ELECTRICAL SCIENCES

FIRST YEAR NOTES

-AKSHANSH CHAUDHARY

Electrical Science Notes, First Edition

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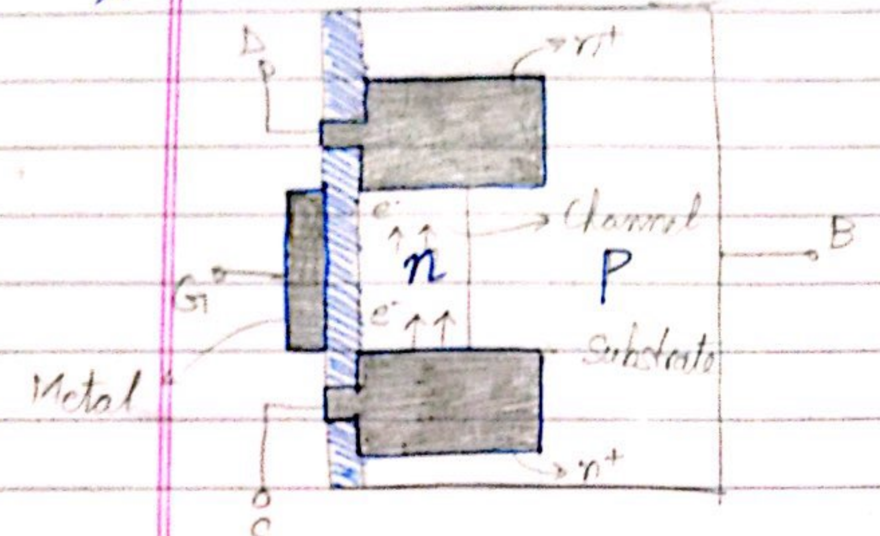
MOSFET

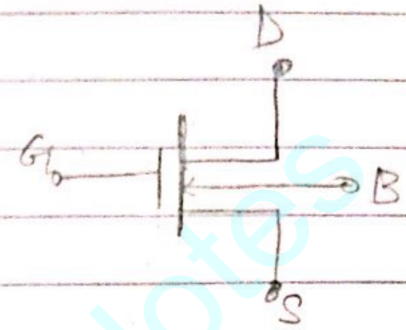
Metal oxide Semiconductor Field Effect Transistors

Depletion MOSFET | Enhancement MOSFET

* Apart from S, D & G, a new component called as substrate or body is introduced.
- Substrate is a p-type Si & forms 2 heavily doped n type regions denoted by n^{+} → signifies heavily doped
- An n type channel is formed b/w 2 n^{+} regions.
- Channel is covered with a thin insulating oxide layer of SiO_2 (0.1 μm).

*

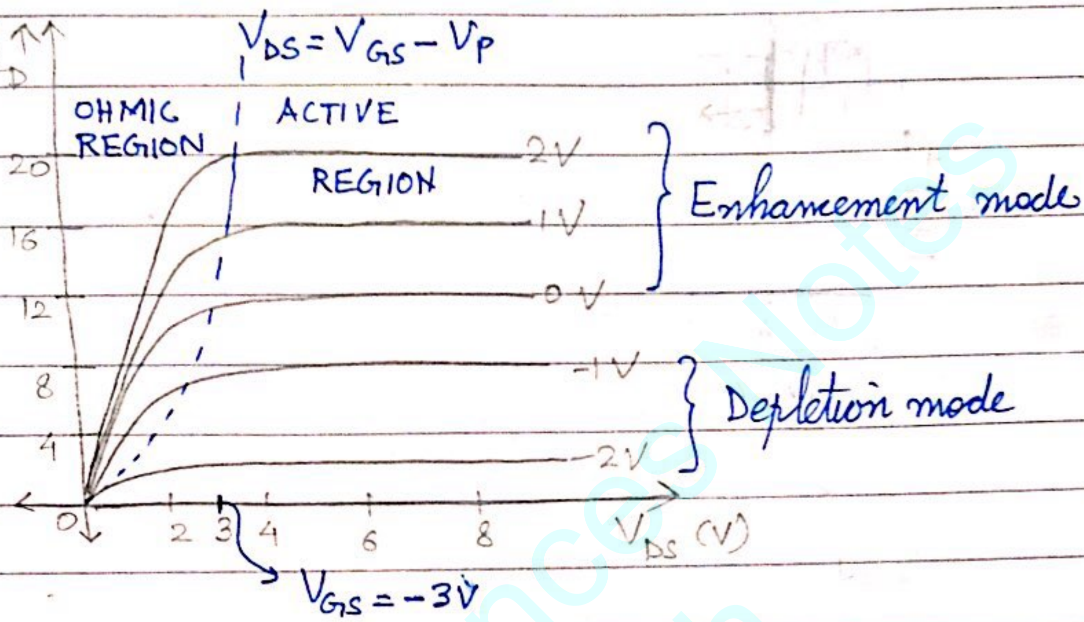




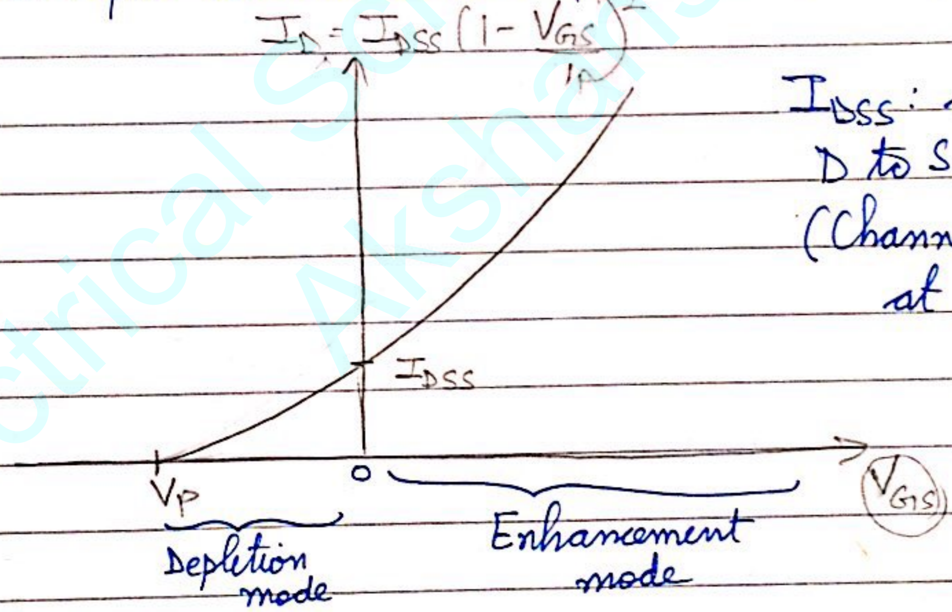
Circuit symbol

- Gate is obtained by depositing a metal on the oxide layer
- Such device is called MOSFET, also called NMOS.
- If n & p are interchanged, its called PMOS.
- $\because$ $\exists$ insulating layer b/w gate & channel, its called INSULATED GATE FET.
- $\because$ of insul^n b/w G & S, resistance is extremely high $= 10^{10}$ to $10^{15}\ \Omega$, hence, $i_G = 0$ for MOSFET (same as JFET)
- Typically the source S & body B are connected.
- V_{GS} is made -ve, +ve charges are induced in the n-type channel, thereby, effectively narrowing it, as in case of JFET.
- A depletion MOSFET has characteristics similar to JFET.
- When V_{GS} is made +ve, $\exists$ more -ve charges induced into n channel, thereby, widening the channel.
- When channel is widened with majority charge carriers, we say its an enhancement mode.

* O/P CHARACTERISTICS of a MOSFET

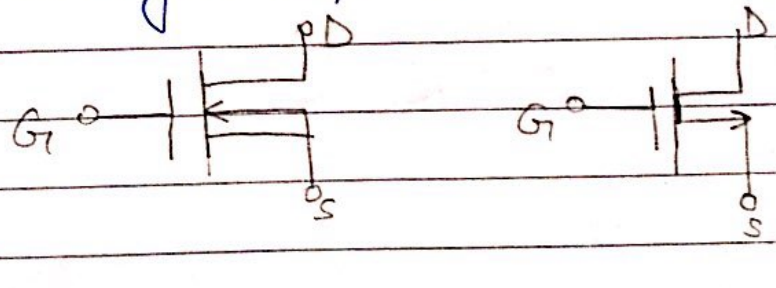


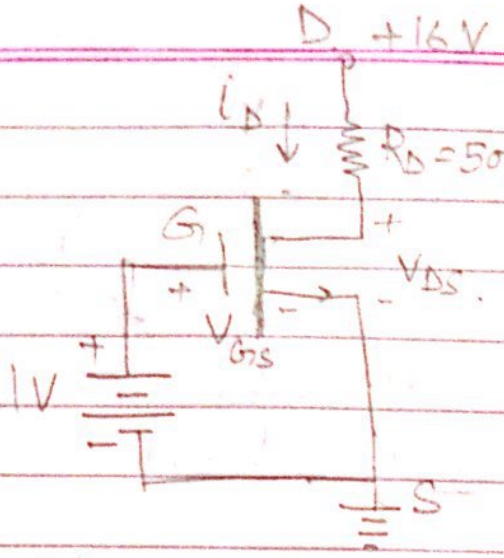
* Transfer Characteristics of a MOSFET.



I_{DSS}: current from D to S for $V_{GS}=0$. (Channel pinch off at V_P).

* Circuit symbol for n-~~chann~~ channel depletion MOSFET



Q 

NMOS

$I_{DSS} = 8\,mA$.

$V_P = -2V$.

(a) Find :- V_{GS}, i_D & V_{DS}.

(b) If $R_D = 750\,\Omega$ instead, is it still in active region.

(a) $V_{GS} = 1V$ (inspection).

For active region.

$$i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 \qquad I_{DSS} \to 8\,mA,\; V_{GS} \to 1V,\; V_P \to -2V$$

$\Rightarrow i_D = 18\,mA$.

KVL $\quad 16 - V_{DS} - 500\,i_D = 0$

$\Rightarrow V_{DS} = 7V$.

$V_{DS} > V_{GS} - V_P \Rightarrow 7 > 3\,V \qquad (V_{DS} \to 7,\; V_{GS} \to 1,\; V_P \to -2)$

$\Rightarrow$ MOSFET is in active.

(b) $i_D = 18\,mA$ (same)

KVL $\quad 16 - V_{DS} - 750\,i_D = 2.5\,V$

$2.5V < 3 \;\; (\to V_{GS} - V_P)$

So, MOSFET is not in active region.

Its in Ohmic region.

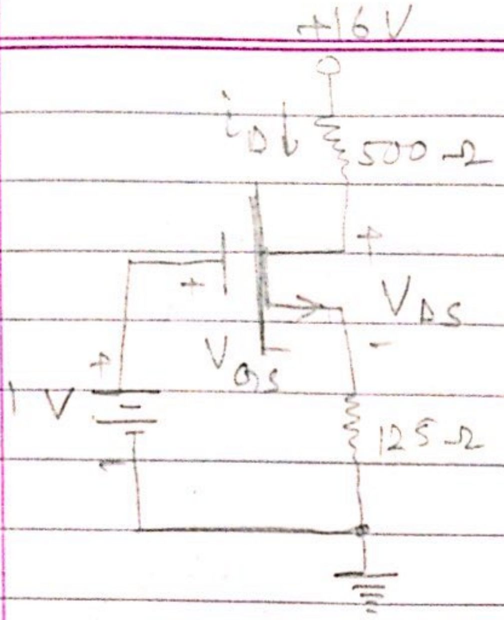
Drill 8.3 Ex:- $I_{DSS} = 8\,mA$, $V_P = -2V$.

Find :- V_{GS}, I_D, V_{DS} = ?

Soln :- Active region.

$$\Rightarrow i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = I_{DSS}\left(1 + \frac{V_{GS}^2}{4} + V_{GS}\right) \qquad I_{DSS} \to 8\,mA$$

$\longrightarrow$ (1)



Also, By KVL

$$V_{GS} + 125\, i_D - 1 = 0$$

$$\Rightarrow i_D = \frac{1 - V_{GS}}{125} \rightarrow (2)$$

From (1) & (2)

$$\Rightarrow \frac{1 - V_{GS}}{125} = (8 \times 10^{-3})\left(1 + V_{GS} + \frac{V_{GS}^2}{4}\right)$$

$$\Rightarrow 1 - V_{GS} = 1 + V_{GS} + \frac{V_{GS}^2}{4}$$

$$\Rightarrow 2V_{GS} + \frac{V_{GS}^2}{4} = 0 \Rightarrow V_{GS}^2 + 8V_{GS} = 0$$

$$\Rightarrow V_{GS} = 0 \text{ or } V_{GS} = -8\text{ V}.$$

$\because V_{GS} > V_P (= -2\text{ V})$

$\Rightarrow V_{GS} = 0\text{ V}$, (not -8 V)

$$\therefore i_D = \frac{1 - V_{GS}}{125} = \frac{1 - 0}{125} = 8\text{ mA}$$

By KVL $V_{DS} + 500\, i_D + 125\, i_D - 16 = 0$.

$\Rightarrow V_{DS} = 11$ V.

Now, $V_{DS} > \underbrace{V_{GS}}_{\to 0} - \underbrace{V_P}_{\to -2}$. $\Rightarrow 11 > 2$ V

$\Rightarrow$ Active region confirmed.

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Chapter - 14.
ELECTROMAGNETICS

* Total flux (ϕ) passing through a given area is

magnetic flux density (T: Tesla) ☆ $\boxed{B = \dfrac{\phi}{A}}$ → magnetic flux (Wb: Weber)
→ Area

$\equiv$ ☆ $\boxed{\phi = \int \vec{B} \cdot d\vec{s}}$

☆ $\boxed{\vec{F} = q(\vec{v} \times \vec{B})}$ → LORRENTZ FORCE

→ $|\vec{F}| = qvB\sin\theta$.
→ Dir^n of force: RHTR (Right Hand Thumb Rule).
: Flemming's Left Hand Rule.

* Current carrying conductor produces magnetic field : given by RHTR.

☆ $\dfrac{\mu}{4\pi}\left(\dfrac{2i}{r}\right) \equiv \boxed{B = \dfrac{\mu}{2\pi d} i}$; $\vec{B}$ for a straight current carrying coil at a distance 'd' from it.

→ permeability of material.

☆ $\dfrac{\mu}{4\pi}\left(\dfrac{2\pi i}{l}\right)N \equiv \boxed{B = \dfrac{\mu N i}{l}}$; $\vec{B}$ for a solenoid of length 'l' & N no. of turns ($l >> r$ (radius)).

$\hookrightarrow \phi = \vec{B} \cdot d\vec{s}$
$= B(\text{Area})$
$\Rightarrow \phi = \dfrac{\mu_0 N i}{l} (\pi r^2)$

☆ Relative permeability (μ_r) = $\dfrac{\mu}{\mu_0}$ (Free space : $4\pi \times 10^{-7}$)

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Q. $r = 0.01m$ Find :- N : when core material is

$l = 0.2m$ (a) Air

$i = 1A$ (b) Iron with $\mu_r = 1200$

$B = 0.1T$. $B = \frac{\mu N i}{l} \Rightarrow N = \frac{Bl}{\mu i}$

$\Rightarrow N = \frac{0.1 \times 0.2}{\mu \times 1}$

(a) $4\pi \times 10^{-7}$ (μ_0)

(b) $\mu_0 \cdot \mu_r = 4\pi \times 10^{-7} \times 1200$

* TOROID

l: length $\simeq 2\pi r$.

r: radius

$$\boxed{\vec{B} = \frac{\mu N}{2\pi R} i} \equiv \frac{\mu}{4\pi}\left(\frac{2i}{R}\right) N$$

length of loop

Radius of toroid ($l = 2\pi R$)

$$\phi = \vec{B} \cdot \vec{ds} = \frac{\mu N}{2\pi R} i \times \pi r^2 = \frac{\mu N r^2}{2R} i.$$

Q. $N = 500$. Find $i = ?$

$\mu_r = 1500$

$R = 0.1m$ $B = \frac{\mu N}{2\pi R} i \Rightarrow i = \frac{2\pi R \times B}{\mu N}$

$r = 0.02m$.

$B = 0.5T$

($R \to 0.1$, $B \to 0.5$, $N \to 500$, $\mu \to \mu_0 \cdot \mu_r$, $\mu_0 \to 4\pi \times 10^{-7}$, $\mu_r \to 1500$)

* For a toroid, $\phi = \frac{\mu_0 N r^2}{2R} i$

$$= \frac{(\mu_0 N)(\pi r^2)}{(2\pi R)} i = \frac{\mu_0 N A}{l} i.$$

$$\Rightarrow \phi \propto N$$
$$\propto i$$
$$\propto Ni$$

** Ni : MAGNETOMOTIVE FORCE (mmf), written as.

** $\boxed{\mathcal{F} = Ni}$; $\mathcal{F}$ units : Amp-turns (A-t)

MAGNETIC CIRCUITS

we know, $\mathcal{F} = Ni$ & $\phi = \frac{\mu N i}{l} \cdot A$.

$\Rightarrow \phi = \left(\frac{\mu N A}{l}\right) i$

$= \left(\frac{\mu A}{l}\right)(Ni)$

$\phi = \left(\frac{\mu A}{l}\right) \mathcal{F}$

$\Rightarrow \boxed{\phi = \frac{\mathcal{F}}{\mathcal{R}}}$

$\mathcal{F} \rightarrow$ MAGNETO MOTIVE FORCE (mmf)

$\mathcal{R} \rightarrow$ RELUCTANCE

$\mathcal{R} = \frac{l}{\mu A}$: Reluctance of path of flux through the core

: units : Ampere-turns per Weber (A-t/Wb).

$\Rightarrow \boxed{\mathcal{F} = \mathcal{R}\phi}$

From previous example.

eg:- $B = 0.5T$, $i = 0.33A$, $A = 0.02$, $N = 500$, $R = 0.1$

$\Rightarrow \phi = B \cdot dS = B \cdot A = (0.5)(0.02)^2$ ✓

So, $\mathcal{R} = \frac{l}{\mu A} = \frac{2\pi R}{\mu(\pi r^2)} = \frac{2(0.1)}{(6\pi \times 10^{-4})(0.02)^2}$ ✓

mmf $= \mathcal{F} = \mathcal{R}\phi$ ✓

$i = \frac{\mathcal{F}}{N} = \frac{\mathcal{F}}{500} = 0.332$

($\simeq$ same as i in previous ex.)

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skill ex 14.1 | Find ϕ $r = 0.01m$, $l = 0.2m$, $N = 100$; $i = 0.1A$

(a) core material : Air

(b) core material : Iron; $\mu_r = 1500$

$\Rightarrow \mu = \mu_0 \mu_r$

(a) $B = \frac{\mu N i}{l} = \frac{\mu_0 N i}{l}$ ✓

$\Rightarrow \phi = B.dS = B(\pi r^2)$ ✓

(b) $B = \frac{\mu N i}{l} = \frac{\mu_0 \mu_r N i}{l}$

$\phi = B.dS = \left(\frac{\mu_0 \mu_r N i}{l}\right)(\pi r^2)$ ✓

14.2 Toroid $R = 0.1m$, $r = 0.02m$

core radius → Crosssectional radius

$\mu_r = 1200$, $\phi = 1\ Wb$, $i = 1A$

Find :- N

$\phi = \vec{B} \cdot \vec{dS} = \left(\frac{\mu N i}{2\pi R}\right)\pi r^2$

$= \left(\frac{\mu_0 \mu_r N i}{2\cancel{\pi} R}\right)(\cancel{\pi} r^2)$ ✓

$\Rightarrow N = \frac{\phi(2R)}{\mu_0 \mu_r i r^2}$ ✓

14.3 Toroid $R = 0.1\text{m}$. Find: (a) $\mathcal{R}$.

$r = 0.02\text{ m}$ (b) mmf ($\mathcal{F}$)

$\mu_r = 1200$ (c) i

$\phi = 1 \times 10^{-3}\text{ Wb}$

$N = 332$

(a) $\mathcal{R} = \dfrac{l}{\mu A} = \dfrac{2\pi R}{\mu A} = \dfrac{2\pi R}{\mu_0 \mu_r (\pi r^2)} =$

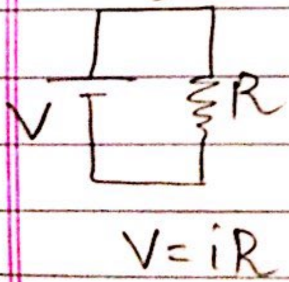
$\Rightarrow \mathcal{R} = 331740.976$

(b) $\mathcal{F} = \mathcal{R}\phi = 331.740976$

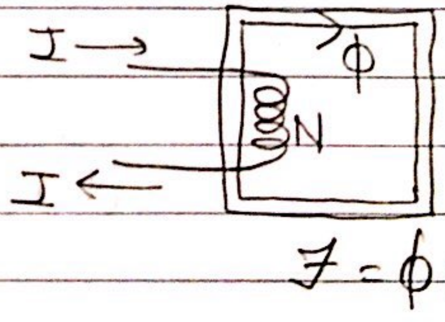
(c) $i = \dfrac{\mathcal{F}}{N} \simeq 0.9992198072\text{ A}$

✲ Analogies for Electric and Magnetic Circuits.

Electric	Magnetic
• Current (i)	• Flux (ϕ)
• Voltage or emf (V)	• mmf ($\mathcal{F}$)
• Resistance (R)	• Reluctance ($\mathcal{R}$)
• $V = Ri$ (Ohm's Law)	• $\mathcal{F} = \mathcal{R}\phi$.
• Electric circuit	• Magnetic circuit.



$V = iR$



$\mathcal{F} = \phi R$

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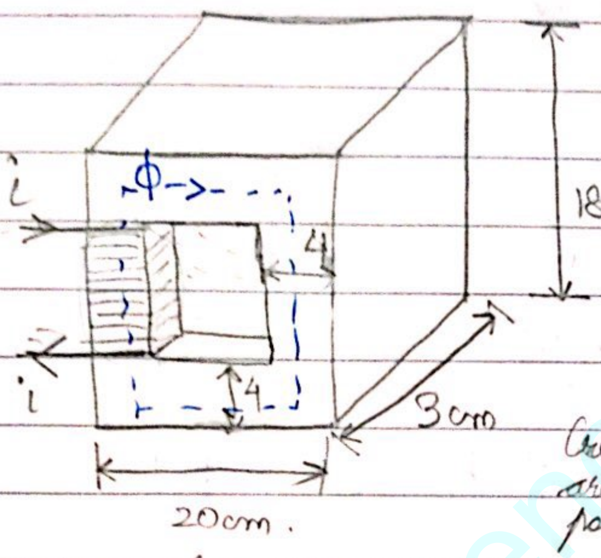
ex 14.4 Rectangular iron core ; $\mu_r = 1500$.
Find:- $\mathcal{R}$, ϕ $N = 200$
$i = 2A$.



Mean length (l) = $16+14+16+14 = 60 cm$
$\Rightarrow l = 0.6 m$.

Area (A) $= 4cm \times 3cm$.
$= 0.04 \times 0.03$
$= 0.0012 m^2$.

Crossectional area of inside portion

(a) $\mathcal{R} = \dfrac{l}{\mu A} = \dfrac{l}{\mu_0 \mu_r A}$ ✓

(b) $\mathcal{F} = Ni = 200 \times 2 = 400$. A-t
$\phi = \dfrac{\mathcal{F}}{R}$ ✓

——×——

Drill 14.4 Rectangular iron core ; $\mu_r = 1500$.
$i = 1A$.
$N = ?$ $\phi = 3 mWb$; l, A → ex 14.4.

$\phi = \dfrac{\mathcal{F}}{\mathcal{R}} = \dfrac{Ni}{\mathcal{R}} = \dfrac{Ni}{l/\mu_0 \mu_r A}$

$\Rightarrow N = \dfrac{\phi l}{(\mu_0 \mu_r A)(i)}$ ✓

——×——

* Magnetizⁿ Curves.

We know,

$$\text{Magnetic flux density } (B) = \frac{\phi}{A}$$

$$\& \quad \phi = \frac{\mathcal{F}}{\mathcal{R}} \quad \& \quad \mathcal{R} = \frac{l}{\mu A}.$$

$$\Rightarrow B = \frac{\mathcal{F}}{\mathcal{R} A} = \frac{\mathcal{F}}{A l/\mu A} = \frac{\mu \mathcal{F}}{l}.$$

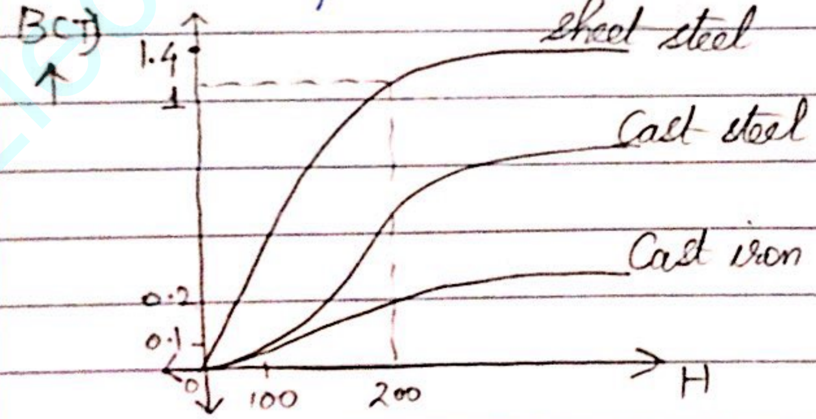
So, $\boxed{B = \mu H}$; $H = \frac{\mathcal{F}}{l} = \frac{Ni}{l}$

Magnetic field or Magnetic flux density

→ magnetic field intensity or magnetizⁿ force.

→ $H \propto N$
$\propto i$
$\propto 1/l$.

* B-H curve or Magnetizⁿ curve :- Plot of B vs H.
* B-H curve for cast iron, cast steel, sheet steel →



Ex 14.6 Toroid Sheet steel

$B = 1T$, $R = 0.1m$, $r = 0.02\,m$, $N = 500$

Find :- (a) μ_r
(b) i

(B-H curve is given) → $H = 200$.

(a) $B = \mu H \Rightarrow \mu = \frac{B}{H}$ ✓ — 1 (Given); H → 200 (graph)

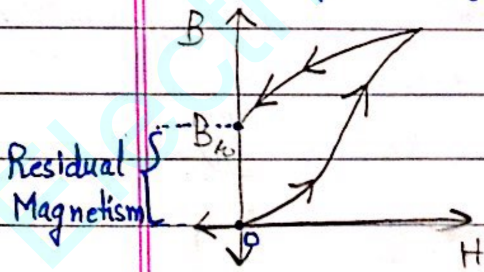
$\Rightarrow \mu_r = \frac{\mu}{\mu_0} = \frac{\mu}{4\pi \times 10^{-7}}$ ✓ (3980.89)

(b) $i = \frac{Hl}{N} = \frac{H \times 2\pi R}{N} = \frac{200 \times 2 \times 3.14 \times 0.1}{500}$ ✓ (0.2512)

Drill 14.6. Toroid $B = 0.8T$, $R = 0.1m$, $r = 0.02m$, $N = 500$
Cast steel $H = 500$ (from graph → given)
Find) (a) μ_r, (b) i
1273.885 0.628 A

HYSTERESIS.

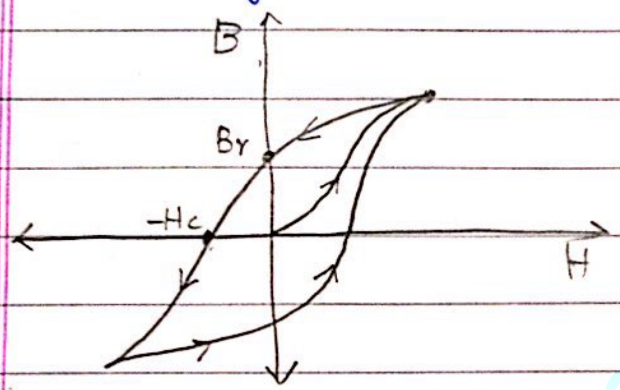
- a demagnetized material is one whose $B = 0$ when no ext. magnetizing force ($H = 0$) is applied.
- If magnetising force is applied, resulting B-H curve.



* For small H, curve is relatively st.
* As H ↑, curve bends, B ↑ & flattens out & further ↑ in H yields no ↑ in B. Hence, material is saturated.

* If after satur^n, H is reduced to zero, B ↓, but, doesn't follow the same path.
* This value of B obtained when $H = 0$ is
$B = B_r$: Residual Magnetism.
* Now, H is decreased from 0 so that for some $H = H_c$, $B = 0$. This H_c : coercive force.

- Now, H is ↓ further, material saturates again, but, in opp. dir^n (-ve region).
- Now, H is ↑ & made large enough, material saturates again, but in +ve region.
- Resulting loop :-



Note :- Some materials have rectangular hysteresis loops. They are called SQUARE LOOP MATERIAL — ⇒ a small change in H, makes large change in B (used in digital computers).

★ TRANSFORMERS

- devices used to transfer electrical energy efficiently.
- They step up & step down voltages - used in power distrib^n - to accomplish max. power transfer b/w source & load.
- They are employed to couple circuits without running a conducting electrical connection.
- They are insulating one circuit from another.

★ MAGNETIC INDUCTION

- Faraday's Law :- $\boxed{e.m.f = N\frac{d\phi}{dt}}$ ★

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Let $N\phi = \lambda$; λ: no. of flux linkages.

$\therefore \; emf = \frac{d\lambda}{dt}$.

[Now, $v = L\frac{di}{dt}$, for an inductor]

$$\left[\because \phi \propto i, \; N\phi = Li \;\Rightarrow N\frac{d\phi}{dt} = L\frac{di}{dt} \;\Rightarrow emf = v = L\frac{di}{dt}\right]$$

equating v and emf

$$\Rightarrow L\frac{di}{dt} = \frac{d\lambda}{dt}.$$

$$\Rightarrow L\frac{di}{\cancel{dt}}\left(\frac{\cancel{dt}}{di}\right) = \frac{d\lambda}{\cancel{dt}}\left(\frac{\cancel{dt}}{di}\right)$$

$$\Rightarrow \boxed{L = \frac{d\lambda}{di}}$$

or $L = N\frac{d\phi}{dt}$.

Now, $\mathcal{F} = Ni$, $\mathcal{F} = \mathcal{R}\phi$

$$\Rightarrow Ni = \mathcal{R}\phi$$

$$\Rightarrow \phi = \frac{Ni}{\mathcal{R}}$$

$$\Rightarrow \phi = \underbrace{k}_{\frac{N}{\mathcal{R}}} i \Rightarrow k = \frac{\phi}{i}$$

Also, $\frac{d\phi}{dt} = k$ (Taking derivative)

$$\therefore \frac{d\phi}{di} = \frac{\phi}{i}$$

$$\therefore L = N\frac{d\phi}{di} = \frac{d\lambda}{di}$$

becomes $L = \frac{N\phi}{i} = \frac{\lambda}{i}$

Now, $\phi = \frac{Ni}{\mathcal{R}}$

$$\therefore L = \frac{N(Ni/\mathcal{R})}{i}$$

$$\Rightarrow \boxed{L = \frac{N^2}{\mathcal{R}}}$$

☆ $\hookrightarrow L \propto N^2$.

ex 14.8 Toroid :- $\mu_r = 1500$, $R = 0.1m$, $r = 0.02m$, $\mathcal{R} = 2.65 \times 10^5$ A-t/Wb
$N = 500$.

Find (L) :- $L = \frac{N^2}{\mathcal{R}}$ ✓

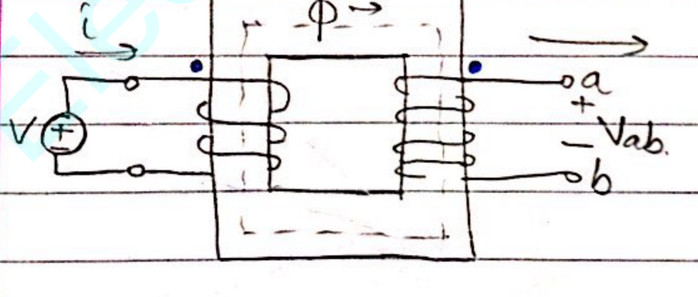
☆ Sequence of Operation.

In transformer design you would normally like to deal in terms of voltages on the windinds. However, the key to understand what happens in a transformer (or other wound component) is to realise that what the transformer really cares about is the current in the windings & that everything follows on from that.

- The current in the winding produces mmf
  $\mathcal{F} = Ni$ A-t .

- mmf produces magnetic field
  $H = \frac{\mathcal{F}}{l}$; A-t/m.
- Field produces magnetic flux density
  $B = \mu H$. T
- Summed over the crossectional area of the core, this equates to a total flux.
  $\phi = B.dS$ (B.A) Wb.
- Flux produces induced voltage (emf) :-
  $emf = N \frac{d\phi}{dt}$ V.

★ Lenz's Law:
Polarity of voltage induced by a changing flux tends to oppose the change in flux that produced the induced voltage



The dir^n of current in rt. hand coil makes the flux (1) oppose the flux induced (2) due to left hand coil, with current i.

* If i ↑ with time, ϕ ↑ too ($\because Ni = \mathcal{R}\phi$)
* Resulting current gives potential drop V_{ab} b/w a & b
* • → dots indicate that the dotted ends are +ve & -ve at same time.

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Chapter - 15

PRINCIPLE OF GENERATOR/MOTOR

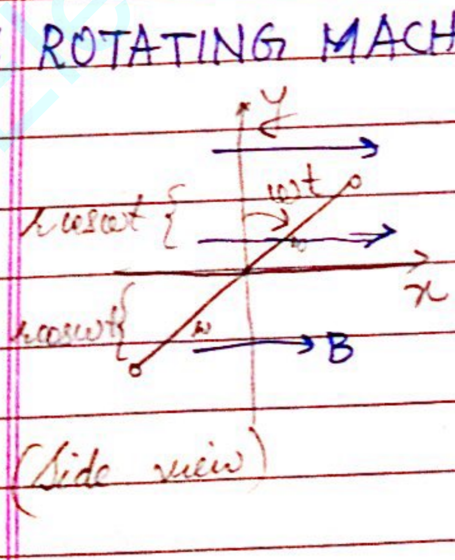
PMI - Whenever a conductor is moved within a magnetic field in such a way that the conductor cuts across magnetic lines of flux, voltage is generated in the conductor.

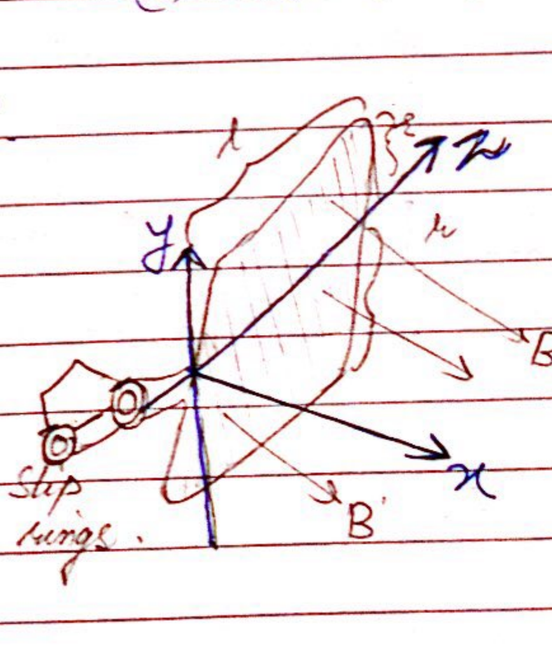
Principle of Magnetic Induction

Amt. of voltage generated depends on
(i) Strength of $\vec{B}$
(ii) Angle at which conductor cuts the magnetic field.
(iii) Speed at which conductor is moved.
(iv) Length of conductor within magnetic field.

To be studied :- D.C Machines
(i) Rotating Machines (ii) Generators & Motors.

ROTATING MACHINES.





Let A be the area of the loop & ϕ be the flux passing through the loop,

So, $A = \cancel{2r}(2r)l$

Also, $\phi = B.ds = B(A)$

$= B(2rl)$

here, $r \to r\cos\omega t$

$\Rightarrow \phi = B(2(r\cos\omega t)\,l)$

$= B\cos\omega t\,(2rl)$

$\Rightarrow \phi = BA\cos\omega t$

According to Faraday's law, emf induced across brushes is :

$$e = \frac{d\phi}{dt} = -BA\omega\sin\omega t.$$

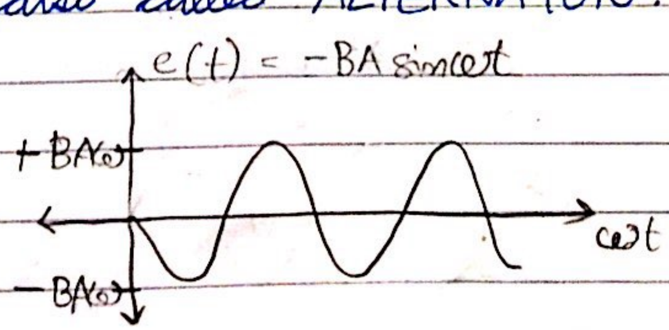
→ For N no. of turns,

Voltage : sinusoidal f^n

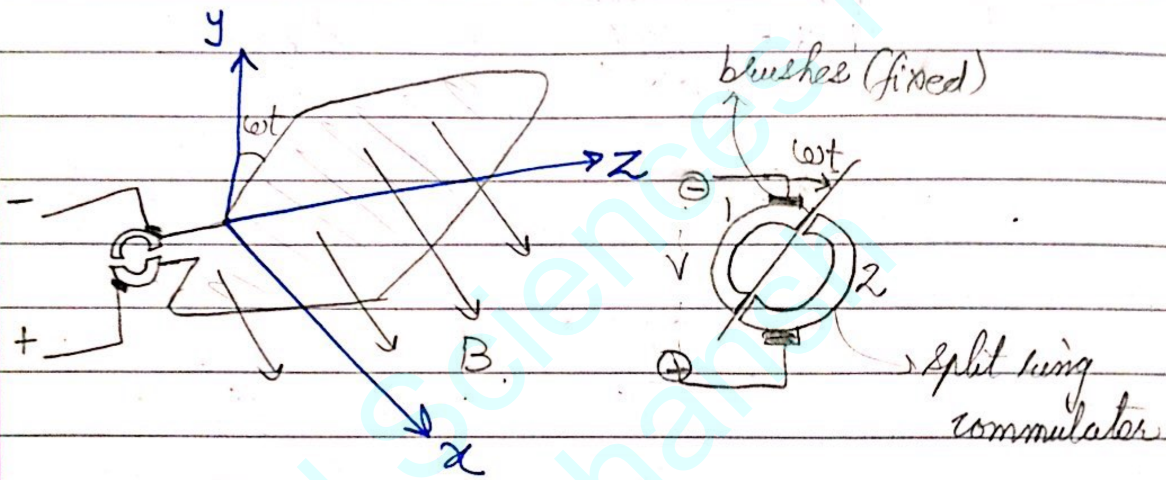
$$\boxed{emf = N\frac{d\phi}{dt} = -NBA\omega\sin\omega t}.$$

$$\left(\boxed{\phi_{N\,turns} = NBA\cos\omega t}\right)$$

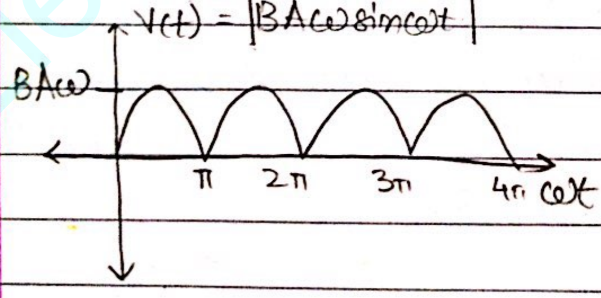
* This rotating machine produces sinusoidal waveform (voltage). So, its an example of AC GENERATOR. also called ALTERNATOR.



* Modify Simple Alternator: $\xrightarrow{\text{to}}$ DC Generator
  - Replace slip rings with split ring commutator.
  - Brushes on either side of split ring commutator.
  - emf = $-BA\omega \sin\omega t$: voltage b/w halves of split ring commutator.

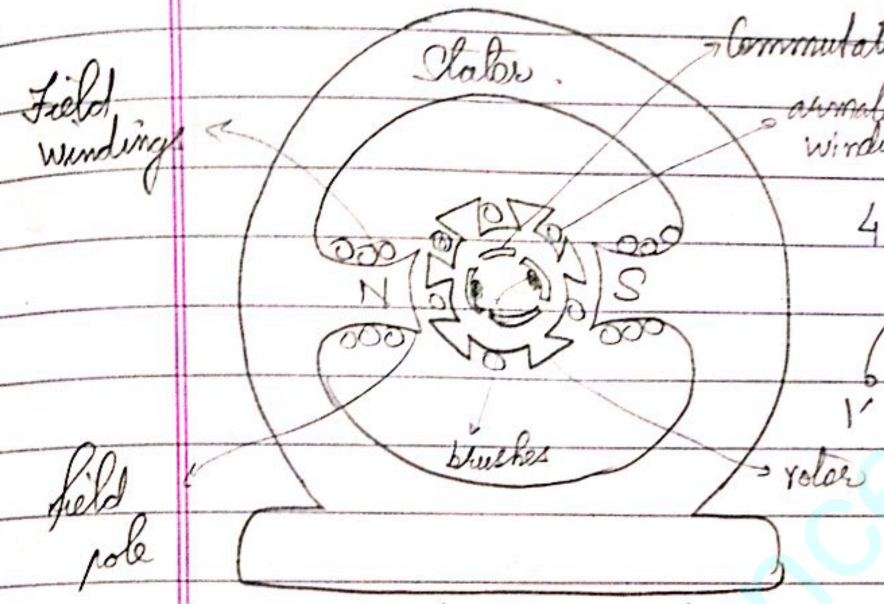


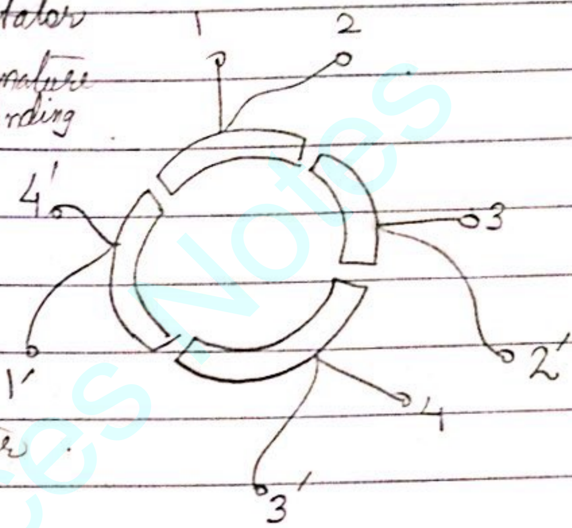
$$v = \begin{cases} -V_{12} = -e = BA\omega \sin\omega t \;;\; 0 < \omega t < \pi \\ V_{12} = e = -BA\omega \sin\omega t \;;\; \pi < \omega t < 2\pi \end{cases}$$



: Voltage never takes a -ve value.
v doesn't change polarity.

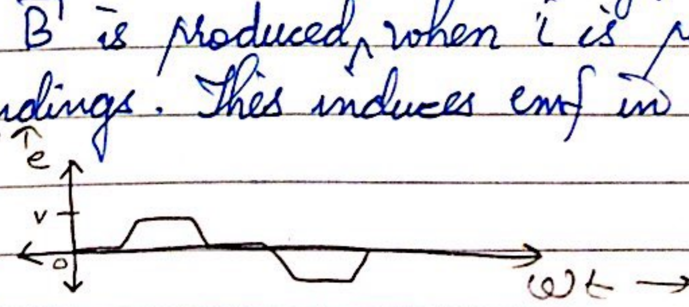
☆ D.C. Generator.





d.c. generator   Coil-commutator connections

* Generator consists of :-
  Stator (Stationary portion) & Rotor (Rotating Portion).
* Field windings: Coils of the stator, in which DC is produced, when magnetic field is applied to it.
* Rotor consists of :-
  Commutator & Armature (conductors ~~acl~~ across which emf is produced.)
* Stator has 2 poles → N & S. (~~Fel~~ ~~Fel~~ Field windings situated on it).
* Rotor has iron core — (having slots which houses the armature conductors and a commutator & brushes).
* Uniform $\vec{B}$ is produced in small air gaps b/w poles & rotor, when i is passed through field windings. This induces emf in the coil :-



- When armature windings are connected ∥ to the commutator (as per connections shown earlier), individual emf gets rectified & all of them add up together.

DC or AC

* Voltage generated by generator, V_g

emf or no load armature voltage

$$\boxed{V_g = \frac{N}{a}\, p\,\phi\, \frac{n}{60}} = k\,\phi\, n \qquad k \rightarrow \frac{Np}{60a}$$

- N : no. of conductors = no. of armature coils × no. of turns × no. of conductors
- a : no. of ∥ paths b/w brushes (path along which current flows)
- p : no. of poles
- ϕ : magnetic flux per pole
- n : speed of rotor (rpm)

—x—

ex DC generator, $p=2$, $a=2$, $A = 0.01\,m^2$, $B = 1T$, $n = 1500$

Find V_g

$\phi = B.dS = 1.0{\cdot}01 = 0.01\ Wb$

$$V_g = \frac{N}{a}\, p\,\phi\, \frac{n}{60} = \frac{N \times 2 \times 0.01 \times}{2}$$

N = 4 × 12 × 2
12 turns
2 conductors
4 armature coils

—x—

drill ex 15.9 DC generator $p=2$, $a=2$, $V_g = 16V$, $N = 4\times10\times2$, $\phi = 10\,mWb$, $n = ?$

$$n = \frac{V_g \times a \times 60}{N \times p \times \phi} = 1200\ rpm$$

Puffin
Date
Page

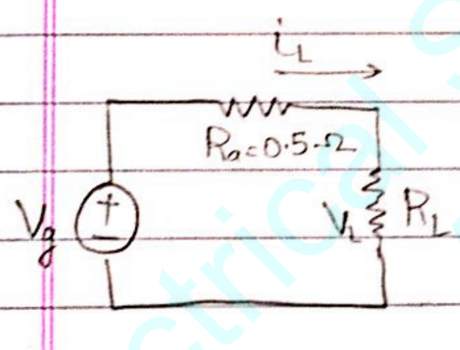
* Generator with a load.

The generated emf, v_g, is voltage across armature terminals (the brushes) when no load is connected to those terminals.

- If $\exists$ some electrical load connected to armature, the resulting load voltage will be diff^t from the no load voltage. Now, it will depend on R_a (resistance) associated with armature due to resistance of the windings and brush contacts.

ex: $P = 8000\,W$, $V_L = 200\,V$, $i_L = 40\,A$, $n = 1200$ rpm, $R_a = 0.5\,\Omega$
R_L resistive load.

Find: Full load voltage for generator at 900 rpm



$$-V_g + i_L(R_a) + V_L = 0 \longrightarrow (1)$$
$$\Rightarrow V_g = V_L + i_L(R_a)$$
$$= 200 + 40(0.5)$$
$$\Rightarrow V_g = 220\,V$$

If ϕ constt., $v_g \propto n$.

1500

So, if ϕ & i_L = constt,

So, $\dfrac{V_{g_1}}{V_{g_2}} = \dfrac{n_1}{n_2} \Rightarrow V_{g_2} = \dfrac{V_{g_1} \times n_2}{n_1} = \dfrac{\cancel{220}^{10} \times \cancel{900}^{3}}{\cancel{1200}_{4}}$

$$\Rightarrow V_{g_2} = 165\,V$$

From (1), $V_L = V_g - i_L(R_a)$
$$\Rightarrow V_L = 165 - (0.5)(40) = 145\,V.$$

drill ex 15.10 $P = 10\,kW$, $V_L = 200V$, $i = 50A$, $n = 1500\,rpm$

If $n = 1800\,rpm$, $V_L = 244V$.

Find : (a) R_a

(b) no load voltage (V_g) at (i) 1500 rpm

(ii) 1800 rpm.

KVL $-V_g + V_L + i_L R_a = 0$

$\Rightarrow V_g = V_L + i_L R_a$

$\Rightarrow V_g = 200 + 50R_a$

Illy, $V_g \propto n$

$\Rightarrow V_{g(1800)} = \left(\frac{1800}{1500}\right) V_{g(1500)}$

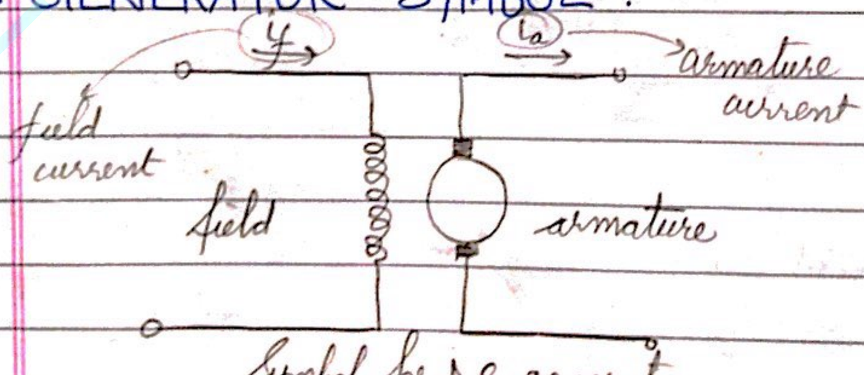
$\therefore \underset{244}{V_L} = -R_a(i_L) + \left(\frac{1800}{1500}\right)(50R_a + 200)$

$\Rightarrow R_a = 0.4\,\Omega$.

(b)(i) $V_{g(1500)} = 50(0.4) + 200 = 220V$

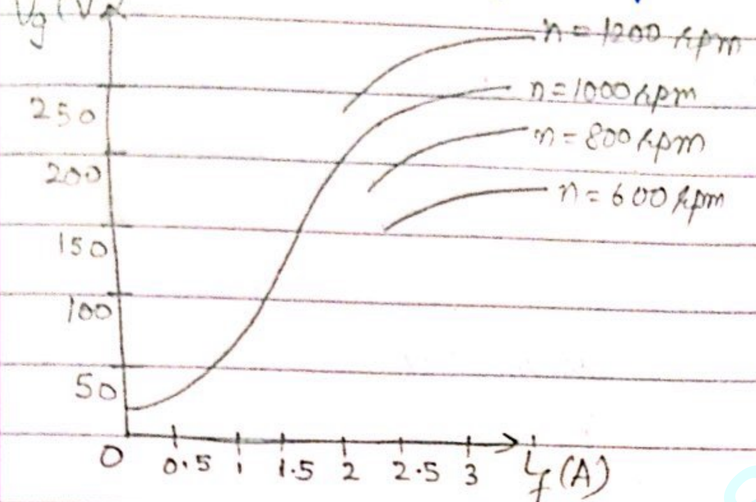
(ii) $V_{g(1800)} = \left(\frac{1800}{1500}\right)\left(V_{g(1500)}\right) = 264\ V$ ✓

✲ GENERATOR SYMBOL :



Symbol for D.C. generator

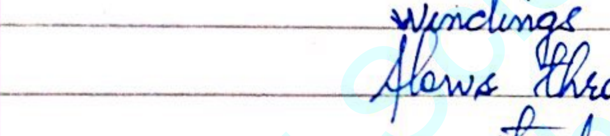
* Plot of no load voltage, V_g vs field current, i_f :



: The curves are called: magnetizⁿ curves of generator

* Generator field excitⁿ

- Field excitⁿ :- When DC voltage is applied to field windings of a D.C. generator, current flows through the windings and sets up a steady $\vec{B}$. This is called . . .
- This excitⁿ voltage can be produced by generator itself or, it can be applied by an outside source, such as a battery.
- If its supplied by an outside source, it's called separately exited generator, as shown:-



Separately excited generator

- The generator that supplies its own field excitⁿ is called Self-Excited Generator.

* Classificⁿ of Generators:

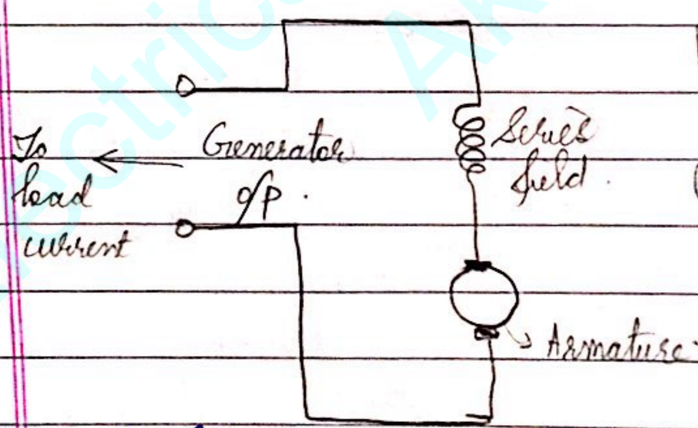
Self excited generators are classified according to the type of field connection they use.

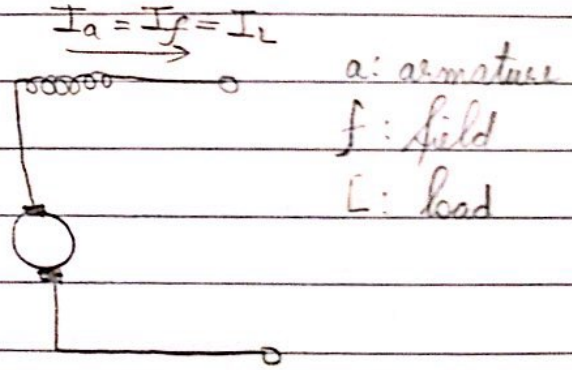
☆ Field connections.

- Series wound
- Shunt-wound (Parallel)
- Compound-wound.
  - Cumulative compound
  - Differential compound.

☆ Series wound generator or Series connected generator.

- In series wound generator, field windings are connected in series with the armature.
- Current that flows in the armature flows through ext. circuit and through field windings.
- The external circuit connected to generator is called load circuit.



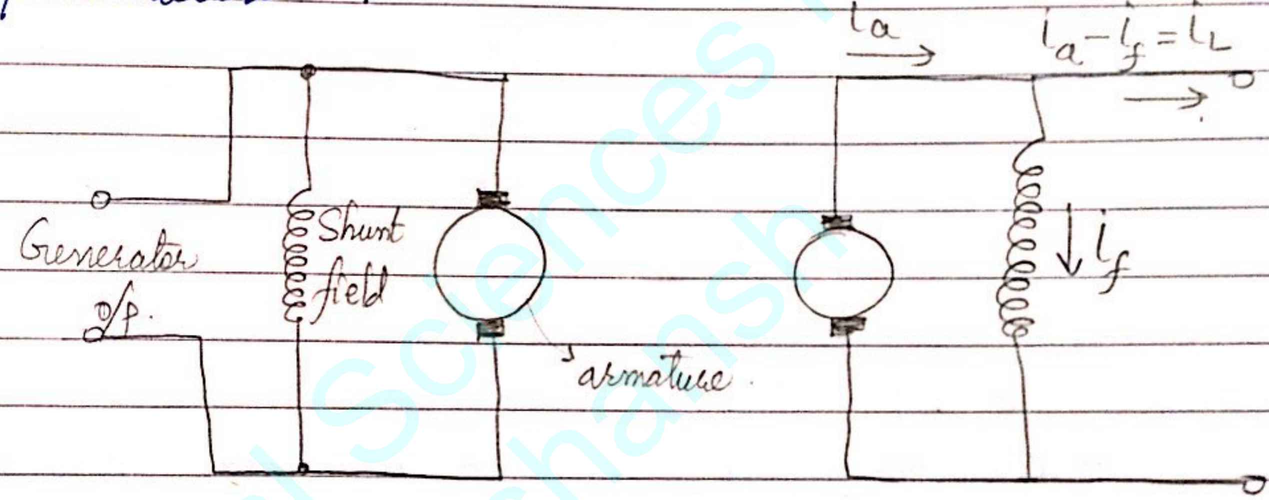


* - The field current (i_f) = armature current (i_a)

↳ Field winding : very few turns
: relatively low resistance.

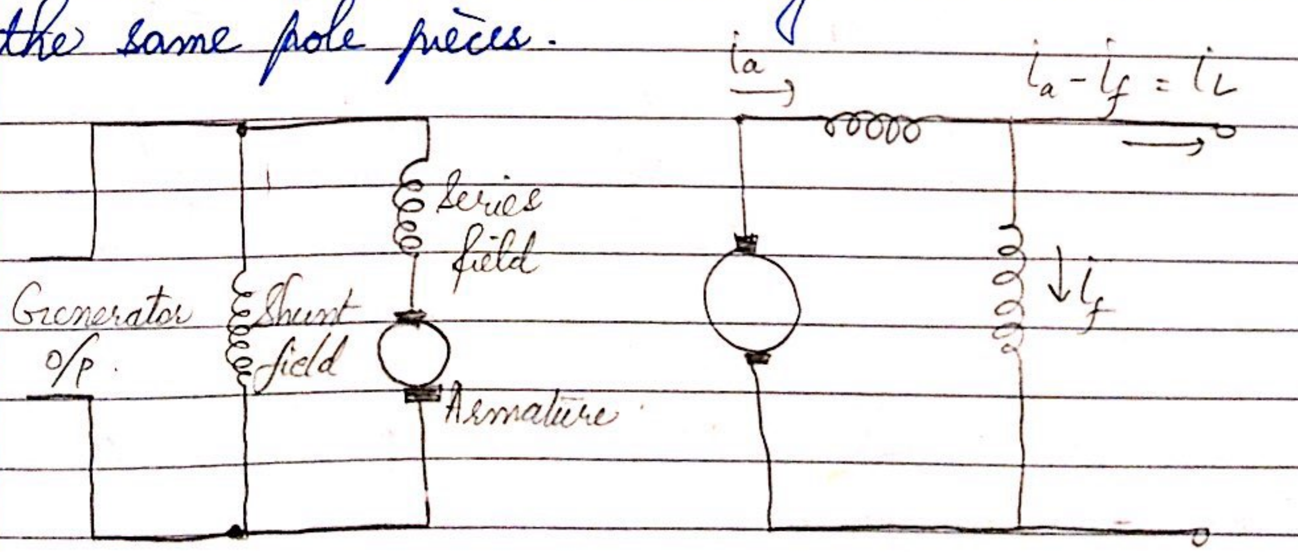
§ ☆ Shunt-Wound generators

- In shunt wound generators, the field coils consist of many turns of small wire & relatively high field resistance.
- They are connected in || with the load. In other words, they are connected across the o/p voltage of armature.



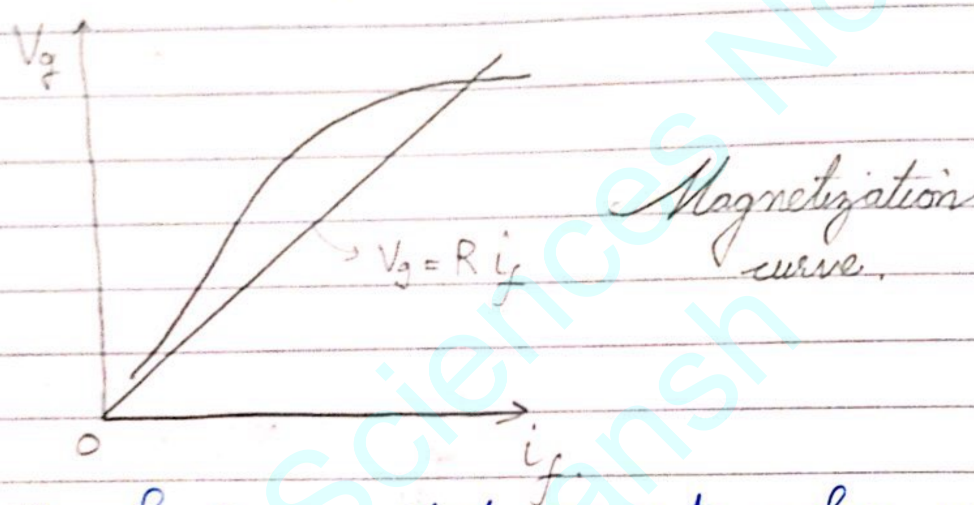
§ ☆ Compound-Wound Generator

- Compound wound generators have a series field winding in add^n to a shunt field winding.
- The shunt and series windings are wound on the same pole pieces.

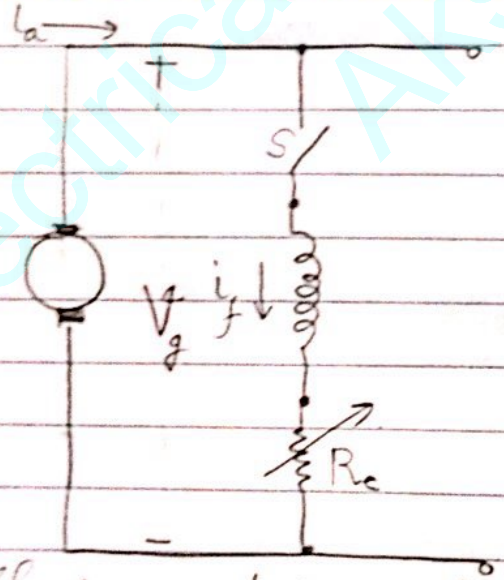


☆ Generator Build Up :
(how generated voltage ↑)

For a separately excited generator turning at n rpm, the value of field current determines the value of generated voltage and following magnetiz^n curve can be used to find it :



- consider shunt connected generator where rheostat & switch are included in the circuit.

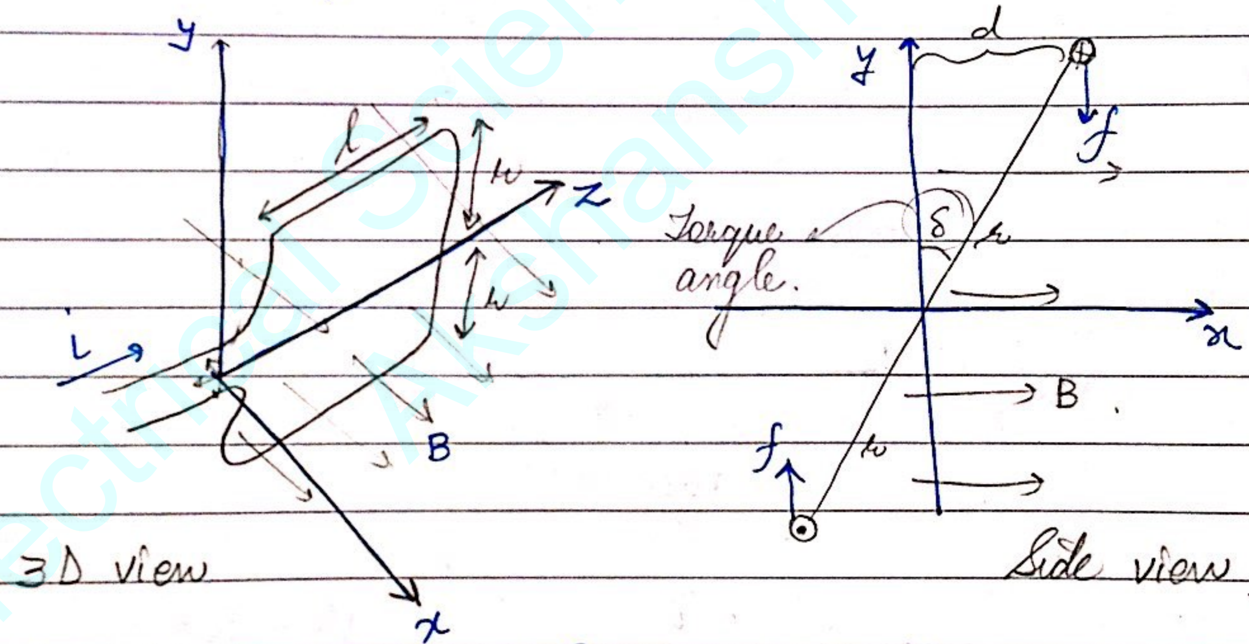


Shunt connected generator

- When switch is open
$i_f = 0$; small generated emf due to residual magnetism.
- When switch is closed
Voltage would be applied across series combin^n of field winding & the control rheostat
⇓
Produces a non zero field current & hence, ↑ the flux, thereby, resulting in ↑ in generated emf.

- This repetitive process of increasing generated voltage and field current is called GENERATOR BUILD UP.
- The ~~on~~ $\cap$ pt. on ~~gaps~~ graph shown previously shows $\rightarrow$ generator buildup has ~~ceased~~ ceased.

☆ DC Motors



- Consider a conducting loop through which, current i is flowing.
- Slip rings and brushes are present (not shown here)
- The end view of the loop is shown in fig (Side view), where, current in the upper conductor is directed into the page. (Shown by ⊗).
- The current in lower conductor is directed out of the page (shown by ⊙).

— By Flemming's left hand rule (or RHTR),
force = $i(l \times B)$ occurs
in upper dir^n : for lower conductor
in lower dir^n : for upper conductor.
Line of action is not same. So, τ is developed.

$$\tau = r \times F = Fd = (ilB)(r\sin\delta)$$

↳ δ : angle formed by y-z plane & plane of loop called as TORQUE ANGLE or POWER ANGLE.

↳ for N turns & 2 conductors.

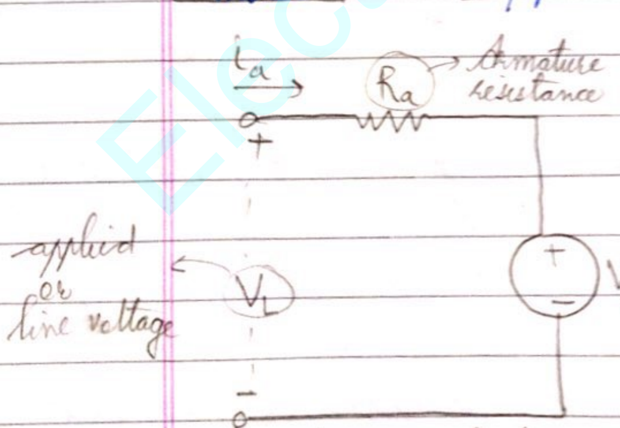
$$\tau = 2N(ilB)(r\sin\delta) = NBAi\sin\delta$$

↳ $A = 2r(l)$: Area of coil.

↳ τ_{max} when $\delta = 90°$, $\sin\delta = 1$.

↳ τ rotates the loop in ↻ dir^n.

Principle of DC motor ← current produced in dir^n opp. to applied current ← emf induced



• Armature model for DC motor.

flux per pole, motor (armature) speed

Now, $V_g = K\phi n$; $K = \frac{Np}{60a}$

For a DC motor, by KVL,

$$V_L = R_a i_a + V_g$$

or $V_L = R_a i_a + K\phi n$.

$$\Rightarrow \boxed{n = \frac{V_L - i_a R_a}{K\phi}} \;*$$

Speed eq^n for DC motor

↳ $K = \frac{Np}{60a}$

* τ developed by DC motor is determined by i_a & $\vec{B}$ & hence ϕ.

$\therefore \boxed{\tau = K' \phi\, i_a}$

K' → constt, determined by construction of motor

✲ IDEAL AMPLIFIER

✲ IDEAL voltage Amplifier

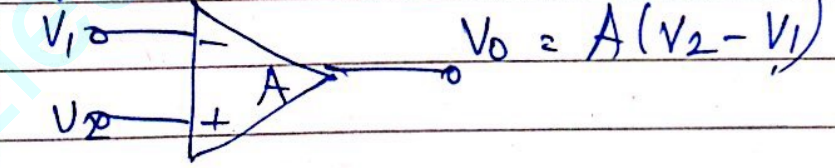
↳ A device with 2 i/p voltages V_1 & V_2 & 1 o/p voltage

Rel^n b/w i/p & o/p voltage is

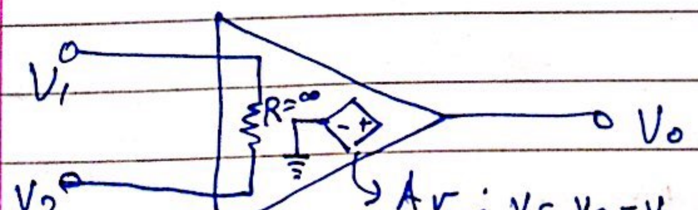
$$V_0 = A(V_2 - V_1) \quad \text{or} \quad \boxed{A = \frac{V_0}{V_2 - V_1}} ✲$$

A: gain of amplifier

✲ Symbol for an ideal amplifier with gain A is :



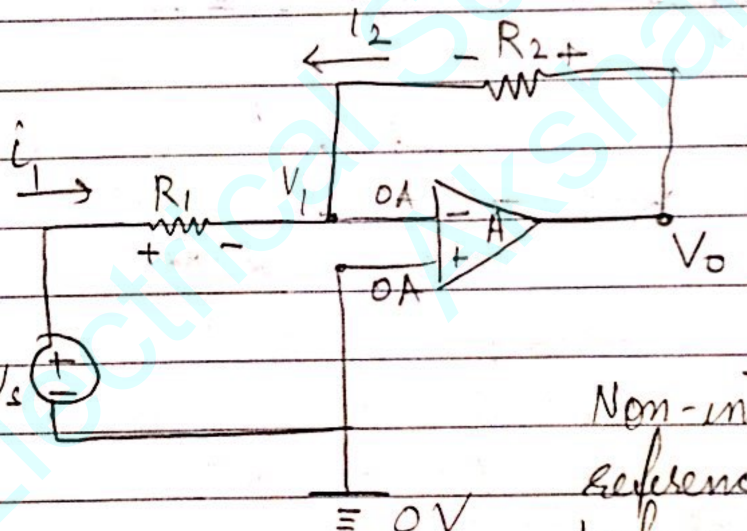
& ~~it~~ in details, its internal circuitry is :



* The resistor, $R \to \infty\ \Omega$ (input resistance) for any ideal voltage amplifier.
* When such an amplifier is connected to any circuit, no current will go into the i/p terminal. However, ∃ current going into or coming out of o/p terminal.
* The i/p terminal labelled – is referred to as inverting i/p & input terminal labelled '+' is non-inverting i/p.

ex. 2.7 Given. $R_1 = 1\ k\Omega$
$R_2 = 10\ k\Omega$
$A = 100,000$
$V_S = 1V$.

Find: V_0, V_1, i_1, i_2, Power absorbed by each resistor, independent voltage source & ideal amplifier (i.e., dependent voltage source).



Non-inverting i/p V_2 is at reference potential, hence, $V_2 = 0$.
Apply nodal analysis at $\underline{\underline{V_1}}$.

$$i_1 + i_2 = 0$$

Ohm's law,

$$\frac{V_S - V_1}{R_1} + \frac{V_0 - V_1}{R_2} = 0 \Rightarrow \frac{R_2 V_S - V_1 R_2 + V_0 R_1 - V_1 R_1}{R_1 R_2} = 0$$

$$\Rightarrow R_2 V_S = (R_1 + R_2) V_1 - R_1 V_0 \longrightarrow (1).$$

Now, $V_o = A(V_2 - V_1)$

$\because V_2 = 0.$

$\therefore V_o = -A V_1$

$$\boxed{V_1 = -\frac{V_o}{A}} \longrightarrow (2) \quad \text{or} \quad A = -\frac{V_o}{V_1}$$

(2) in (1)

$$\Rightarrow R_2 V_s = -(R_1 + R_2)\frac{V_o}{A} - R_1 V_o$$

$$\Rightarrow R_2 V_s = -\left[\frac{1}{A}(R_1 + R_2) + R_1\right] V_o$$

$$\Rightarrow \boxed{V_o = \frac{-R_2 V_s}{R_1 + \frac{1}{A}(R_1 + R_2)}} \longrightarrow (3)$$

Put values of R_1, R_2, V_s & A

$$V_o = \frac{-10(1)}{1 + \frac{1}{100{,}000}(1 + 10)} = -10\,V.$$

$$\& \quad V_1 = -\frac{V_o}{A} = \frac{10}{100{,}000} = 0.1\,mV.$$

$$i_1 = \frac{V_s - V_1}{R_1} = \frac{1 - 0.1}{1} = 0.9\,mA$$

$$i_2 = \frac{V_o - V_1}{R_2} = \frac{-10 - 0.1}{10} = -1\,mA$$

$$P_{R_1} = i^2 R_1, \quad P_{R_2} = i_2^2 R_2 \quad ; \quad P_s = V_s(i_1), \quad P_A = V_o i_2$$

✓ ✓ ✓ ✓

From (3), $$V_o = \frac{-R_2 V_s}{R_1 + \frac{1}{A}(R_1 + R_2)}$$

↳ If A is very large $(A \to \infty)$

then, $V_o = -\frac{R_2 V_s}{R_1}$ or $\boxed{\frac{V_o}{V_s} = -\frac{R_2}{R_1}}$ & $V_1 = -\frac{V_o}{A} \to 0$

as (Gain is ∞)

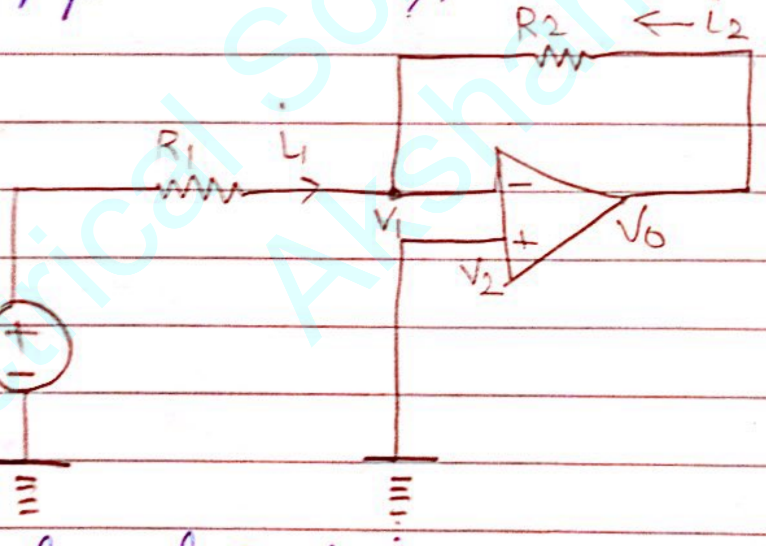
$\Rightarrow V_1 = 0\,V$

~~This is called -ve feedback i.e, portion of o/p is fed back into i/p through R_2.~~

★ The Operational Amplifier (OP-AMP).

- An ideal amplifier with gain ($A \to \infty$) is known as general amplifier or OP-AMP.
- In OP-AMP, $\because$ gain is infinite we must have a feedback resistor b/w o/p & i/p terminals (either inverting or non inverting).

  i.e, when $A \to \infty$, $V_1 = 0$.
- Amplifier takes no i/p currents.



Nodal analysis at V_1,

$$i_1 + i_2 = 0.$$

$$\Rightarrow \frac{V_s - V_1}{R_1} + \frac{V_0 - V_1}{R_2} = 0$$

Now, $V_1 = 0$.

$$\Rightarrow \frac{V_s}{R_1} = -\frac{V_0}{R_2}. \Rightarrow V_0 = -\frac{R_2}{R_1}(V_s)$$

or ★★ $\boxed{\frac{V_0}{V_s} = -\frac{R_2}{R_1} = A}$ → Gain of amplifier

* This circuit is called inverting amplifier

- We have seen $V_1 = 0$ & V_2 is at 0 V, ⇒ no differential b/w the i/p. voltages V_1 & V_2 (Hence $V_1 = V_2$).

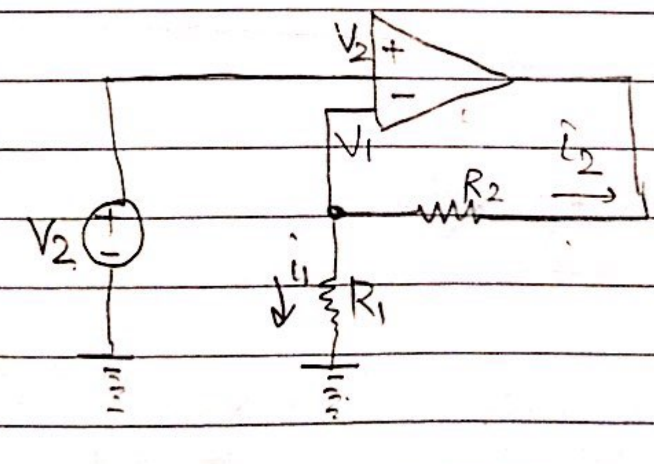
∴ This leads to max gain: $\frac{V_o}{V_S} = -\frac{R_2}{R_1}$

Imp * Hence, cond^ns for <u>Inverting amplifier</u> :-

1. Amplifier takes no i/p currents.
2. Gain is max.
3. -ve feedback is present.
4. Non inverting i/p is connected to ground.
5. $V_1 \sim V_2 \simeq 0$.
6. Inverting i/p serves as signal.

* Cond^ns for <u>Non-inverting amplifier</u>.

1. Inverting i/p is connected to ground.
2. Non-inverting i/p serves as signal.
3. When feedback is given (when R_2 is connected b/w V_1 & V_o), then, $V_1 \sim V_2 \simeq 0$ or $V_1 = V_2$ i.e $A \to \infty$
4. Amplifier takes no i/p current.



<u>KCL at V_1</u>:

$i_1 + i_2 = 0$ &

$$\frac{V_1}{R_1} + \frac{V_1 - V_o}{R_2} = 0.$$

Now, $V_1 = V_2$

$$\Rightarrow \frac{V_2}{R_1} + \frac{V_2 - V_o}{R_2} = 0.$$

$$\Rightarrow V_0 = \frac{R_2 V_1 + R_1 V_2}{R_1}$$

$$\Rightarrow V_0 = \left(\frac{R_2 + R_1}{R_1}\right) V_2 \quad (V_1 \simeq V_2)$$

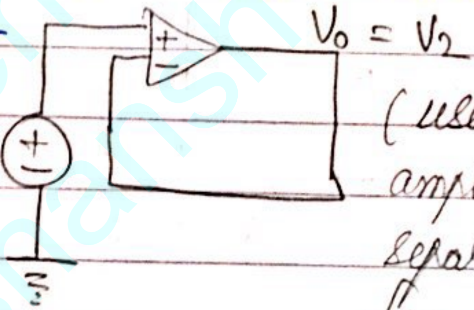
$$\Rightarrow V_0 = \left(1 + \frac{R_2}{R_1}\right) V_2$$

$$\Rightarrow \boxed{\frac{V_0}{V_2} = 1 + \frac{R_2}{R_1}} \quad \text{(OVERALL GAIN)}$$

↳ Non-inverting amplifier.

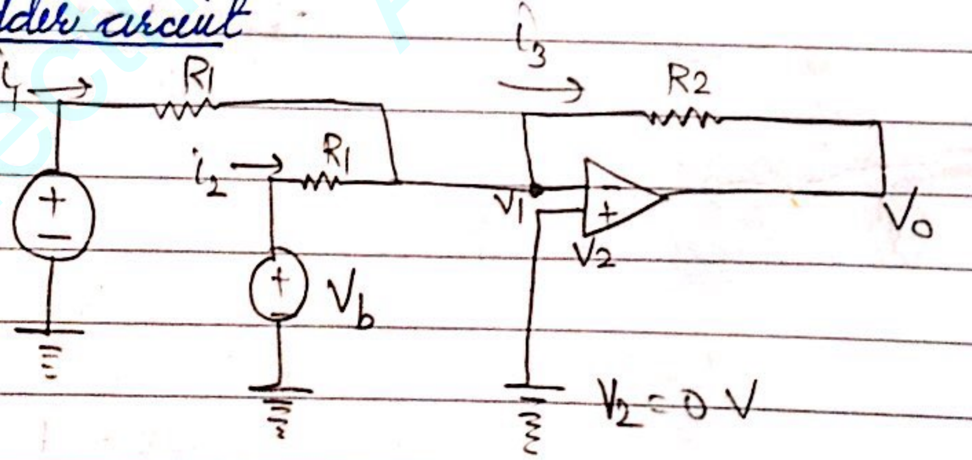
↳ If $R_2 = 0\,\Omega$, then, $V_0 = V_2$

↳ When this cond^n is applied, the resulting OP-Amp is called VOLTAGE FOLLOWER & looks like :-



(used as a buffer amplifier - to separate one circuit from another).

Ex. 2.9 **Adder circuit**



Here, we would obtain o/p voltage v_0 in terms of V_a & V_b.

$\because \exists$ a -ve feedback path, $v_1 = v_2 = 0$

KCL at inverting pt.

$$i_1 + i_2 = i_3 \Rightarrow \frac{V_a}{R_1} + \frac{V_b}{R_1} - \frac{(V_1 - V_0)}{R_2} = 0$$

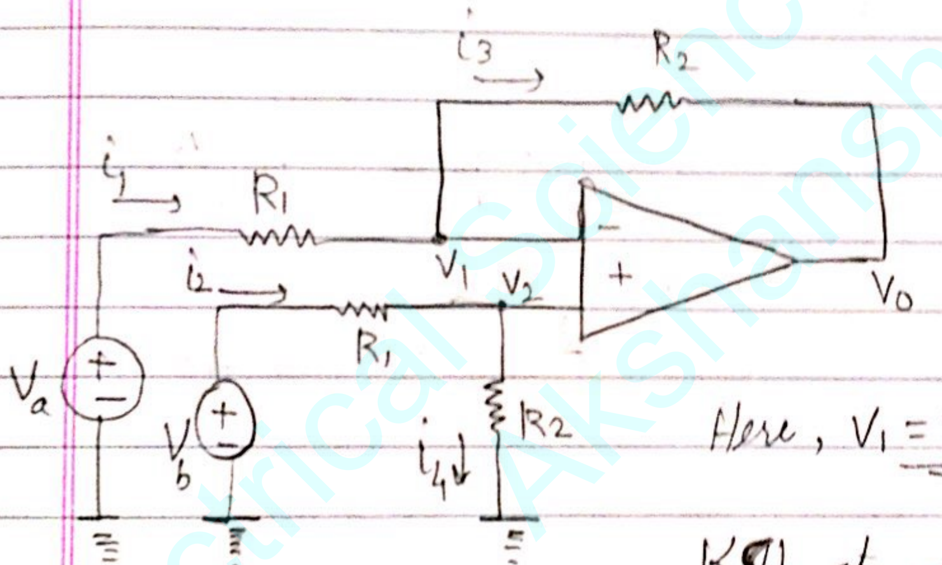
$$\Rightarrow \frac{V_a}{R_1} + \frac{V_b}{R_1} = \frac{\overset{=0}{V_1} - V_0}{R_2}$$

$$\Rightarrow \boxed{V_0 = -\frac{R_2}{R_1}\left(V_a + V_b\right)}$$

→ This circuit is called Adder circuit or Summer

→ Used by DJ's for audio mixer.

ex. 2.10 Difference Amplifier or Differential Amplifier



Find :- o/p voltage (V_0) in terms of V_a & V_b.

Here, $V_1 = V_2 = V$

KCL at inverting i/p,

$$i_1 = i_3$$

$$\Rightarrow \frac{V_a - V_1}{R_1} = \frac{V_1 - V_0}{R_2}$$

$$\Rightarrow \frac{V_a - V}{R_1} = \frac{V - V_0}{R_2}$$

$$\Rightarrow V_0 = V + \frac{R_2}{R_1}\left(V - V_a\right) \longrightarrow (1)$$

KCL at non inverting i/p,

$$i_2 = i_4$$

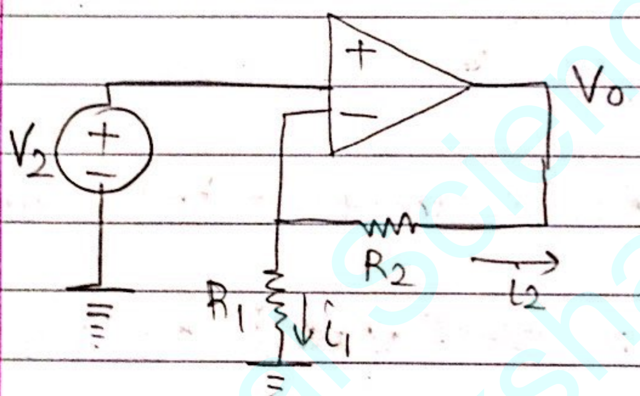
$$\Rightarrow \frac{V_b - V_2}{R_1} = \frac{V_2}{R_2} \Rightarrow \frac{V_b - V}{R_1} = \frac{V}{R_2} \Rightarrow V = V_b\left(\frac{R_2}{R_1 + R_2}\right)$$

$$\Rightarrow \boxed{V_0 = \frac{R_2}{R_1}\left(V_b - V_a\right)}$$

☆ ↳ Differential amplifier.

drill ex 2.8 $R_1 = 1\,k\Omega$
$R_2 = 9\,k\Omega$
$V_2 = 1\,V$

Find :- (a) V_0, i_1, i_2
(b) Power absorbed by each resistor, the independent voltage source and o-p amp.



KCL at inverting pt.

$i_1 = i_2$

$$\Rightarrow \frac{1}{1000} = \frac{1 - V_0}{9000}.$$

$\Rightarrow V_0 = 10\,V.$

$$i_1 = \frac{1}{1000} = 1\,mA$$

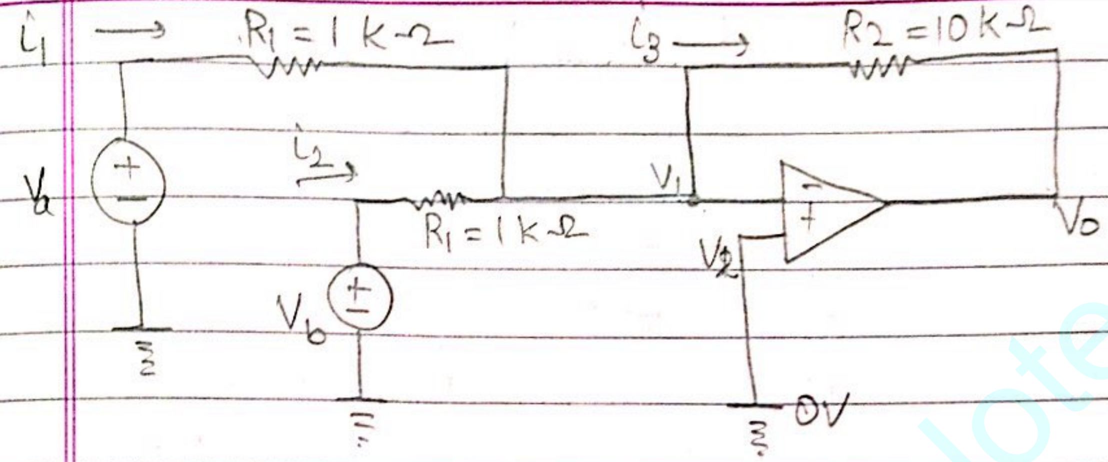
$$i_2 = \frac{-9}{9000} = -1\,mA.$$

$P_1 = 10^{-3}\,W.$
$P_2 = +9 \times 10^{-3}\,W.$
$P_S = V_S(i_S) = 0\,W$
$P_A = V_0 i_2 = -10\,mW.$

drill 2.9 Op-amp adder.

$R_1 = 1\,k\Omega$
$R_2 = 10\,k\Omega$
$V_a = -0.2\cos(2000\pi t)\ V$
$V_b = 0.3\cos(4000\pi t)\ V.$

Find: V_0, i_1, i_2, i_3



KCL

$$i_1 + i_2 = i_3$$

$$\Rightarrow \frac{V_a}{R_1} + \frac{V_b}{R_1} = \frac{V_1 - V_o}{R_2}$$

$$V_1 = 0 \text{ (adder)}$$

$$\Rightarrow \quad V_o = -\frac{R_2}{R_1}\left(0.3\cos(4000\pi t) - 0.2\cos(2000\pi t)\right)$$

$$= \frac{R_2}{R_1}\left(0.2\cos(2000\pi t) - 0.3\cos(4000\pi t)\right)$$

$$V_o = 2\cos(2000\pi t) - 3\cos(4000\pi t)$$

$$i_1 = (-2\times10^{-4})\cos(2000\pi t) \text{ A}$$

$$i_2 = (3\times10^{-4})\cos(4000\pi t) \text{ A}$$

$$i_3 = 0.3\cos(4000\pi t) - 0.2\cos(2000\pi t) \text{ mA}$$

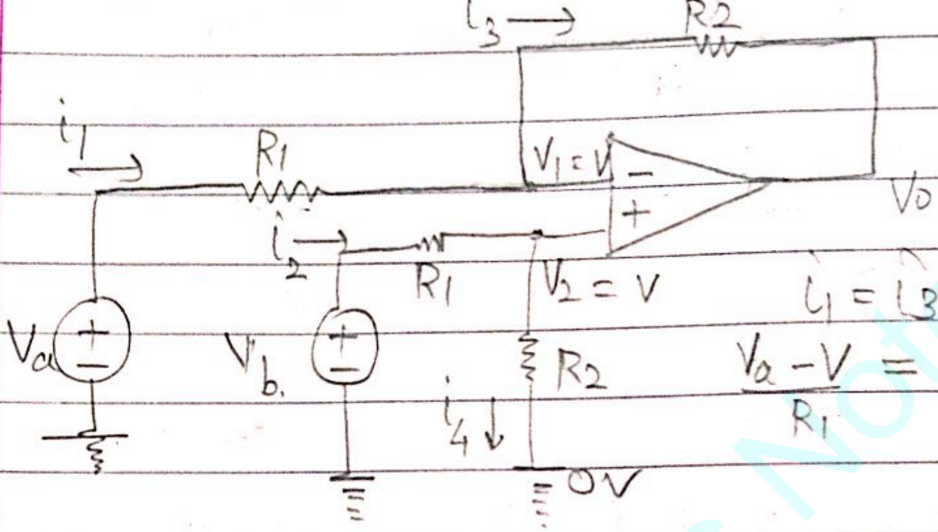
Drill 2.10 Differential amplifier

$R_1 = 1\,k\Omega$ Find: $V_o, v, i_1, i_2, i_3, i_4$

$R_2 = 9\,k\Omega$

$V_a = -0.2\cos(2000\pi t)$

$V_b = 0.3\cos(4000\pi t)$



$$i_1 = i_3$$

$$\frac{V_a - V}{R_1} = \frac{V - V_0}{R_2}$$

$$V_0 = 9\left(0.3\cos(4000\pi t) + 0.2\cos(2000\pi t)\right)$$

$$\frac{V}{R_2} + \frac{V}{R_1} = \frac{V_a}{R_1} + \frac{V_0}{R_2}$$

$$\Rightarrow \frac{V}{9\times\cancel{10^3}} + \frac{V}{\cancel{10^3}} = \frac{V_a}{\cancel{10^3}} + \frac{V_0}{9\times\cancel{10^3}}$$

$$\Rightarrow 10V = 9V_a + V_0$$

$$\Rightarrow V = 0.27\cos(4000\pi t)$$

Now

$$i_1 = i_3 = \frac{V_a - V}{R_1} = \frac{-0.2\cos(2000\pi t) - 0.27\cos(4000\pi t)}{10^3}.$$

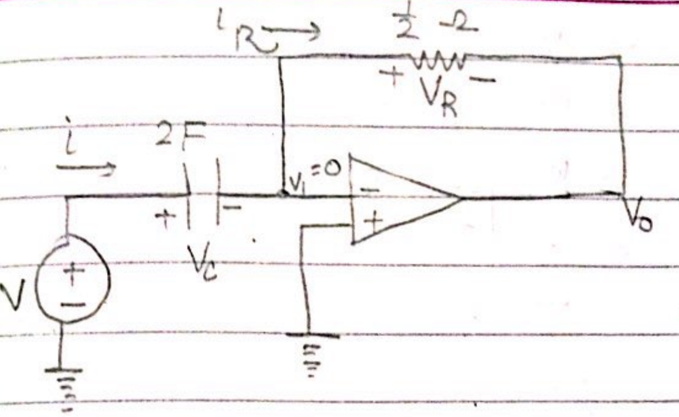
or $$\frac{V_a - V_0}{R_1 + R_2} = -0.2\cos(2000\pi t) - 0.27\cos(4000\pi t)$$

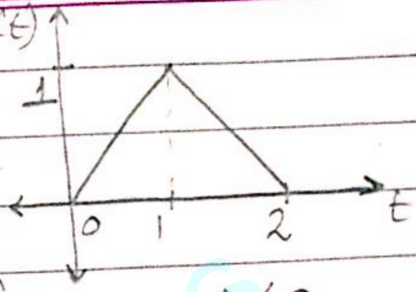
$$i_2 = i_4 = \frac{V_b - 0}{R_1 + R_2} = \frac{V_b}{10} = \frac{0.3\cos(4000\pi t)}{10}$$

$$\Rightarrow i_2 = i_4 = 0.03\cos(4000\pi t) \quad A$$

—x—

ex. 3.4 Find: V_0 in terms of v
op-amp circuit





$$v(t) = \begin{cases} 0 & t<0 \\ t & 0<t<1 \\ -(t-2) & 1<t<2 \\ 0 & t>2 \end{cases}$$

Inverting i/p V_1 is at 0V

So, $V_c = v$

$\therefore\ i = C\dfrac{dV_c}{dt} = 2\dfrac{dv}{dt}$

$\because$ The inputs of op-amp didn't draw any current,

$i_R = i$

So, $V_R = \frac{1}{2} i_R = \frac{1}{2} i = \frac{1}{2}\left(2\frac{dv}{dt}\right) = \frac{dv}{dt}$.

By KVL, $V_o + V_R = 0$

$\Rightarrow V_o = -V_R$

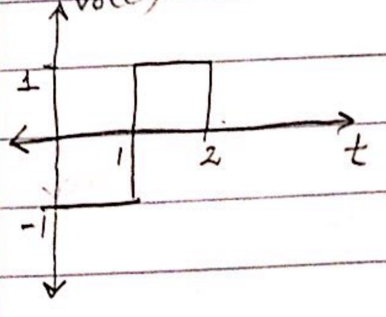
$\Rightarrow \boxed{V_o = -\dfrac{dv}{dt}}$

→ o/p voltage is derivative of i/p voltage.

→ circuit called as differentiator.

o/p voltage:

$$V_o(t) = -\frac{dv}{dt} = \begin{cases} 0 & ; t\le 0 \\ -\frac{d}{dt}(t) = -1 & ; 0<t<1 \\ +1 & ; 1<t<2 \\ 0 & ; t>2 \end{cases}$$



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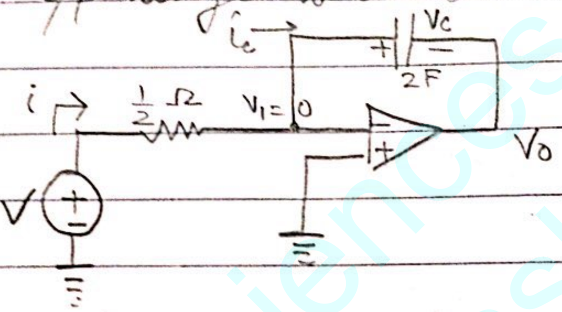
ex 3.7 Find :- o/p voltage v_o in terms of i/p voltage v of op-amp



$\because$ $v_1 = 0V$; $i = 2v$,

$\because$ i/p terminals dont draw any current,

$$i_c = i = 2v$$

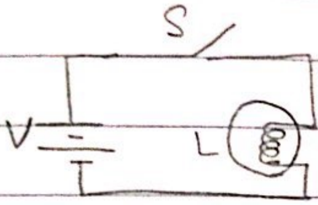
$$\therefore \quad v_c = \frac{1}{c}\int_{-\infty}^{t} i_c(t)\,dt = \frac{1}{2}\int_{-\infty}^{t} 2v(t)\,dt = \int_{-\infty}^{t} v_{(t)}\,dt$$

KVL $\quad v_o + v_c = 0 \Rightarrow v_o = -v_c$

$$\therefore \quad v_o(t) = -\int_{-\infty}^{t} v_{(t)}\,dt .$$

Chapter - 11
DIGITAL LOGIC CIRCUITS.

- can be expressed by 0 ~~or~~ &/or 1.



When S is closed, $S = 1$,
L is ON, $L = 1$.
When S is open, $S = 0$
L is OFF, $L = 0$
$\therefore S = L$.

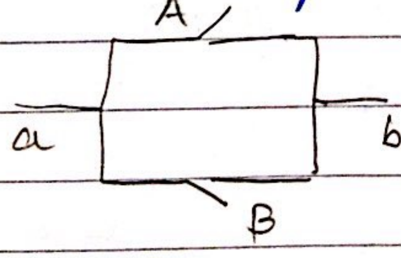
Truth table for L & S

(a)		(b)	
S	L(=S)	S	$\bar{L}$
0	1	0	1
1	1	1	0

$\bar{L}$: complement ~~component~~ of L.
$\bar{L} = \bar{S}$.

☆ Switching circuits:
Circuit shown above where values of L depend upon S, &, it is ON or OFF accordingly.

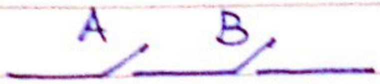
☆ OR CIRCUIT (GATE):
- Consider 2 switches A & B connected in ||. Battery & light bulb are present, but, not shown.



OR

A	B	L = A+B
0	0	0
0	1	1
1	0	1
1	1	1

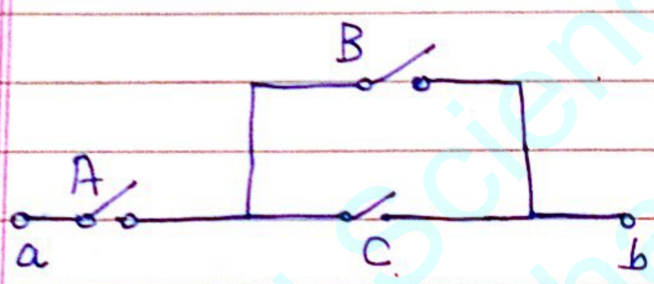
✯ AND GATE



A	B	$L = A.B$
0	0	0
1	0	0
0	1	0
1	1	1

0 ≡ open
1 ≡ closed

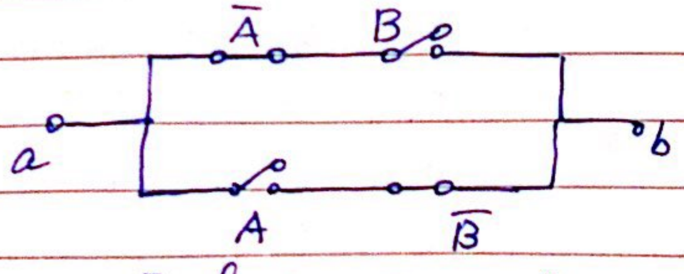
✯ 3 switch ~~combin~~ combinations



$A.(B+C)$
and or

	A	B	C	$L = A(B+C)$
0	0	0	0	0
1	0	0	1	0
2	0	1	0	0
3	0	1	1	0
4	1	0	0	0
5	1	0	1	1
6	1	1	0	1
7	1	1	1	1

✯ Concept of Complement.



$\bar{A}$, $\bar{B}$: complement of A & B.

Exclusive OR operⁿ.

Truth table

A	B	$L = \bar{A}B + A\bar{B}$
1	0	1
0	1	1
0	0	0
1	1	0

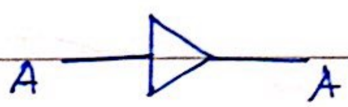
* Binary operⁿˢ such as AND, OR, exclusive ~~ex~~ OR & complement are called logical operⁿˢ & circuits that perform these operⁿˢ are called Logic gates.

LOGIC GATES

1. BUFFER :

A digital logic gate whose i/p is a binary variable (0 or 1) and whose o/p is also A.

Symbol :-

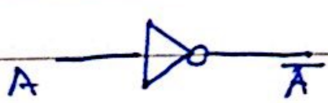


A	L
0	0
1	1

2. INVERTER or NOT GATE :-

i/p :- A   o/p : $\bar{A}$.

Symbol :-

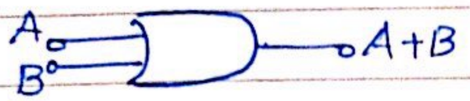


A	$L=\bar{A}$
0	1
1	0

3. OR GATE :

i/p :- A and B (or more) o/p : $L = A + B$ (+ more)

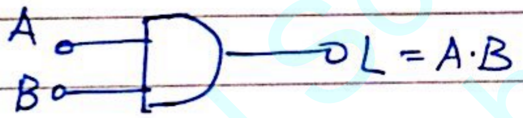
Symbol :-



A	B	$L = A + B$
0	0	0
0	1	1
1	0	1
1	1	1

4. AND GATE

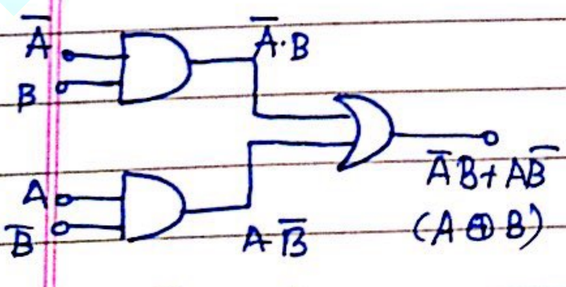
i/p :- A & B (or more) o/p :- $L = A \cdot B$ (or more)



A	B	$L = A \cdot B$
1	0	0
0	1	0
0	0	0
1	1	1

5. EXCLUSIVE OR GATE

i/p :- A & B o/p :- $A \oplus B = \bar{A}B + A\bar{B}$

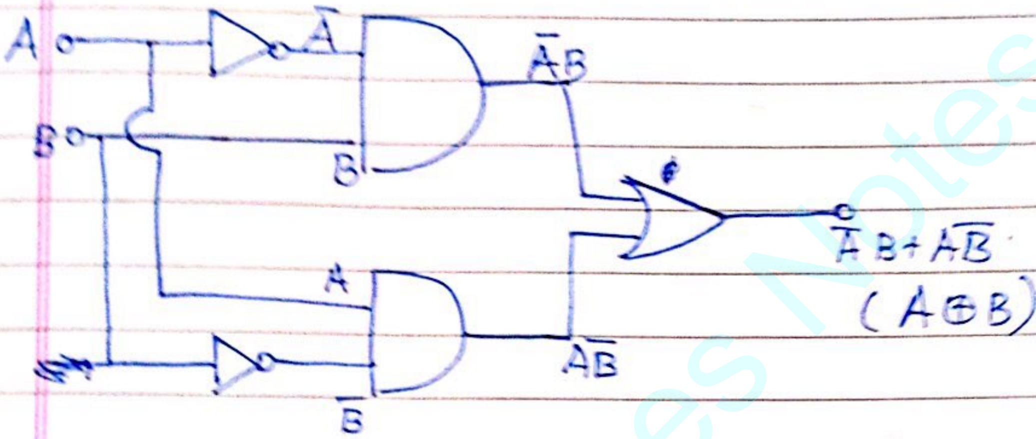


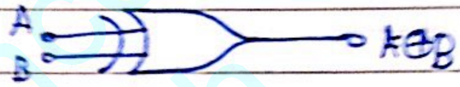
A	B	$L = \bar{A} \oplus B$
1	0	1
0	1	1
0	0	0
1	1	0

~~Symbol~~

* Exclusive or gate can be written by using AND & OR gates.

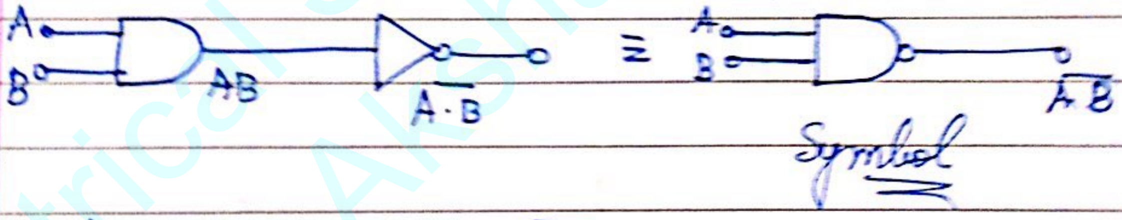
Another way for making exclusive OR circuit :-



Circuit Symbol :- 

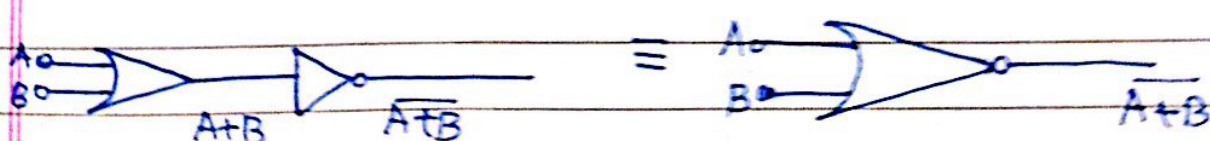
6. NAND GATE

Combinⁿ of AND & NOT gate.



A	B	$L = \overline{A \cdot B}$
1	0	1
0	1	1
0	0	1
1	1	0

7. NOR gate :- Combinⁿ of OR & NOT gate.

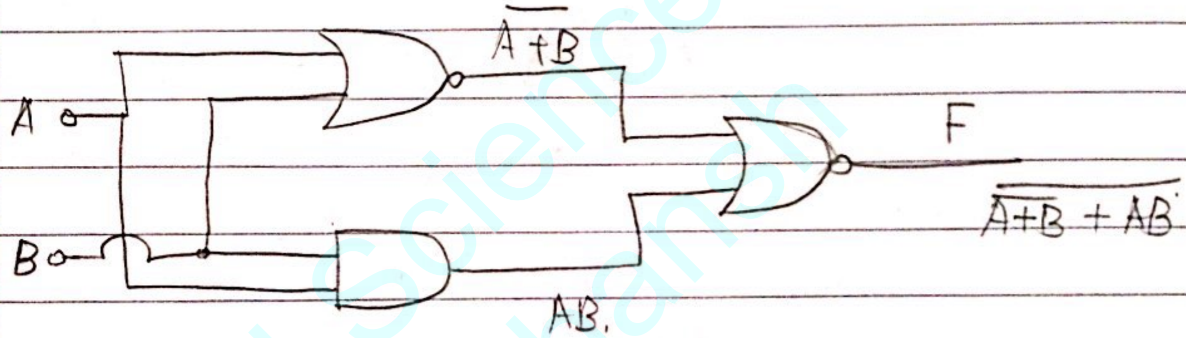


the truth table.

A	B	$L = \overline{A+B}$
1	0	0
0	1	0
0	0	1
1	1	0

Q. Consider a logic circuit,

$$F = \overline{\overline{A+B} + AB}$$



A	B	$\overline{A+B}$	AB	$\overline{\overline{A+B}+AB}$
1	0	0	0	1
0	1	0	0	1
0	0	1	0	0
1	1	0	1	0

★ RULES for BOOLEAN ALGEBRA.

$A \cdot 1 = A$	$A + 0 = A$
$A \cdot A = A$	$A + A = A$
$A \cdot 0 = 0$	$A + 1 = 1$
$A \cdot \overline{A} = 0$	$A + \overline{A} = 1$

Involution $\overline{\overline{A}} = A$.

Commutative $AB = BA$ & $A+B = B+A$

Associative :- $A(BC) = (AB)C$ & $A+(B+C) = (A+B)+C$

Distributive :- $A(B+C) = AB + AC$ & $\underbrace{A + BC = (A+B)(A+C)}_{**}$

Absorption :- $A + AB = A$.

$$\left(A\cdot 1 + A\cdot B = A\underbrace{(1+B)}_{1} = A\cdot 1 = A \right)$$

$$A(A+B) = A$$

$$(AA + AB = A + AB = A)$$

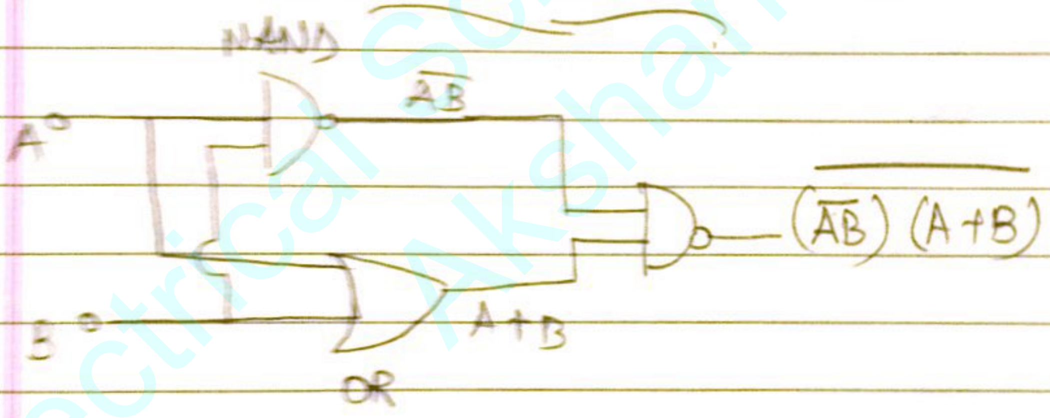
$$A + \bar{A}B = A + B$$

$$((A+\bar{A})(A+B) = 1(A+B) = A+B.$$

$$A(\bar{A}+B) = AB$$

$$(A\bar{A} + AB = 0 + AB = AB)$$

Eg:-



A	B	$\overline{AB}$	A+B	$\overline{(\overline{AB})(A+B)}$
1	0	1	1	0
0	1	1	1	0
0	0	1	0	1
1	1	0	1	1

* De-Morgan's theorem :

$\overline{A+B} = \bar{A}\cdot\bar{B}$ & $\overline{AB} = \bar{A} + \bar{B}$.

Q- TPT : $\overline{\overline{A+B} + AB} = \bar{A}B + A\bar{B}$

LHS

$\overline{\overline{A+B} + AB} = \overline{\overline{A+B}}\cdot\overline{AB}$

$= (A+B)\,\overline{AB}$

$= (A+B)\,[\bar{A}+\bar{B}]$

$= \underbrace{A\bar{A}}_{0} + \bar{A}B + A\bar{B} + \underbrace{B\bar{B}}_{0}$

$= \bar{A}B + A\bar{B}$

$=$ RHS H.P

Q TPT : $\overline{(\overline{AB})(A+B)} = \bar{A}\bar{B} + AB$

LHS $= \overline{(\overline{AB})(A+B)} = \overline{\overline{AB}} + \overline{A+B}$

$= AB + \bar{A}\cdot\bar{B} =$ RHS H.P

* Duality :

2 expressions are called duals if you interchange

AND & OR

0's & 1's

ex :- AB and A+B

$A+0=A$ & $A\cdot 1 = A$.

$B\cdot 0 = 0$ & $B+1 = 1$

$A(BC) = (AB)C$ & $A+(B+C) = (A+B)+C$.

☆ The change that occured in laws.

- $A(BC) = (AB)C$ & $A+(B+C) = (A+B)+C$
  — Associative law
- $A\cdot(B+C) = AB+AC$ & $A+BC = (A+B)(A+C)$
  — Distributive Law.
- $A+AB = A$ & $A(A+B) = A$
  — Absorption Law.
- $A+\bar{A}B = A+B$ & $A(\bar{A}+B) = AB$
  — Absorption Law.
- $\overline{A+B} = \bar{A}\bar{B}$ & $\overline{AB} = \bar{A}+\bar{B}$
  — De morgan's law.

☆ Dual of exclusive OR

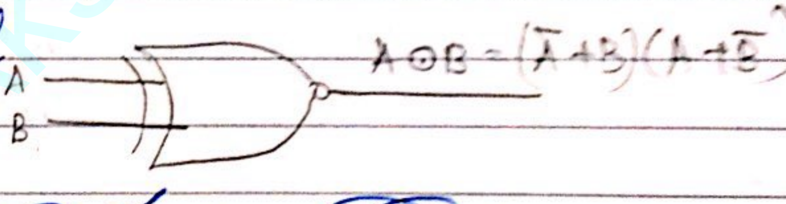
$$A \oplus B = \bar{A}B + A\bar{B}.$$

becomes exclusive NOR & denoted by

$$A \odot B = (\bar{A}+B)(A+\bar{B})$$

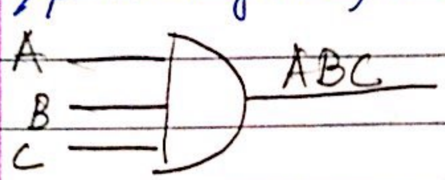
* Exclusive NOR

↳ circuit symbol

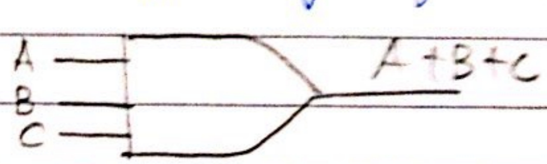


☆ Multiple Input Gates.

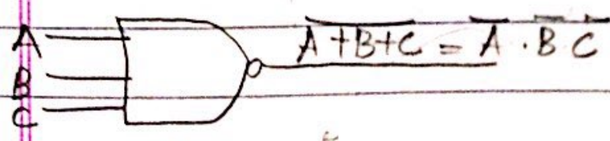
- i/p AND gate for 3 i/p.



- i/p OR gate for 3 i/p.

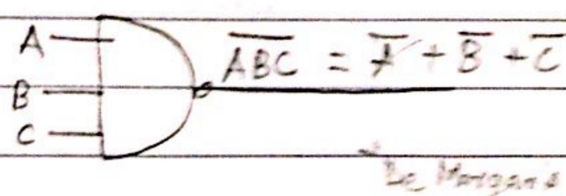


- i/p NOR gate for 3 i/p.



De Morgan's

- i/p NAND gate for 3 i/p.



De Morgan's

Q. Find dual of $(\overline{A}+\overline{B})(A+B)$

$$(\overline{A}\cdot+\overline{B})(A+B) = \overline{A}\,\overline{B} + AB.$$

A	B	$\overline{A}$	$\overline{B}$	AB	$\overline{A}\,\overline{B}+AB$
1	0	0	1	0	0
0	1	1	0	0	0
0	0	1	1	0	1
1	1	0	0	1	1

☆ Sum of Products.

- A given f^n F has n variables and the corresponding truth table has 2^n rows.
- Suppose,

$$F = \overline{A}\,\overline{B}C + \overline{A}B\overline{C} + A\overline{B}\,\overline{C} + ABC$$

F has 4 terms called MINTERMS which are combined by OR (sum) oper^n. F is said to be the sum of 4 minterms.

- Every minterm consists of ~~4~~ 3 variables, each being complemented or uncomplemented which are combined by the AND (product) oper^n.
- Because AND oper^n is represented as multiplic^n, each of the 4 minterms is said to be product of 3 variables.
- For these reasons, the expression for the Boolean algebra f^n F is said to be in the form of sum of products.
- For a boolean f^n of 3 variables, $\exists$ $2^3 = 8$ minterms — 1 for each row.

Truth table for Boolean f^n F.

A	B	C	F	Minterms	Minterms for variables A,B,C	
0	0	0	0	0	m_0	$\bar{A}\,\bar{B}\,\bar{C}$
0	0	1	1	1	m_1	$\bar{A}\,\bar{B}\,C$
0	1	0	1	1	m_2	$\bar{A}\,B\,\bar{C}$
0	1	1	0	0	m_3	$\bar{A}\,B\,C$
1	0	0	1	1	m_4	$A\,\bar{B}\,\bar{C}$
1	0	1	0	0	m_5	$A\,\bar{B}\,C$
1	1	0	0	0	m_6	$A\,B\,\bar{C}$
1	1	1	1	1	m_7	$A\,B\,C$

Now, the expression for a Boolean f^n F is obtained by summing the minterms that correspond to rows in which $\exists$ 1 in the column labelled F.

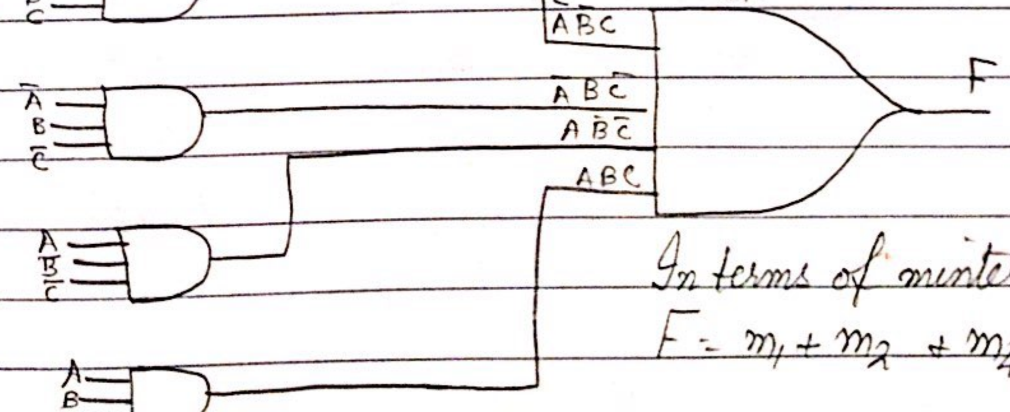
$$F = m_1 + m_2 + m_4 + m_7$$
$$= \bar{A}\,\bar{B}\,C + \bar{A}\,B\,\bar{C} + A\,\bar{B}\,\bar{C} + ABC$$

- A logic circuit whose o/p is described by this Boolean f^n:

$$F = \bar{A}\,\bar{B}C + \bar{A}\,B\bar{C} + A\bar{B}\bar{C} + ABC$$

is like shown below.

We will have 4 AND Gates with 3 i/ps & one 4 i/p OR Gate



In terms of minterms;
$F = m_1 + m_2 + m_4 + m_7$.

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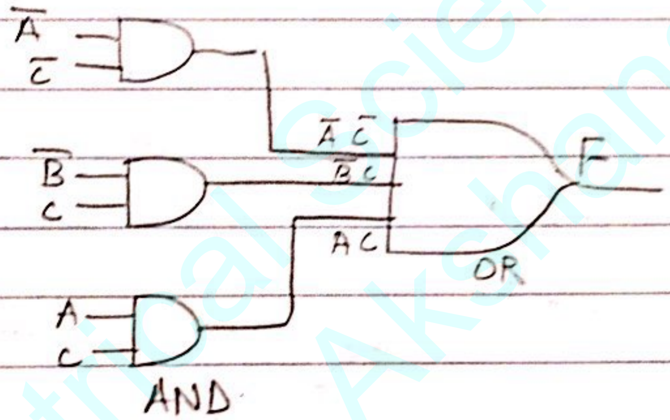
Q: Express the Boolean f^n

$$F = \bar{A}\bar{C} + (A+\bar{B})C = \bar{A}\bar{C} + \bar{B}C + AC \longrightarrow (1)$$

as a sum of minterms

$\times$ (1) by 1 & use $A + \bar{A} = 1$.

$$= \bar{A}\bar{C}\cdot 1 + AC1 + \bar{B}C\cdot 1$$
$$= \bar{A}[B+\bar{B}]\bar{C} + A[B+\bar{B}]C + [A+\bar{A}]\bar{B}C$$
$$= \bar{A}B\bar{C} + \bar{A}\bar{B}\bar{C} + ABC + A\bar{B}C + A\bar{B}C + \bar{A}\bar{B}C$$
$$= \bar{A}B\bar{C} + \bar{A}\bar{B}\bar{C} + ABC + A\bar{B}C + \bar{A}\bar{B}C$$
$$= m_2 + m_0 + m_7 + m_1 + m_5$$
$$= m_0 + m_1 + m_2 + m_5 + m_7 \checkmark$$



Q: Express the Boolean f^n:- $F = \bar{A}\bar{B} + B\bar{C}$ as a sum of minterms

$$F = \bar{A}\bar{B} + B\bar{C} \longrightarrow (1)$$

$\times$ (1) by 1.

$$\Rightarrow F = \bar{A}\bar{B}\cdot 1 + 1\, B\bar{C}$$
$$= \bar{A}\bar{B}(C+\bar{C}) + (A+\bar{A})B\bar{C}$$
$$= \bar{A}\bar{B}C + \bar{A}\bar{B}\bar{C} + AB\bar{C} + \bar{A}B\bar{C}$$
$$= m_1 + m_0 + m_6 + m_2$$
$$= m_0 + m_1 + m_2 + m_6.$$

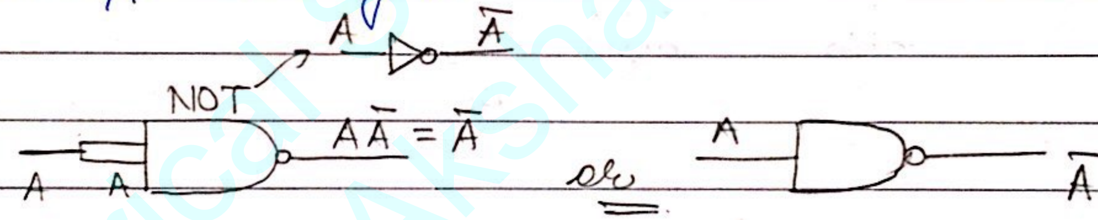
Q. Express $F = A\cdot\bar{B} + B\bar{C} + AB\bar{C} + \bar{A}C$ as a sum of minterms → (1)

× (1) by 1, some terms

$$\Rightarrow F = A\bar{B}(C+\bar{C}) + (A+\bar{A})B\bar{C} + AB\bar{C} + \bar{A}(B+\bar{B})C$$
$$= A\bar{B}C + A\bar{B}\bar{C} + AB\bar{C} + \bar{A}B\bar{C} + AB\bar{C} + \bar{A}BC + \bar{A}\bar{B}C$$
$$= m_5 + m_4 + m_6 + m_2 + m_3 + m_1$$
$$F = m_1 + m_2 + m_3 + m_4 + m_5 + m_6.$$

✲ NAND GATE REALIZATIONS :

- Suppose: same i/p is applied to both i/ps of a 2 i/p NAND gates.



- The o/p of a NAND gate is always a complement. Hence, the gate is an inverter, i.e, NOT gate.
- This is NAND gate realizⁿ of a NOT gate.

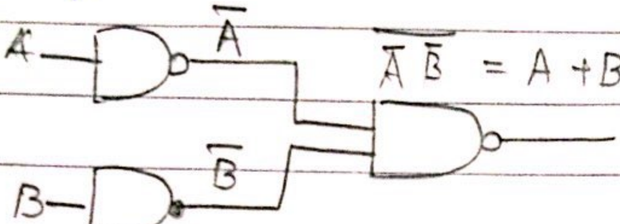
✲ Let's see how NAND gates can be connected to form an OR gate & AND gate.

By De Morgan's Law:

$$A + B = \overline{\overline{A+B}} = \overline{\bar{A}\,\bar{B}}$$

This expression can be realized by a logic circuit which is an OR Gate. We know, $AB = \overline{\overline{AB}}$. So, this can be realized by a circuit which is an AND gate.

2 i/ps A & B.



A+B : o/p of OR gate.

* NAND gate realiz^ns of AND gate:

AB: o/p of AND gate

- ∵ any Boolean f^n can be implemented with AND, OR and NOT gates, it can also be implemented using only NAND gates.
- This is also because AND, OR & NOT gates can be constructed from NAND gates.

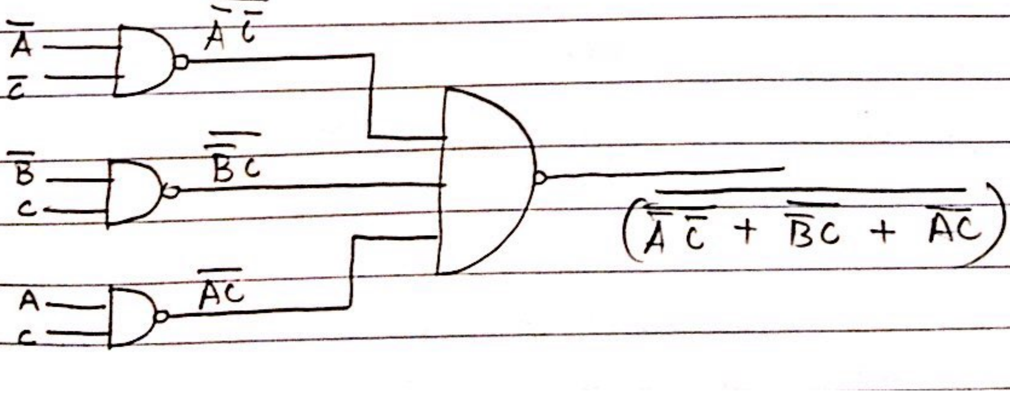
ex Use De-Morgan's theorem & determine NAND gate realiz^n of

$$F = \bar{A}\bar{C} + \bar{B}C + AC.$$

$$F = \overline{\overline{\bar{A}\bar{C} + \bar{B}C + AC}}$$

$$= \overline{(\overline{\bar{A}\bar{C}})\,(\overline{\bar{B}C})\,(\overline{AC})}$$

This can be shown by a 2 level NAND circuit.



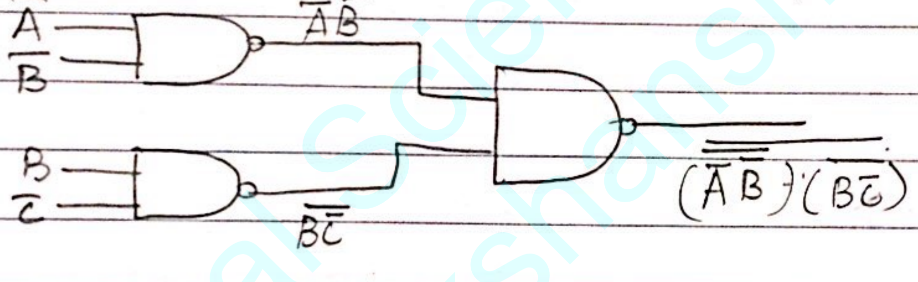
This is NAND gate implementⁿ of F

Reason → * NAND gate : also called Universal Gate.
* Any arbitrary f^n can be implemented by a logic circuit consisting of NAND gates.

11.11 ex 2 level realizⁿ of $F = \bar{A}\bar{B} + B\bar{C}$ using NAND gates.

Sl Involution

$$F = \overline{\overline{\bar{A}\bar{B} + B\bar{C}}}$$
$$= \overline{\overline{\bar{A}\bar{B}} \cdot \overline{B\bar{C}}} \quad \text{(De Morgan's thm)}$$



☆ Product of Sums.

1.
- Given a truth table, the Boolean f^n, F, can be expressed as a f^n which is a sum of minterms.
- An alternate equivalent can also be obtained.
- F as a sum of minterms is

$$F = \bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC.$$

Complement of $F = \bar{F} = AB\bar{C} + A\bar{B}C + \bar{A}BC + \overline{ABC}$.

Truth table.

A	B	C	F	$\overline{F}$		
0	0	0	0	1	m_0	$\overline{A}\,\overline{B}\,\overline{C}$
0	0	1	1	0	m_1	$\overline{A}\,\overline{B}\,C$
0	1	0	1	0	m_2	$\overline{A}\,B\,\overline{C}$
0	1	1	0	1	m_3	$\overline{A}\,B\,C$
1	0	0	1	0	m_4	$A\,\overline{B}\,\overline{C}$
1	0	1	0	1	m_5	$A\,\overline{B}\,C$
1	1	0	0	1	m_6	$A\,B\,\overline{C}$
1	1	1	1	0	m_7	ABC.

Here, $\overline{F} = m_0 + m_3 + m_5 + m_6$

$$= \overline{A}\,\overline{B}\,\overline{C} + \overline{A}BC + A\overline{B}C + AB\overline{C}.$$

Sum of product

$$\Rightarrow \overline{(\overline{F})} = \overline{\overline{A}\,\overline{B}\,\overline{C} + \overline{A}BC + A\overline{B}C + AB\overline{C}}$$

$$= \left(\overline{\overline{A}\,\overline{B}\,\overline{C} + \overline{A}BC}\right)\left(\overline{A\overline{B}C + AB\overline{C}}\right)$$

$$= \left(\overline{\overline{A}\,\overline{B}\,\overline{C}}\right)\left(\overline{\overline{A}BC}\right)\left(\overline{A\overline{B}C}\right)\left(\overline{AB\overline{C}}\right)$$

$$\Rightarrow F = (A+B+C)(A+\overline{B}+\overline{C})(\overline{A}+B+\overline{C})(\overline{A}+\overline{B}+C)$$

Product of sum

(By De Morgan's Law).

- each sum is called maxterm. The maxterms are designated as M_0, M_1, M_2, M_3. M_4, M_5, M_6, M_7.
- each maxterm consists of a sum of 3 variables, where each variable is either complemented &/or uncomplemented.
- given the truth table for a Boolean f^n, F, an alternate expression to the sum of minterms is obtained by taking the product

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Page

of maxterms that correspond to the rows in which ∃ a 0 in the column labelled as F (as column labelled as $\bar{F} = 1$).

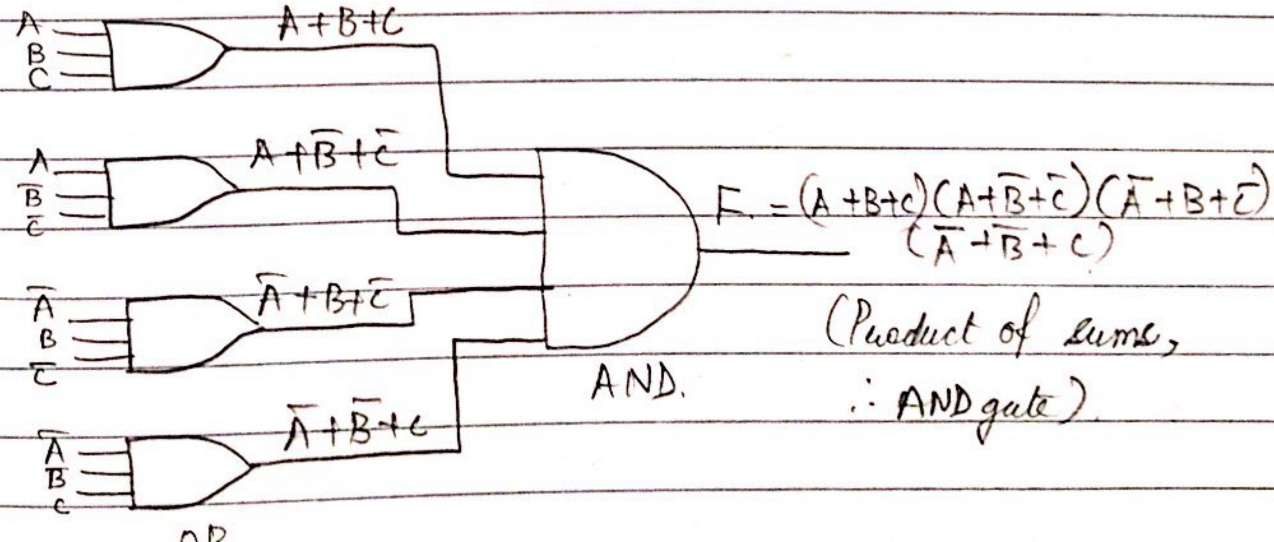
Truth table for F and $\bar{F}$

A	B	C	F	$\bar{F}$	Maxterms of variables A, B & C.
0	0	0	0	1	$M_0 = A+B+C$
0	0	1	1	0	$M_1 = A+B+\bar{C}$
0	1	0	1	0	$M_2 = A+\bar{B}+C$
0	1	1	0	1	$M_3 = A+\bar{B}+\bar{C}$
1	0	0	1	0	$M_4 = \bar{A}+B+C$
1	0	1	0	1	$M_5 = \bar{A}+B+\bar{C}$
1	1	0	0	1	$M_6 = \bar{A}+\bar{B}+C$
1	1	1	1	0	$M_7 = \bar{A}+\bar{B}+\bar{C}$

$$\therefore F = M_0 M_3 M_5 M_6$$

$$\Rightarrow F = (A+B+C)(A+\bar{B}+\bar{C})(\bar{A}+B+\bar{C})(\bar{A}+\bar{B}+\bar{C})$$

- The 2nd level logic circuit for this f^n is shown below. Here, ∃ 4 OR gates with 3 i/ps each & one 4 i/p AND gate.



(Product of sums, ∴ AND gate).

Q. Express F as a product of maxterms. (Simple method)

M1

$$F = \bar{A}\bar{B} + B\bar{C}$$
$$= \bar{A}\bar{B}(\bar{C}+C) + (A+\bar{A})B\bar{C}$$
$$= \bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}C + AB\bar{C} + \bar{A}B\bar{C}$$
$$= m_1 + m_0 + m_6 + m_2$$

(F corresponds to terms which have 1 in F column)

Remaining 4 minterms correspond to $\bar{F}$

($\bar{F}$ corresponds to terms which have 1 in $\bar{F}$ column).

$$\therefore \bar{F} = m_3 + m_4 + m_5 + m_7$$

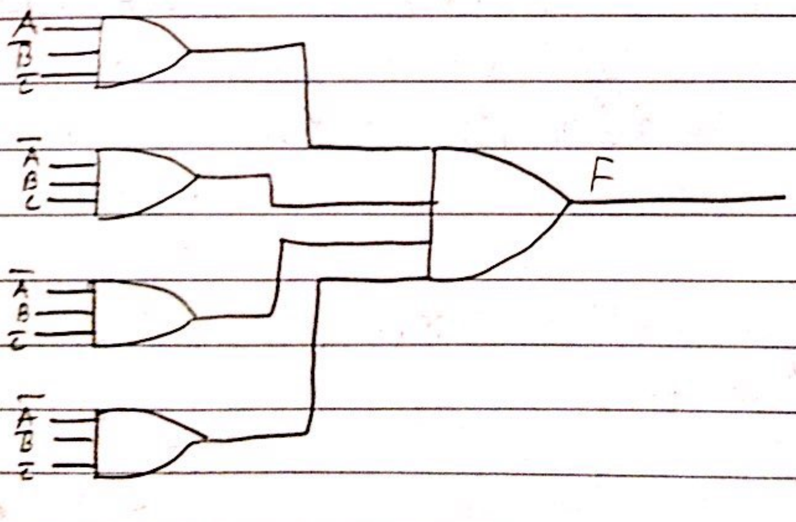
Now,

$$\overline{(\bar{F})} = \overline{m_3 + m_4 + m_5 + m_7}$$
$$= \bar{m}_3 \cdot \bar{m}_4 \, \bar{m}_5 \, \bar{m}_7 \quad \text{(DeMorgan's)}$$

$$\Rightarrow F = M_3 M_4 M_5 M_7$$

* The complement of minterms = Maxterms.

eg: $\bar{m}_0 = M_0$, $\bar{m}_1 = M_1$ ...



11.12

Q. Express F as a product of maxterms.

$$F = \overline{A}\,\overline{C} + (A+\overline{B})C$$

M2 (using Algebraic manipulation)

Distributive law: $A + BC = (A+B)(A+C)$

$$F = \underbrace{(\overline{A}\,\overline{C})}_{A} + \underbrace{(A+\overline{B})}_{B}\underbrace{C}_{C}$$

$$\Rightarrow F = (\overline{A}\,\overline{C} + A + \overline{B})(\overline{A}\,\overline{C} + C)$$

$$\Rightarrow F = (A + \overline{A}\,\overline{C} + \overline{B})(C + \overline{A}\,\overline{C}) \longrightarrow ①$$

Consider $A + \overline{A}\,\overline{C}$

$\times$ A by $1+\overline{C}$ $(\because 1+\overline{C} = 1)$

$$\Rightarrow A(1+\overline{C}) + \overline{A}\,\overline{C}$$

$$\Rightarrow A + A\overline{C} + \overline{A}\,\overline{C}$$

$$= A + \overline{C}(\overline{A}+A)$$

$$= A + \overline{C}$$

||ly, $C + \overline{C}\,\overline{A} = C + \overline{A}$.

So, eqⁿ ① becomes

$$F = \underbrace{(A+\overline{C}+\overline{B})}_{\text{max term}}\underbrace{(C+\overline{A})}_{B \text{ not there}}$$

$$= (A+\overline{B}+\overline{C})(\overline{A} + 0 + C)$$

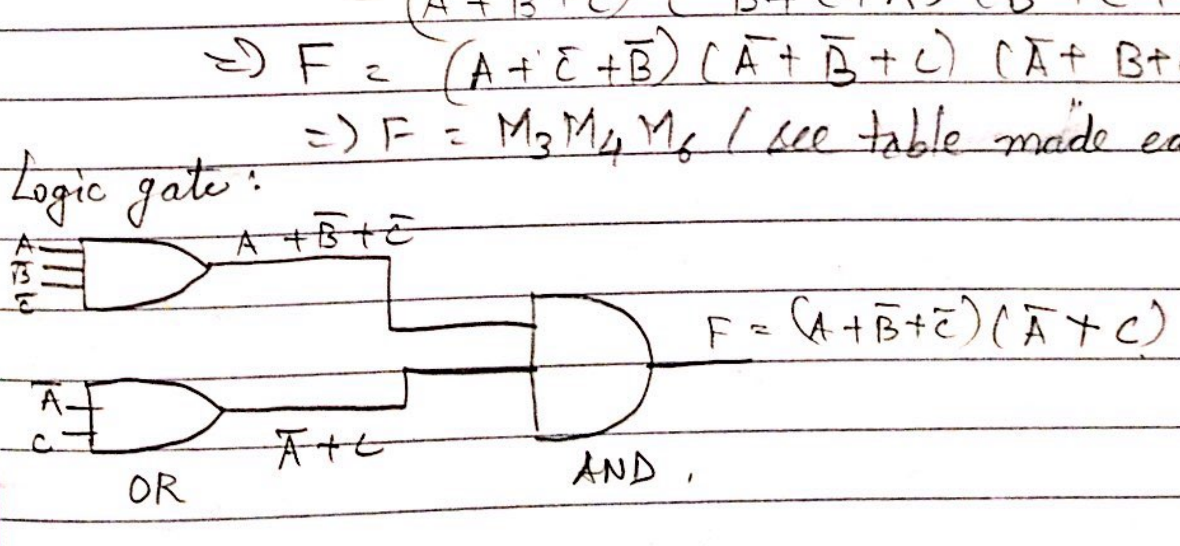
$$= (A+\overline{B}+\overline{C})(\overline{A} + B\overline{B} + C)$$

$$= (A+\overline{B}+\overline{C})(B + C + \overline{A})(\overline{B} + C + \overline{A})$$

$$\Rightarrow F = (A+\overline{C}+\overline{B})(\overline{A}+\overline{B}+C)(\overline{A}+B+C)$$

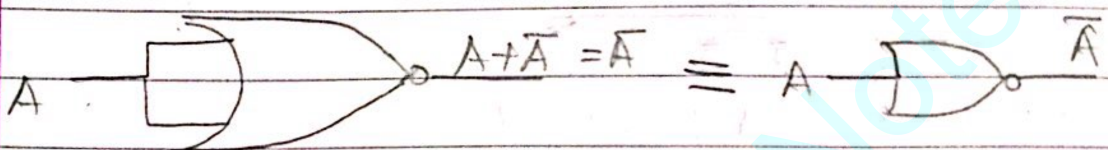
$$\Rightarrow F = M_3 M_4 M_6 \text{ (see table made earlier)}$$

Logic gate:



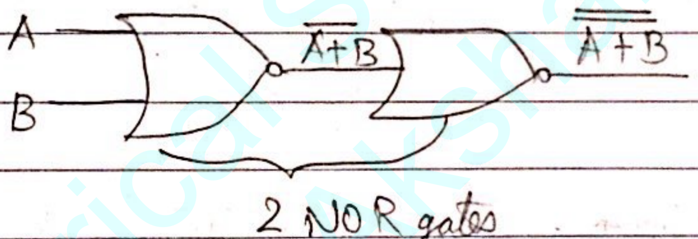
☆ NOR GATE REALIZATION.

- We show that AND, OR and NOT gates can be constructed from NOR gates (same way as we did for NAND).



- Connecting both i/p of a NOR gate together, we obtain NOT gate.

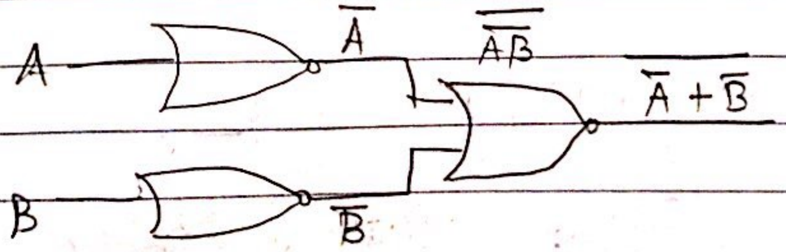
Now, we know $A+B = \overline{\overline{A+B}}$. So, connection of ~~nor~~ NOR gates will give OR gate.



$= \underbrace{A+B}_{\text{OR gate}}$

Now, Also, $AB = \overline{\overline{AB}} = \overline{\overline{A}+\overline{B}}$, then, NOR gate circuit realizes an AND gate.

* Just like NAND gate, NOR gate is also a universal gate.



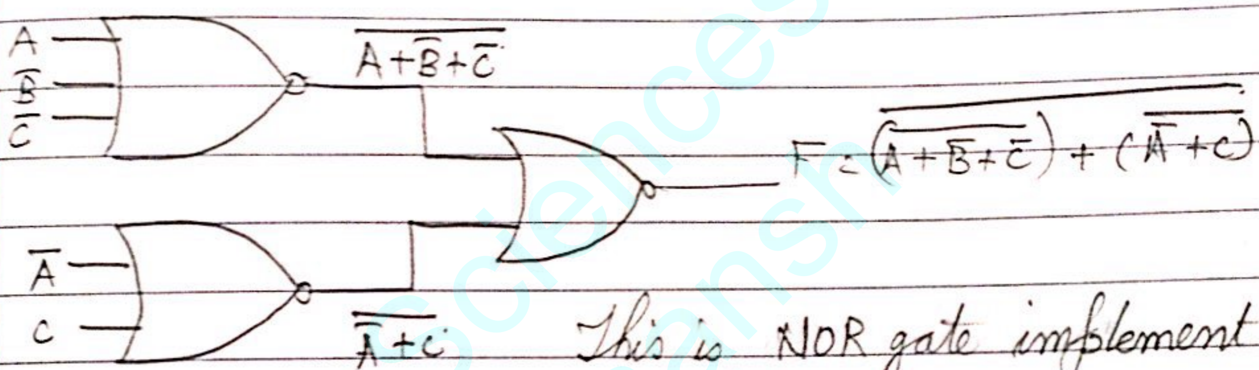
$\overline{\overline{A}+\overline{B}} = \underbrace{AB}_{\text{AND gate}}$

ex 11.3

Q. For f^n $F = (A + \overline{B} + \overline{C})(\overline{A} + C)$
Implement it by a 2-level NOR circuit

$$F = (A + \overline{B} + \overline{C})(\overline{A} + C)$$
$$= \overline{\overline{(A + \overline{B} + \overline{C})(\overline{A} + C)}}$$
$$= \overline{\overline{(A + \overline{B} + \overline{C})} + \overline{(\overline{A} + C)}}$$

The 2 level NOR circuit is :-



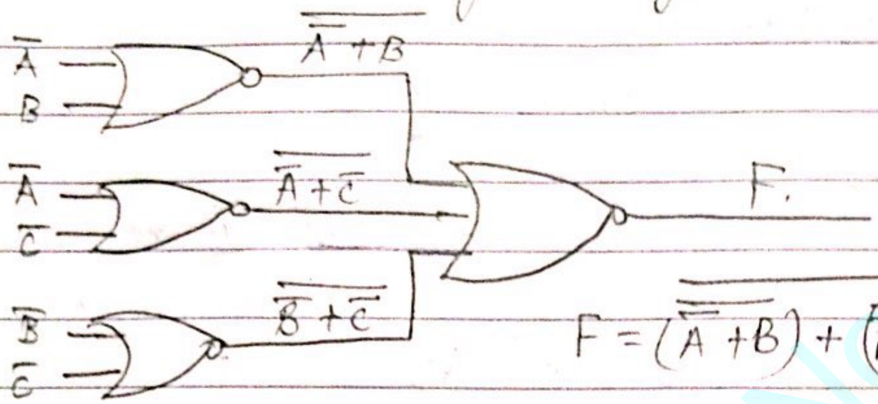
This is NOR gate implement^n of F

Drill ex 11.13 Use de-Morgan's thm. to obtain a 2 level NOR gate realiz^n of $F = \overline{A}\,\overline{B} + B\overline{C}$.

We know, $(A + BC) = (A+B)(A+C)$

$$\Rightarrow F = \overline{A}\,\overline{B} + B\overline{C}$$
$$= (\overline{A}\,\overline{B} + B)(\overline{A}\,\overline{B} + \overline{C})$$
$$= (\overline{A} + B)\underbrace{(\overline{B} + B)}_{\to 1}(\overline{A} + \overline{C})(\overline{B} + \overline{C})$$
$$= (\overline{A} + B)(\overline{A} + \overline{C})(\overline{B} + \overline{C})$$
$$\Rightarrow \overline{\overline{F}} = \overline{\overline{(\overline{A} + B)(\overline{A} + \overline{C})(\overline{B} + \overline{C})}}$$
$$= \overline{\overline{(\overline{A} + B)} + \overline{(\overline{A} + \overline{C})} + \overline{(\overline{B} + \overline{C})}}$$

2 level NOR gate realiz^n :-



$$F = \overline{\overline{(\overline{A}+B)} + \overline{(\overline{A}+\overline{C})} + \overline{(\overline{B}+\overline{C})}}$$

Ans

Q. 11.49 $F = AB + BC + AC$

Use algebraic manipul^n to express F as sum of minterms & product of sums.

As sum of min terms

$$F = AB + BC + AC$$
$$= AB(C+\overline{C}) + (A+\overline{A})BC + A(B+\overline{B})C$$
$$= ABC + AB\overline{C} + ABC + \overline{A}BC + ABC + A\overline{B}C$$
$$\Rightarrow F = m_7 + m_6 + m_3 + m_5$$

(Take common terms just once)

As product of sums

$$F = AB + BC + AC$$
$$= AB + C(A+B)$$
$$= (AB+C)(AB+A+B)$$
$$= (AB+C)(A(\underbrace{B+1}_{\to 1}) + B)$$
$$= (AB+C)(A+B)$$
$$= (C+B)(A+C)(A+B) \quad (\because AB+C = (C+A)(C+B))$$
$$= (B+C+A\overline{A})(A+B\overline{B}+C)(A+B+C\overline{C})$$

$\because A\overline{A} = 0.$

$= (A+B+C)(\bar{A}+B+C)(A+B+C)(A+B+C)$
$(A+B+C)(A+B+\bar{C})$

(Again :- $AB+C = (A+C)(B+C)$)

$= (A+B+C)(\bar{A}+B+C)(A+\bar{B}+C)(A+B+\bar{C})$

(Take common terms just once)

$\Rightarrow F = M_0 M_1 M_2 M_4$

✓ Ans

Q. 11.5(b) Use algebraic manipul^n to express
$F = \bar{A}\bar{B} + B\bar{C}$ as
(i) sum of minterms
(ii) product of maxterms

(i) $F = \bar{A}\bar{B} + B\bar{C}$
$= \bar{A}\bar{B}(C+\bar{C}) + (A+\bar{A})B\bar{C}$ $\quad (\because A+\bar{A}=1)$
$= \bar{A}\bar{B}C + \bar{A}\bar{B}\bar{C} + AB\bar{C} + \bar{A}B\bar{C}$
$= m_1 + m_0 + m_6 + m_2$

(ii) $F = \bar{A}\bar{B} + B\bar{C}$
$= (\bar{A}\bar{B}+B)(\bar{A}\bar{B}+\bar{C})$
$= (\bar{A}+B)\underbrace{(B+\bar{B})}_{=1}(\bar{A}+\bar{C})(\bar{B}+\bar{C})$
$= (\bar{A}+B)(\bar{A}+\bar{C})(\bar{B}+\bar{C})$
$= (\bar{A}+B+C\bar{C})(\bar{A}+B\bar{B}+\bar{C})(A\bar{A}+\bar{B}+\bar{C})$
$= (\bar{A}+B+C)(\bar{A}+B+\bar{C})(\bar{A}+B+\bar{C})(\bar{A}+\bar{B}+\bar{C})$
$(A+\bar{B}+\bar{C})(\bar{A}+\bar{B}+\bar{C})$
$= (\bar{A}+B+C)(\bar{A}+B+\bar{C})(\bar{A}+\bar{B}+\bar{C})(A+\bar{B}+\bar{C})$
$= M_4 M_5 M_7 M_3$

Q.11·48 Implement the Boolean f^n $F = A+BC = (A+B)(A+C)$ with a 2 level logic circuit employing only NAND gates & (b) NOR gates

$$F = A+BC = (A+B)(A+C)$$

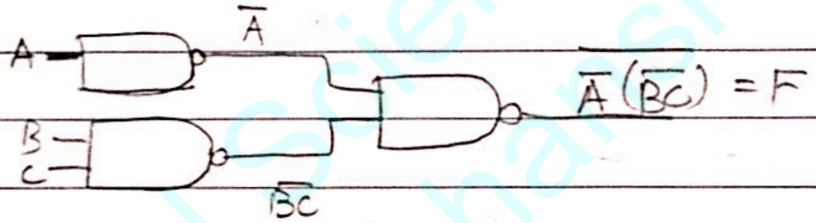
$$\Rightarrow \overline{F} = \overline{A+BC} = \overline{(A+B)(A+C)}$$

$$= \overline{(\overline{A+B}) + (\overline{A+C})}$$

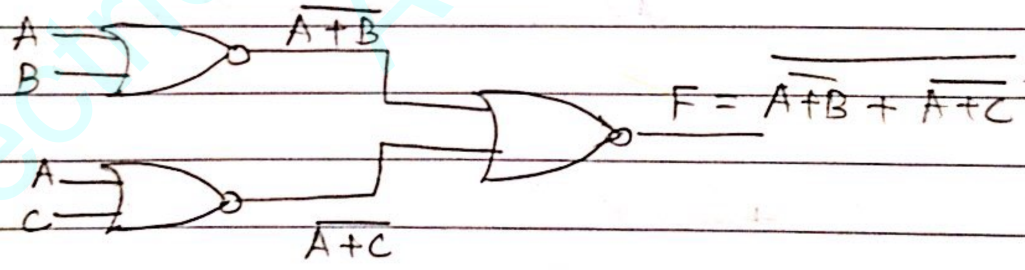
(using De Morgan's)

$$\overline{A+BC} = \overline{(\overline{A})(\overline{BC})}$$

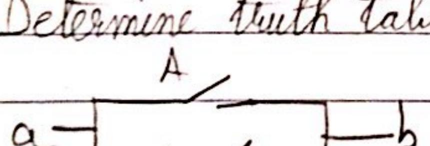
2 level NAND Gate :-



2 level NOR gate :-



Q.11.20 Determine truth table for connection shown :-

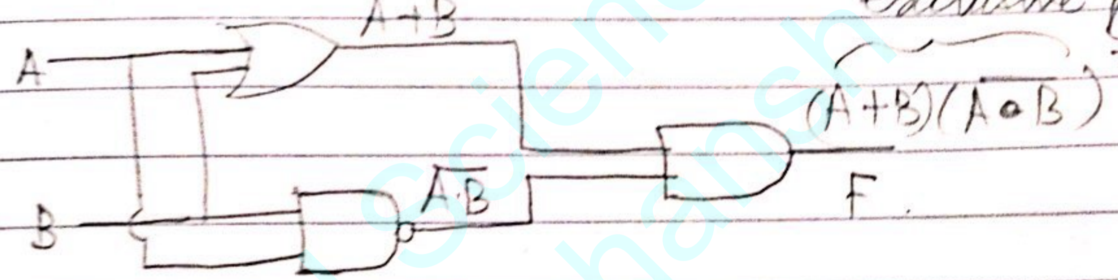


$L = A + BC.$

A	B	C	$L = A + BC$
1	0	0	1
0	1	0	0
0	0	1	0
0	1	1	1
1	0	1	1
1	1	0	1
1	1	1	1
0	0	0	0

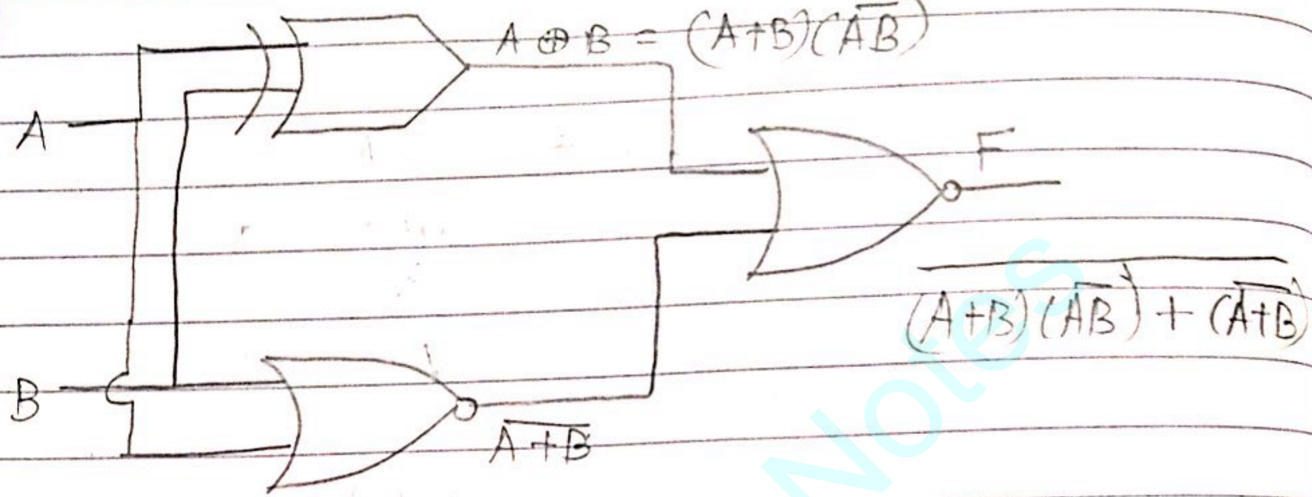
Q.11.27

exclusive OR



$$L = (A+B)(\overline{A \cdot B})$$

A	B	A+B	$(\overline{A \cdot B})$	L
1	0	1	1	1
0	1	1	1	1
0	0	0	1	0
1	1	1	0	0



A	B	$\overline{A+B}$	$\overline{AB}$	A+B	$A \oplus B$	F
1	0	0	1	1	1	0
0	1	0	1	1	1	0
0	0	1	1	0	0	0
1	1	0	0	1	0	1

$$F = \overline{\left[(\overline{\overline{A}+\overline{B}}) + (\overline{\overline{A}B\overline{C}})\right]}\, ABC$$

Q. Use algebraic manipul^n to show : exclusive NOR oper^n has this form.

$$A \odot B = (A+\overline{B})(\overline{A}+B) = AB + \overline{A}\,\overline{B}$$

$$(A+\overline{B})(\overline{A}+B) = \overline{\overline{(A+\overline{B})(\overline{A}+B)}}$$
$$= \overline{(\overline{A+\overline{B}}) + (\overline{\overline{A}+B})}$$
$$= \overline{A\overline{B} + \overline{A}B}$$

$$(A+\overline{B})(\overline{A}+B) = A\overline{A} + AB + \overline{A}\,\overline{B} + B\overline{B}$$
$$= AB + \overline{A}\,\overline{B} \quad (\because A\overline{A} = 0)$$

Q. Simplify:-

$$\overline{(A\bar{B} + \bar{A}B) + \overline{(A+B)}} = \overline{(A\bar{B} + \bar{A}B)} \cdot \overline{\overline{(A+B)}}$$

$$= \overline{(A\bar{B} + \bar{A}B)} \cdot (A+B)$$

$$= (\overline{A\bar{B}})(\overline{\bar{A}B})(A+B)$$

$$= (\bar{A}+B)(A+\bar{B})(A+B)$$

$$= (\cancel{A\bar{A}} + \bar{A}\bar{B} + AB + B\bar{B})(A+B)$$

$$= (\bar{A}\bar{B} + AB)(A+B)$$

$$= A\bar{A}\bar{B} + AAB + AB\bar{B} + ABB$$

$$= AAB + ABB$$

Now, $\because AA = A$

$$= AB + AB$$

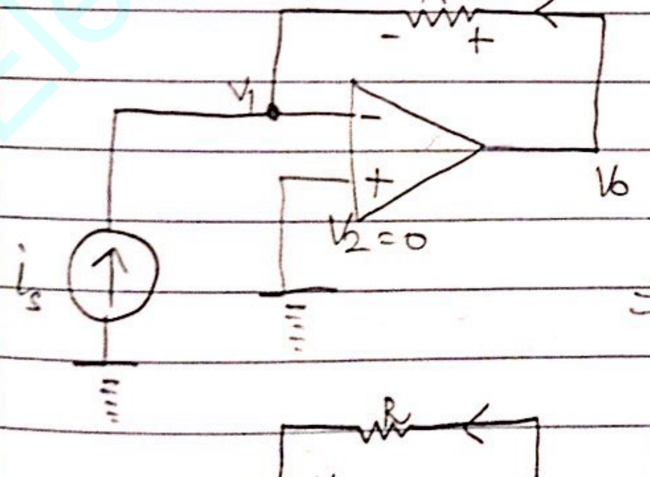
$$= (AB+A)(AB+B)$$

$$= A\underbrace{(B+1)}_{1}(B)(A\underbrace{+1)}_{1}$$

$$=$$

$$= \underline{\underline{AB}}.$$

Q. Find V_0 when an ideal amplifier is
(a) an OP-amp.
(b) when it has finite gain



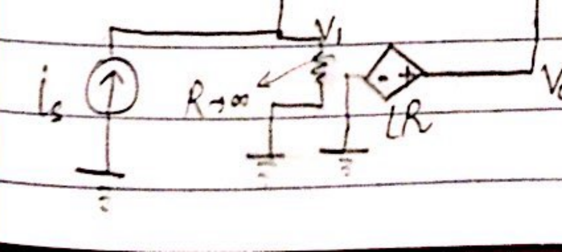
(a) $V_2 = 0$.

$V_1 = V_2 \Rightarrow V_1 = 0$

KCL at $\underline{\underline{V_1}}$.

$$\Rightarrow i_s = -\left(\frac{V_0 - V_1}{R}\right) \Rightarrow \frac{V_0}{R} = -i_s$$

$$\Rightarrow V_0 = \underline{\underline{-i_s R}},$$



(b) $$i_s + \frac{V_0 - V_1}{R} = 0$$

$$\Rightarrow V_0 = R\left(\frac{V_1}{R} - i_s\right) = V_1 - \underline{\underline{i_s R}}$$

Also, $V_o = A(\underbrace{V_2}_{\to 0} - V_1)$

$$\Rightarrow V_o = -AV_1$$

$$\Rightarrow V_1 = -\frac{V_o}{A}$$

$$\Rightarrow V_o = -\frac{V_o}{A} - i_s R$$

$$\Rightarrow V_o\left(1 + \frac{1}{A}\right) = -i_s R$$

$$\Rightarrow V_o = -\frac{A i_s R}{1 + A}$$ Ans.