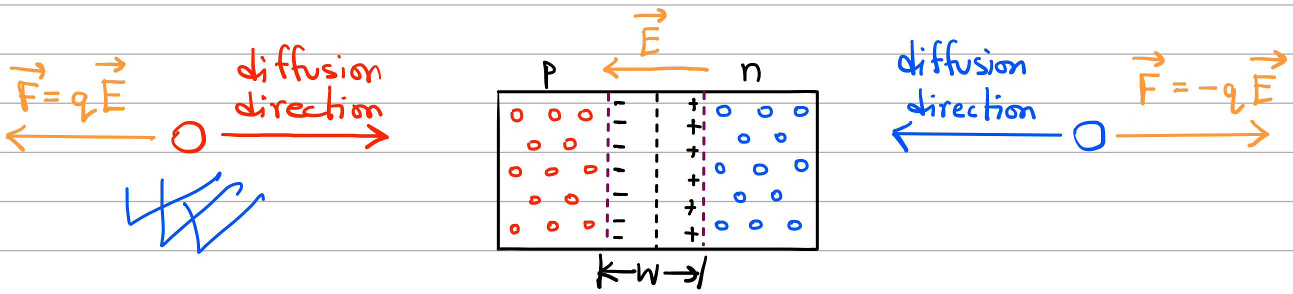
→ particles can diffuse. More charge uncovered. $\vec{E}$ increases.

3



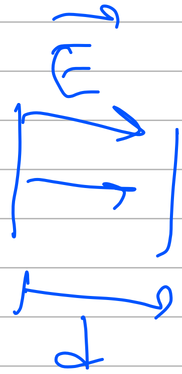
→ particles can diffuse. More charge uncovered. $\vec{E}$ increases.

4

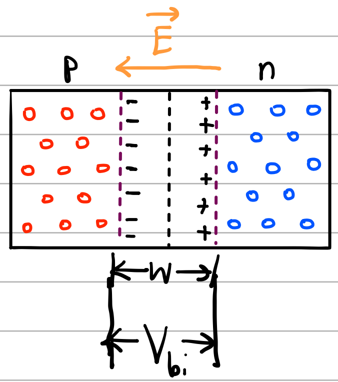


→ particles can no longer diffuse. Equilibrium reached.

Thus, at equilibrium:

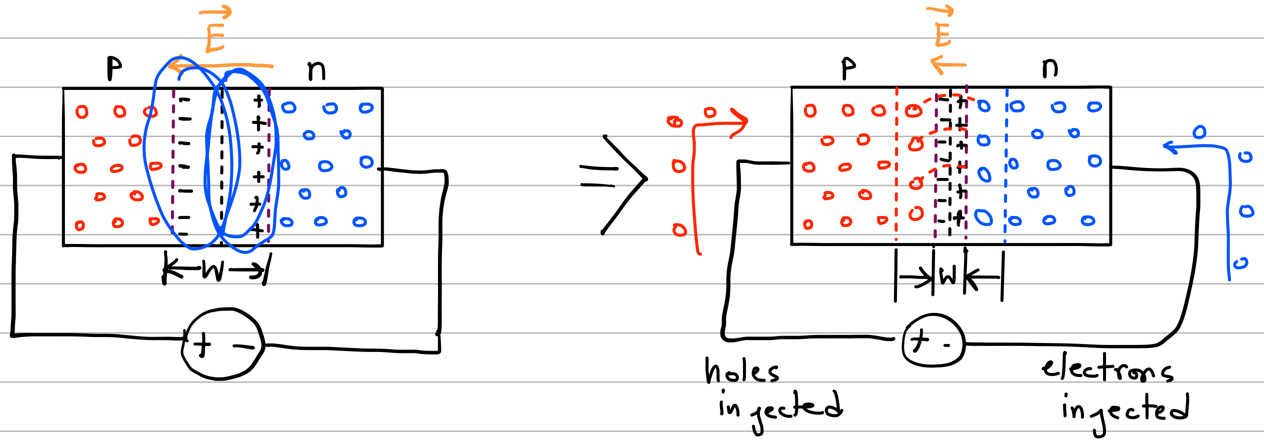


$$\boxed{V = Ed}$$



$$\boxed{V_{bi} = W \times |\vec{E}|}$$

With forward bias voltage:



→ holes injected in p side. electrons injected in n side

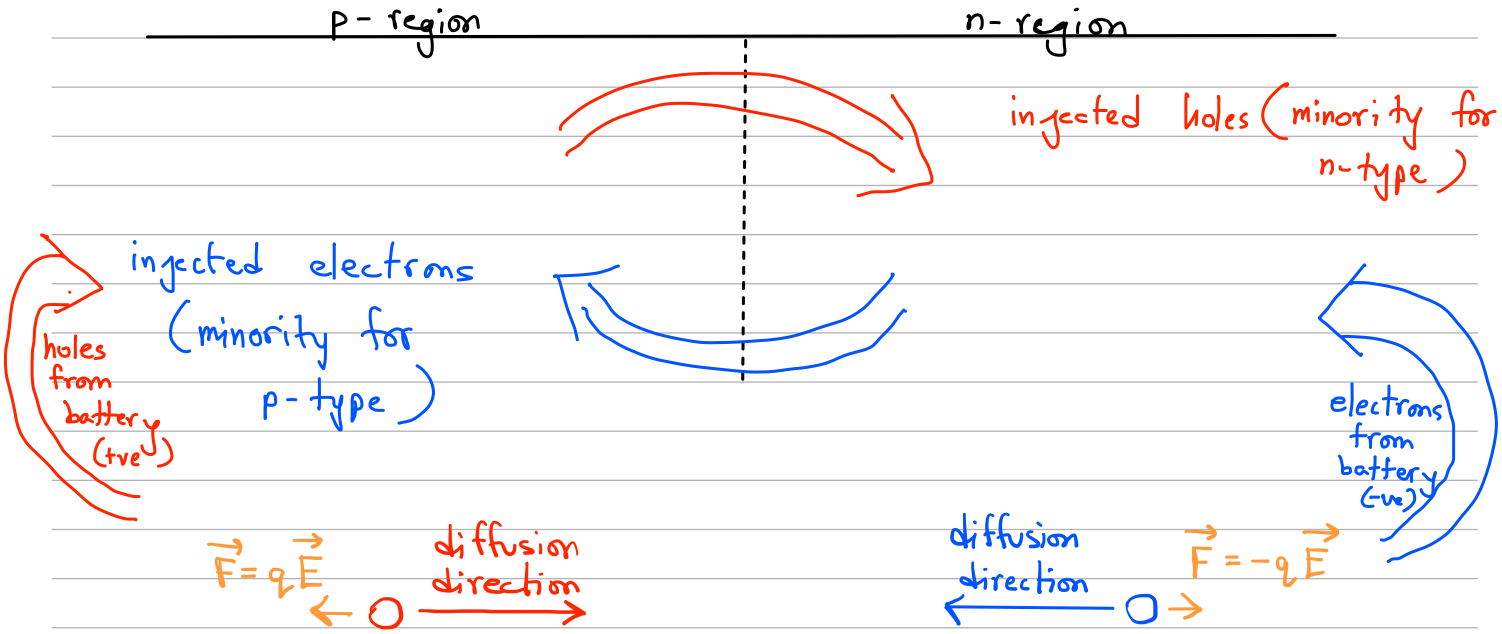
→ some uncovered charges neutral:

p-type: injected holes help return holes to donor atoms. removes −ve charge.

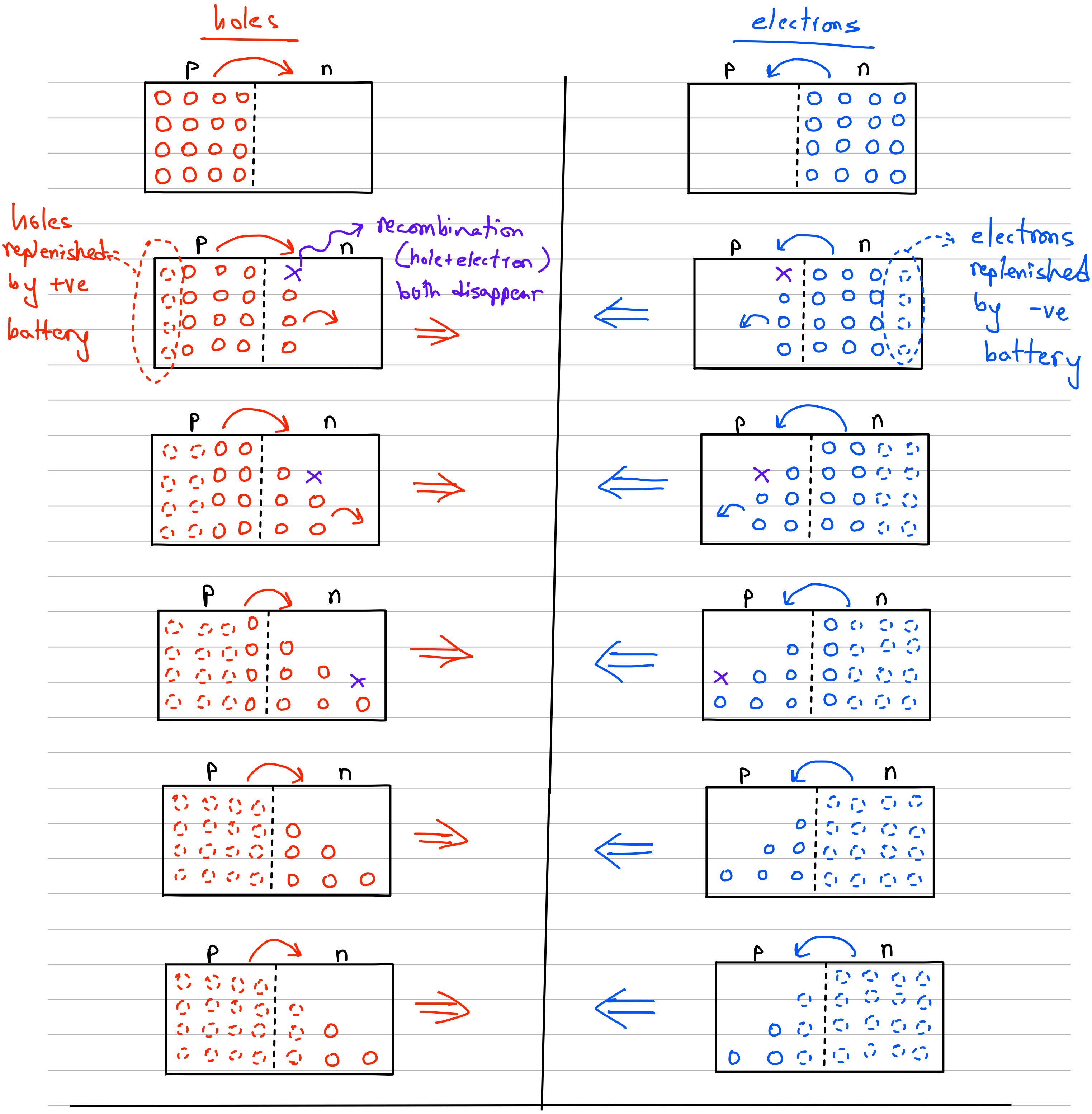
n-type: injected electrons help return electrons to donor atoms. removes +ve charge.

→ Thus, depletion region 'squeezed'. Equilibrium disturbed.

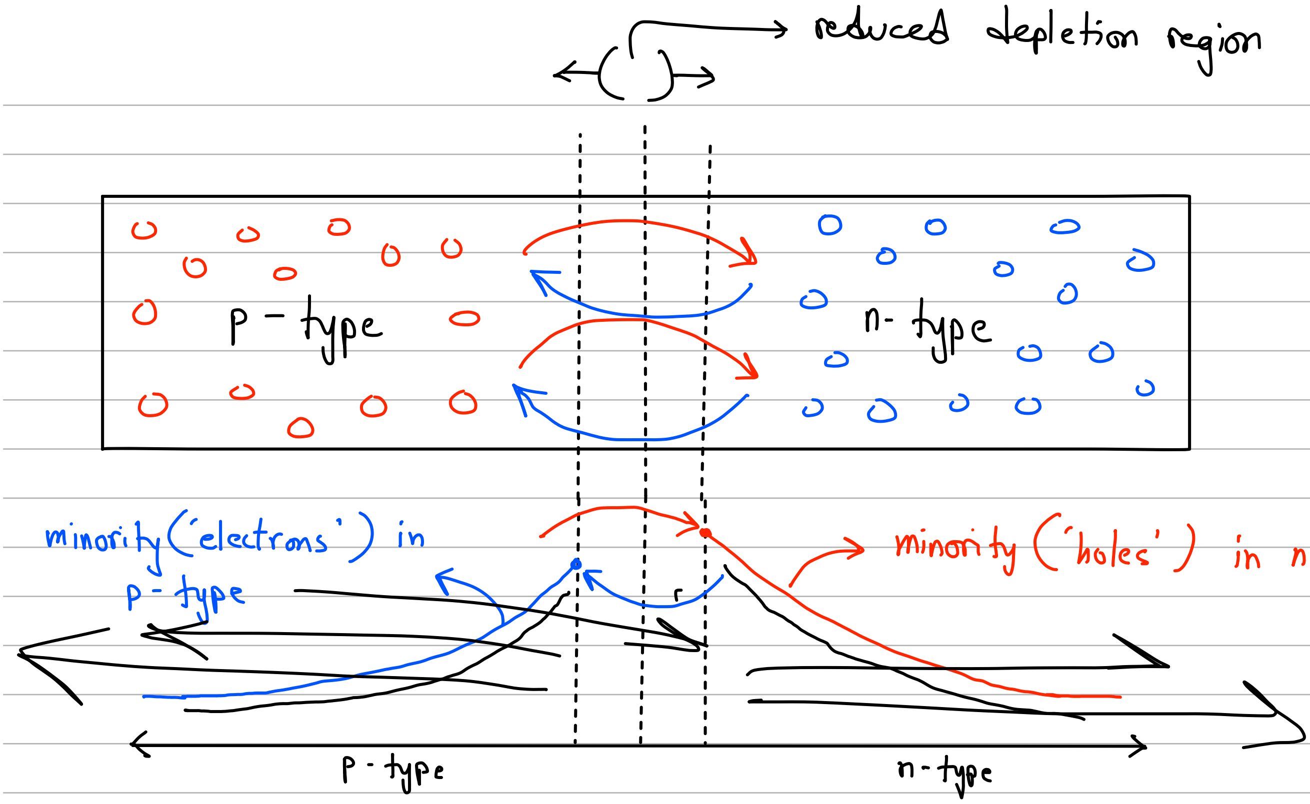
Huge injection of minority carriers:



→ injected holes and electrons 'replenished' by battery



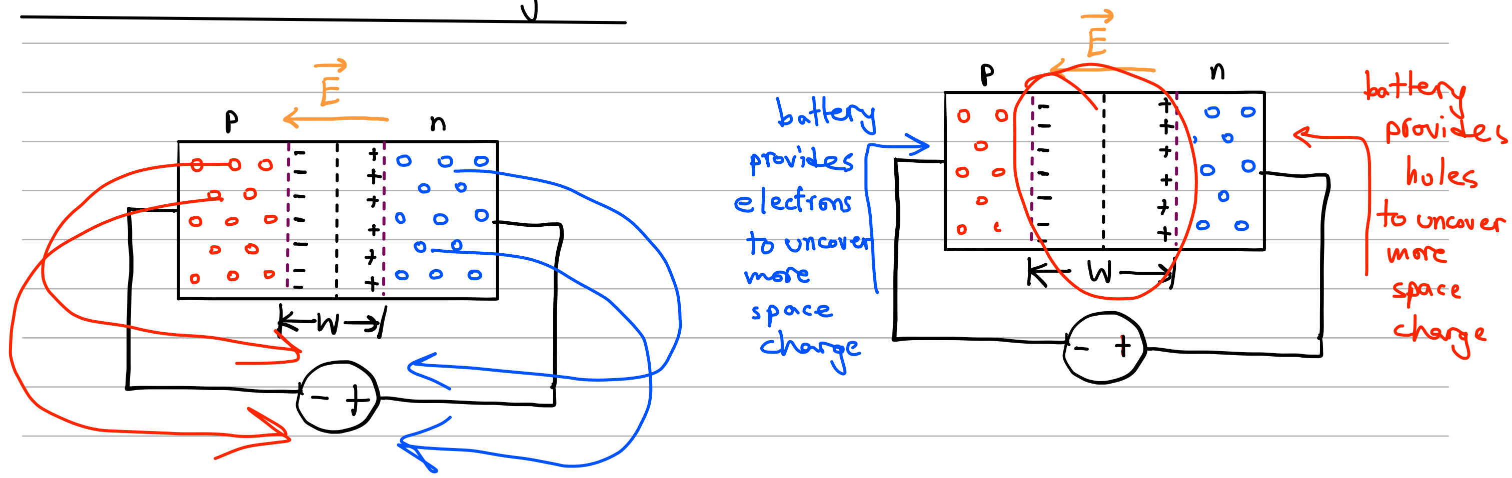
→ minority carrier conc. largest near interface. Drops the farther it goes from interface. This concentration distribution does not change with time as battery replenishes holes and electrons.



→ The varying concentration of minority carriers in respective regions cause them to be in continuous movement as seen above.

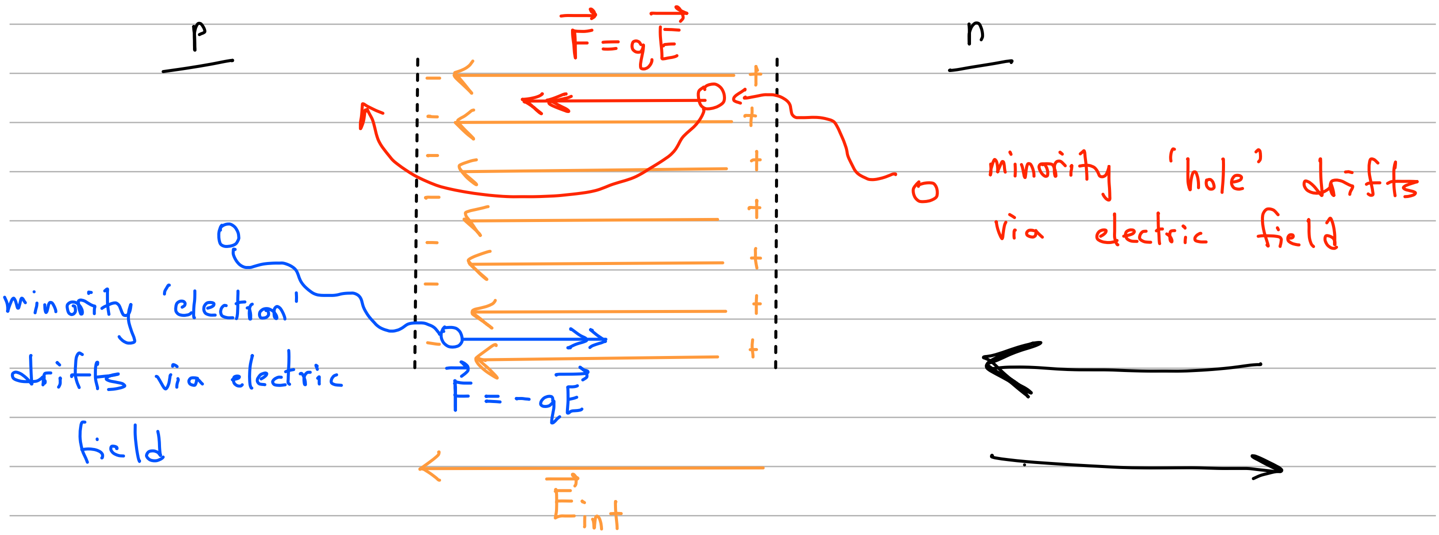
→ So, diode with +ve voltage carries this huge diffusion current, limited only by the external circuit.

Diode Reverse Voltage :



→ Impossible for remotely any current to flow. Nearly 'cut off'.

→ However, minority carriers may come near space charge region and 'drift' to other region, causing reverse drift current.



Thus, diode:

1. at forward bias, conducts.
2. at reverse bias, cuts off current flow through it.

100,000 Si atom → 1 Boron atom

1 hole

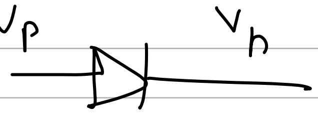
10^{23} Si atom → $\frac{10^{23}}{100,000} = \frac{10^{23}}{10^5}$

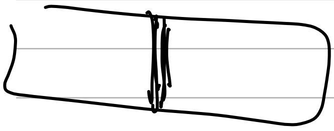
$= 10^{17}$ Boron atom

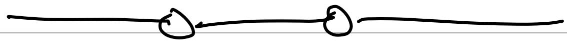
$= 10^{17}$ hole

10^{17} electrons for n-type

$V_p > V_n \longrightarrow$ forward biased



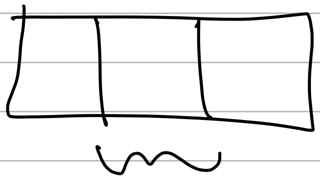




acts as 'short'

$V_n > V_p$

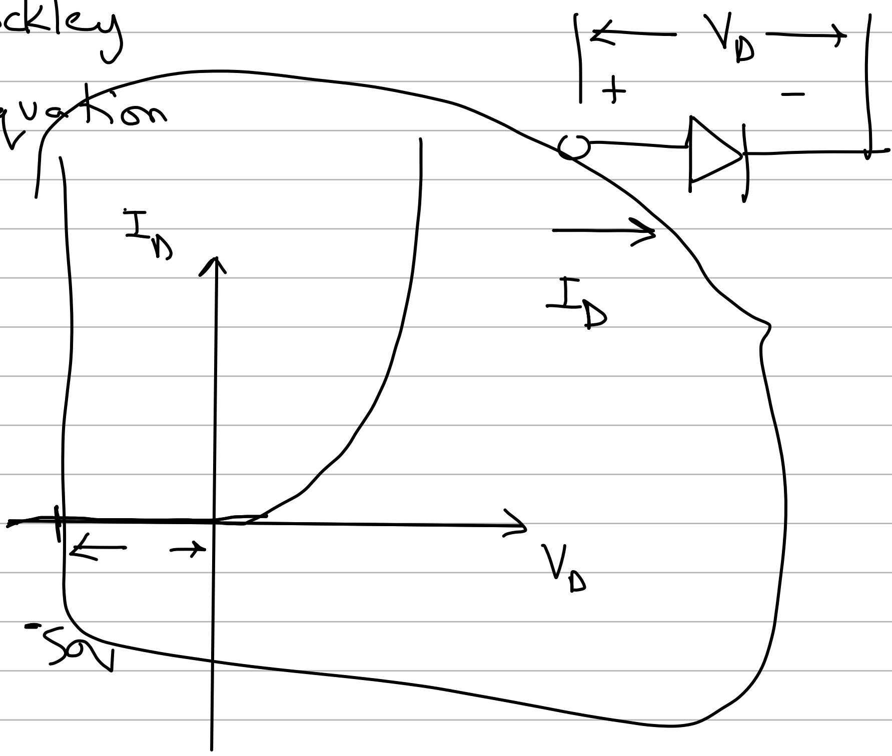
acts as 'open'



big depletion region

$$\boxed{I_D = I_S\left(e^{\frac{V_D}{nV_T}} - 1\right)}$$

Schockley equation

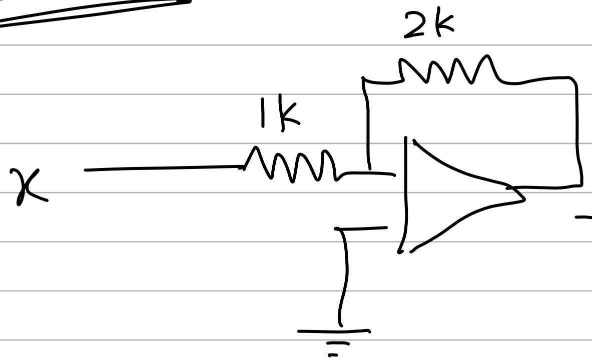


$\boxed{n \approx 1}$

$\boxed{V_T \approx 25.9\,mV}$

$f = -2x$

$$\frac{R_f}{R_i} = 2$$



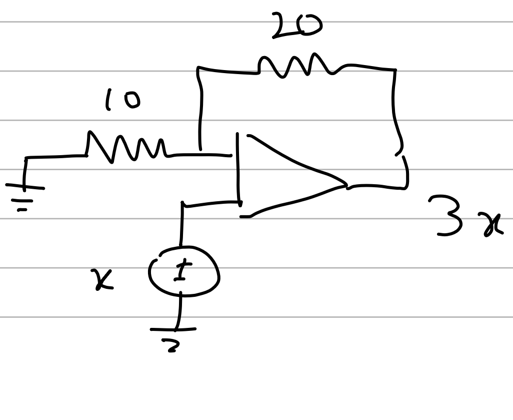
$$-\left(\frac{R_f}{R_i}\right)x$$

$f = -5x$

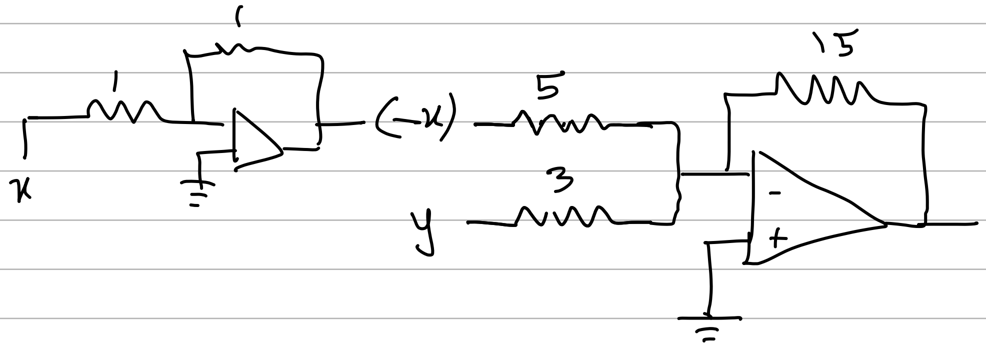
$$\left(1 + \frac{R_f}{R_i}\right)x$$

$f = 3x = (1+2)x$

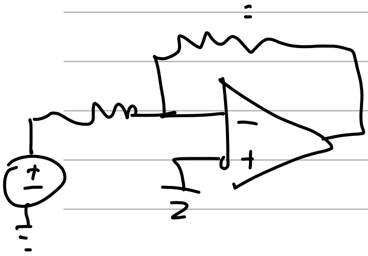
$$= \left(1 + \frac{R_f}{R_i}\right)x$$



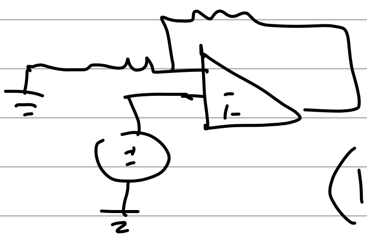
$$f = 3x - 5y = (3x) + (-5y) = -\{ -3x + 5y \}$$



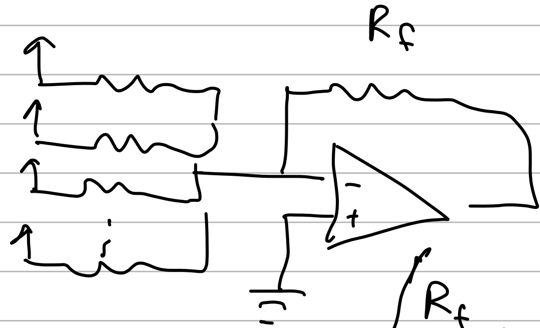
$$-\left\{ \frac{15}{5}(-x) + \frac{15}{3}y \right\} = -\{ -3x + 5y \}$$



$$\left(-\frac{R_f}{R_i}\right) v_i$$

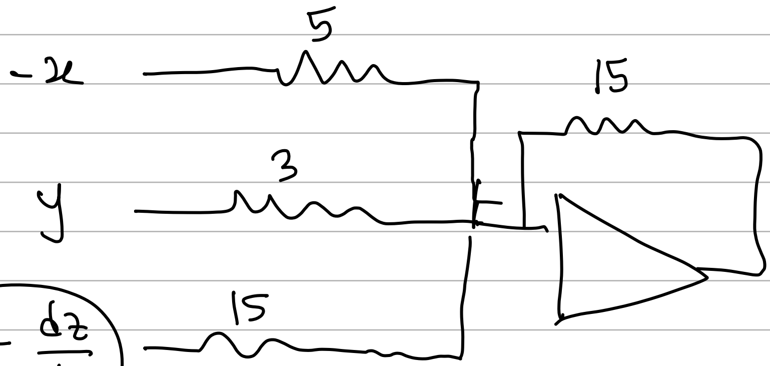


$$\left(1 + \frac{R_f}{R_i}\right) v_i$$

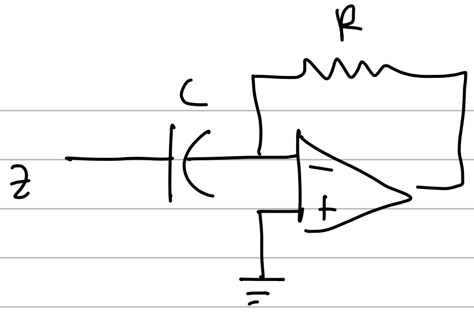


$$-\left(\frac{R_f}{R_{i1}} v_1 + \frac{R_f}{R_{i2}} v_2 + \cdots \frac{R_f}{R_{in}} v_n \right)$$

$$f = 3x - 5y + \frac{dz}{dt} = -\left(-3x + 5y - \frac{dz}{dt} \right)$$



$$-\frac{dz}{dt}$$



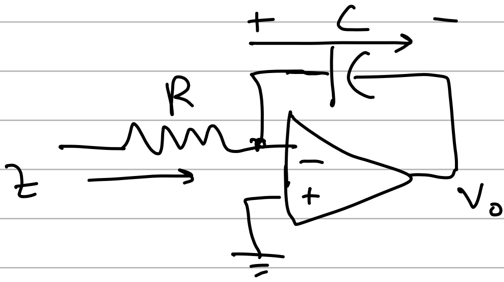
$-RC \frac{dz}{dt}$

$C \rightarrow 1\ mF$

$R \rightarrow 1\ k\Omega$

$RC = 10^{3} \times 10^{-3}$

$= 1$



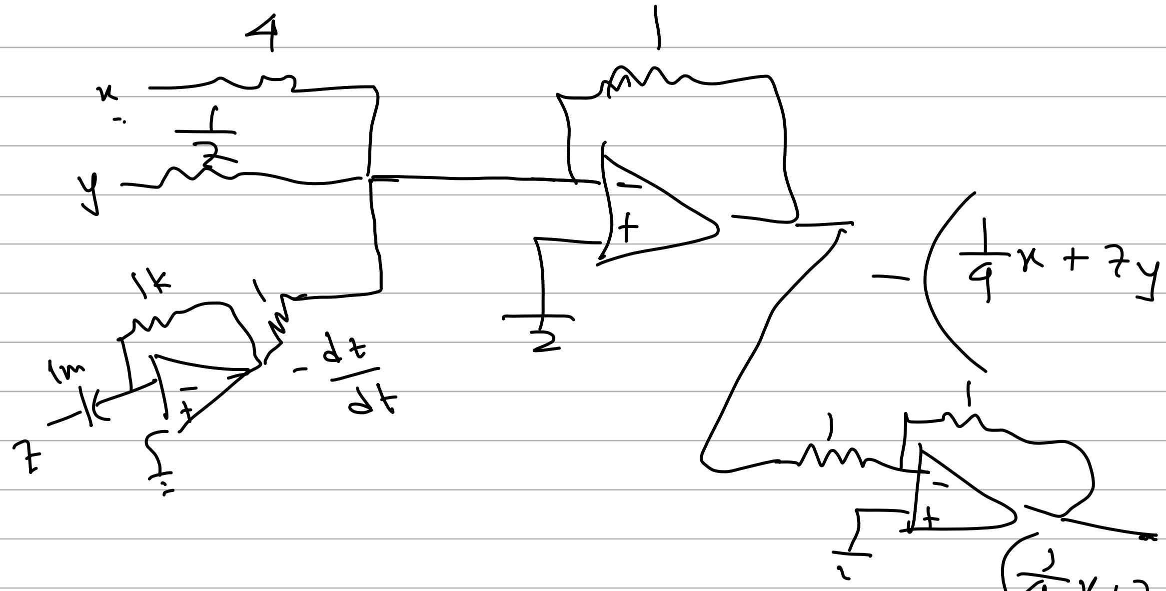
$V_o = -\frac{1}{RC}\int z\,dt$

$\frac{z}{R} = C\frac{d(0-V_o)}{dt}$

$\rightarrow \frac{z}{RC} = -\frac{dV_o}{dt}$

$-\frac{1}{RC}\int z\,dt = V_o$

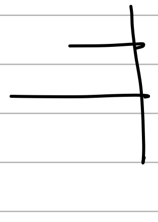
$f = \frac{1}{4}x + 7y - \frac{dz}{dt} = -\left(-\frac{1}{4}x - 7y + \frac{dz}{dt}\right)$



$-\left(\frac{1}{4}x + 7y - \frac{dz}{dt}\right)$

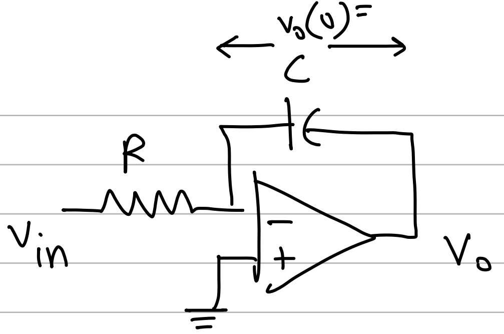
$\left(\frac{1}{4}x + 7y - \frac{dz}{dt}\right)$

$f =$



$x + y$

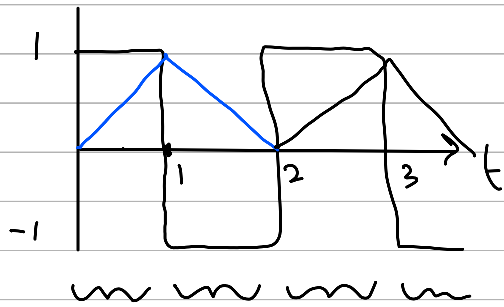
$x - y = x + (-y)$



$\cancel{0.1}\times 10^{-6} \times \cancel{10} \times 10^{3}$

$RC = 10^{-3} = \frac{1}{1000}$

$\frac{1}{RC} = 1000$



$F(t) = \int f(t)\,dt + \cancel{F(0)}^{\,0}$

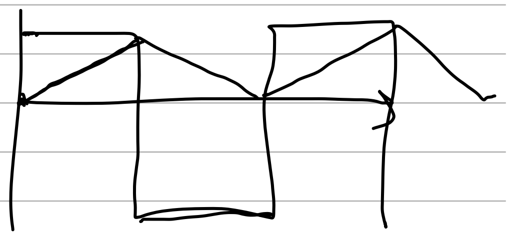
$= \int_0^t 1\,dt + 0 = t + 0$

$= t \longrightarrow$ in sec

$f(t) = 1$

$f(t) = -1$

$F(1) = 1$ ✓

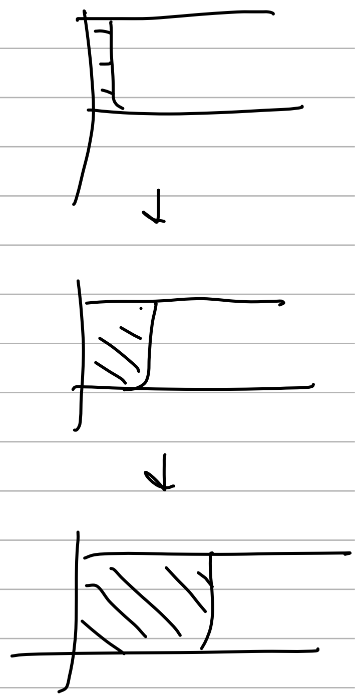


$F(t) = \int_1^t -1\,dt + F(1)$

$= \left[-t\right]_1^t + 1$

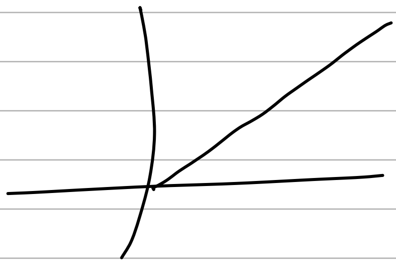
$= \left[-t + 1\right] + 1 = -t + 2$

$F(2) = 0$

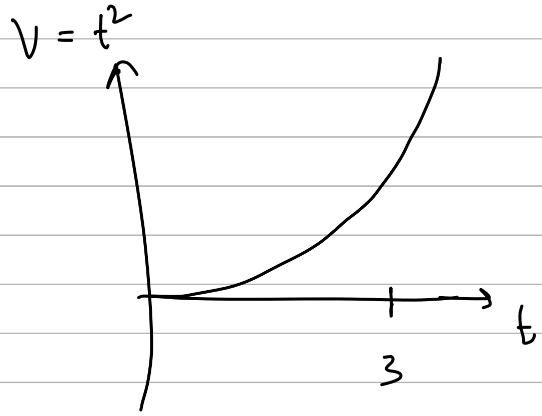


$F(t) = \int_2^t 1\,dt + F(2)$

$= t - 2$



$$\int_0^1 1\,dt = [t]_0^{1\times10^{-3}} = 1-0 = 1\times10^{-3}$$



$$\int_0^3 t^2\,dt$$