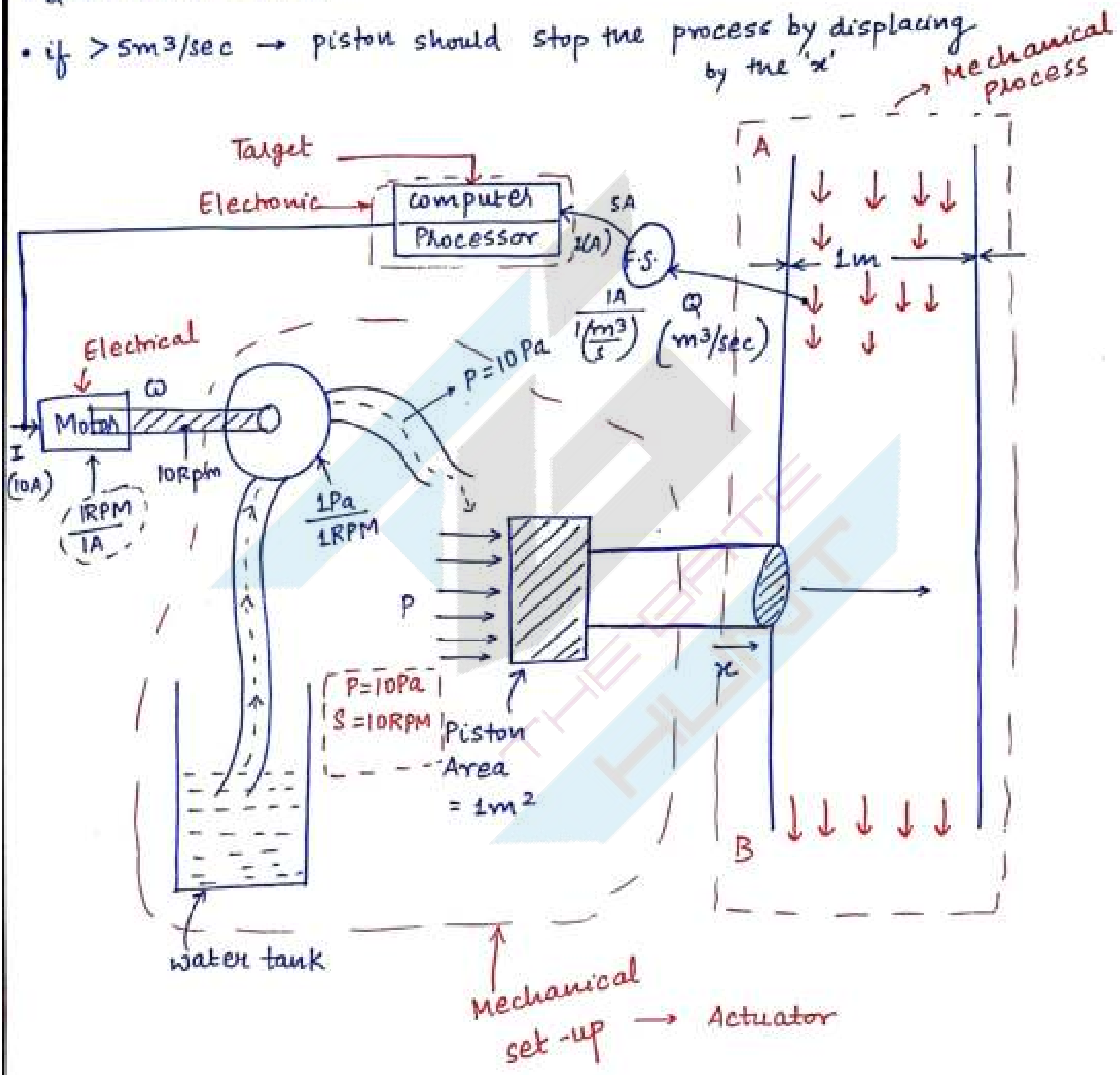
17/10/2016

Mechatronics

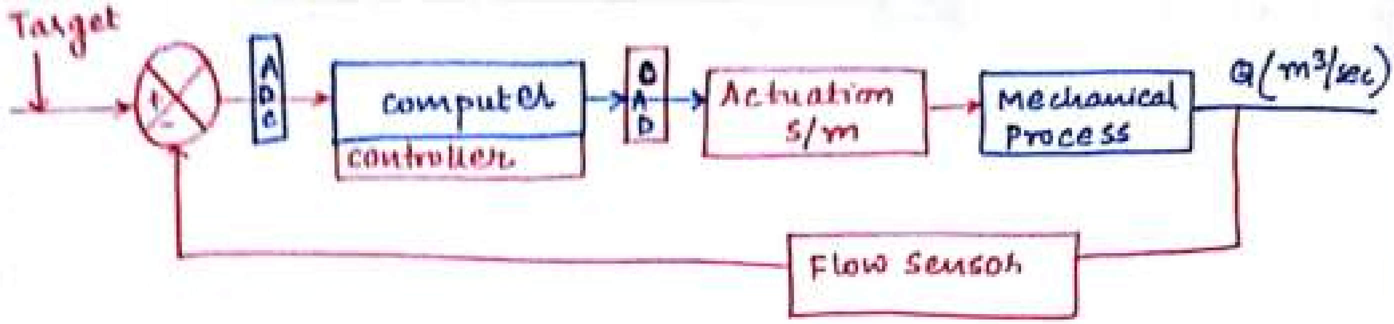
Integration of electronic and electrical devices in the mechanical system leads to the technology mechatronics. In mechatronics engineering, we generally control the mechanical variables by using electronic sensors and electrical devices.

- $Q \rightarrow 5m^3/sec \leftarrow$ limit
- if $> 5m^3/sec \rightarrow$ piston should stop the process by displacing by the 'x'



$I \propto \omega \propto P \propto F \propto x$

↑
Main

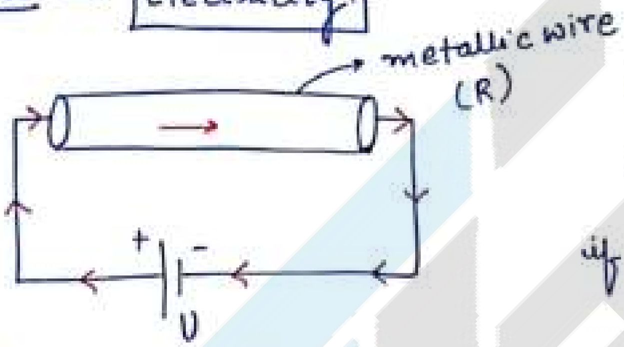


*** Block Diagram of Mechatronics :-**

ADC → Analog to Digital.
DAC → Digital to analog.

Note :- Every mechatronic system by default includes the control action.

*** Basics → Electricity :-**

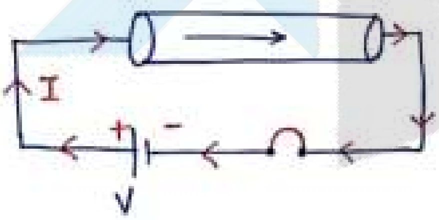


$V = RI$ [@ constant tempr.]

$I = V/R$

if $R\uparrow\uparrow\uparrow$; $I\downarrow\downarrow\downarrow$

on Breaking the loop

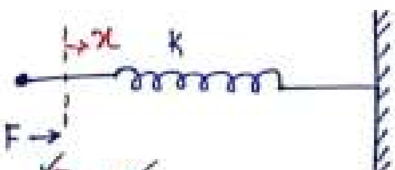


If you/we reverse the polarity of voltage, then the direction of current can be reversed.

$V = R\,I$ — Result

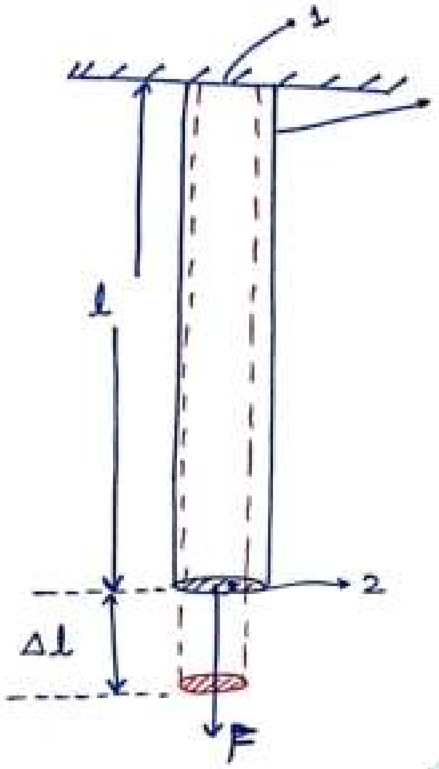
Battery

we can control this (controllable)



$F = kx$

* **Strain Gauge** :- Strain gauge is a metallic or semi-conductor based element which changes its resistance because of the applied load



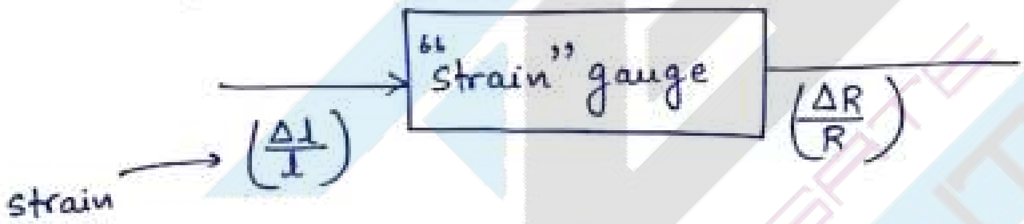
metallic wire (strain gauge)

$$F \propto \Delta l \propto \Delta R \propto \Delta I$$

for Metallic wire

$$R = \frac{\rho l}{A}$$

$$R = f(\rho, l, A)$$



$$\left(\frac{\Delta R}{R}\right) \propto \left(\frac{\Delta l}{l}\right)$$

$$\frac{\Delta R}{R} = K \frac{\Delta l}{l}$$

$$\frac{\left(\frac{\Delta R}{R}\right)}{\left(\frac{\Delta l}{l}\right)} = K = G_f$$

Strain gauge is a resistive sensor which is used to measure force and torque and acceleration.

F ✓
τ ✓
a ✓

$$\frac{\Delta R}{R} = G_f \cdot \frac{\Delta l}{l}$$

$$\Delta R = R\, G_f \cdot (\text{strain})$$

$$\Delta R = R\, G_f \left(\frac{F}{AE}\right)$$

$$\boxed{\Delta R = \left(\frac{R G_f}{AE}\right) F}$$

Q1 A strain gauge is fully attached to a specimen of length 20 cm which is subjected to a tensile force. The nominal resistance of the strain gauge is 100 ohms (at unstrained condition). The changes in the resistance and along the elongation of the specimen are measured to be 0.35 Ω and 0.2 mm resp. The gauge factor of the gauge is ——.

Gate 2001

Sol

$l = 20\,cm$

$R = 100\,\Omega$

$R = 0.35\,\Omega$

$\Delta l = 0.2\,mm$

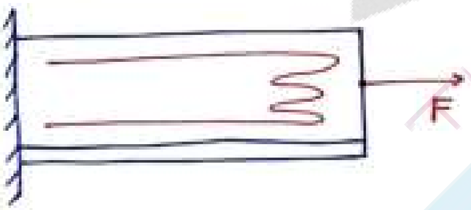
$G_f = ?$

$$G_f = \frac{(\Delta R/R)}{(\Delta l/l)} = \frac{(0.35/100)}{\left(\frac{0.2\times10^{-3}}{20\times10^{-2}}\right)} = 3.5$$

Q2 A strain gauge is placed on a specimen as shown below if an axial load of 10 N is applied to the specimen, then find the change in resistance of the gauge for the applied load given that $E = 2\times10^{11}\,N/m^2$ and the Nominal Resistance $R = 100\,\Omega$ and the surface area under the applied load is $10^{-6}\,m^2$. Gauge factor (G_f) is 2.0.

Gate 2004

Sol



$$\Delta R = R\cdot G_f\,(\text{strain})$$

$$= R\cdot G_f\cdot\left(\frac{F}{A\cdot E}\right)$$

$$= 100\times2\times\left(\frac{10}{10^{-6}\times2\times10^{11}}\right)$$

$$\boxed{\Delta R = 0.01\,\Omega}$$

Q3 A p-type semiconductor strain gauge has a nominal resistance of 1000 Ω and a gauge factor of +200 at 25°C. The change in the resistance of the strain gauge when it is subjected to a strain of $10^{-4}\,\frac{m}{m}$?

Sol $R = 1000\,\Omega$

$G_f = +200$

$\Delta R = ?$

Strain $= 10^{-4}$ m/m

$\Delta R = R \cdot G_f (\text{strain})$

$= 1000 \times 200 \times 10^{-4}$

$\Delta R = 20\,\Omega$

$R_G = R + \Delta R$

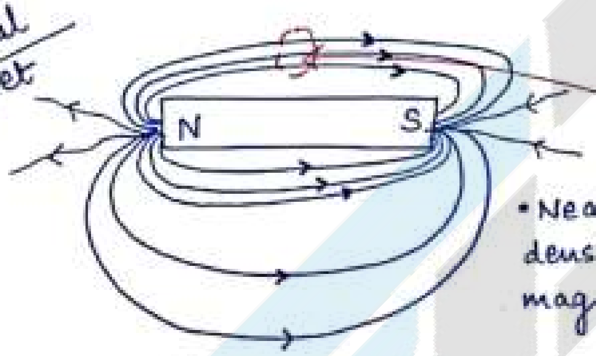
$= 1000 + 20$

$= 1020\,\Omega$.

* Basics of Magnetism :-

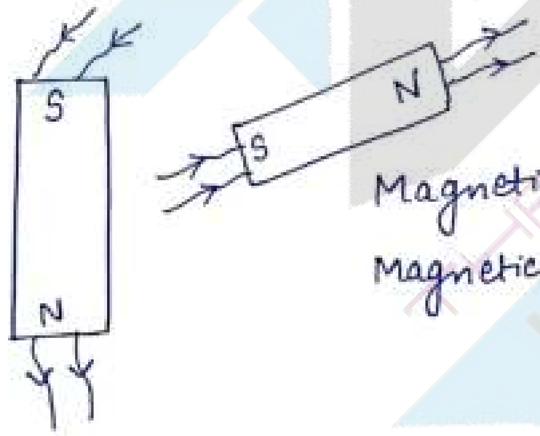
Magnet → Naturally.
→ electro-magnet.

Natural magnet



• Near to the magnet, the magnetic flux density will be more & away from the magnets the magnetic flux density will be less.

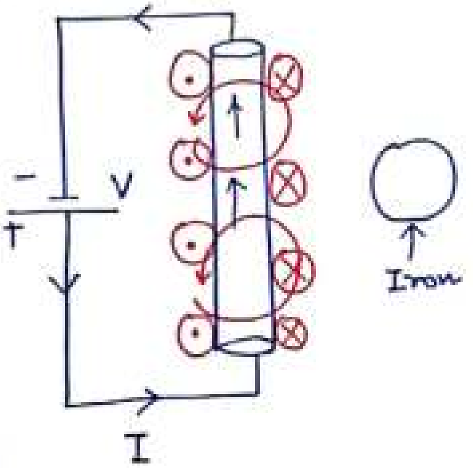
• Magnetic field as well as magnetic flux both are vector quantities.



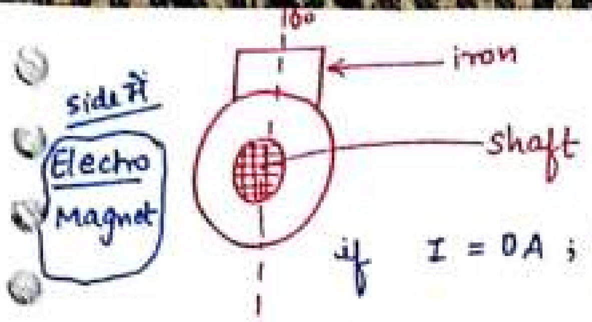
Magnetic flux $(\vec{\phi})$ — directional properties.

Magnetic field $(\vec{B})$ $\left[\frac{Wb}{m^2}\right]$

Electro-Magnet



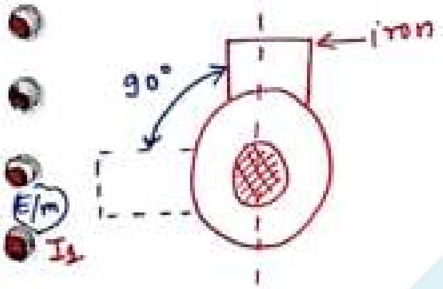
$\phi \propto I$



if $I = 0A$; $\phi = 0$, $\theta = 0°$

[even if $I_1 = 20A$, Rotation will be also $90°$.]

if $I \neq 0A$; $\phi \neq 0$; $\theta = 90°$.



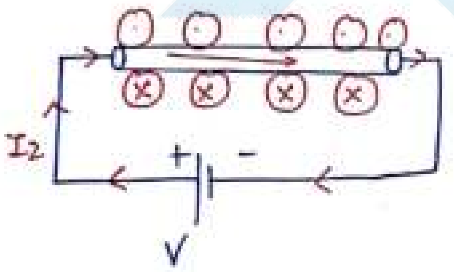
if $I_1 = 0A$; $\phi_1 = 0$; $\theta = 0°$

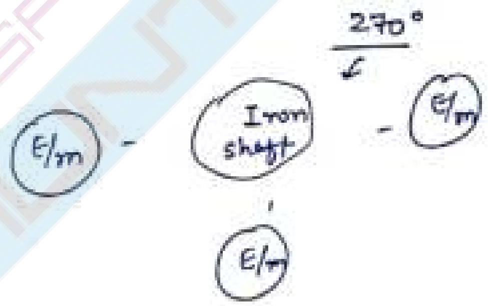
if $I_1 \neq 0A$; $\phi_1 \neq 0$; $\theta = 90°$

if $I_2 \neq 0A$; $I_1 = 0A$

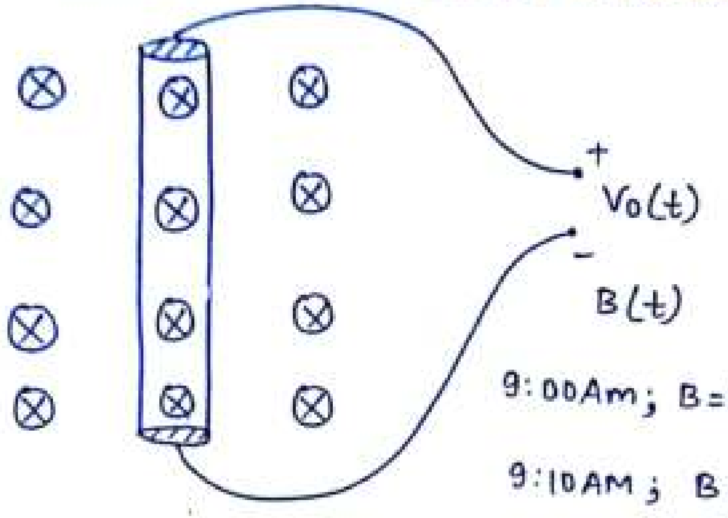
$\phi_2 \neq 0$; $\theta = 180°$

for 180° Rotation





Electromagnetic Induction 2nd principle :- If a conductor is placed in a time varying magnetic field then voltage will be induced across the conductor.



$V_0(t) \propto \frac{d}{dt} B(t)$

$V_0(t) \propto \frac{d}{dt} \phi(t)$

for fixed time

$V_0(t) \propto \phi(t)$

9:00Am; $B = 10 \frac{Wb}{m^2}$

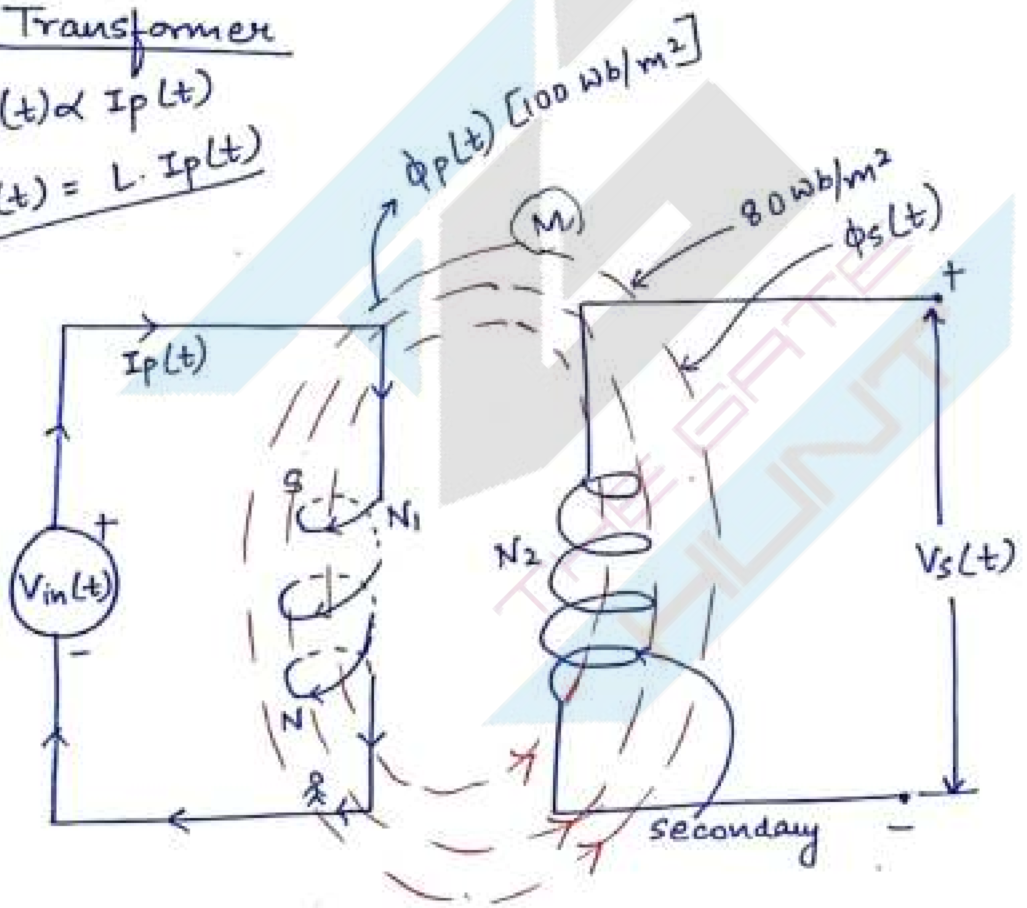
9:10AM; $B = 12 \frac{Wb}{m^2}$

9:20am; $B = 14 \frac{Wb}{m^2}$

Transformer

$\phi_p(t) \propto I_p(t)$

$\phi_p(t) = L \cdot I_p(t)$



$I_p(t) \propto V_{in}(t)$

$I_p(t) = K' \cdot V_{in}(t)$

for fixed Time

$V_s(t) \propto \phi_s(t)$

$\phi_s(t) = M \cdot \phi_p(t)$

$V_s(t) \propto M \, \phi_p(t)$

$V_s(t) \propto M \cdot L \cdot I_p(t)$

$V_s(t) \propto M \cdot L \cdot (k' \cdot V_{in}(t))$

$V_s(t) \propto M \cdot L \cdot k' \cdot V_{in}(t)$

$$\boxed{V_s(t) = k \, V_{in}(t)}$$

$$\frac{V_s(t)}{V_{in}(t)} = k = \frac{N_2}{N_1}$$

k → Transformation Ratio

N_2 → No. of turns on secondary winding.

N_1 → " " " primary " "

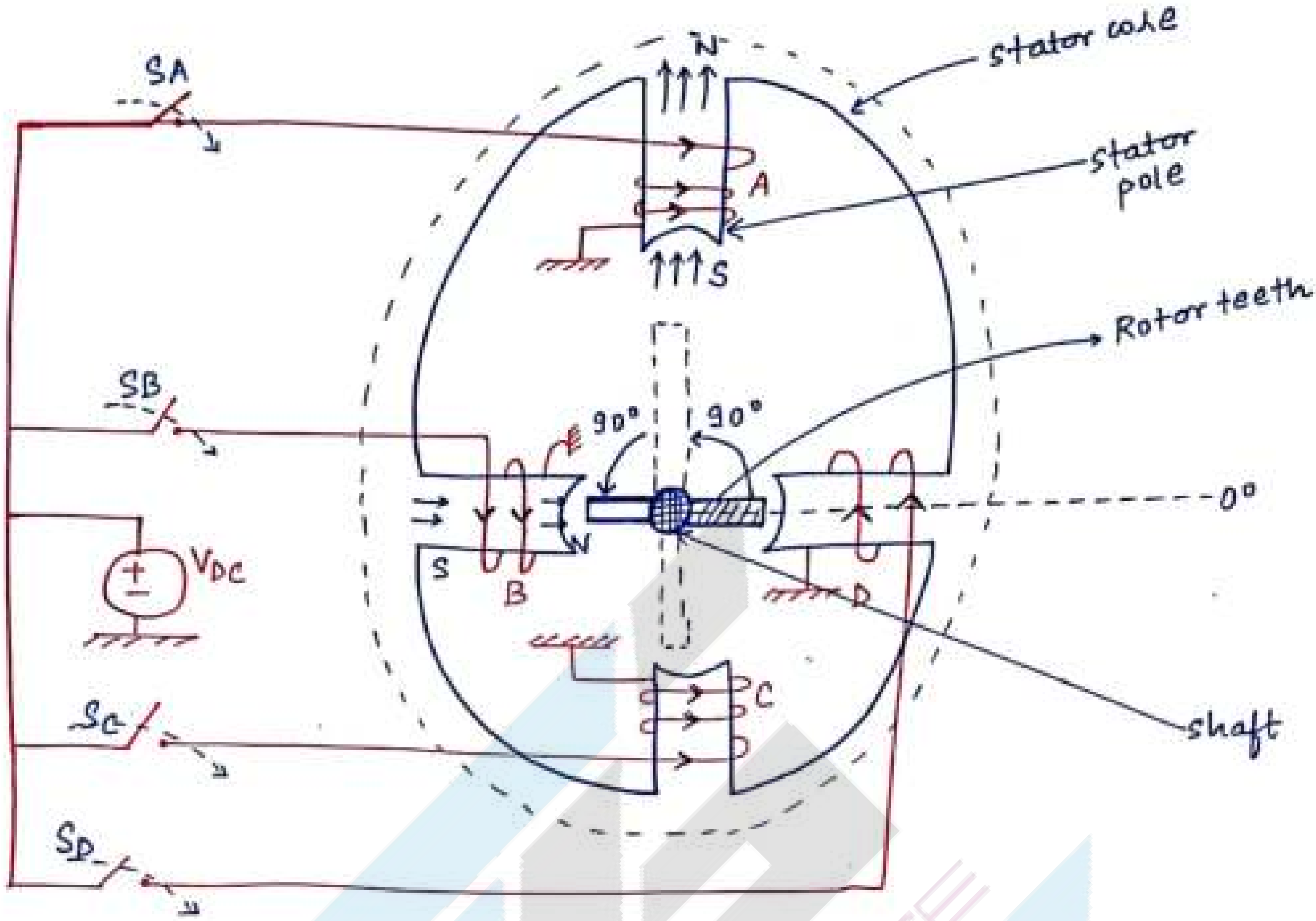
if $N_2 < N_1$; step-down

if $N_2 > N_1$; step-up

* Stepper Motor :- It is a electrical actuator which converts pulsed electrical energy into step-wise angular rotation of the shaft.

"[N.P.]"

4-Pole stator/ 2-teeth Rotor like stepper Motor:-



Operation

→ if S_A is closed and S_B, S_C, S_D are opened

$I_A \neq 0A$, $\phi_A \neq 0$, $\theta = 90°$

→ if S_B is closed and S_A, S_C, S_D are opened

$I_B \neq 0A$, $\phi_B \neq 0$, $\theta = 180°$

→ if S_C is closed and S_A, S_B, S_D are opened

$I_C \neq 0A$; $\phi_C \neq 0$; $\theta = 270°$

→ if S_D is closed and S_A , S_B, S_C are opened

$I_D \neq 0A$; $\phi_D \neq 0$; $\theta = 360°$

Switching Sequence of stepper motor

S_A	S_B	S_C	S_D	θ
0	0	0	0	0°
1	0	0	1	45°
1	0	0	0	90°
1	1	0	0	135°
0	1	0	0	180°
0	1	1	0	225°
0	0	1	0	270°
0	0	1	1	315°
0	0	0	1	360° (0°)

- Stator pitch :- The angular seperation between 2 successive poles of the stator is called stator pitch.

$$\theta_S = \frac{360°}{\text{No. of poles of stator}} = \frac{360°}{4} = 90°.$$

- Rotor pitch :- The angular seperation between 2 successive teeth of the rotor is called Rotor pitch

$$\theta_R = \frac{360°}{\text{No. of teeth of Rotor}} = \frac{360°}{2} = 180°.$$

- Full step angle :- The angle rotated by the shaft of the motor b/w 2 successive switching sequences is called full-step angle.

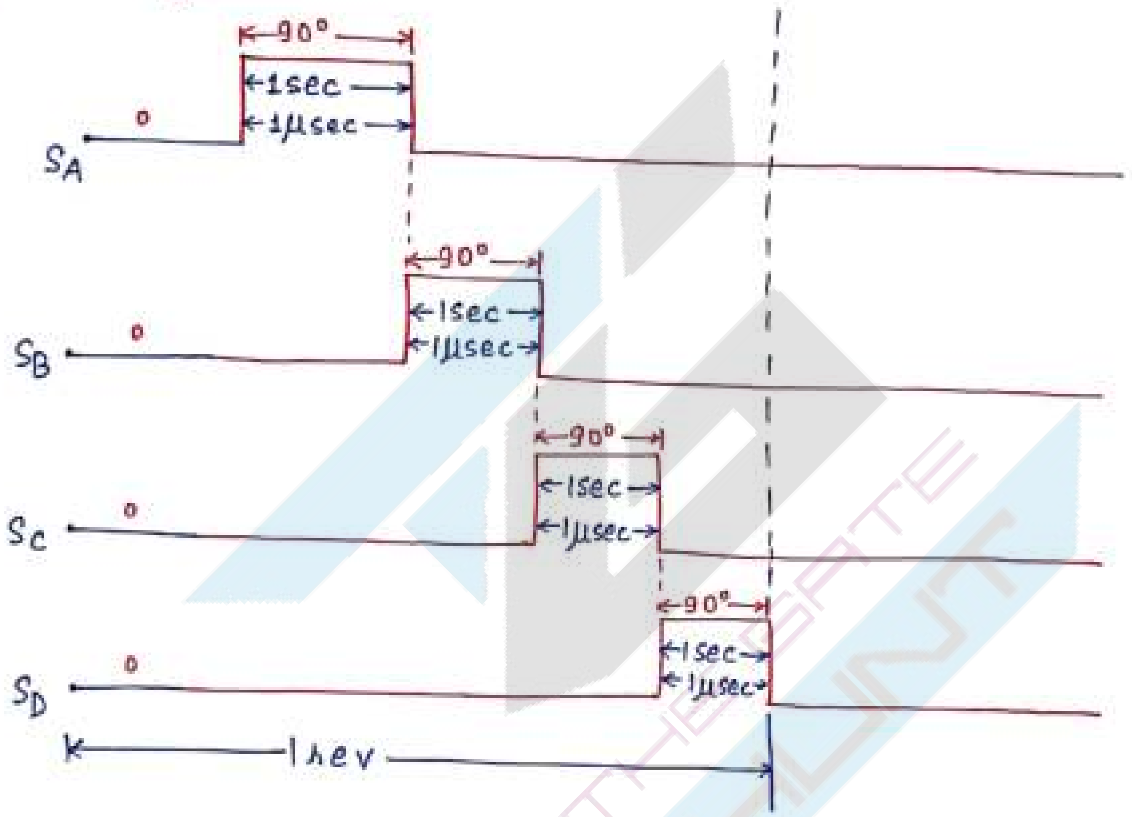
$$\boxed{\theta_{FS} = \theta_R - \theta_S} = \text{here } (180° - 90°)$$

To get a full step angle, we should energised only one winding at a time.

• Half step Angle :- $\theta_{HS} = \frac{\theta_R - \theta_S}{2}$

To get a half step angle, 2 successive windings are energised at a time.

18/10/2016 Digital pulses :-



1 step → 1 pulse

if

1 Rev → 4 sec

1 sec → 1/4 Rev → 90°

60 sec (1min) → 15 Rev

(1min) → 15 Rev

shaft speed = 15 rpm

if 1Rev → 4μ sec

1sec → $\frac{1}{4} \times 10^6$ Rev

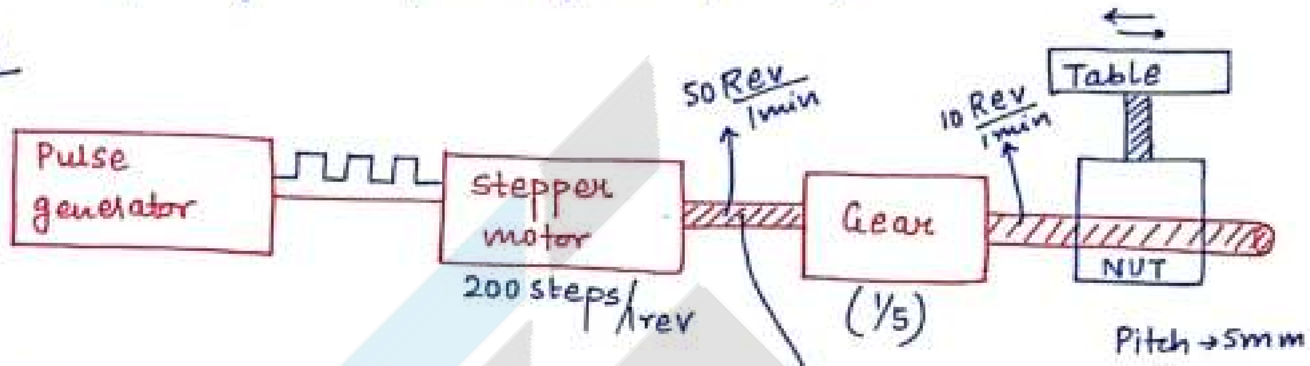
60 sec (1min) → 15×10^6 Rev

Shaft speed = 15×10^6 Rpm

Q. In the feed drive of a point to point open loop CNC drive, a stepper motor rotating at a constant speed drives a table through a gear box and screw nut mechanism (pitch = 5mm) and gear ratio = 1/5. if the stepper motor is driven by a pulse generator of 10,000 pulses per minute (pulse rate).

(a) If the stepper motor is at a speed of 200 steps per revolution, then the basic length unit, the table moveme̲nt corresponding to 1 pulse of the pulse generator is ____.

Sol



10,000 pulses/min

1min → 10,000 pulses

1 Rev ← 200 steps

1 Rev ← 200 pulses

50 Rev ← 10,000 pulses ← 1min

But Pitch → 5mm

10 Rev → 1 min → after G.R.

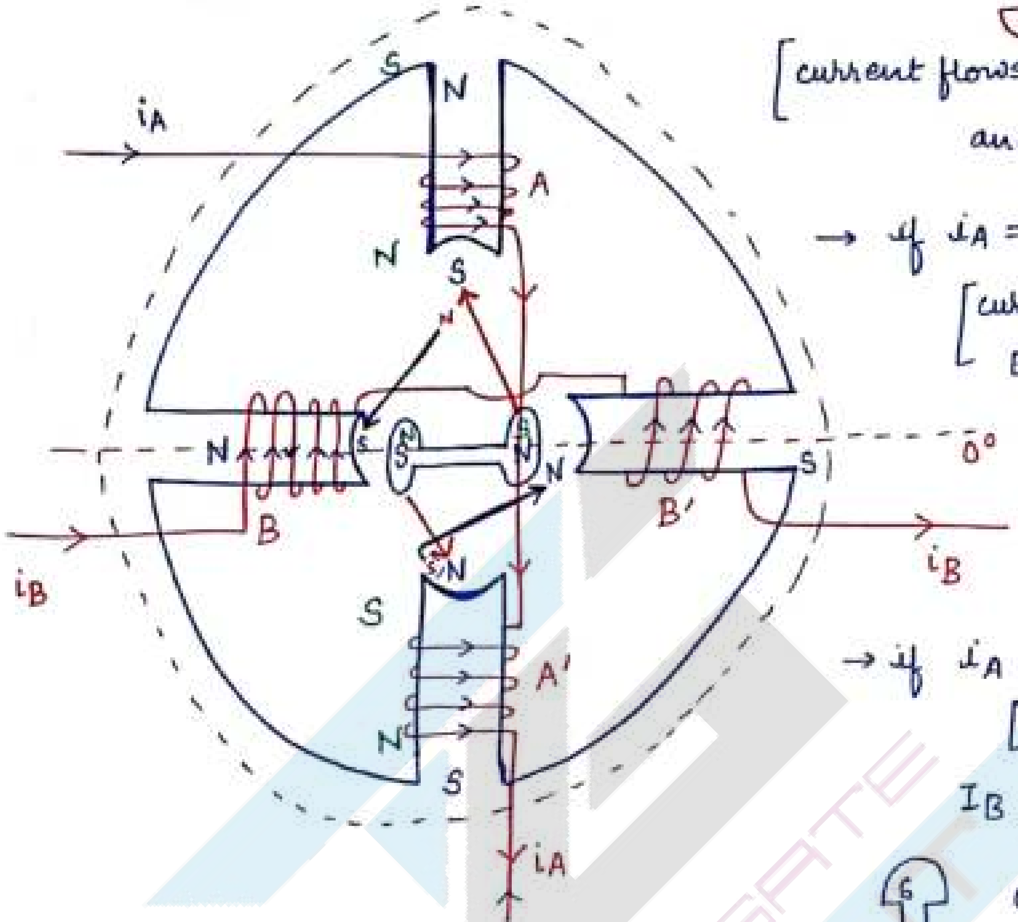
1 Rev → 5mm

10 Rev → 50mm

10,000 pulses → 50mm

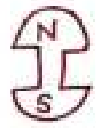
$$1 \text{ pulse} \rightarrow \frac{50 \text{ mm}}{10,000} = 5\times10^{-6} \text{ m} \quad \text{(Ans)}$$

✱ Permanent Magnet Type stepper motor :-



if $i_A = 0$; $\theta = 0°$

→ if $i_A \neq 0A$;



$\theta = 90°$

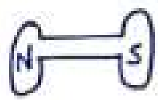
[current flows from A to A']

and $I_B = 0A$

→ if $i_A = 0A$; $i_B \neq 0A$

[current flows from B to B']

;



$\theta = 180°$

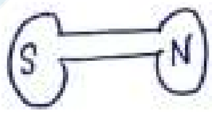
→ if i_A is Reversed [A' to A] ;

$I_B = 0A$

$\theta = 270°$

→ i_B is Reversed [B' to B] ;

$I_A = 0A$

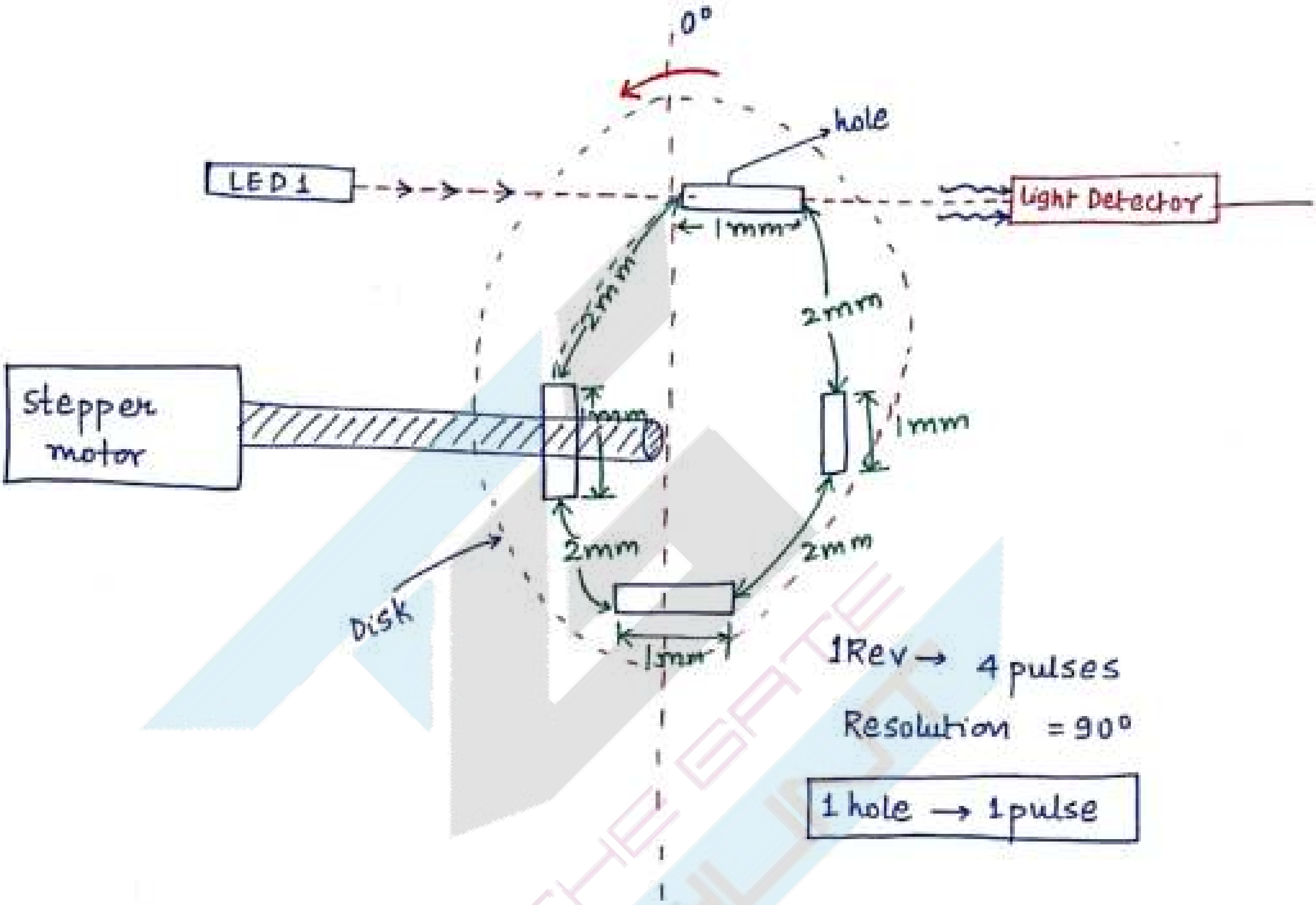


$\theta = 360°$

In permanent magnet type stepper motor, the Rotor will be permanent magnet itself.

* OPTICAL Encoder :- is a digital transducer which generates pulses corresponds to angular rotation of the shaft. optical encoders are divided into two types :- (a) Incremental Type O.E. (b) absolute type optical encoder.

Incremental encoder :- It generates equally spaced pulses based on the angular rotation of the shaft.



1Rev → 4 pulses

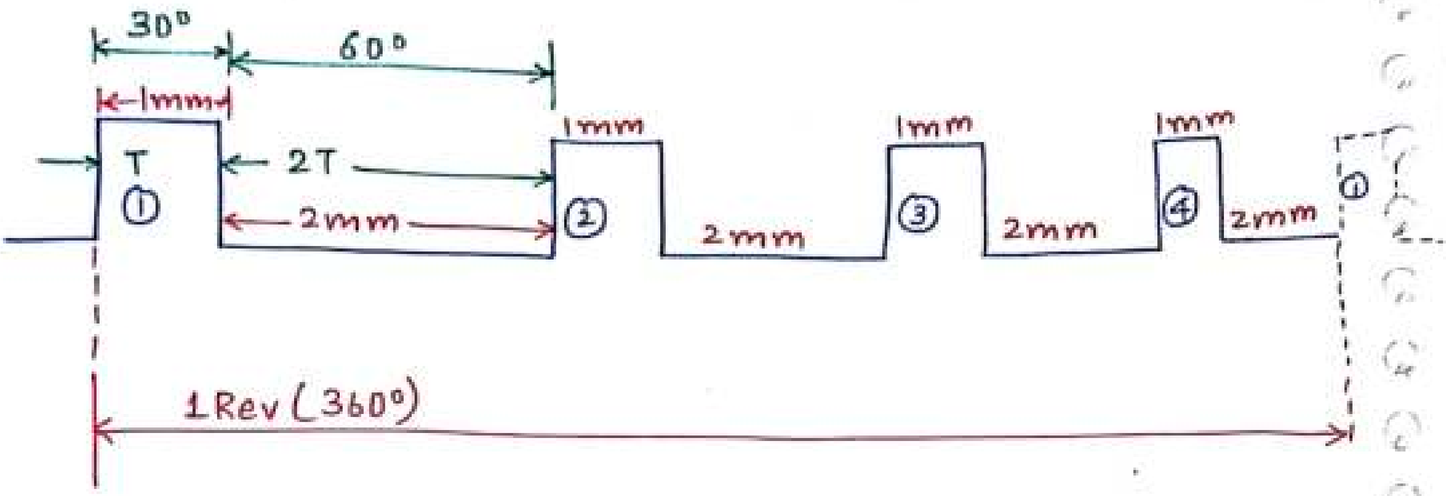
Resolution = 90°

1 hole → 1 pulse

Incremental encoders are divided into two types :-

(a) Single Track incremental encoder.

(b) Multiple Track incremental encoder



12T → 12mm → 360°

1mm → 30°

$T = \dfrac{360°}{12}$

<u>Resolution</u> :- The angular rotation made by the shaft b/w the two successive pulses is called Resolution.

1 hole → 360°

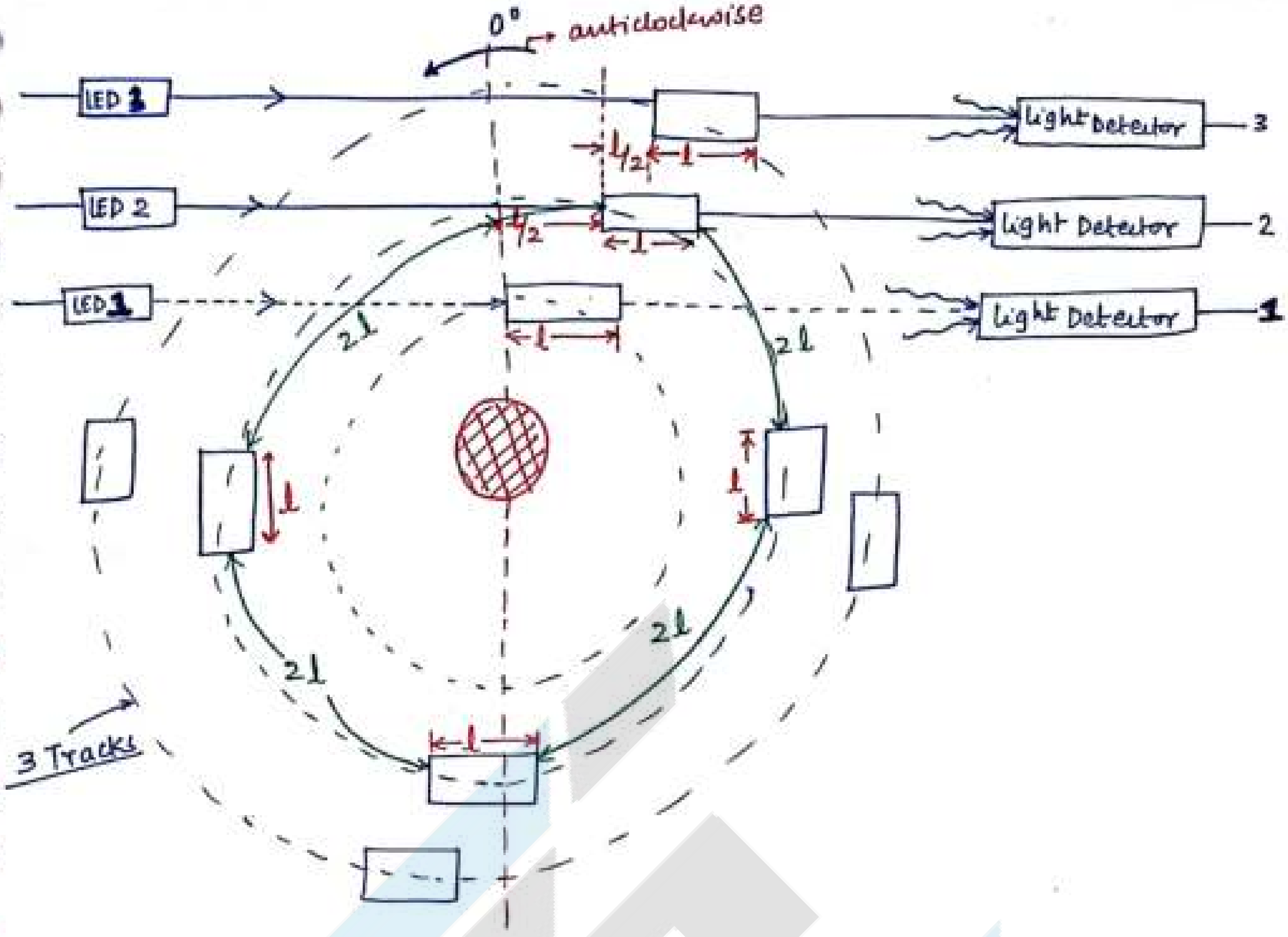
2 hole → 180°

If the disc has N poles, then the

$$\text{Resolution} = \frac{360°}{N}$$

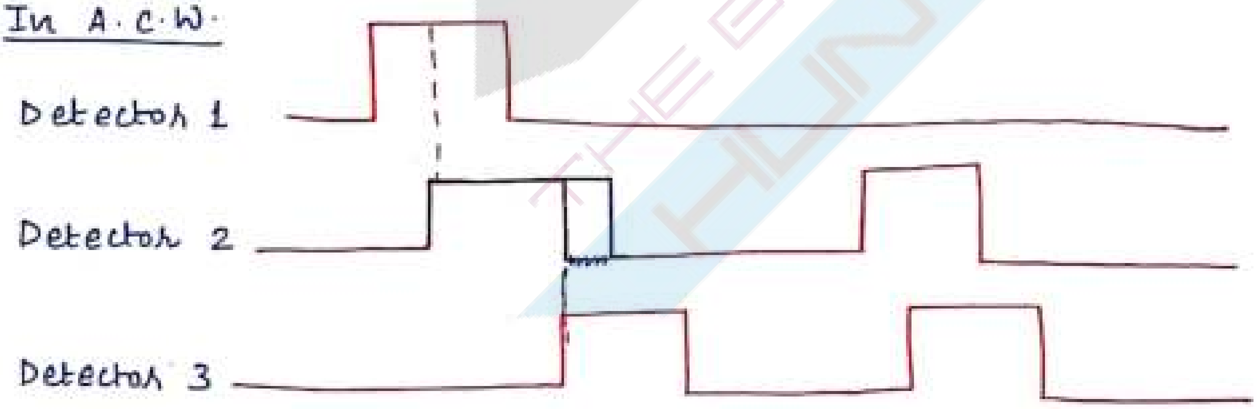
*~~Pulses (Random order)~~

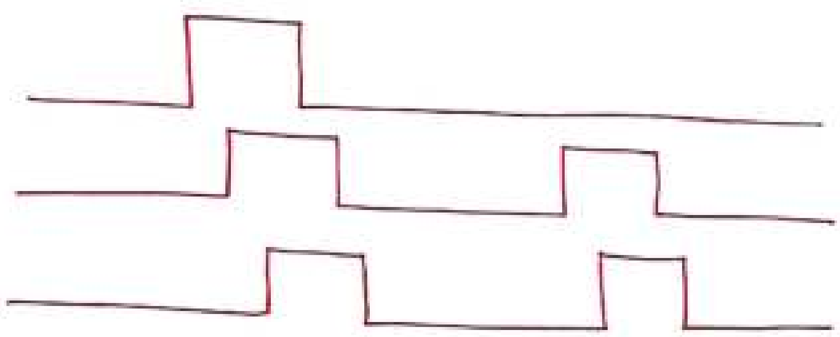
- With the single track optical encoder, we can find the speed of the shaft but we cannot find the direction of rotation of the shaft. To find the dirn. of rotation, we generally prefer Multitrack Incremental encoder.



3-Track (optical) incremental Type Encoder :-

In A.C.W.





12 l mm → 360°

$$1\ mm \rightarrow \frac{360^\circ}{12} = 30^\circ$$

l	0°	D_1	D_2	D_3
	0°+	1	0	0
	15°+	1	1	0
	30°+	0	1	1

In the above case, resolution depends on no. of holes on the disc but not on the no. of tracks on the disc.

Absolute Type Optical Encoder :-

It generates directly Binary logic based on the angular rotation of the shaft.

Binary logic [D → 0, 1] (digital)

- → Single Bit [b_0] → 0/1
- → Two Bit [b_1 b_0], each 0/1
- → Three Bit [b_2 b_1 b_0], each (0/1)
- → N Bit [b_{n-1} b_{n-2} … b_0] → 2^N states

Single bit binary logic (b_0)

$$D = b_0 2^0$$

D	b_0
0	0
1	1

Two Bit Binary logic (b_1 b_0)

$$D = b_1 2^1 + b_0$$

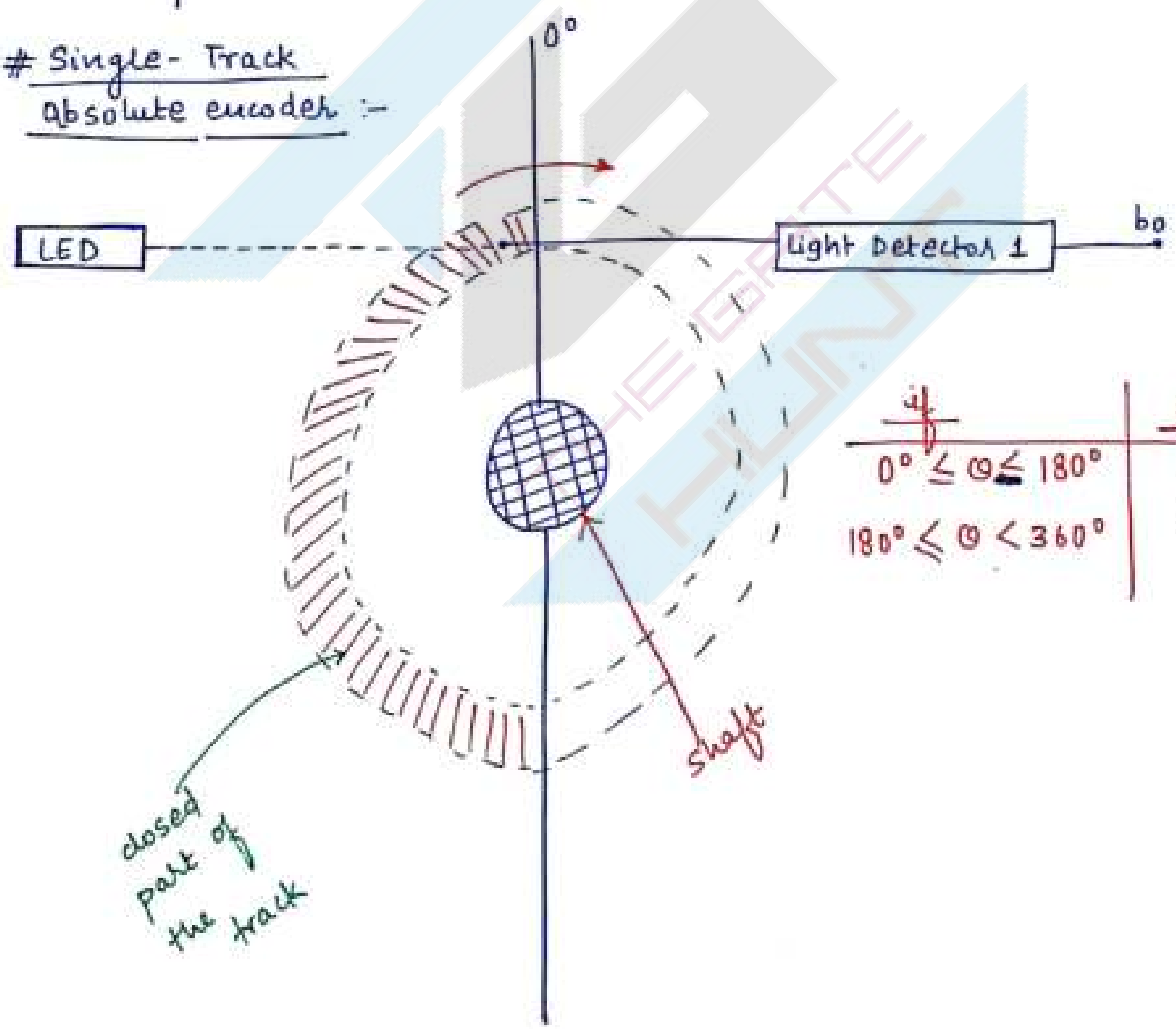
D	b_1	b_0
0	0	0
1	0	1
2	1	0
3	1	1

Three Bit Binary logic $[b_2\ b_1\ b_0]$ (MSB ← b_2, b_0 → LSB)

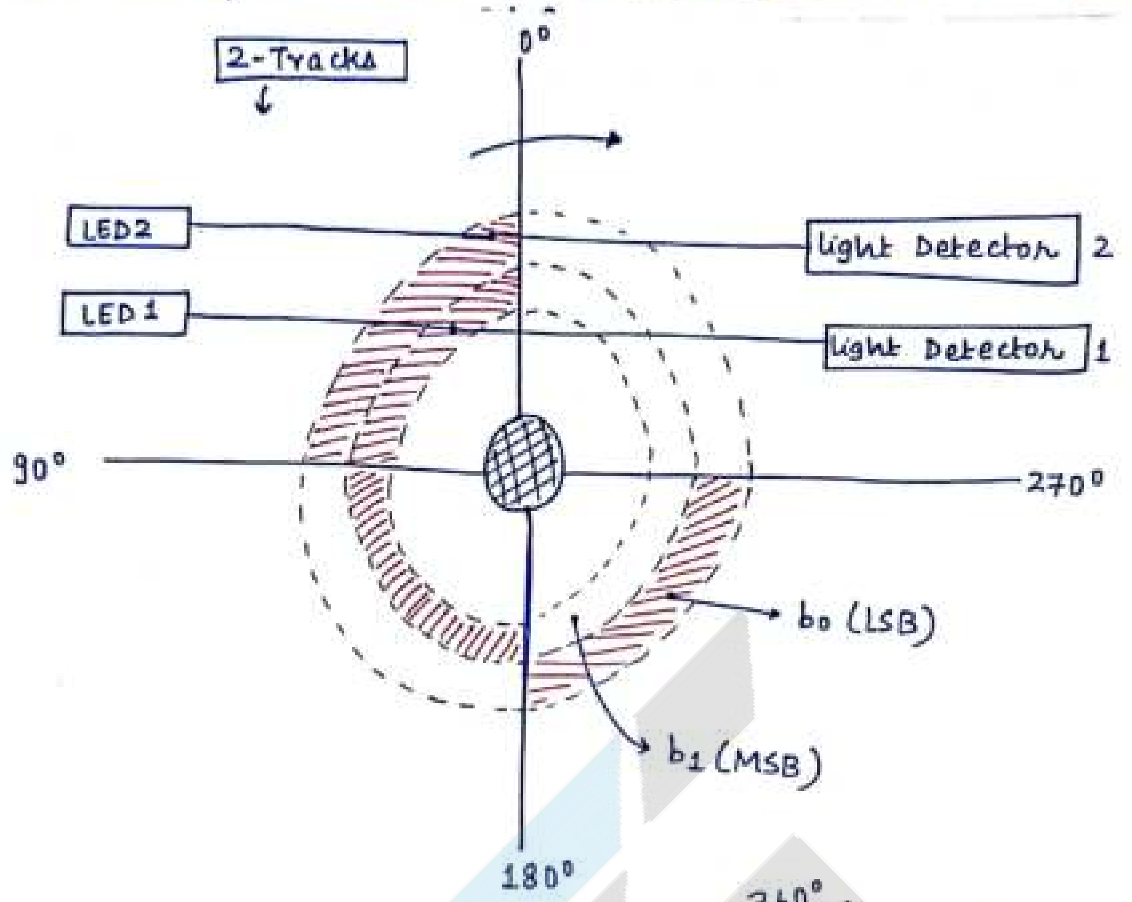
$$D = b_2 2^2 + b_1 2^1 + b_0$$

D	b_2	b_1	b_0
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1

Single-Track absolute encoder :-



if	b_0
$0° \leq \theta \leq 180°$	0
$180° \leq \theta < 360°$	1



Resolution $= \frac{360°}{2^N}$ → No. of Binary Bits.

N → No. of Tracks on the coded disc.

$\frac{360°}{}$ θ	b_1	b_0
$0° \le θ < 90°$	0	0
$90° \le θ < 180°$	0	1
$180° \le θ < 270°$	1	0
$270° \le θ < 360°$	1	1

for, 3 Tracks ⇒ $\frac{360°}{2^3} = 45°$ → Resolution magnitude goes down ↓

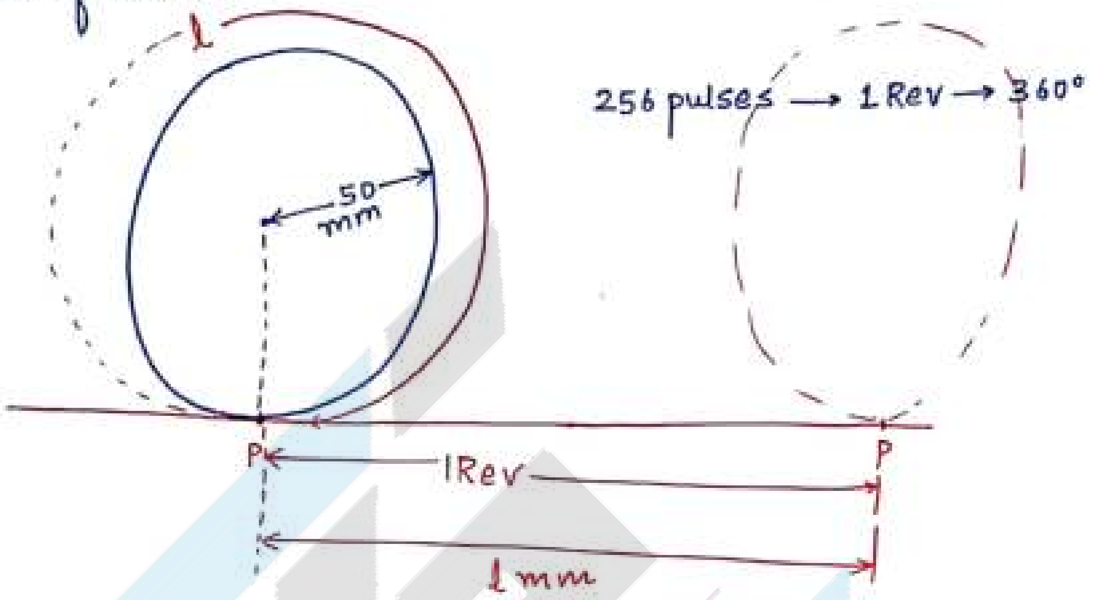
D	b_2	b_1	b_0
$0 \le θ < 45°$	0	0	0
$45° \le θ < 90°$	0	0	1
$90° \le θ < 135°$	0	1	0
	0	1	1
	1	0	0
	1	0	1
	1	1	0
	1	1	1

Smallest value of the resolution is possible by using absolute encoder.

like in Robot, 4.5° → $2^n = \frac{360°}{4.5}$ N= ___ .

Q A shaft encoder is to be used with 50mm radius tracking wheel to monitor the linear displacement, if the encoder produces 256 pulses per revolution, what will be the no. of pulses produced for a linear displacement of 200mm.

Sol



256 pulses → 1 Rev → $(2\pi r)$ mm

256 pulses → 2 × 3.14 × 50 mm

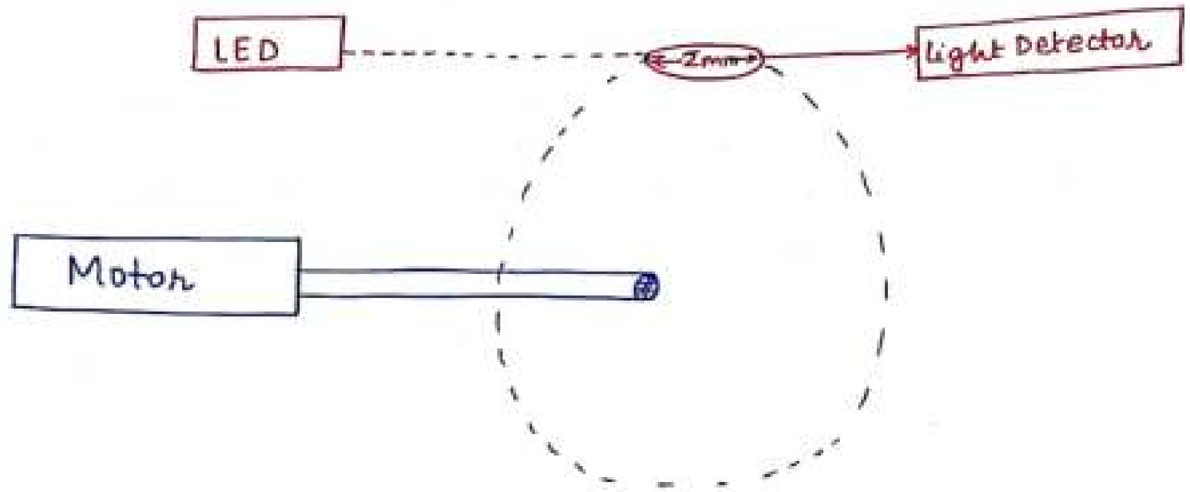
→ 314 mm

← 200 mm

$\frac{256 \times 314}{200}$ → **162.97 pulses**

Q Gate 2009 A measurement system for the rotational speed of the motor is as shown in the figure. The system consist of a disc attached to motor shaft which is running at 120 rpm. if the diameter of the circular hole is 2mm as indicated and the diameter of the disc is 200mm, then find the percentage of duration of light passes through the hole in 1 revolution.

Sol.



% of Time, light passes through hole $= \frac{2mm}{l\,mm} \times 100$

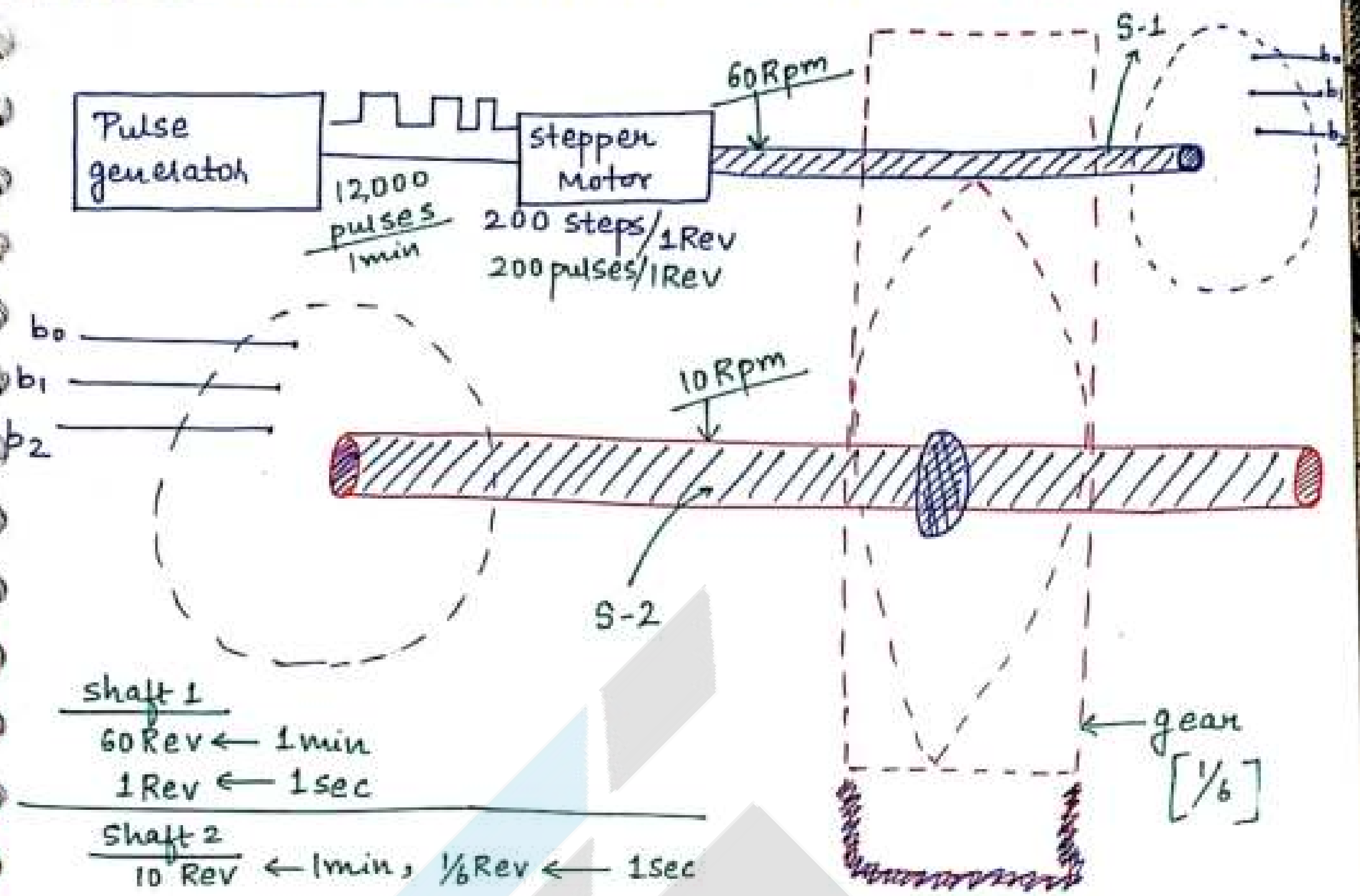
$= \frac{2mm}{2\pi r\,mm} \times 100$

$= 0.318\%$

Q A stepper motor which has a constant of 200 steps/revolution is supplied pulses from pulse generator at a rate of 12,000 pulses per minute. If the stepper motor shaft is attached to a 3 track absolute optical encoder, a gear of ratio 1/6 as shown in the figure. shaft 2 is passed through gear and connected to second three track absolute encoder as shown.

(a) find the minm. time required at which the Binary display of encoder 1 and encoder 2 ~~remains~~ becomes same.

Notes by Mohit Chouksey



Shaft 1
60 Rev ← 1 min
1 Rev ← 1 sec

Shaft 2
10 Rev ← 1min, 1/6 Rev ← 1 sec

Shaft 1

		b_2	b_1	b_0
@ 0^+ sec	; θ =	0	0	0
@ 1^+ sec	; θ = 360^+	0	0	0
@ 2 sec^+	; θ = 720^+	0	0	0
⋮		⋮	⋮	⋮
@ 6 sec^+	; θ = $(6 \times 360°)^+$	0	0	0

Shaft 2

		b_2	b_1	b_0
		0	0	0
@ 1 sec^+	θ = $60°^+$	0	0	1
@ 2 sec^+	θ = $120°^+$	0	1	0
⋮		⋮	⋮	⋮
@ 6 sec^+	θ = $360°^+$	0	0	0

Notes by Mohit Chouksey

But

S-1

@ 1.125 sec$^+$ 1.125 rev$^+$ → 1.125 (360°)$^+$
→ 405° + (001)

S-2

@ 1.125 sec$^+$ 1.125 [1/6 Rev] → 67.5°$^+$ → (001)

Ans → 1.125 sec$^+$

Q previous qn. data

(b) if the gear ratio change to 1/4, then the binary display of both the encoders when they are showing same.

Q Gate 2007 A shaft encoder which is attached to a wheel has a sensitivity of 500 pulses per revolution. A digital pulse counter connects to the output of the encoder indicates 5500 pulses in one second. The speed of the shaft in Rpm is ———.

Sol

500 pulses ⟶ 1 Rev.

5500 pulses ⟶ 11 Rev ⟶ 1 sec

660 Rev ⟵ 60 sec (1 min)

Shaft speed = 660 Rpm.

Notes by Mohit Chouksey

31/10/2016 Mechatronics → Mechanics + Electronics

↓

Mechanics

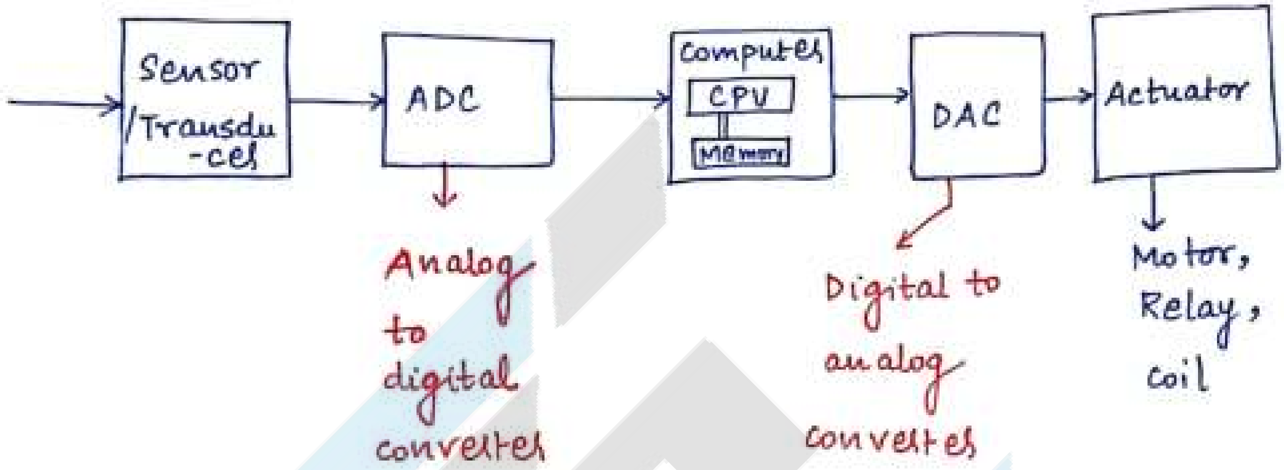
Electronics

Control System

Computer Science

Physical world

T, P, flow, speed



Mechatronics :- It is an approach aiming at the synergistic integration of mechanics, electronics, control theory and computer science within product design and manufacturing in order to improve and /or optimised its functionality.

① μp, μc & PLC.

② Sensors & actuators.

③ Control Systems.

Notes by Mohit Chouksey

Microprocessor :-

1947 - Transistor

Small scale integration.

SSI - < 10 components

MSI - 10 - 100 —"—

LSI - 100 - 10k —"—

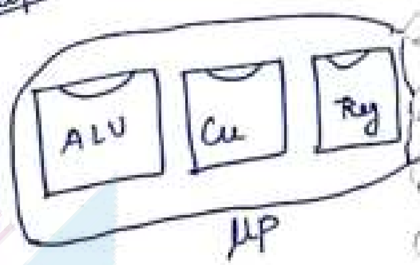
VLSI - >10K —"—

VLSI

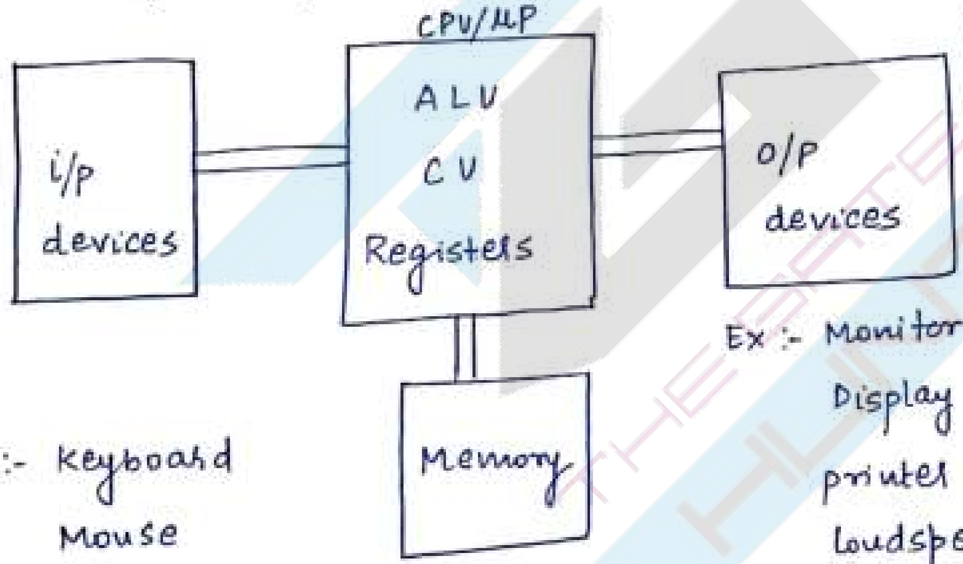
SLSI

1st Intel - DRAM

in µP



Block diagram of a Computer



Ex :- Keyboard
Mouse
Scanner
Joystick

Ex :- Monitor
Display
printer
Loudspeaker

Processor :- It is a semiconductor component designed by using VLSI Technology and it contains ALU, CU and Registers of a CPU in a single package.

NOTE :- For a microprocessor, memory is connected externally. The Registers inside the processor cannot be considered as memory as they are used to hold the data temporarily (latest processors may have some memory inside), Ex :- cache memory, to store frequently used data and instructions).

* Bit → Binary Digit

→ 0/1

M/M → Memory

Nibble → 4 Bits

Byte → 8 bits

word length → Depends on Type of μp.

* Word length → no. of bits that can be processed by a processor parallely at a time.

Ex :- 8 bit μp → 8 bits / 1 byte

16 —"— → 2 Bytes

32 —"— → 4 Bytes

$2^4 \to 16$

0 0 0 0
0 0 0 1
⋮
1 1 1 1 } 16

0 0 0 1
+ 0 0 0 1
—————
1 0 0 1 ✓

1971 → Intel 4004 → 4 bit μp

1972 → Intel 8008 → 8 bit μp

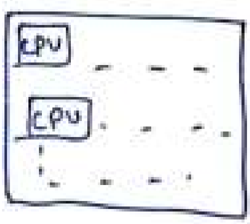
1974 → Intel 8080 → 8 bit μp

1977 → Intel 8085 → 8 bit μp → Gate, IES, PSU's

1978 → Intel 8086 → 16 bit → IES → 1st 16 bit Processor

8088, 80186, 80286, 80386 (32 bit)

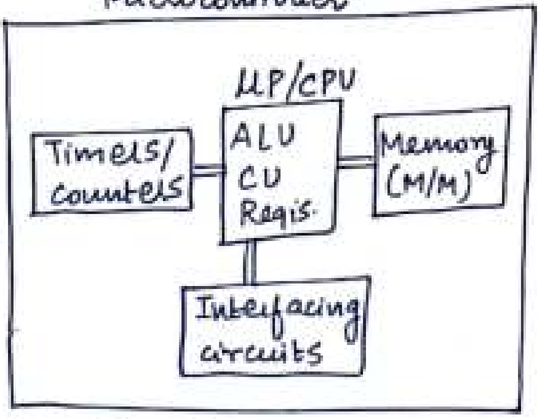
pentium, ---- Dual core ----- i3, i5, i7 (64 bit)



octa core

(μP) Micro processor	Microcontroller (μC)
① It has ALU, CU { Registers	① has ALU, CU } Registers
② No internal M/M.	② has internal M/M
③ No interfacing circuits, Timers /counters.	③ has interfacing circuits, Timers/counters
④ Used for general purpose applications.	④ Used for specific purpose applications.

Microcontroller



CAN Bus (Bosch)
↓
control area Network

⑤ Ex :- Intel 8085, i7, MC 6800,	⑤ Ex :- Intel 8051 (8Bit) Intel 80196 (16 Bit), PIC → 8 bit { 16 bit TMS1000 (4 bit),
AMD, Z80, phillips, Rockwell, Fair child, National Semiconductor	AT89C51, Motorolla, Toshiba, freescale

* Depending on how programs and data are stored in the memory. There are 2 types of architecture.

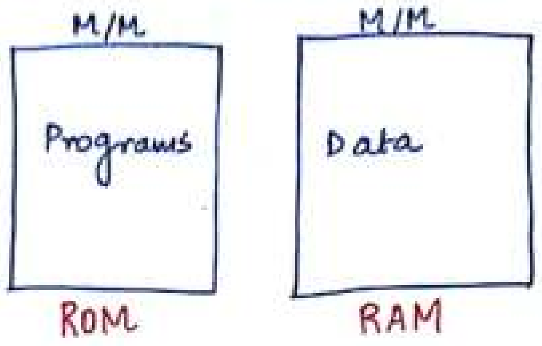
:- ⓐ Von - Neumann or Princeton architecture

ⓑ Harvard Architecture.

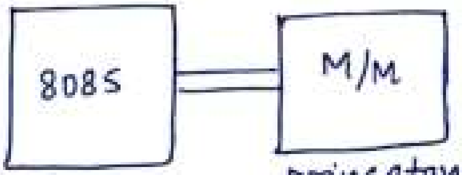
Notes by Mohit Chouksey

Ex:- Intel 8085, Intel 8086

Ex:-



Ex:- Intel 8051 (Micro controller)



princeton architecture

ROM & RAM
↳ Temporary, volatile/ Read/write.

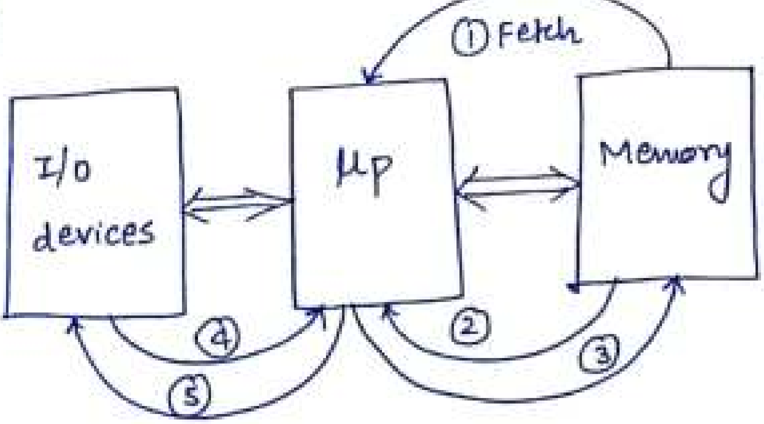
NOTE :- Both ROM & RAM are random in accessing the data from memory that is the time taken to access any of the memory locations is same.

* Basic operations of μp :-

1. opcode Fetch
2. M/M Read
3. M/M write
4. I/o Read
5. I/o write

} machine cycles

opcodes (operation code)
↑
Instructions
↑
Programs and Data's.



Notes by Mohit Chouksey

MOV A, B

↓

Assembler (software)

↓

XX (78H) → 0111 1000

opcode / Machine code.

* **Opcode fetch** → Reading or accessing ~~data~~ opcode from memory into processor, that is operation code (in some instructions, executing may also be completed in fetch operation.

* **Memory Read** :- Reading / accessing data from M/M.

* **M/M write** :- Sending / transferring data to memory

* **I/O Read** :- Reading or accessing data from I/P port/device

Port indicates connection of an i/o device

USB port

[—] KB

[—] → display

* **I/O write** :- transferring data to O/P port/device.

Number Systems :-

BITE → Boring + Tough

Decimal   Octal   Binary   Hexadecimal

N.P.

Decimal
0
↓
9
10 ← Ten
⋮
19
20

Octal	Dec
0	0
↓	↓
7	7
$(10)_8$ →	$(8)_{10}$
$(11)_8$ →	$(9)_{10}$
↓	
17	
20	

Binary	Dec
0	0
1	1
$(10)_2$ →	$(2)_{10}$
$(11)_2$ →	$(3)_{10}$
$(100)_2$ →	$(4)_{10}$

99 → 100

Hexadecimal	Decimal
0	0
↓	↓
9	9
A →	10
B →	11
C →	12
D →	13
E →	14
F →	15
10H →	$(16)_{10}$

Hex. deci	dec.
10H →	16
11H →	17
12H →	18
13H →	19
14H →	20

$2^4 = 16$

Hex-dec	Binary ($2^3\ 2^2\ 2^1\ 2^0$)
0H →	0 0 0 0
1H →	0 0 0 1
2H →	0 0 1 0
⋮	⋮
9H →	1 0 0 1
A →	1 0 1 0
B →	1 0 1 1
C →	1 1 0 0
D →	1 1 0 1
E →	1 1 1 0
F →	1 1 1 1

* Converting decimal value to another number system:-

Method :- devide the decimal value with Base of required number system. consider the remainders from last to first.

Ex :- $(15)_{10} \longrightarrow (?)_2$

Sol :-

$2 \,|\, 15$
$2 \,|\, 7 \quad 1$
$2 \,|\, 3 \quad 1$
$\quad\; 1 \quad 1$

$\longrightarrow (1111)_2$

$1\times2^3 + 1\times2^2 + 1\times2^1 + 1\times2^0$ ← Bit position

$\downarrow \quad \downarrow \quad \downarrow \quad \downarrow$

$(15)_{10} \longleftarrow 8 + 4 + 2 + 2^0\times1$

Q $(20)_{10} \longrightarrow (\quad)_{16}$

Sol

$16 \,|\, 20$
$\quad\;\; 1 \quad 4$

$\longrightarrow (14H)_{16} \longrightarrow 1\times16^1 + 4\times16^0$

$\Rightarrow 16 + 4$

$\downarrow$

20 ✓

Q $(1111001110010111)_2 \longrightarrow (\quad)_{16}$

Sol One Hexa dec. have 4 bits

$(\underset{F}{\underline{1111}}\ \underset{3}{\underline{0011}}\ \underset{9}{\underline{1001}}\ \underset{7}{\underline{0111}})_2 \longrightarrow (F\,3\,9\,7)_{16}$

for octal $\longrightarrow 2^{③} = 8 \longrightarrow$ 1 digit $\longrightarrow$ <u>3 Bits</u>

Tricks

Dec.

9	9
+(7)	+5
16	14

Dec.

0 ↓ 9

10

+0 → 10

1 → 11

⋮

9 → 19

20

Hexa-dec.

$x \rightarrow 0-F$

0 ↓ 9 A ↓ F

10H

+0 → 10H

1 → 11H

⋮

9 → 19H

A → 1AH

B → 1BH

⋮

F → 1FH

20H

10H
+ x
1xH

Hex-dec

F	F
+(7)	+5
16H	14H

Q

```
   ¹
   F F H
 + 8 (9) H
 ---------
   8 8 H
```

Q

```
   ¹ ¹ ¹
   F F F F H
 + 9 8 7 6 H
 -------------
 1 9 8 7 5 H
```

Q.

```
  ¹ ¹ ¹
  D E D E H
  8 5 7 9 H
 -----------
 16 4 5 7 H
```

E + 1 → F
↑
+ 9 − 1 → 8
+
17H

Q.

```
   B 6 D 3 H
 + 4 8 2 9 H
 ------------
   F E F C H
```

E
+8 → +F
−1
7 → 7
16H

* Finding one's complement of a Binary value :-
(1S)

Method :- complement / shuffle the Bits from 1 to 0 (or) 0 to 1

Notes by Mohit Chouksey

Ex :- $(1\,0\,0\,1\,0\,0\,1\,1)_2$

0 1 1 0 1 1 0 0 ← 1's complement

* Finding 2's complement :-

Method :- add 1 to the LSB (Least significant Bit) of 1's complement

Ex :-

MSB							LSB
0	1	1	0	1	1	0	0
+							1
0	1	1	0	1	1	0	1

↑ 2's complement

* -ve value of hexa.dec. → Binary ka 2's complement

$(1001\ 0011)_2$

↓

$(0110\ 1101)$

0110 → 6, 1101 → D_H

−93H = 6DH

Trick :-

* F | 10H
  − 9 | 3H
  = 6 DH

−93H = 6DH

* F | 10H
  − 5 | 4 H
  = A C

−54H = AC

* Subtraction :-

Manual		Processor
A - B	=	A + (-B)

97 H → A
-43 H → B
54 H

97 H → A
+BD H → (-B)
54 H
carry on 1 (discard)

F | 10 H
- 43 H
BD H

-43H = BDH

Solve

85 H
- 29 H
5 C H

85 H
+ D7 H
5CH
carry on 1 (discard)

16
85H
- 29H
5C H ✓

21
- 9
12

F | 10 H
- 29 H
D 7 H

85 H
+ D7 H
22 H

16
- 9
7

15
- 2
13

9
+ 13
22

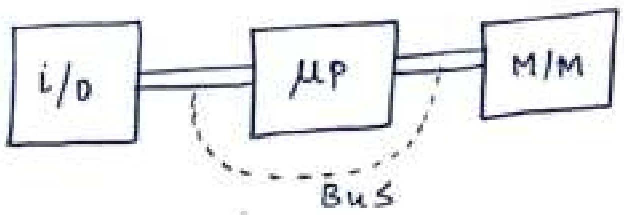
* 8085 Syllabus

1. System Bus
2. Internal Architecture - Interrupt
3. pin layout
4. programming Model
5. Instruction format
6. Addressing Modes
7. Timing diagram
8. Instruction set classification
9. Simple programs
10. Interfacing → I/O's
    → M/M

Modules		Marks
I. Architecture	① - ③	50% - 60%
II. programming	④ - ⑨	40% - 50% (II + III)
III. Interfacing	⑩	

* **System Bus** :- Bus is a group of wires or conductors used for communication between processor, memory and i/o devices. There are 3 types of Buses:-

ⓐ address Bus
ⓑ Data Bus
ⓒ Control Bus



ⓐ **address Bus** :- **purpose** :- (i) It is used to transfer the adress of either memory or i/o from the processor.

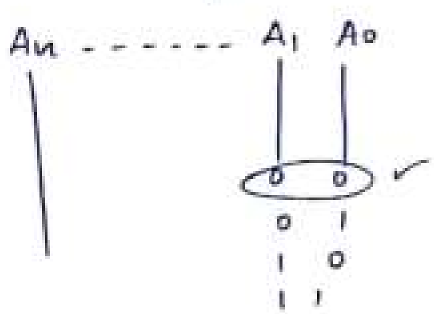
(ii) It defines the maxm. memory that can be connected to a processor given by the Relation

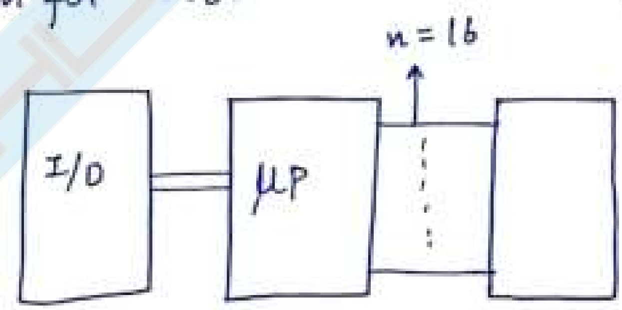
$$2^n = N$$

N → No. of Address/Memory locations

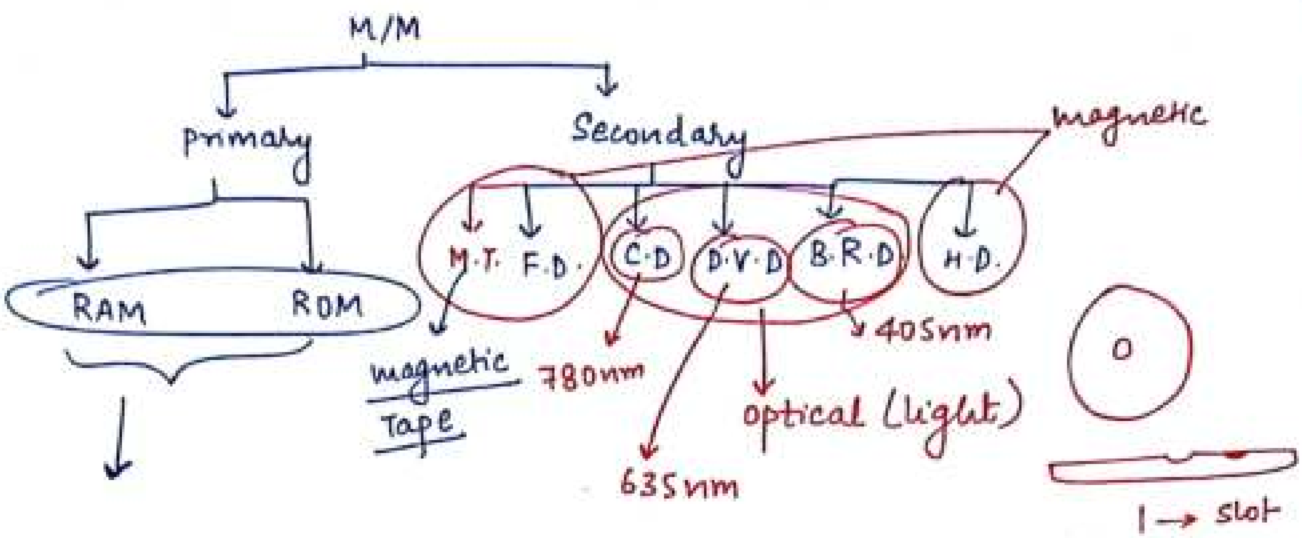
n → no. of Address lines

length :- It is of 16 Bits in length for 8085.

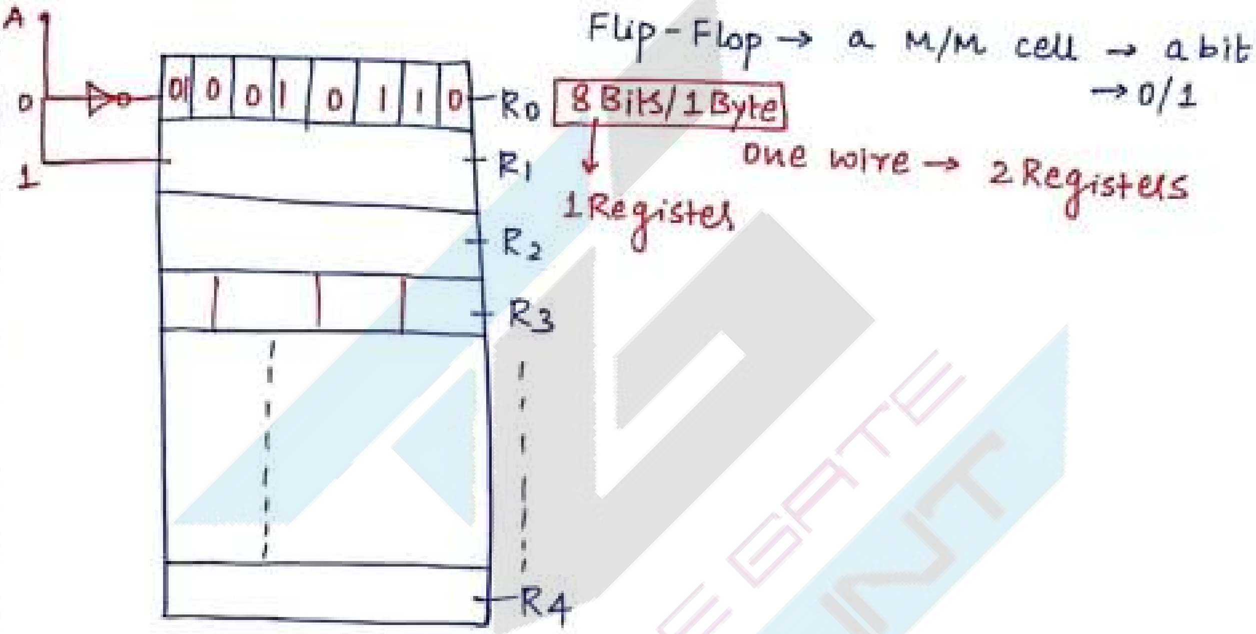




Direction :- Unidirectional.



* Memory



- Memory is a group of Registers. A Register is a group of flip-flops. a flip-flop is a memory cell which can store a Bit that is 0 or 1.
- Most of the memories are designed to store or hold 8 Bits per each register or M/M location or address location. ∴ M/M is represented in terms of Bytes.
- The standard word length of M/M is 8 Bits or 1 Byte.

* Relation b/w address line & Memory :-

address line ← $2^1 \rightarrow$ 2Byte

$2^2 \rightarrow 4B$

$2^3 \rightarrow 8B$

$2^4 \rightarrow 16B$

$2^5 \rightarrow 32B$

$2^6 \rightarrow 64B$

$2^7 \rightarrow 128B$

$2^8 \rightarrow 256B$

$2^9 \rightarrow 512B$

$2^{10} \rightarrow 1024B$

$\rightarrow 1KB$ → only if 1 Register can accomodate 8 Bits.

$2^{10} \rightarrow$ 1 Kilo Byte / 1KB

$2^{20} \rightarrow$ 1 Megabyte / 1 Mb

$2^{30} \rightarrow$ 1 Gigabyte / 1GB

$2^{40} \rightarrow$ 1 Tera Byte / 1TB

01/11/2016

Q) A processor has 24 address lines. find the max^m. memory that can be connected

$2^{24} \rightarrow$

Sol

$2^{24} \Rightarrow 2^4(2^{20})$

$16(1MB)$

16 MB

Q. A max^m. memory of 512 TB can be connected to a processor. Find the address lines Required

Sol

$2^n = 512\ TB$

$= 2^9(2^{40})$

$2^n = 2^{49}$

$n = 49$

Q It is required to interface or connect a MM of 100 GB to a processor. find the minm. address line required.

Sol

$2^n = 100\,GB$

$1GB \rightarrow 2^{30}$

$2^{36} \longrightarrow 64GB$

100GB

$2^{37} \longrightarrow 128GB$ ✓ Ans

Q

16 address lines.

maxm. M/M = ?

Sol $2^{16} \rightarrow 2^6 (2^{10})$

64 (1KB)

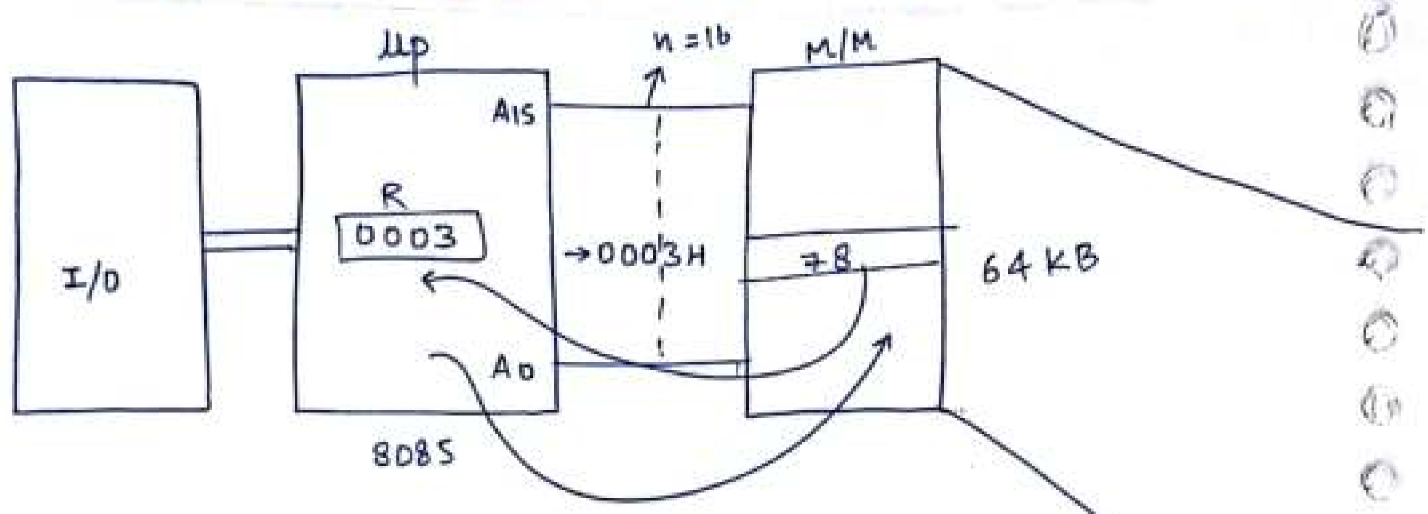
64 KB

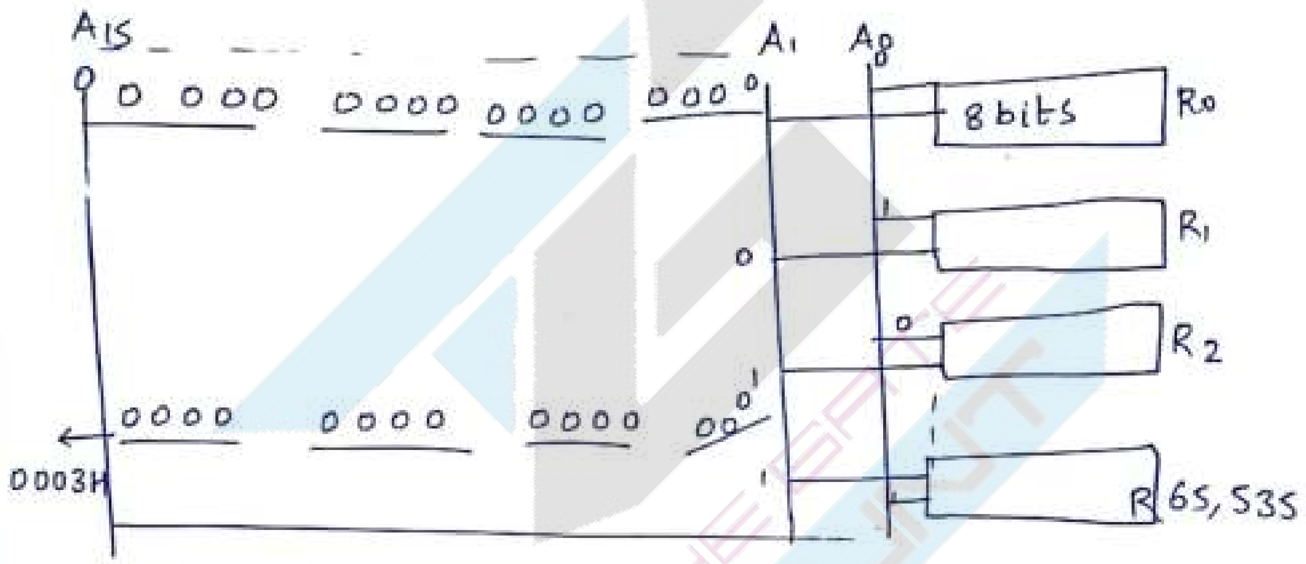
64 × 1024 B

65,536 Byte → maxm. M/M that can be connected to 8085

Note :- ① wrt memory there is no difference b/w opcode and data. both are present in Binary form.

[N.P.]





* **Data Bus**

purpose :- It is used to transfer data b/w processor, M/m and I/O devices

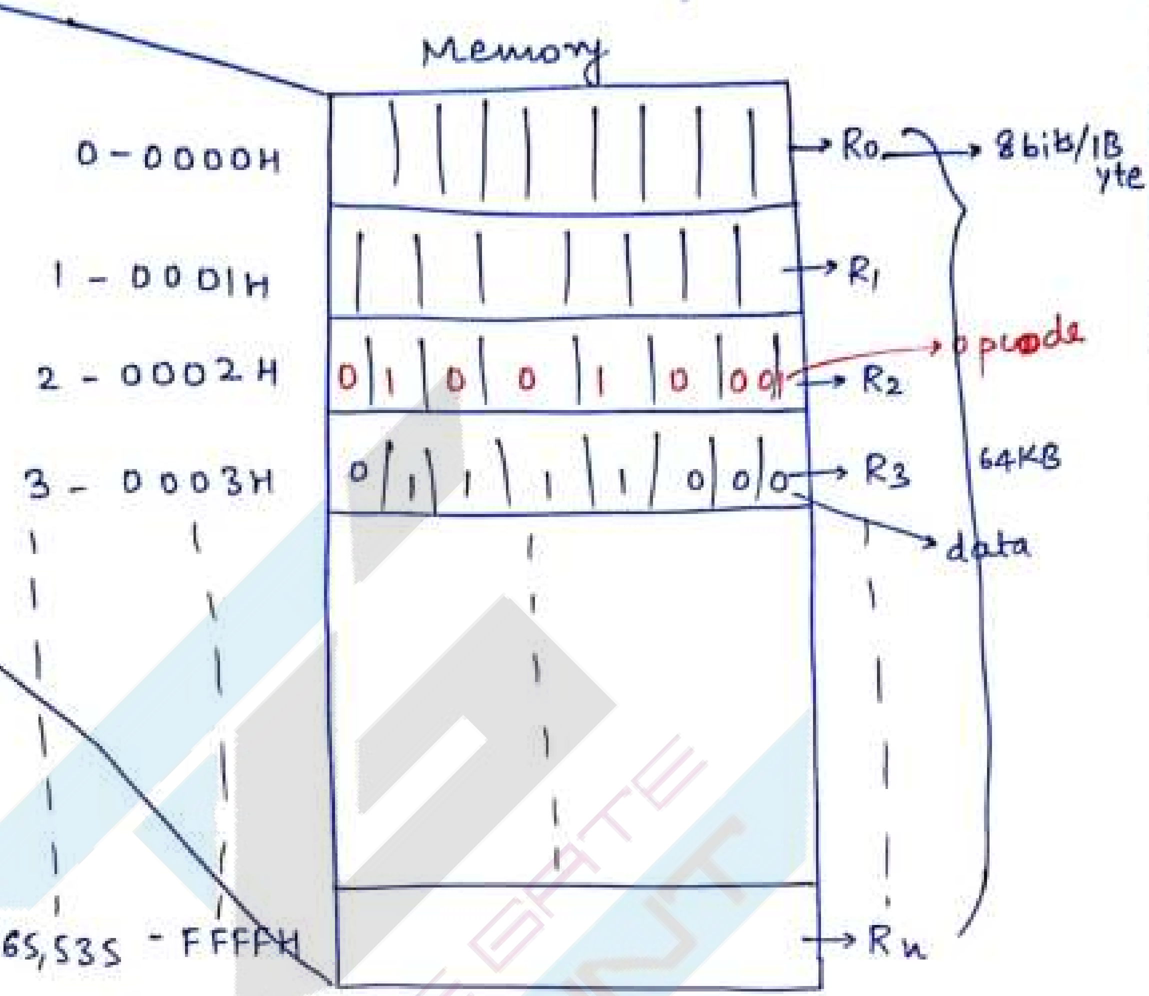
length :- It is of 8 Bits in length.

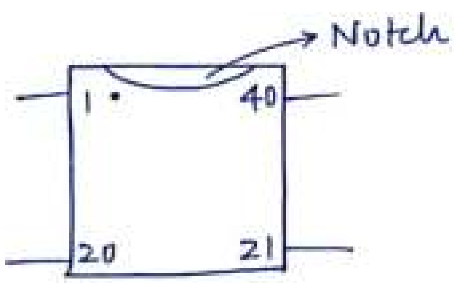
Dirn :- Data bus is Bidirectional.

Note :- 8085 does not have separate databus. The lower 8 address lines can be used either as address or data bus with the help of a signal known as ALE (address latch enable). → Interfacing component.

0101 0001
5 1H

0111 1000
7 8H





16
+8
24

ALE → 1 ; All 16 lines → address bus

→ 0 ; A_{15} - A_8 → address bus

AD_7 - AD_0 → Databus

↓

Multiplied address/data bus.

$A_{15} - A_8$	$AD_7 - AD_0$
ALE → 1 ; Higher order address bus	lower order address bus
→ 0 ; address Bus	Data Bus

* <u>Control Bus</u> :- It is a group of different control signals required for various operations of the processor.

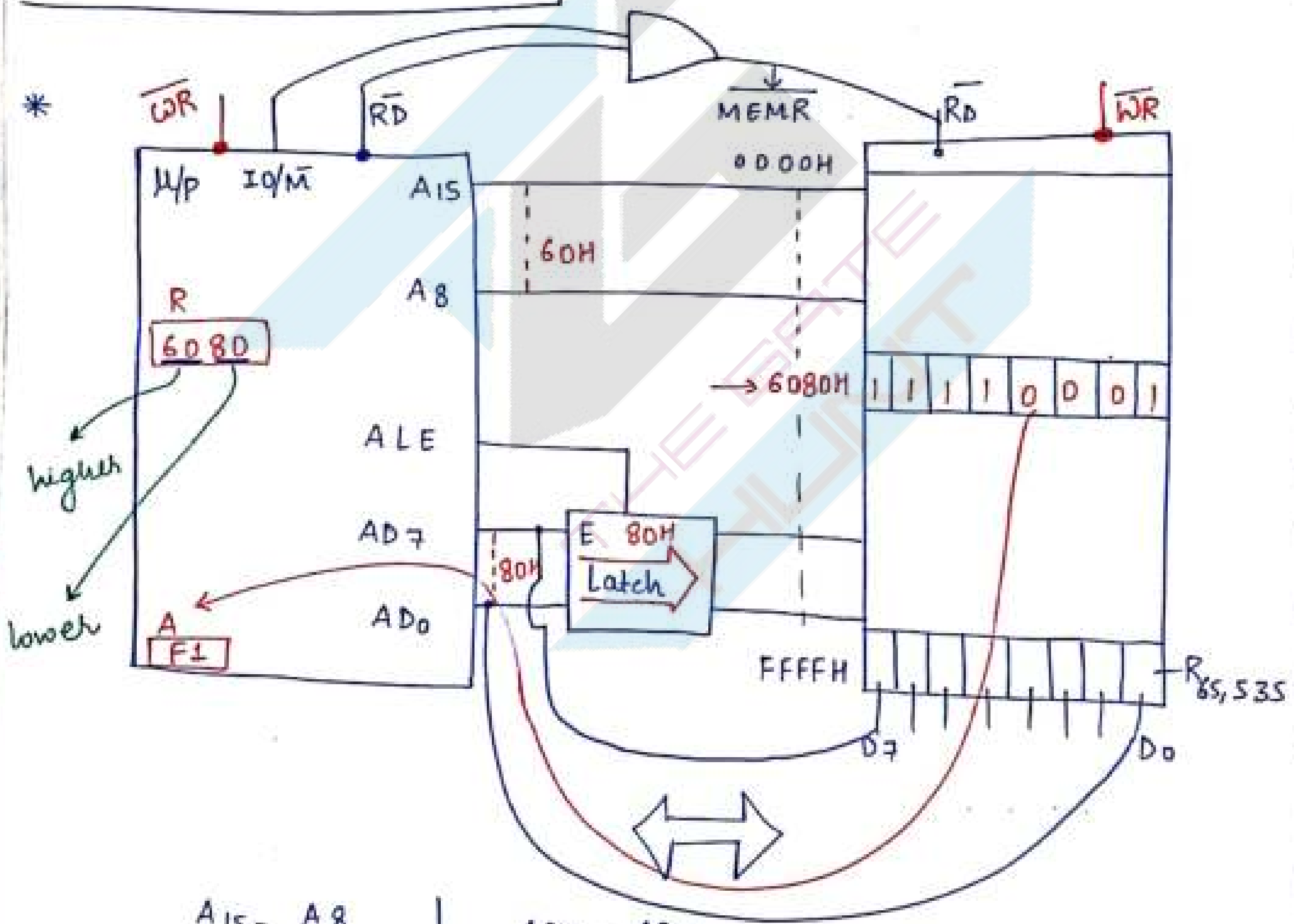
$\overline{RD}$ →

$\overline{WR}$ →

ALE →

A_{15}	A_8
0110	0000

*



$A_{15} - A_8$	$AD_7 - AD_0$
ALE → 1 ; address 60H	address 80H
ALE → 0 ; Address Bus 60H	Databus F1H

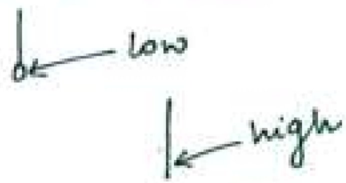
$IO/\overline{M}$ → 0 ; M/M operation
→ 1 ; I/O —"— ——

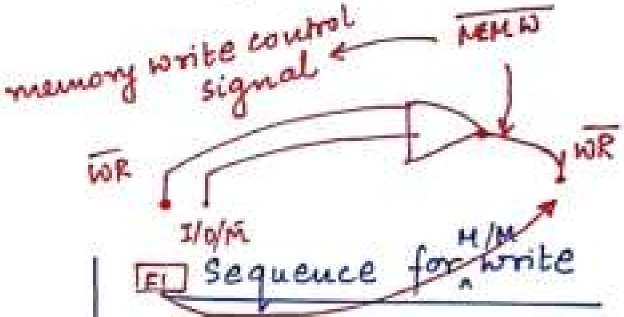
$\overline{RD}$ → Read control signal
→ 0 ; Active

$\overline{WR}$ → write control signal
→ 0 ; Active

$\overline{MEMR}$ → M/M Read control signal

$\overline{RD}$ → Active low





Sequence for M/M Read

1. ALE → 1 ; select M/M address
2. ALE → 0 ; $AD_7 - AD_0$ → Data bus
3. $\overline{RD}$ → control signal is activated
4. Data is placed on $D_7 - D_0$ i.e. $AD_7 - AD_0$

Sequence for write

1. ✓
2. ✓
3. $\overline{WR}$
4. Data is placed on $AD_7 - AD_0$ then to M/M

Note :- ① Memory has separate address lines and separate data lines whereas processor does not have seperate address lines and separate data lines as AD_0 to AD_7 can be used either as address or data bus.

② Latch → It is an interfacing component use to hold the lower Bit of address till read or write operations are completed.

$2^n = N = m$

Fig: Notation of a Memory chip

No. of bits/location

↑

m × n

↓

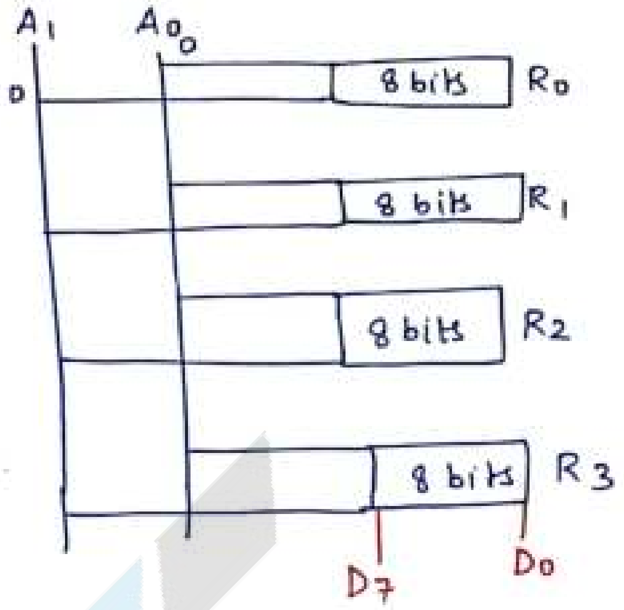
No. of address locations

RAM

4 × 8

4 → Byte (maxm.)

8 → Bits



Q RAM 256 × 8

find address lines → 8 Bits

Data lines → 8 Bits

Capacity of chip in Bytes → 256 B

Sol

D.L. → 8

256 × 8

↓

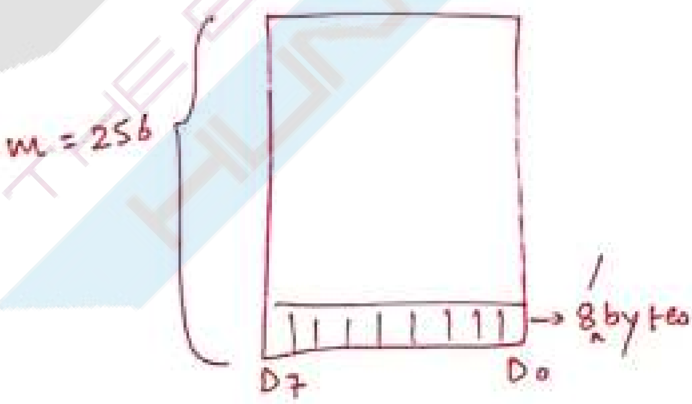
$m = 2^n$

$= 256 = 2^8$

n → 8

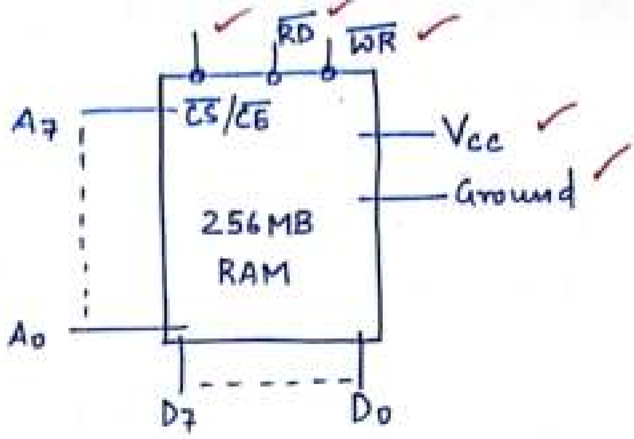
↓

address lines



? No. of pins :-

8 + 8 + 5 = 21



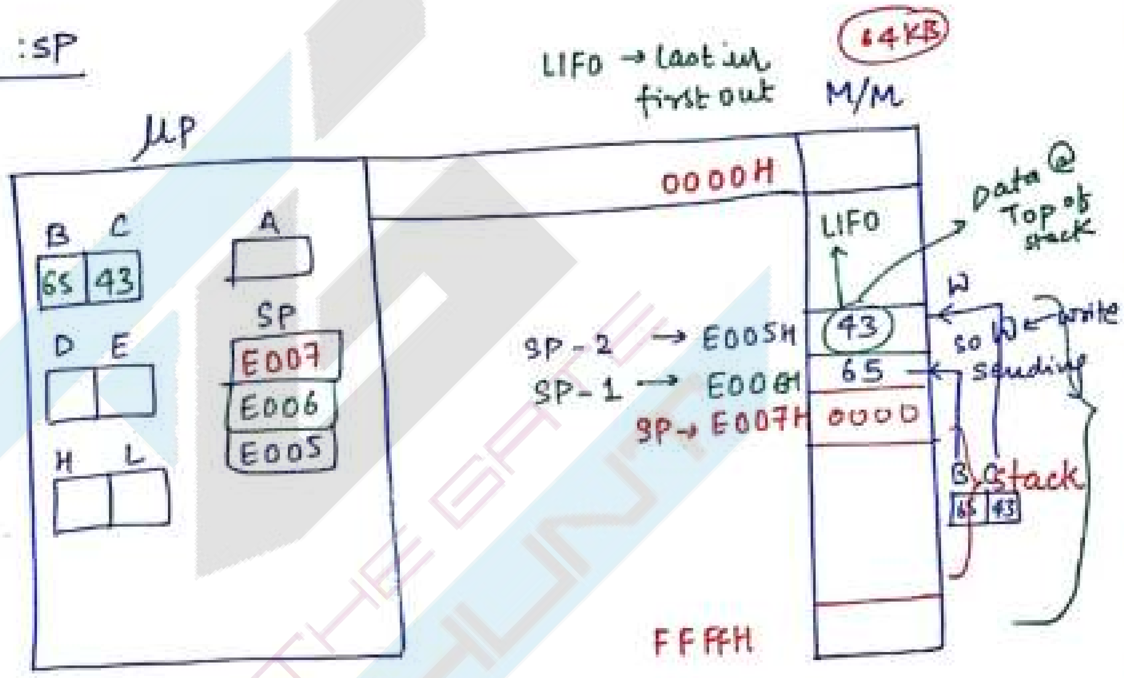
$\overline{CS}$ / $\overline{CE}$ → chip select / Enable

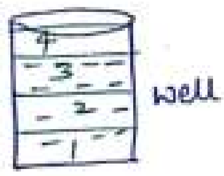
→ used to select the chip using decoding logic

★★★

Stack pointer : SP

SP → 16 Bit Register





Ex :- Q :

SP ⟶ 9004H

If (DE) ⟶ pushed on to stack

DE	
98	67

then SP ⟶ (9002H) ✓

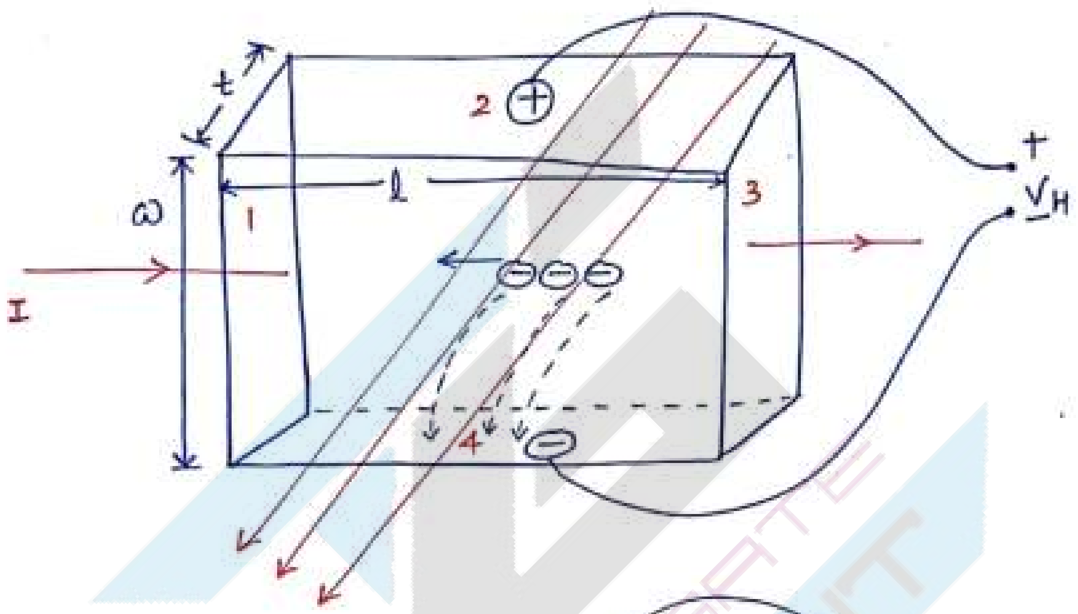
Data @ Top of stack → ? (67H) ✓

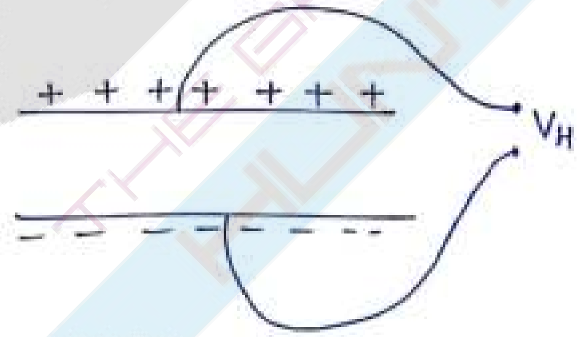
Notes by Mohit Chouksey

07/11/2016

Hall Sensors :- hall sensors works on principle hall effect.

Hall Effect :- If a charged particles or charged carriers placed in a magnetic field, then they will deviate from their original path and acquires new path. Hall Effect can be observed both in conductors as well as semiconductors.





→ current density

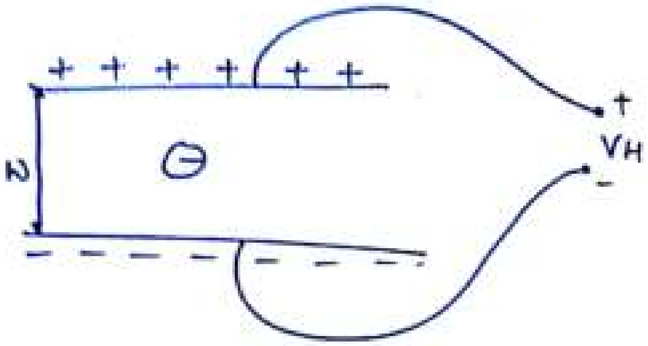
$$J = \frac{I}{A} = \frac{I}{w \times t} = \frac{N \cdot e \cdot x l}{w \times t \times l \times time}$$

$$= \frac{N \cdot e \cdot V_d}{V} \quad (V \to \text{volume})$$

$$\boxed{J = \frac{I}{A} = n \cdot e \cdot V_d} \rightarrow (1)$$

→ Force Acting on electron in Magnetic field

$$F_B = e V_d B \quad [q(\vec{V} \times \vec{B})] \longrightarrow (2)$$



$$F_E = e \cdot E$$

$$F_E = e \cdot \left(\frac{V_H}{W}\right)$$

at steady state

$$F_B = F_E$$

$$e V_d B = e \cdot \frac{V_H}{W}$$

$$V_H = W \times V_d B$$

$$= W \times \frac{IB}{W \times t\, n e}$$

$$\boxed{V_H = K_H \cdot \frac{IB}{t}}$$

(t → dimension ∥ to magnetic field B.)

where $\boxed{K_H = \frac{1}{ne}}$

K_H → hall coefficient

n → no. of electrons per volume

e → charge of e⊖

$$V_H = K_H \cdot \frac{IB}{t}$$

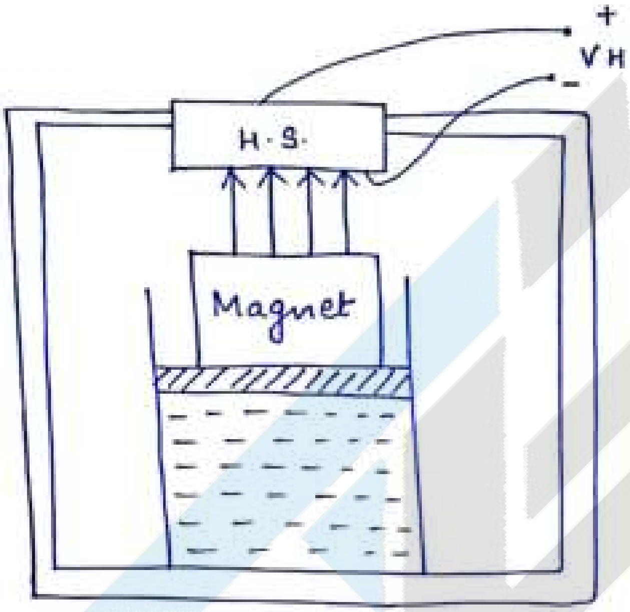
$$V_H = K_H \cdot \left(\frac{\vec{I} \times \vec{B}}{t}\right)$$

$$V_H = f(I, B, t).$$

Notes by Mohit Chouksey

Q. For the liquid level measurement hall sensor setup is used as shown below. The sensor carries a current of 2 amperes ⊥ to the magnetic field. The magnetic field associated with the sensor changes with the liquid level as $B(h) = (0.2h + 0.1)\frac{Wb}{m^2}$, if the output voltage of the hall sensor is ⊥r to the both applied magnetic field and current, then find the change in output voltage when the liquid level in the tank increased from 1m to 3m. The thickness of the sensor is 0.1m and the magnitude of the Hall coefficient is 10 units.

Sol



$B(h) = (0.2h + 0.1)\,Wb/m^2$

$t = 0.1m$

$K_H = 10$ units

$I = 2A$

80 ↑ Ans

@ h = 0m (tank is empty)

$B(0) = 0.2 \times 0 + 0.1$

$B(0) = 0.1\ Wb/m^2$

$V_H(0) = K_H \frac{I \cdot B(0)}{t}$

$= 10 \times \frac{2 \times 0.1}{0.1}$

offset voltage → $V_H(0) = 20V$

$\Delta h = 2m$

$B(\Delta h) = 0.2\Delta h + 0.1$

$= 0.2 \times 2 + (0.1)$

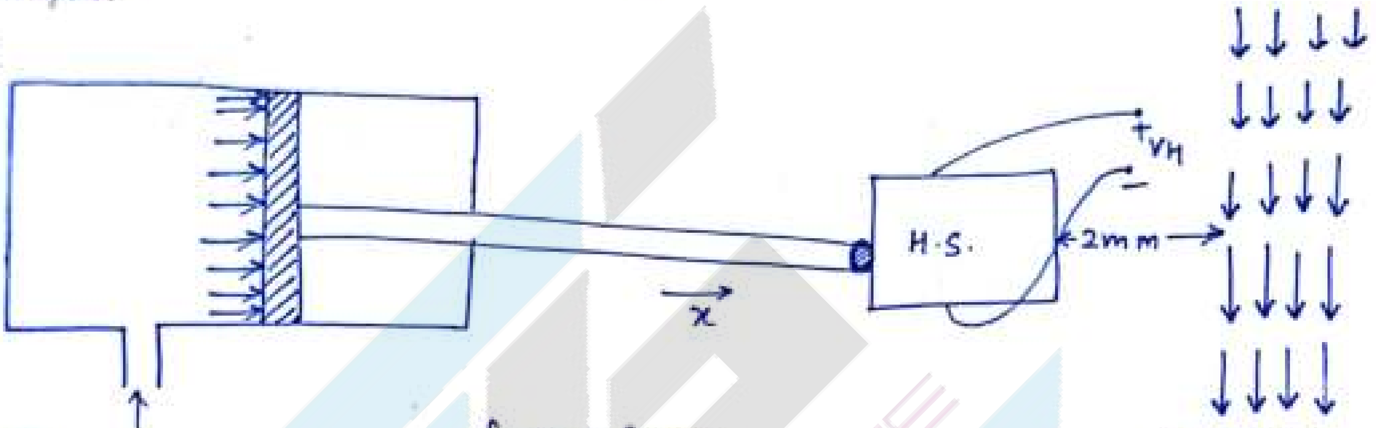
$y = mx$

$y = mx + c$ → Non-linear fn.

Note :- $y = mx$ is the linear function but $y = mx + c$ is not the linear relation.

Q Consider the following figure where the gap between the cylinder and hall sensor is assumed to be zero. If the cylindrical rod mechanism has sensitivity of 1 mm/10 N, then find the minimum input pressure of the oil which acts on the piston can generate output voltage. The diameter of the piston is 100 mm and the thickness of the hall sensor is 0.1 mm and the hall coefficient of the sensor is 10 units. Hall sensor carries a current of 2 A and strength of magnetic field is 5 Wb/m²

Sol



magnetic field (5Wb/m²)

(1mm / 10N)

for $x = 2mm$

the required force = 20N

$$\text{the required pressure} = \frac{F}{A_p} = \frac{20}{\frac{\pi}{4}(100 \times 10^{-3})^2}$$

$$= 2.546 \text{ KPa}$$

Q In the above setup, if the volumetric flow rate of the oil is 10 ml/sec then find the minimum time required, after which voltage will be generated.

Sol

$$Q = \frac{10 ml}{sec}$$

$$Q = \frac{10 \times 10^{-3} \times 10^{-3} \ m^3}{sec}$$

$$\text{Velocity of Rod} = \frac{Q}{A_p} = \frac{10 \times 10^{-6}}{\frac{\pi}{4}(100 \times 10^{-3})^2}$$

$V = 1.27$ mm/sec

1 sec → 1.27 mm

1.57 sec ↔ 2 mm

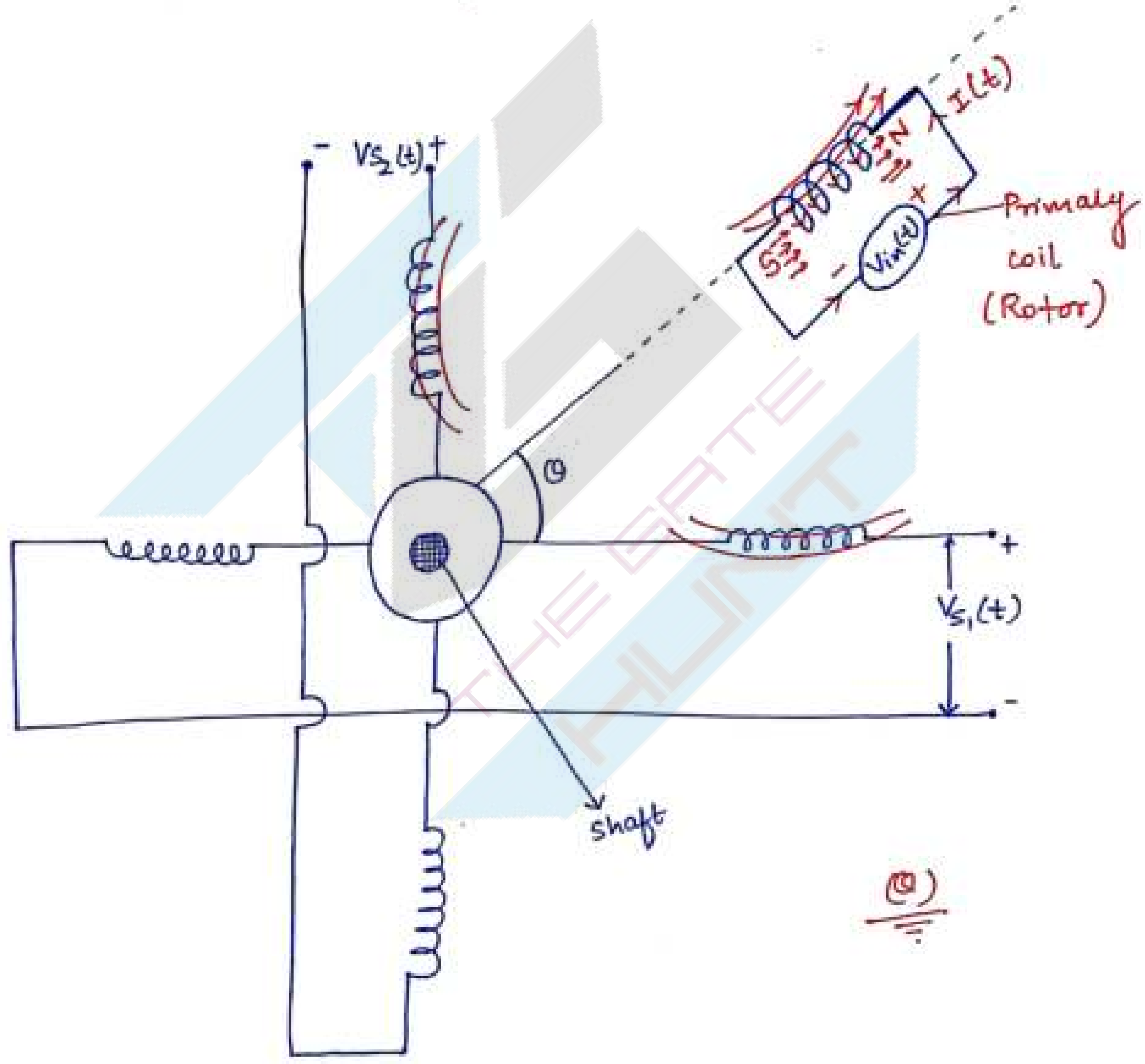
$t = 1.57$ sec

* Transformers

$$\frac{V_s(t)}{V_{in}(t)} = k$$

$$V_s(t) = k \cdot V_{in}(t)$$

RESOLVER → 1 Primary coil
2 Sec. coil
4 windings



$$V_{S_1}(t) = K V_{in}(t) \cos\theta$$

$$V_{S_2}(t) = K V_{in}(t) \sin\theta$$

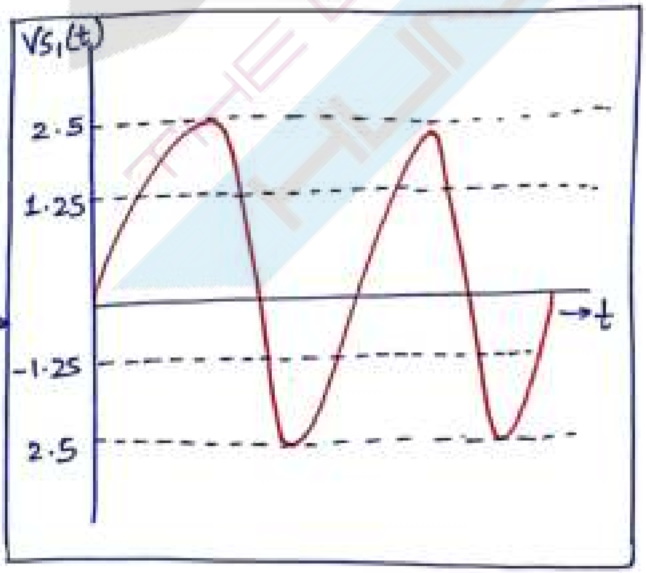
Notes by Mohit Chouksey

Resolver is a electrical device which is used to measure angular position of the shaft (θ) as well as angular velocity. Resolver works on the principle electro-magnetic induction. The Resolution of Resolver is very good compared to optical encoder. Resolver consist of one single primary coil and 2 secondary coil which are connected as shown Below :→ Previous page.

Q A Resolver, which is used to measure the angular displacement θ generates 2 components of output. The cosine output of resolver is connected to C.R.O. (cathode Ray oscilloscope), which displays the output as shown in the figure. If the transformation ratio is 0.5 and the input applied to primary coil is 10 sin ωt (the frequency of the supply voltage is very high compared to the shaft speed). For the wave form which is shown on CRO, the angular position of the shaft is ____.

ⓐ 60°
ⓑ 30°
ⓒ 90°
ⓓ 120°.

C.R.O. →



Sol

$K = 0.5$

$V_{in}(t) = 10 \sin \omega t$

Cosine output

$$V_{S_1}(t) = K \cdot \cos\theta \cdot V_{in}(t)$$

$$= K \cdot \cos\theta \cdot [10 \sin\omega t]$$

$$= (5 \cdot \cos\theta) \sin\omega t$$

Amplitude $= 2.5$ | $\theta = 60^\circ$ (or) $\theta = 300^\circ$

$5\cos\theta = 2.5$

$\cos\theta = 1/2$

1 Rev/1 sec

$\frac{360^\circ}{1\,sec}$ → θ $\frac{360^\circ}{0.01\,sec}$

Display

0° → 60° $(1/6\ sec)$ (30°)

*** NOTE :-** For the proper display, It is mandatory to keep the supplied frequency very high compare to the shaft speed.

Q. If the wave form amplitude becomes 2.5, 10 times in one sec then the shaft speed is ____.

Sol

10 times → 5 Rev → 1 sec

300 Rev ← 60 sec (1 min)

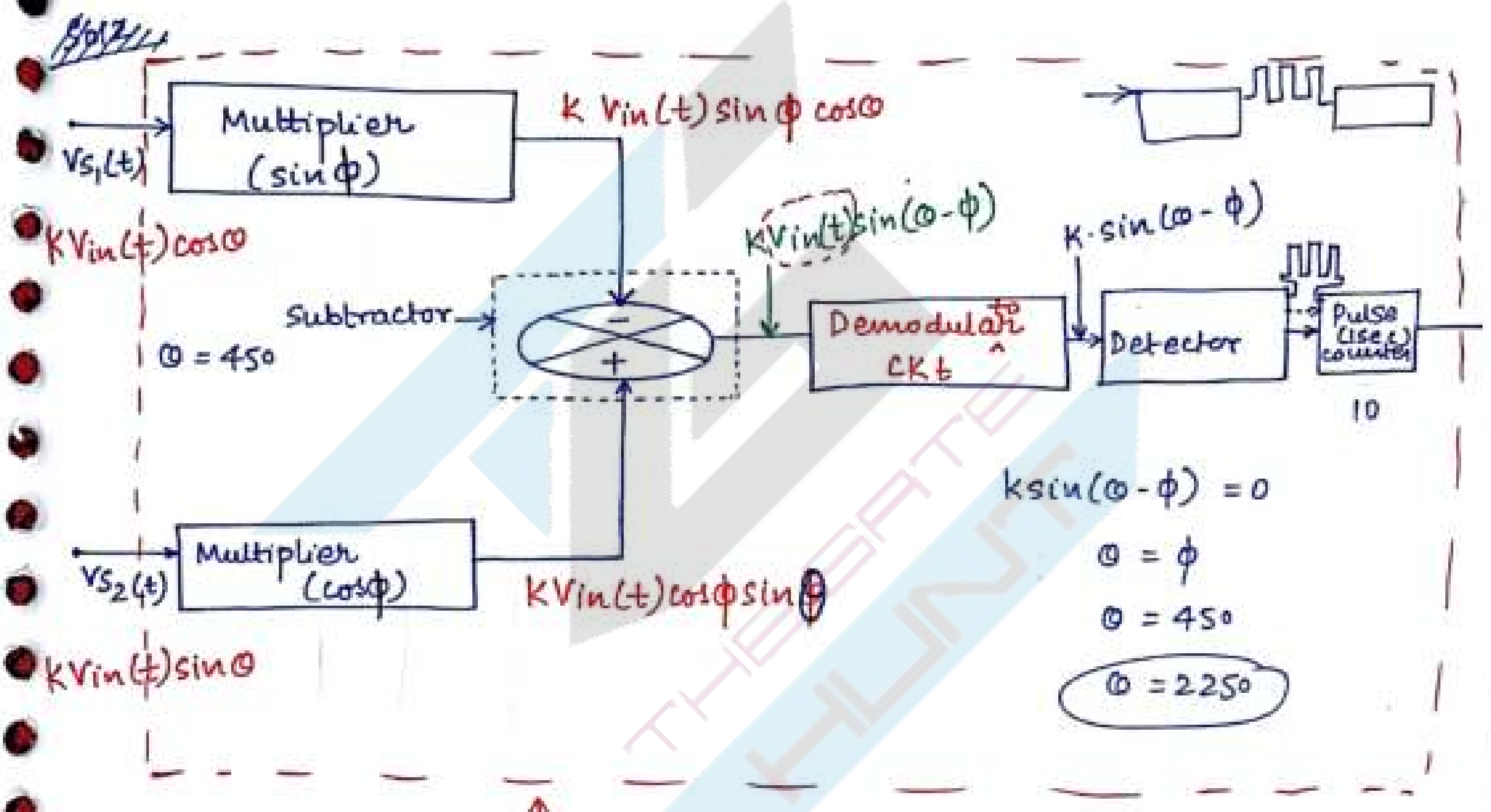
Shaft speed = 300 RPM

Q2 The Resolver output signals are processed as shown by using multiplier and detector mechanism. both multiplier and detector or electronic devices and detector properties are sensitive to angular position of the shaft only.

Detector generates a pulse when it own input becomes 0. Determine :-

(a) the angular position of the shaft when the detector generates a pulse.

(b) ____.



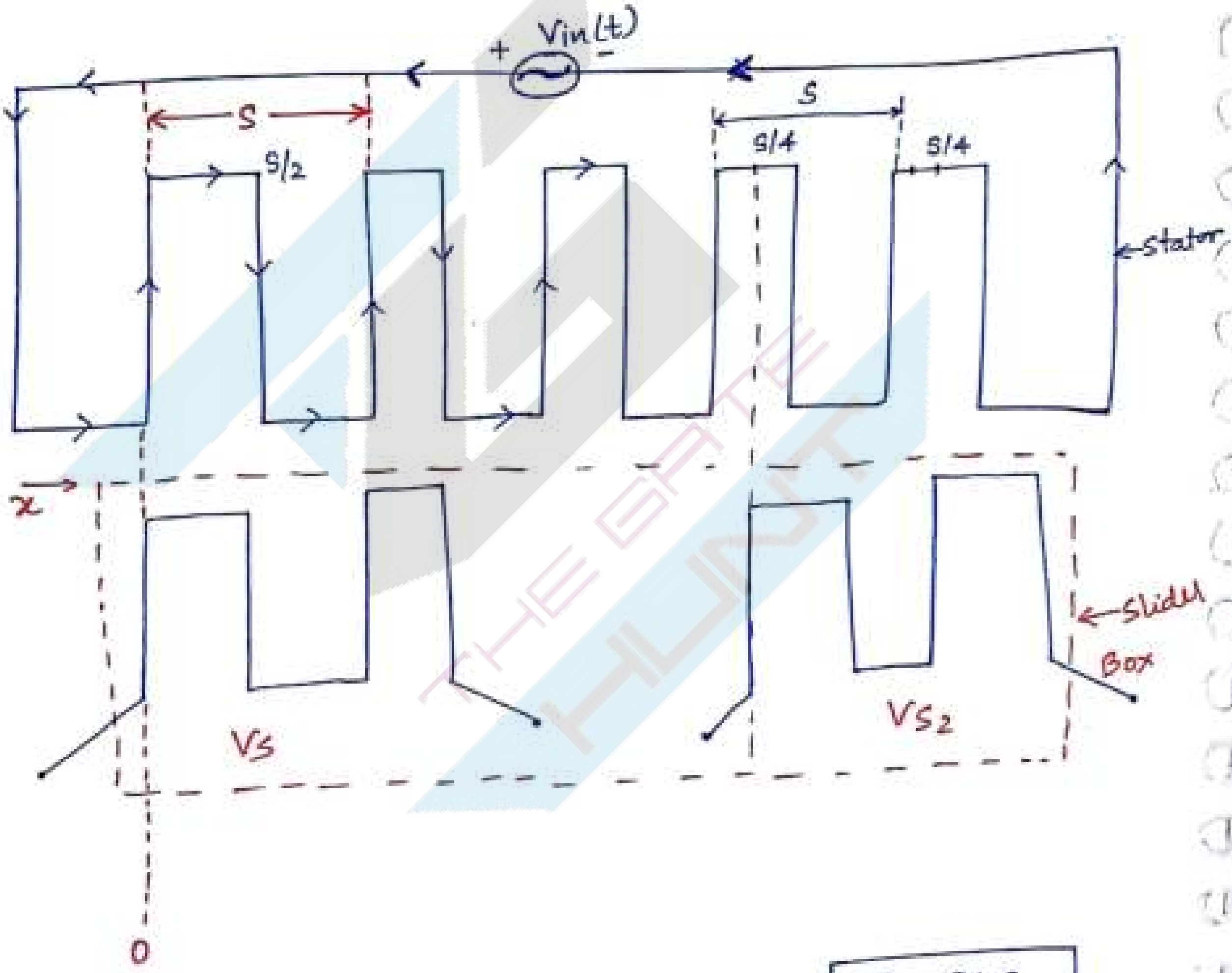
Signal processing Block

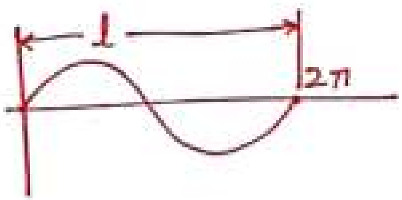
Inductosyn → It is a electrical device which is used to measure linear displacement (x).

Inductosyn operates on principle electromagnetic induction. The operation of Resolver as well as inductosyn both are same, the only difference is resolver is used to measure angular displacement and inductosyn is used to measure linear displacement. Inductosyn consist of stator and slider as shown below.

The slider moves laterally above the stator

~~and then~~





$S \rightarrow 360°$

$S/4 \leftarrow 90°$

$T \rightarrow S \rightarrow 360°$

$t \rightarrow x \rightarrow \theta$

$$\frac{t}{T} = \frac{x}{S} = \frac{\theta}{360°}$$

x	V_s
0	V_{max}
$\frac{S}{2}$	$-V_{max}$
S	V_{max}

$V_{S_1} = K \cdot V_{in}(t) \cdot \cos\theta$

$= K \cdot V_{in}(t) \cdot \cos(\omega t)$

$= K \cdot V_{in}(t) \cdot \cos(2\pi f \cdot t)$

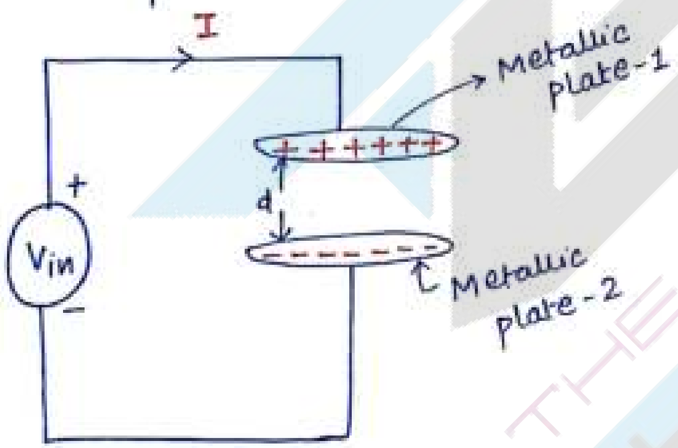
$= K \cdot V_{in}(t) \cdot \cos\left(2\pi \cdot \frac{t}{T}\right)$

$V_{S_1} = K \cdot V_{in}(t) \cdot \cos(2\pi \cdot x/s)$

$V_{S_2} = K \cdot V_{in}(t) \cdot \sin(2\pi \cdot x/s)$

The resolution of the inductosyn is very good, as we can measure displacement of small units.

* **BASICS OF CAPACITANCE** :- The ability to store electric field is called capacitance.



$\boxed{q = CV}$; $I = \frac{dq}{dt} = \frac{d(C \cdot V)}{dt}$

$C = \frac{\epsilon \cdot A}{d}$

$\Rightarrow C = \frac{\epsilon_0 \cdot \epsilon_r \cdot A}{d}$; $C = f(\epsilon_r, A, d)$

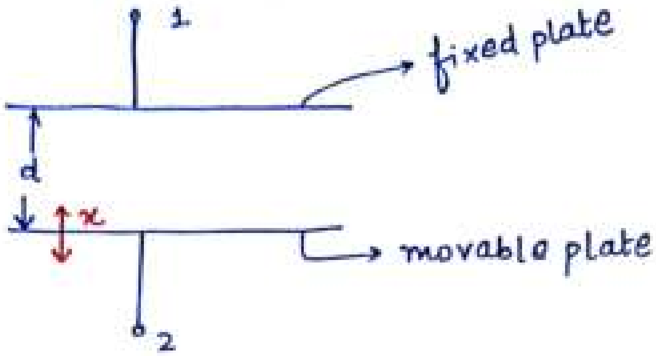
$\epsilon_0 \rightarrow$ permitivity of free space $= 8.85 \times 10^{-12} \left(\frac{F}{m}\right)$

$\epsilon_r \rightarrow$ Relative —"— of medium

$A \rightarrow$ Area of overlapping (m^2)

$d \rightarrow$ distance b/n both the plate (m)

Measurement of Displacement



@ $x = 0\,mm$

$$C_0 = \frac{\epsilon A}{d}$$

@ $x \neq 0\,mm$ (↓)

$$C = \frac{\epsilon A}{d+x}$$

$$\Rightarrow C = \frac{\left(\frac{\epsilon A}{d}\right)}{1+\frac{x}{d}}$$

$$\Rightarrow C = \frac{C_0}{1+x/d}$$

$$\Rightarrow C = C_0\left[1+x/d\right]^{-1}$$

$$\Rightarrow C = C_0\left[1-x/d\right]$$

$$\Rightarrow C = C_0 - C_0\,x/d$$

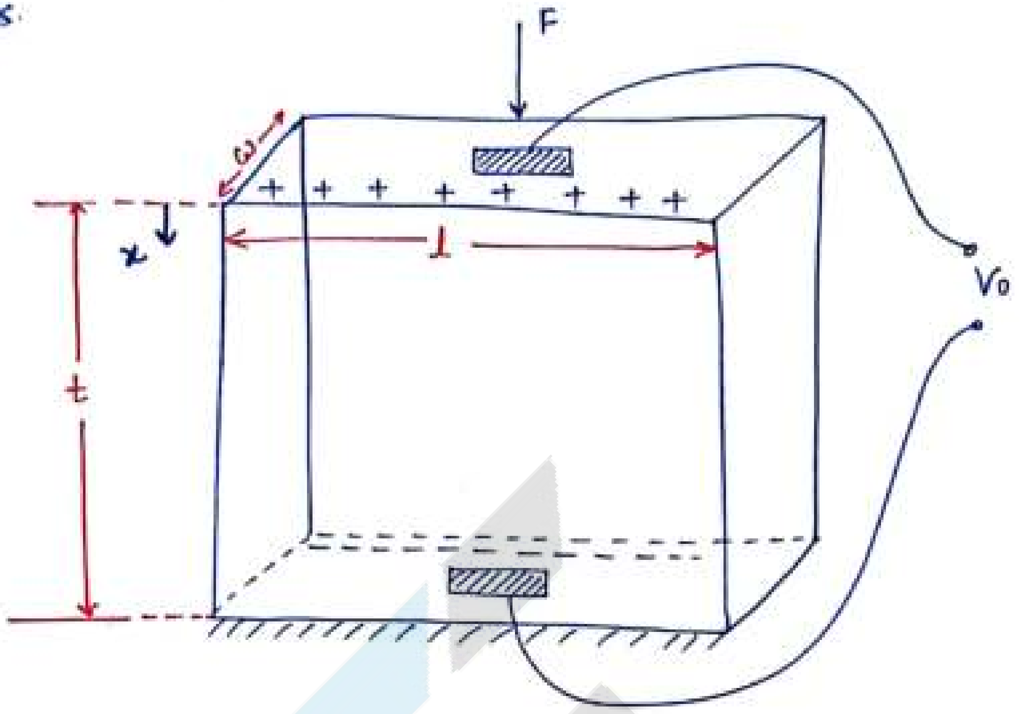
$$\Rightarrow C = C_0 - \Delta C$$

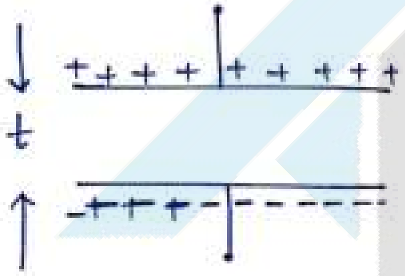
$$\Delta C = \frac{C_0 x}{d}$$

(y, m)

$\boxed{\Delta C \propto x}$

Piezoelectric Sensors :- piezoelectric sensors are made up of piezoelectric crystals which works on the principle piezoelectric properties.





$$q = CV_0 \longrightarrow (1)$$

$$q \propto F$$

$$q = dF \longrightarrow (2)$$

$d \rightarrow$ charge sensitivity (C/N)

$$CV_0 = dF$$

$$V_0 = \frac{d}{C} F$$

$$V_0 = \frac{d}{\left(\frac{\epsilon A}{t}\right)} F$$

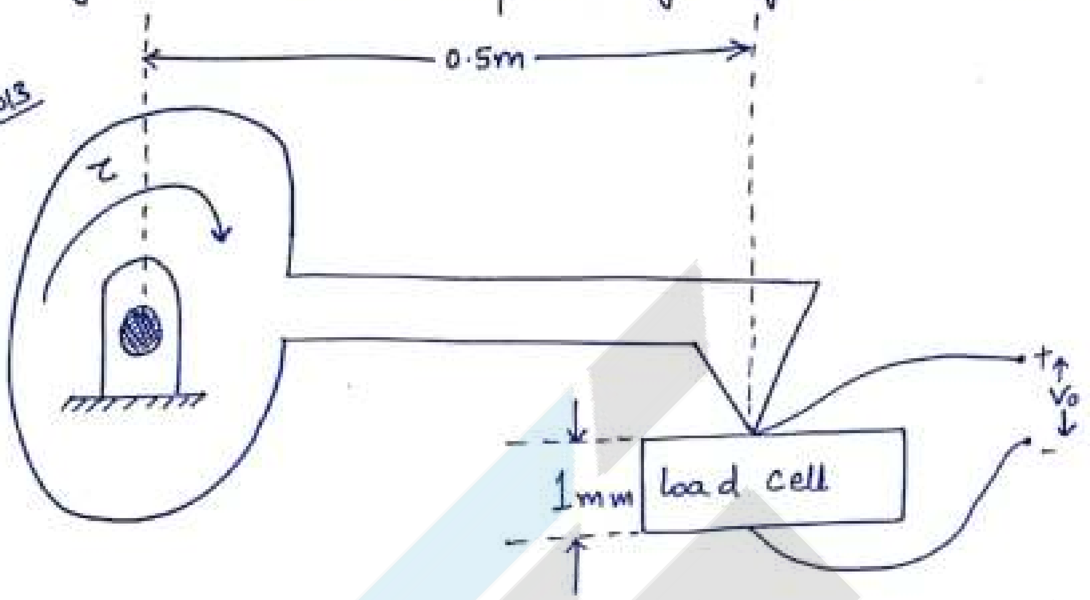
$$V_0 = \frac{d}{\epsilon} \times t \times \frac{F}{A}$$

$$\frac{V_0}{t} = \frac{d}{\epsilon} \times \frac{F}{A}$$

$$\frac{\left(\frac{V_0}{t}\right)}{\left(\frac{F}{A}\right)} = d/\epsilon = \text{"}g\text{" constant}$$

Q A dynamometer makes contact with piezoelectric load cell as shown. The g constant of the piezoelectric load cell is $50 \times 10^{-3} \left(\frac{Vm}{N}\right)$ and the surface area of the load cell is $4\ cm^2$, if a torque of 20 N-m applied to dynamometer, the output voltage V_0 generated will be ——.

IN 2013



Sol

$$g = 50 \times 10^{-3} \left(\frac{Vm}{N}\right)$$

$$A = 4\ cm^2$$

$$\tau = 20\ N\text{-}m$$

$$\boxed{\tau \propto F \propto q \propto V_0}$$

$$V_0 = g \times t \times F/A$$

$$= 50 \times 10^{-3} \times 1 \times 10^{-3} \times \left(\frac{\frac{20}{0.5}}{4 \times 10^{-4}}\right)$$

$$= 5V$$

Q A piezoelectric crystal has a young's modulus of $9 \times 10^{10}\ N/m^2$, has a diameter of 10 mm and thickness of 2mm. If the voltage sensitivity is 4600 Volt/micro m (V) (μm). If the generated voltage is 127.3 Volt, then the applied load is ——N.

Notes by Mohit Chouksey

Sol> $E = 9\times10^{9\,..}\ (N/m^2)$

$D = 10\ mm$

$t = 2\ mm$

$4500V/\mu m$

$V_0 = 127.3V$

______N

Sol → $V_0 = g \times t \times \frac{F}{A}$

$= \dfrac{V_0 / t}{F/A}$

But sir → $1\ \mu m \longrightarrow 4500V$

change in dimension

$\dfrac{127.3\times10^{-6}}{4500}\ m \longleftarrow 127.3V$

Δt

$E = \dfrac{(F/A)}{\left(\frac{\Delta t}{t}\right)}$; $F = E \times A \times \dfrac{\Delta t}{t}$

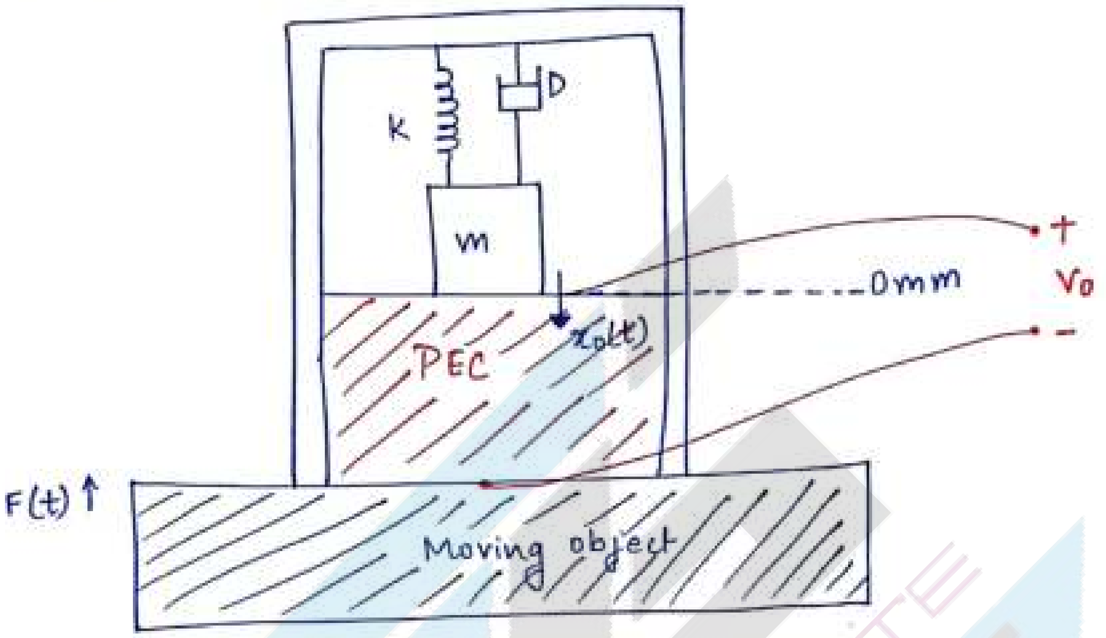
$F = 9\times10^{10} \times \frac{\pi}{4}(10\times10^{-3})^2 \times \dfrac{127.3\times10^{-6}}{4500\times 2\times10^{-3}}$

$\boxed{F = 100N}$

Notes by Mohit Chouksey

Piezoelectric Accelerometer :- It is a sensor which is used to measure acceleration by using piezoelectric crystal.

Piezoelectric Accelerometer generates voltage based on the acceleration applied. piezoelectric accelerometer consist of piezoelectric crystal which is supported by mass, spring, damper system as shown below.



$q \propto F$	$q \propto x$
$q = dF$	$q = k_q x$

from mass - damper - spring s/m

$$F(t) = M \cdot \frac{d^2 x_o(t)}{dt} + D \frac{dx(t)}{dt} + K x_o(t)$$

@ steady state

$$F(t) = K x_o(t)$$

$$x_o(t) = \frac{1}{K} F(t)$$

from PEC

$$q(t) = K_q x_o(t)$$

$$q(t) = C \cdot V_o(t)$$

$$V_o(t) = \frac{1}{C} q(t)$$

$$= \frac{1}{C} \times K_q \times x_o(t)$$

$$V_o(t) = \frac{K_q}{C} \cdot \frac{1}{K} (F(t))$$

$$V_o(t) = \frac{K_q}{K \cdot C} \cdot M \cdot a_i(t)$$

$$V_o(t) = \frac{K_q M}{K \cdot C} a_i(t)$$

$$\boxed{V_o(t) \propto a_i(t)}$$

* $F_{in}(t) = M \cdot \frac{d^2 x_o(t)}{dt^2} + D \cdot \frac{dx_o(t)}{dt} + K x_o(t)$

Apply L.T. on both sides

$\Rightarrow F_{in}(s) = M \cdot s^2 x_o(s) + D \cdot s \cdot x_o(s) + K x_o(s)$

$$T.f = \frac{x_o(s)}{F_{in}(s)} = \frac{1}{Ms^2 + Ds + K}$$

$\boxed{\text{if } D = 0}$

M=1
D=2
K=1

$$\frac{x_o(s)}{F_i(s)} = \frac{1/M}{s^2 + \left(\sqrt{K/M}\right)^2}$$

$$\frac{x_o(s)}{F_i(s)} = \frac{1/M \times \sqrt{M/K} \times \sqrt{K/M}}{s^2 + \left(\sqrt{K/M}\right)^2}$$

$$\Rightarrow \frac{X_o(s)}{F_i(s)} = \frac{\frac{1}{\sqrt{MK}} \times \left(\sqrt{\frac{K}{M}}\right)}{s^2 + \left(\sqrt{K/m}\right)^2}$$

$$\Rightarrow x_o(t) = \frac{1}{\sqrt{MK}} \times \sin\left(\sqrt{\frac{K}{m}}\, t\right)$$

ω_n

Natural frequency

$$= \sqrt{\frac{K}{m}} \left(\frac{rad}{s}\right)$$

8/11/2016 **Q** A piezoelectric crystal of dimensions 10mm × 10mm × 10mm is subjected to dynamic load $10^6 \sin 100t$. Find the amplitude of charge and voltage generated at study state. Given the charge sensitivity $d = 2\times10^{-12}\,(C/N)$ and youngs Modulus of the crystal is $6\times10^{10}\,(N/m^2)$ and permittivity $= 42\times10^{-12}\,(F/m)$

10mm × 10mm × 10mm

$f(t) = 10^6 \sin 100t$

$d = 2\times10^{-12}\,(C/N)$

$E = 6\times10^{10}\,(N/m^2)$

(ϵ) Permittivity $= 42\times10^{-12}\,(F/m)$

Sol

$$\Rightarrow q(t) \propto F(t)$$

$$q(t) = d\,F(t)$$

$$q(t) = 2\times10^{-12} \times 10^6 \sin 100t$$

$$\boxed{q(t) = 2\times10^{-6} \sin 100t}$$

$$V_0(t) = \frac{1}{C} \cdot q(t)$$

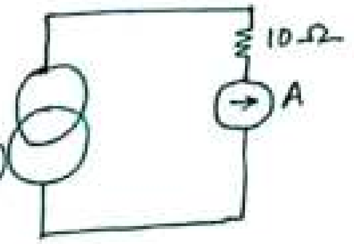
$$V_0(t) = \frac{1}{\left(\frac{\epsilon A}{t}\right)} \cdot q(t)$$

$$V_0(t) = \frac{t}{\epsilon A}\, q(t)$$

$$= \frac{10\times10^{-3}}{42\times10^{-12} \times (10\times10^{-3})^2} \times 2\times10^{-6} \sin(100)t$$

$$\boxed{V_0(t) = 4.76\times10^6 \sin 100t}$$

Q. A piezoelectric accelerometer has a mass of 0.005 Kg and piezoelectric properties. If it is subjected to a input acceleration of $10^8 \times \sin 2t$. If the output of the accelerometer is amplified by a charge amplifier of gain $= 10^4$, then find current measured by ammeter which is shown below

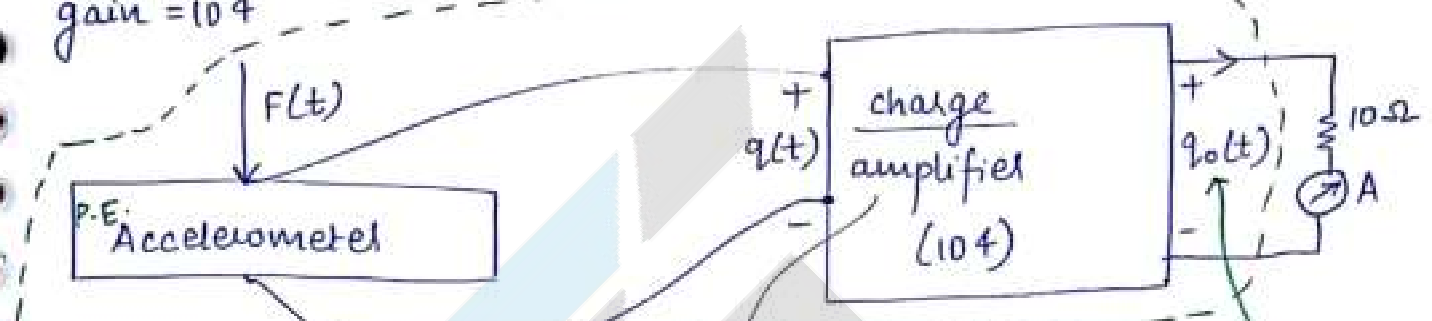


$M = 0.005\,kg$

$a_i(t) = 10^8 \sin 2t$

charge source

gain $= 10^4$



$d = 2\times10^{-12}\ (C/N)$

amplifies the charge

$q_0(t) = 10^4 \cdot q(t)$

magnified charge

if here $\to 10^{-4}$ or 10^{-1} $\to$ then accumulator

$$q_0(t) = 10^4\left[d \times M a_i(t)\right]$$

$$\boxed{q_0(t) = 10^{-2} \sin 2t}$$

Now, $I(t) = \dfrac{dq_0(t)}{dt}$

$\Rightarrow I(t) = 2\times10^{-2} \cos 2t\ A$

ammeter only displays this value not wave form.

दिखलाएगा

CONTROL SYSTEM

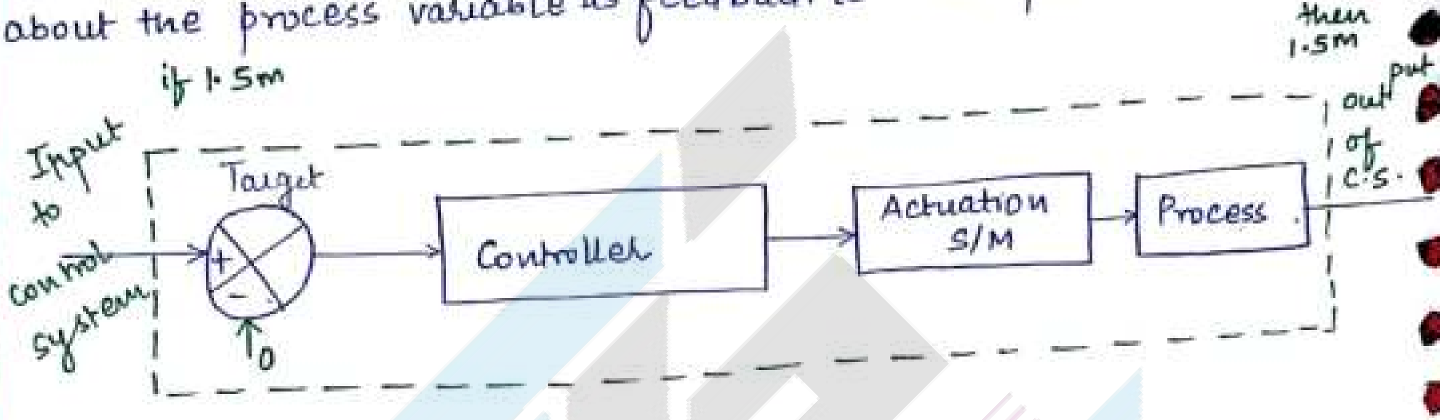
A group of components connected together to perform a desired task forms control system.

Control systems are of 2 types :-

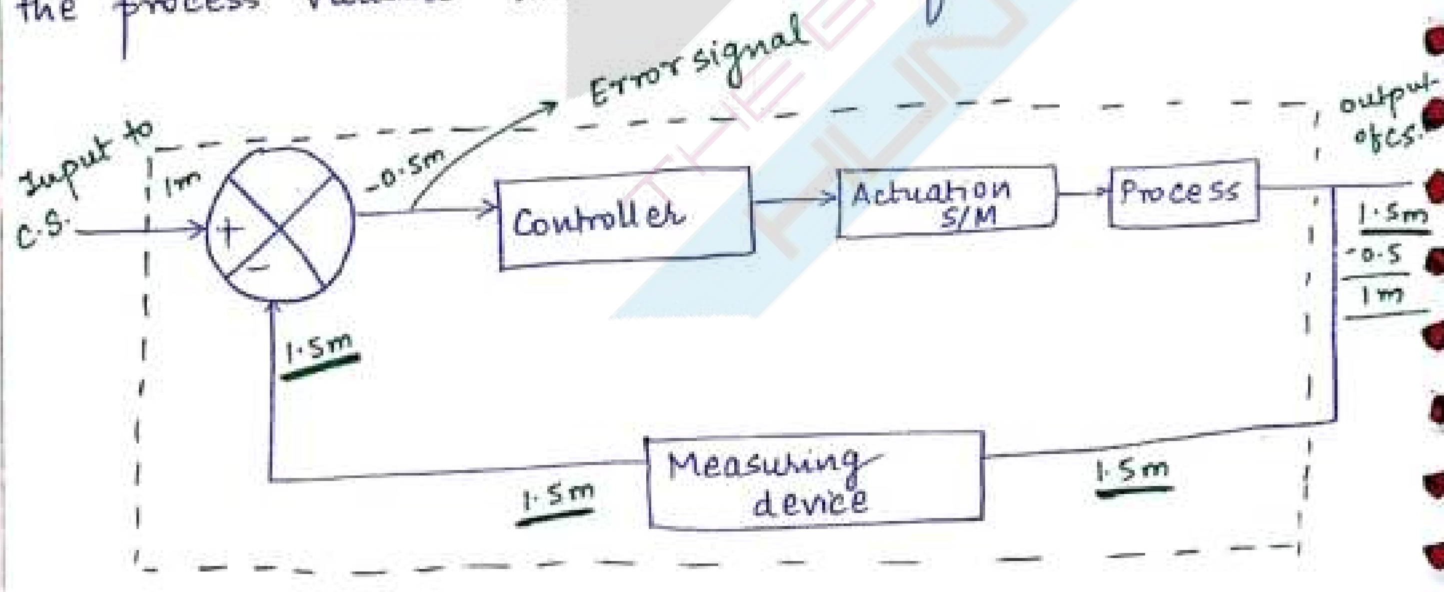
① Open loop control system

② Closed loop control system

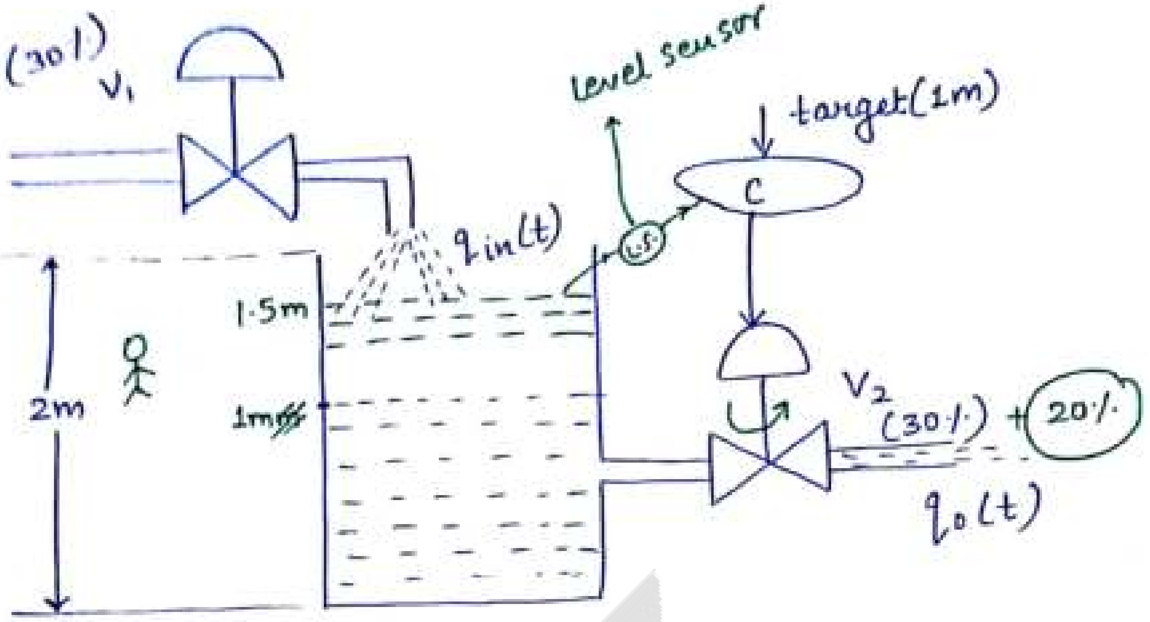
① OLCS :- In this case controller does not get any information about the process variable as feedback is not present.



② CLCS :- In this case controller gets the information of the process variable time to time as feedback is present.



1m - 1.5m
= -0.5m



Note :- ① open loop system works ideally in the absence of disturbance

② Closed loop system can work ideally even in the presence of disturbance as well as in the absence of disturbance (if the feedback device is ideal.

③ Even in open loop c.s. as well as C.L.C.S., ideally the output of the c.s. should be equals to input applied to the c.s.

④ In C.L.C.S., controller works till the error value becomes 0.

⑤ In open loop control system as well as closed loop control system, we should train the controller with a predefined algorithms. To generate predefined algorithms, we should have the mathematical model of a physical system.

* MATHEMATICAL Modelling

The process of developing mathematical expression for a physical system is called Modelling.

Steps to find the mathematical Model →

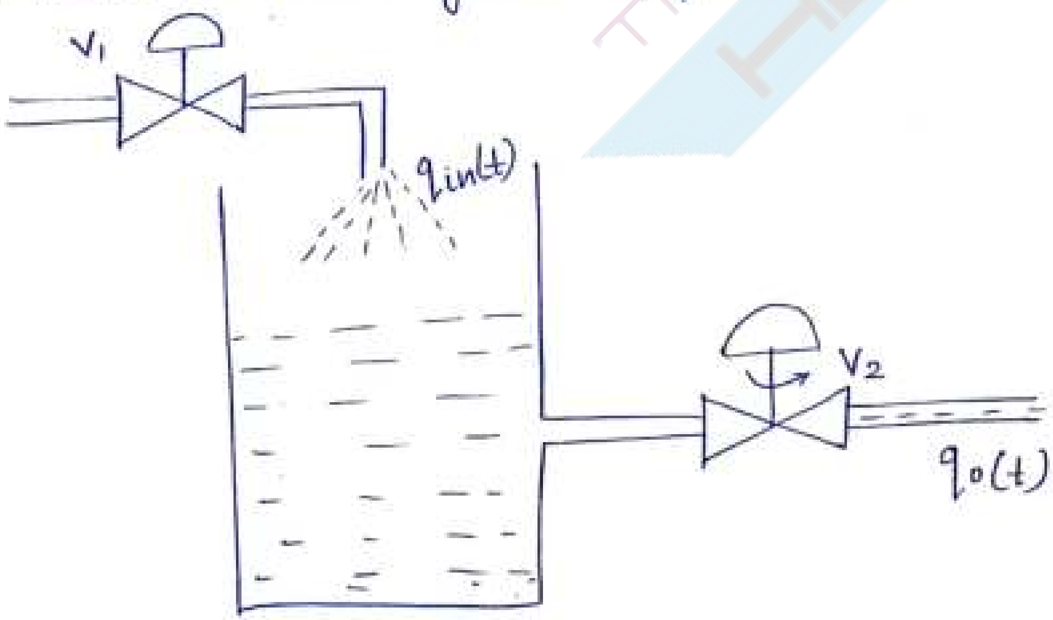
Step1 → Apply conservation of energy of flow rate or force or voltage ; etc based on the physical nature of the system.

Step2 → Rearrange step 1 to form a differential equation and then find the order of the system.

Step3 → Apply Laplace transform on both sides or differential equation concepts to find the required variable with respect to time.

Ex :-

① Model the Below system to find h(t)



Notes by Mohit Chouksey

(Input flow rate) − (output flow rate) = Accumulation of water in Tank

$$\Rightarrow q_{in}(t) - q_o(t) = A\frac{dh(t)}{dt}$$

$$\Rightarrow q_{in}(t) - \frac{h(t)}{(K)} = A\frac{dh(t)}{dt}$$

$$\Rightarrow \frac{dh(t)}{dt} + \frac{h(t)}{AK} = \frac{1}{A} q_{in}(t) \Longrightarrow h(t)$$

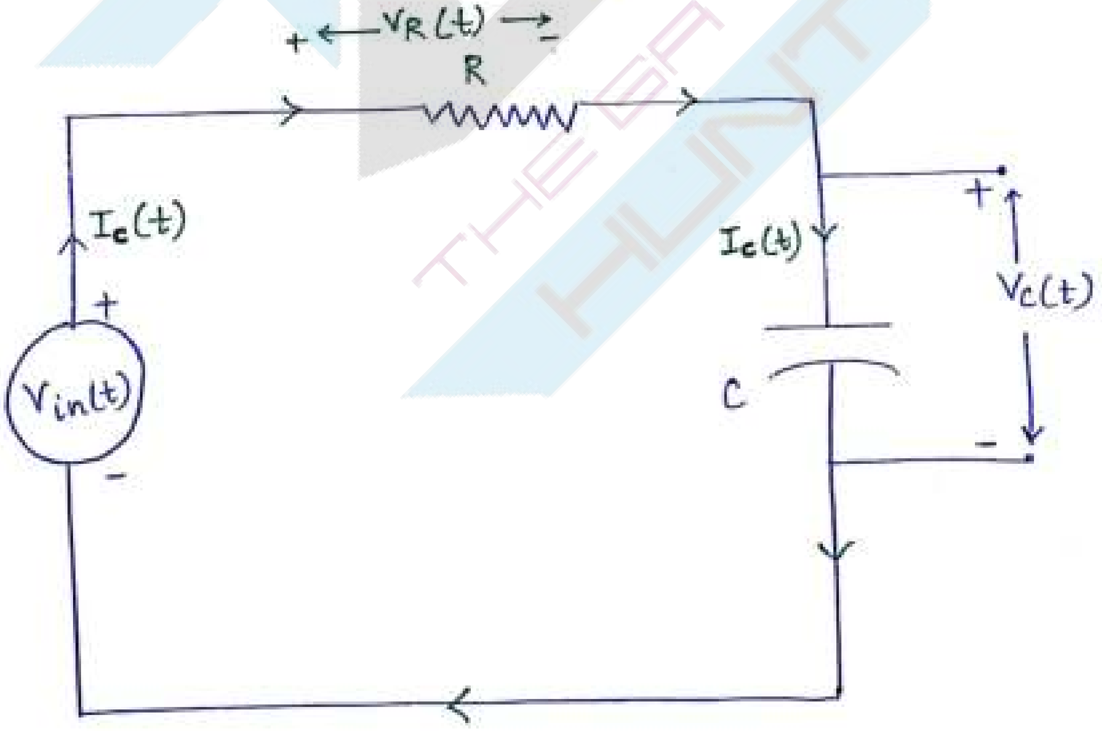
L.T. → Laplace Transform → $H(s)$ → inverse laplace → $h(t)$

$$\frac{dy(x)}{dx} + py(x) = Q \xrightarrow{D.E.} y(x)\cdot I.f. = \int Q(I.f.)dx + c$$

$$\Rightarrow y(x)$$

$h(t) \longrightarrow$ function

(II) Model the Below system for the capacitor voltage $V_c(t)$



Apply Conservation of voltage

$$V_{in}(t) = V_R(t) + V_c(t)$$

$$V_{in}(t) - V_c(t) = V_R(t)$$

$$V_{in}(t) - V_c(t) = R \cdot I_c(t)$$

$$V_{in}(t) - V_c(t) = R \cdot C \cdot \frac{dV_c(t)}{dt}$$

$$q = C \cdot V_c$$

$$I_c(t) = \frac{dq(t)}{dt} = \frac{d}{dt}(C \cdot V_c(t))$$

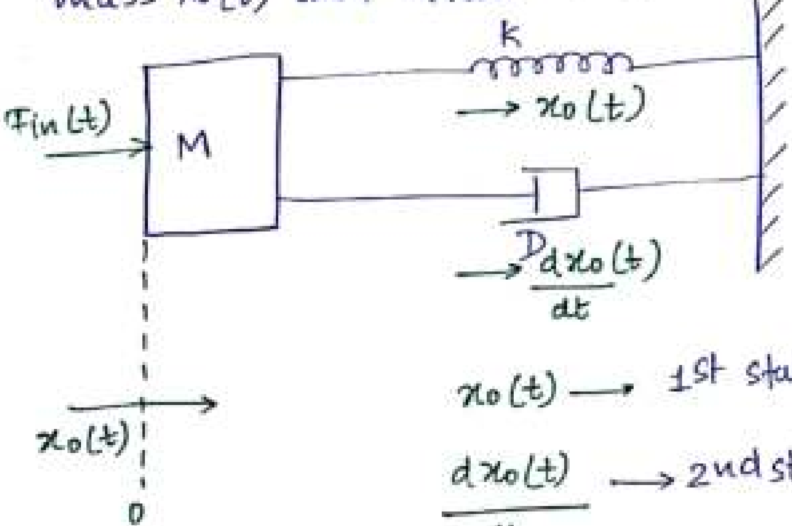
$$= C \cdot \frac{dV_c(t)}{dt}$$

$$\boxed{\frac{dV_c(t)}{dt} + \frac{1}{RC} V_c(t) = \frac{1}{RC} V_{in}(t)}$$

$V_{in}(t) \longleftrightarrow q_{in}(t)$

capacitor $\longleftrightarrow$ water tank

(III) Model the below system to find displacement of the mass $x_o(t)$ and draw. . . .



$x_o(t) \longrightarrow$ 1st state $\longrightarrow P_1(t)$

$\frac{dx_o(t)}{dt} \longrightarrow$ 2nd state $\longrightarrow P_2(t)$

Notes by Mohit Chouksey

$$\begin{pmatrix}\text{Net motion of} \\ \text{mass}\end{pmatrix} = F_{in}(t) - F_D(t) - F_K(t)$$

$$\boxed{F_{in}(t) = M \cdot \frac{d^2 x_o(t)}{dt^2} + D \cdot \frac{dx_o(t)}{dt} + K x_o(t)}$$

~~$\frac{d^2 x_o(t)}{dt^2} + \frac{D}{M} d$~~

State-space Representation

Representing the mathematical model in matrix form is the main objective of state space Representation.

In state-space representation, the order of the system matrix is equals to no. of state variables of the system and equals to order of the system.

Prob Convert Mass-damper spring Model into state space Representation

$$\frac{d^2 x_o(t)}{dt^2} + \frac{D}{M}\frac{dx_o(t)}{dt} + \frac{K}{M} x_o(t) = \frac{1}{M} F_{in}(t)$$

$x_o(t) \rightarrow P_1(t)$

$\frac{dx_o(t)}{dt} \rightarrow P_2(t) = \dot{P}_1(t)$

$\frac{d^2 x_o(t)}{dt^2} \rightarrow \dot{P}_2(t)$

$$\dot{P}_2(t) + \frac{D}{M} P_2(t) + \frac{K}{M} P_1(t) = \frac{1}{M} F_{in}(t)$$

$$\Rightarrow \boxed{\dot{P}_2(t) = -\frac{K}{M} P_1(t) - \frac{D}{M} P_2(t) + \frac{1}{M} F_{in}(t)}$$

Notes by Mohit Chouksey

$$\begin{bmatrix} \dot{P}_1(t) \\ \dot{P}_2(t) \end{bmatrix} = \underbrace{\begin{bmatrix} 0 & 1 \\ -K/M & -D/M \end{bmatrix}_{2\times2}}_{\text{system matrix }[A]} \begin{bmatrix} P_1(t) \\ P_2(t) \end{bmatrix} + \underbrace{\begin{bmatrix} 0 \\ 1/M \end{bmatrix}_{2\times1}}_{\text{input vector }[B]} F_{in}(t)$$

$$(x_0(t)) = \underbrace{\begin{bmatrix} 1 & 0 \end{bmatrix}}_{\text{output vector }[C]} \underbrace{\begin{bmatrix} P_1(t) \\ P_2(t) \end{bmatrix}_{2\times1}}_{\text{state-vector}}$$

* **Controllability** → If the internal states of the system are changed to one value to another value in a finite time by a finite input, then we can say the system is controllable otherwise it is not controllable.

To check Controllability, consider controllability matrix (ϕ_c)

$$\boxed{[\phi_c] = [A^0B \quad A^1B]_{2\times2}} \quad ; [\phi_c] = [A^0B \quad A^1B \quad A^2B]_{3\times3}$$

if $|\phi_c| = 0$; then the system is uncontrollable

if $|\phi_c| \neq 0$; then —"— —"— controllable

* **Observability** → If the internal states of the system can be evaluated from the output of the system at any time, then we can say, the system is observable otherwise it is not observable.

To check observability, consider observability matrix

$$[\phi_0] = \begin{bmatrix} C^T & AC^T \end{bmatrix}_{2\times 2} \rightarrow \text{2nd order}$$

$$; [\phi_0] = \begin{bmatrix} C^T & AC^T & A^2C^T \end{bmatrix}_{3\times 3}$$

if $|\phi_0| = 0$; Then system is not-observable.

if $|\phi_0| \neq 0$; Then —"—"— observable.

Prob: A physical system is mathematically modelled as

$$\frac{d^3y(t)}{dt^3} + 4\frac{d^2y(t)}{dt^2} + 3\frac{dy(t)}{dt} + 2y(t) = x(t)$$

where $x(t)$ is a input to the system and $y(t)$ is the output of the system. Find whether the system is controllable or not. Find whether the system is observable or not.

Sol: order → 3

state variables → 3

$$\frac{d^3y(t)}{dt^3} + 4\frac{d^2y(t)}{dt^2} + 3\frac{dy(t)}{dt} + 2y(t) = x(t)$$

$y(t) \rightarrow P_1(t)$

$\frac{dy(t)}{dt} \rightarrow$ $P_2(t) = \dot{P}_1(t)$

$\frac{d^2y(t)}{dt^2} \rightarrow$ $P_3(t) = \dot{P}_2(t) = \ddot{P}_1(t)$

$\frac{d^3y(t)}{dt^3} \rightarrow$ $\dot{P}_3(t) + 4P_3(t) + 3P_2(t) + 2P_1(t) = x(t)$

$$\Rightarrow \boxed{\dot{P}_3(t) = -2P_1(t) - 3P_2(t) - 4P_3(t) + 1\cdot x(t)}$$

$$\begin{bmatrix} \dot{P}_1(t) \\ \dot{P}_2(t) \\ \dot{P}_3(t) \end{bmatrix} = \overbrace{\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -2 & -3 & -4 \end{bmatrix}}^{A} \begin{bmatrix} P_1(t) \\ P_2(t) \\ P_3(t) \end{bmatrix} + \overbrace{\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}}^{B} x(t)$$

$$[y(t)] = \underbrace{[1 \quad 0 \quad 0]}_{C} \begin{bmatrix} P_1(t) \\ P_2(t) \\ P_3(t) \end{bmatrix}$$

for controllability

$$[\phi_c] = [A^0B \quad A^1B \quad A^2B]_{3\times3}$$

$$= \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & -4 \\ 1 & -4 & 13 \end{bmatrix}_{3\times3} ; \ |\phi_c| = -1 \neq 0$$

So the S/M (system) is controllable

for observability

$$[\phi_o] = [C^T \quad AC^T \quad A^2C^T]_{3\times3} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & -2 \\ 0 & -2 & 8 \end{bmatrix} ; \ |\phi_o| = -4 \neq 0$$

the S/M is observable

Prob2 The mathematical model of a 2nd order system is given as

$$\frac{d^2y(t)}{dt^2} + \alpha \cdot \frac{dy(t)}{dt} + \beta \cdot y(t) = 2 \cdot x(t)$$

Find the value of α and β for which the system is not controllable as well as not observable.

Sol $\frac{d^2y(t)}{dt^2} + \alpha \frac{dy(t)}{dt} + \beta y(t) = 2 \cdot x(t)$

$y(t) \rightarrow P_1(t)$

$\frac{dy(t)}{dt} \rightarrow P_2(t) = \dot{P}_1(t)$

$\dot{P}_2(t) + \alpha P_2(t) + \beta P_1(t) = 2 \cdot x(t)$

$$\dot{P}_2(t) = -\beta P_1(t) - \alpha P_2(t) + 2x(t)$$

$$\begin{bmatrix} \dot{P}_1(t) \\ \dot{P}_2(t) \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -\beta & -\alpha \end{bmatrix} \begin{bmatrix} P_1(t) \\ P_2(t) \end{bmatrix} + \begin{bmatrix} 0 \\ 2 \end{bmatrix} x(t)$$

$$[y(t)] = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} P_1(t) \\ P_2(t) \end{bmatrix}$$

for Controllability

$[\phi_c] = [A^0B \quad A^1B]$

$= \begin{bmatrix} 0 & 2 \\ 2 & -2\alpha \end{bmatrix}$; $|\phi_c| = -4$ → always controllable independent of the value of α.

→ the s/m is controllable.

for observability

$[\phi_0] = [C^T \quad A C^T] = \begin{bmatrix} 1 & 0 \\ 0 & -\beta \end{bmatrix}$; $|\phi_0| = -\beta$; if $\beta = 0$ Then the system is not observable.

Gate 2015
Prob 3 (2M) A system is represented in state-space model with system matrix $A = \begin{bmatrix} 1 & 2 \\ \alpha & 6 \end{bmatrix}$ and input vector $B = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$, the value of α for which the system is not controllable.

Sol $A = \begin{bmatrix} 1 & 2 \\ \alpha & 6 \end{bmatrix}$

$B = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$; $[\phi_c] = [B \quad AB]_{2\times2}$ ⇒ The S/m is uncontrollable if $|\phi_c| = 0$

$= \begin{bmatrix} 1 & 3 \\ 1 & \alpha+6 \end{bmatrix}_{2\times2}$

$(\alpha+6) - 3 = 0$

$\alpha + 3 = 0$

$\boxed{\alpha = -3}$

Gate 2012 2Marks

Prob 4 The state variable representation of the 3rd order system is as shown below.

$$\begin{bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \\ \dot{x}_3(t) \end{bmatrix} = \begin{bmatrix} 0 & a_1 & 0 \\ 0 & 0 & a_2 \\ a_3 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \\ x_3(t) \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u(t)$$

$$[Y(t)] = [1 \ 0 \ 0] \begin{bmatrix} x_1(t) \\ x_2(t) \\ x_3(t) \end{bmatrix}$$

where $y(t)$ is the output of the system and where $u(t)$ is the input to the system. then the system is controllable for

(a) $a_1 \neq 0,\ a_2 = 0,\ a_3 \neq 0$

(b) $a_1 = 0,\ a_2 \neq 0,\ a_3 \neq 0$

(c) $a_1 = 0,\ a_2 \neq 0,\ a_3 = 0$

✓(d) $a_1 \neq 0,\ a_2 \neq 0,\ a_3 = 0$

Sol $[\phi_c] = [B \quad AB \quad A^2B]$

$|\phi_c| \neq 0$ $|\phi_c| \rightarrow$

$$\begin{bmatrix} 0 & a_1 & 0 \\ 0 & 0 & a_2 \\ a_3 & 0 & 0 \end{bmatrix}_{3\times3} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}_{3\times1}$$

$$\begin{bmatrix} 0 \\ a_2 \\ 0 \end{bmatrix}_{3\times1}$$

$$\begin{bmatrix} 0 & a_1 & 0 \\ 0 & 0 & a_2 \\ a_3 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & a_1 & 0 \\ 0 & 0 & a_2 \\ a_3 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 0 & ? \\ 1 & \end{bmatrix}$$

$$[\phi_c] = \begin{bmatrix} 0 & 0 & a_1 a_2 \\ 0 & a_2 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

; $|\phi_c| = -a_1 a_2^2$

$|\phi_c| \neq 0$; $-a_1 a_2^2 \neq 0$

2011 (2M) Probs The transfer fn. of a 2nd order system is given as

$$\frac{Y(s)}{X(s)} = \frac{4}{s^2 + 2s + \alpha}$$, Find the condition for α for which the given system is ~~stable~~ not controllable.

Sol

$$\frac{Y(s)}{X(s)} = \frac{4}{s^2 + 2s + \alpha}$$

$$(s^2 + 2s + \alpha) Y(s) = 4 X(s)$$

$$s^2 Y(s) + 2s Y(s) + \alpha Y(s) = 4 X(s)$$

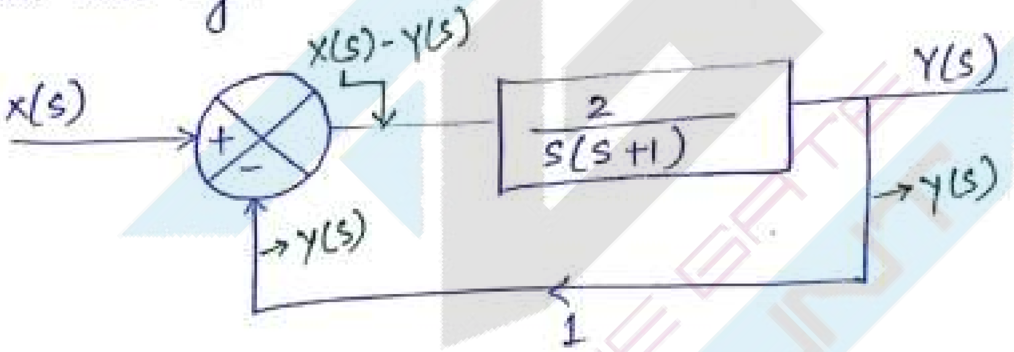
$$\frac{d^2y(t)}{dt^2} + 2\cdot\frac{dy(t)}{dt} + \alpha\cdot y(t) = 4x(t).$$

$$A = \begin{bmatrix} 0 & 1 \\ -\alpha & -2 \end{bmatrix} \qquad B = \begin{bmatrix} 0 \\ 4 \end{bmatrix}$$

$$[\phi_c] = \begin{bmatrix} 0 & 4 \\ 4 & -8 \end{bmatrix}; \quad |\phi_c| = -16 \neq 0$$

The system is always controllable and independent of value of α.

Prob 6 A second order closed loop system is as shown below. find whether the system is controllable or not.



Sol

$$Y(s) = \frac{2}{s(s+1)}\left(x(s) - y(s)\right)$$

$$Y(s) = \frac{2}{s(s+1)}\left\{x(s) - \frac{2}{s(s+1)}\right\}$$

$$\left[1 + \frac{2}{s(s+1)}\right] Y(s) = \left[\frac{2}{s(s+1)}\right] x(s)$$

$$\left[\frac{s^2+s+2}{s(s+1)}\right]Y(s) = \frac{2}{s(s+1)}X(s)$$

$$\frac{Y(s)}{X(s)} = \frac{2}{s^2+s+2}$$

$$(s^2+s+2)Y(s) = 2X(s)$$

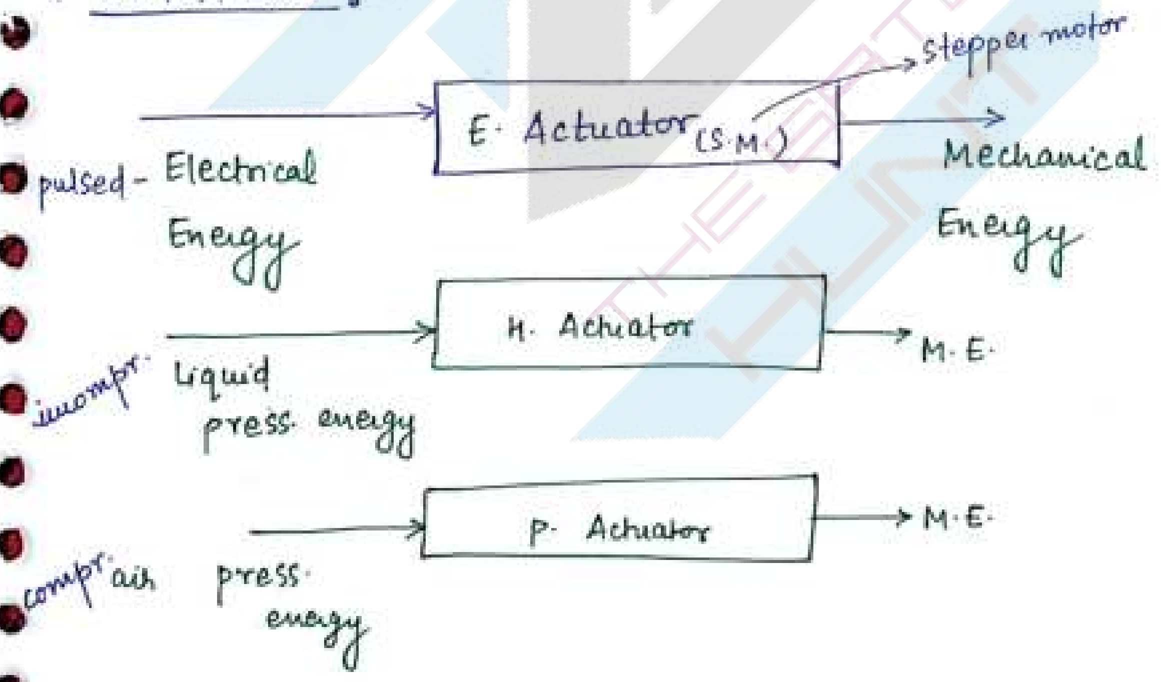
$$\Rightarrow s^2Y(s) + sY(s) + 2Y(s) = 2X(s)$$

$$\Rightarrow \frac{d^2y(t)}{dt^2} + \frac{dy(t)}{dt} + 2y(t) = 2x(t)$$

I.L.T. inverse Laplace transform

Final Ans → Controllable

ACTUATORS :-

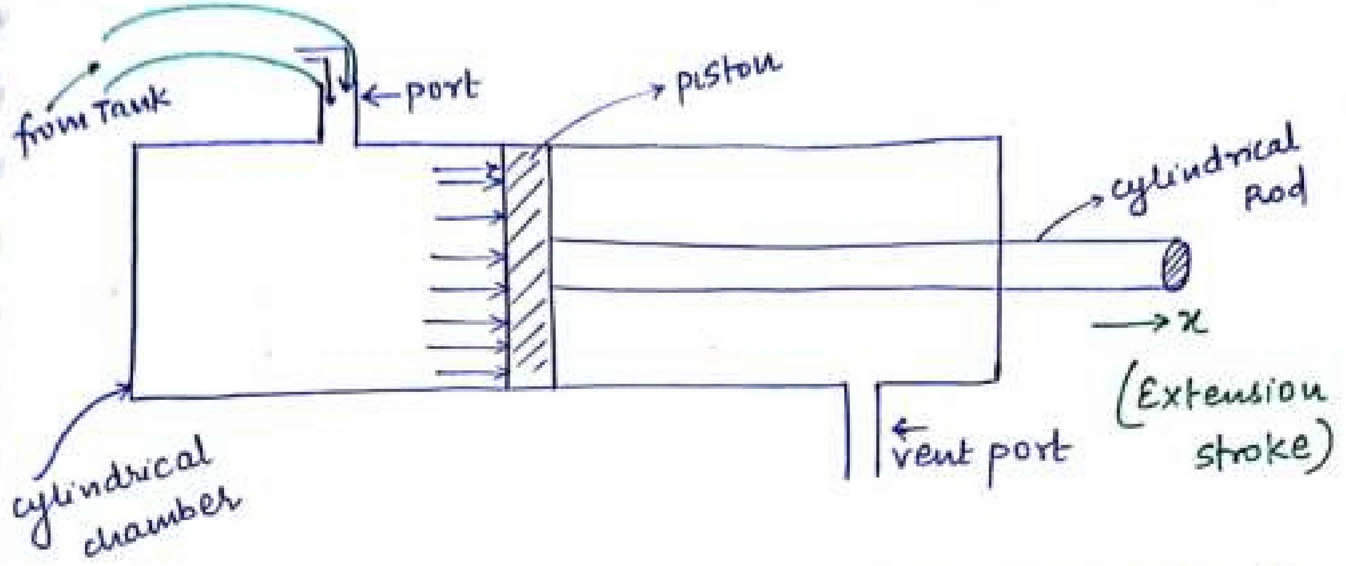


Actuator → It is the device which converts electrical or liquid pressure or air pressure into mechanical energy. The amount of mechanical power at output side depends on the liquid flow rate as well as pressure applied.

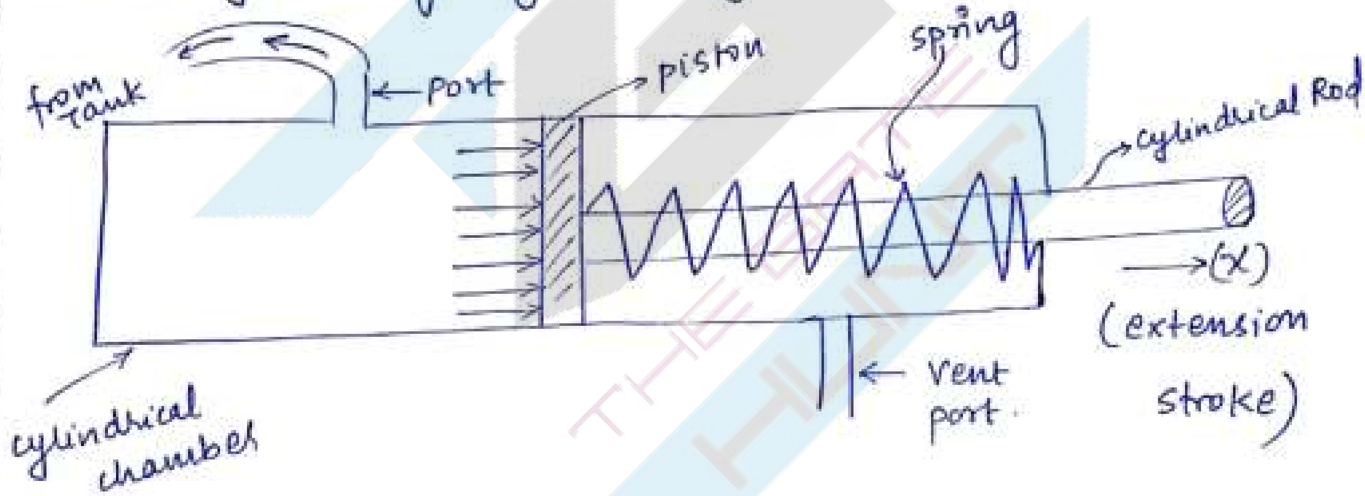
Hydraulic Actuators → ① These actuators converts liquid pressure energy into mechanical energy.
② Hydraulic actuators are divided into two types :-
(i) Hydraulic Cylinders.
(ii) Hydraulic Motors.

(i) Hydraulic Cylinders → hydraulic cylinders are used to provide linear displacement 'x'.
Hydraulic Cylinders are also called linear actuators. hydraulic cylinders are divided into 4 types, the
(i.) Single Acting type.
(ii.) Double Acting type.
(iii.) Telescopic type.
(iv.) Tandem type.

(i.) Single Acting Type Hydraulic Cylinders :- In these actuators, only one direction is possible hydraulically.
Single Acting Type hydraulic Cylinders consist of cylindrical chamber in which piston as well as cylindrical rod are placed as shown below.

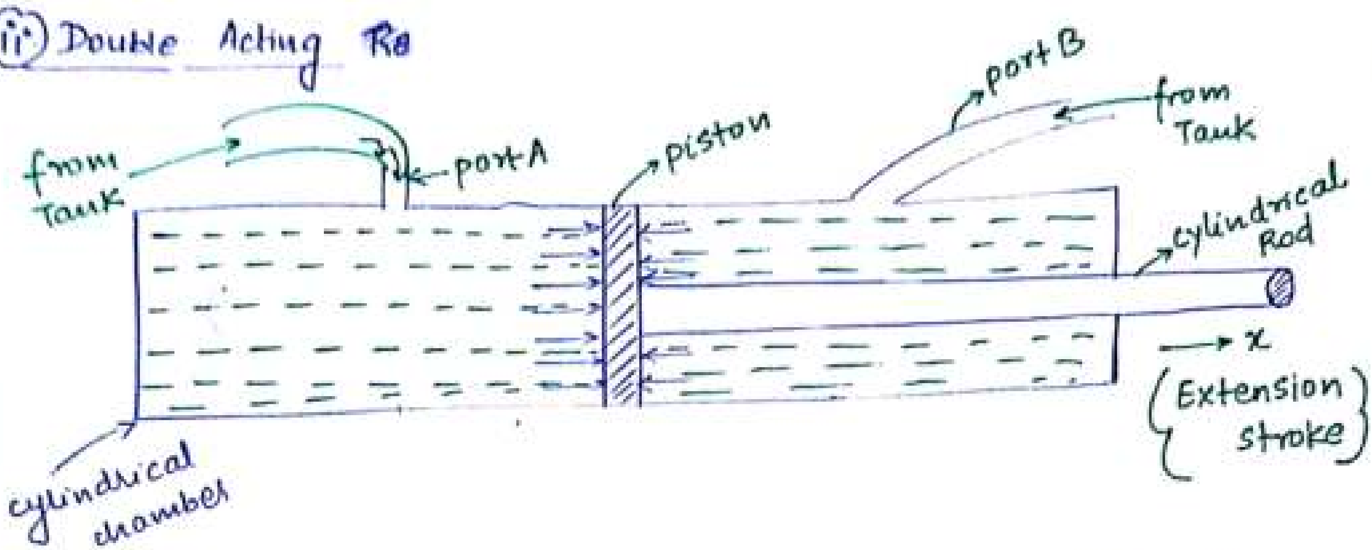


As shown in the above case, only extension stroke is possible with the help of liquid pressure energy. To get the return stroke or retraction stroke we generally prefer spring based single acting hydraulic cylinders.



during extension stroke, liquid enters into the cylindrical chamber through the port and during retraction, liquid leaves the chamber through the same port. The dirn. of liquid flow can be changed by using external control port.

(ii) Double Acting RA



Double Acting type Hydraulic cylinders → In these actuators, extension as well as retraction, both will be perform hydraulically.

* **During extension stroke**

* if the volumetric flow rate of liquid is Q_1 (m^3/sec)

* Velocity $(V_1) = \dfrac{Q_1}{A_p}$

* Pressure Applied $(P_1) = \dfrac{F_1}{A_p}$

* Power Transmitted $= F_1 \times V_1 = P_1 A_p \times \dfrac{Q_1}{A_p} = \underline{P_1 Q_1}$

* **During Retraction Stroke**

* if the volumetric flow rate of liquid, Q_2 (m^3/sec)

* Velocity $(V_2) = \dfrac{Q_2}{(A_p - A_r)}$

* pressure applied $(P_2) = \dfrac{F_2}{(A_p - A_r)}$.

* power Transmitted $= F_2 \times V_2$

$= P_2 (A_p - A_r) \times \frac{Q_2}{(A_p - A_r)}$

$= P_2 Q_2$

Q A pump supplies oil at $0.002\ m^3/sec$ to a 50mm diameter cylindrical chamber. The diameter of the cylindrical rod is 20mm and the load is 6000N in both extension as well as retraction strokes.

Find the piston velocity and the pressure applied and power transmitted in both extension stroke as well as retraction stroke.

Sol $Q = 0.002\ m^3/sec$

$D_p = 50mm$

$D_r = 20mm$

$F = 6000N$

During extension stroke

$Q = 0.002\ m^3/sec$

$V_1 = \frac{Q_1}{A_p} = \frac{0.002}{\frac{\pi}{4}(50 \times 10^{-3})^2}$

(A_p ← area of piston)

$V_1 = 1.018\ m/sec$ (← velocity)

Pressure applied $= \frac{F}{A_p} = \frac{6000}{\frac{\pi}{4}(50 \times 10^{-3})^2}$

$= 3.05\ MPa$

Power Transmitted $= F \times V = 6000 \times 1.018 = 6.11\ kW$

(During Retraction stroke

$$V_2 = \frac{Q}{(A_p - A_r)}$$

$$V_2 = \frac{0.002}{\frac{\pi}{4}\left[(50\times10^{-3})^2 - (20\times10^{-3})^2\right]}$$

$$V_2 = 1.21 \text{ m/sec}$$

Pressure applied $= \dfrac{F}{A_p - A_r} = 3.63\text{MPa}$

Power Transmitted $= F \times V_2 = 6000 \times 1.21 = \underline{7.27\text{KW}}$.

Q2) A hydraulic cylinder has to move a rate of 13 KN. The speed of the cylinder is to be accelerated upto a velocity of 0.13 m/sec in 0.5 sec. assume coefficient of sliding friction as 0.15 and the cylindrical chamber has a diameter of 50mm. Find the input pressure of oil that should be supplied.

Sol $F_w = 13$ KN

$u = 0$ m/sec → initially starting from rest

$V = 0.13$ m/sec

$t = 0.5$ sec

$\mu = 0.15$

$D_p = 50$ mm

Required force $= \left(\frac{F_w}{g}\right)a + \mu F_w$

$= \frac{13 \times 10^3}{9.81} \times 0.26 + 0.15 \times 13 \times 10^3$

$= 2.294$ KN

<u>Using Kinematic Eqn.</u>

$v = u + at$

$0.13 = 0 + a \times 0.5$

$a = 0.26 \ m/sec^2$

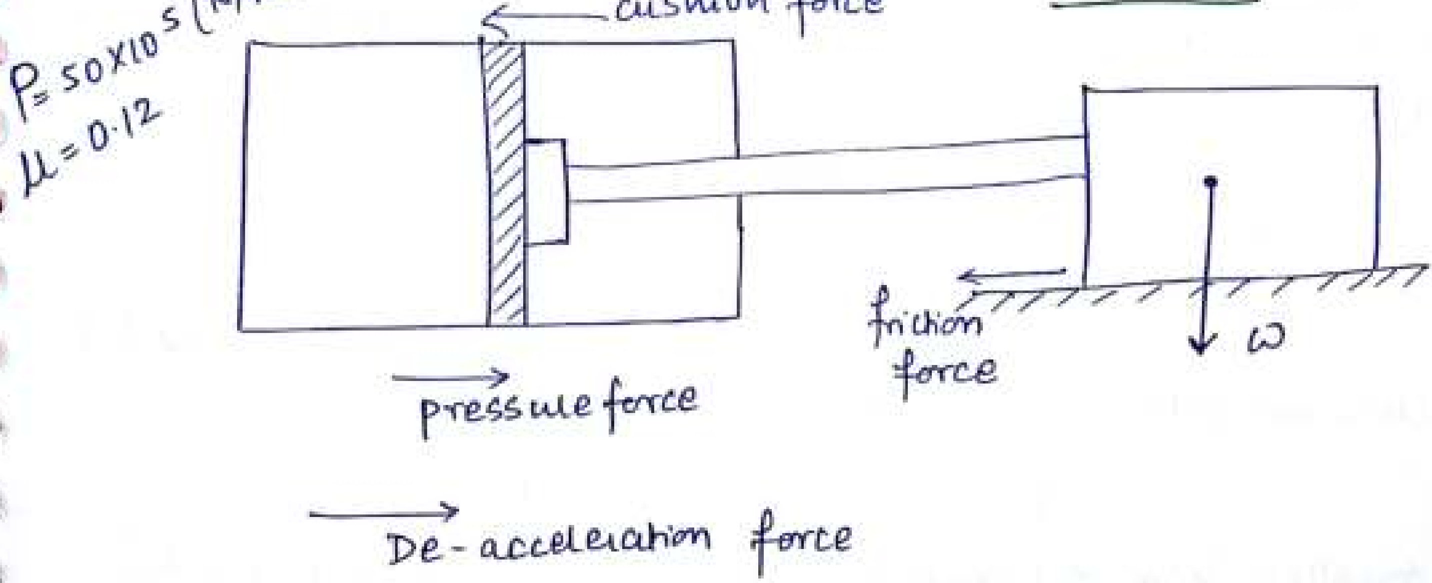
Pressure required to apply $= \frac{F}{A_p}$

$= \frac{2.294}{\frac{\pi}{4}(50 \times 10^{-3})^2}$

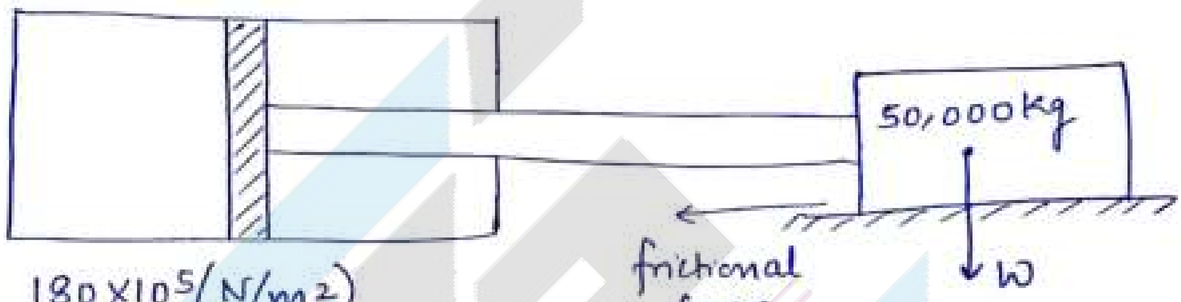
$= 1.16$ MPa

Q3. A hydraulic cylinder has a diameter of 80mm and the rod of 45mm. The load required to display is 7000N, travelling at a velocity of 15m/min. the load slides on flat horizontal surface having a coefficient of friction 0.12. The load is deaccelerated to, within a cushion length of 20mm. If the input pressure supplied is $50 \times 10^5 (N/m^2)$, then calculate the pressure develop in the cushioning and the direction of forces acting are as shown below:-

7.4 MPa ← Ans



(Q4 A hydraulic cylinder is used to accelerate a load of 50,000 kg horizontally from rest to a velocity of 10 m/min to 50 mm distance. The coefficient of friction between the load and the sliding contact is 0.1, assume 0 Back pressure then find :- ① A suitable size of cylindrical chamber if the maxm. allowable pressure applied is 180×10^5 N/m².
② The fluid flowing rate required to drive the piston forward at a velocity of 3 m/min



① Dia. = 66.72 mm of cyc. chamber

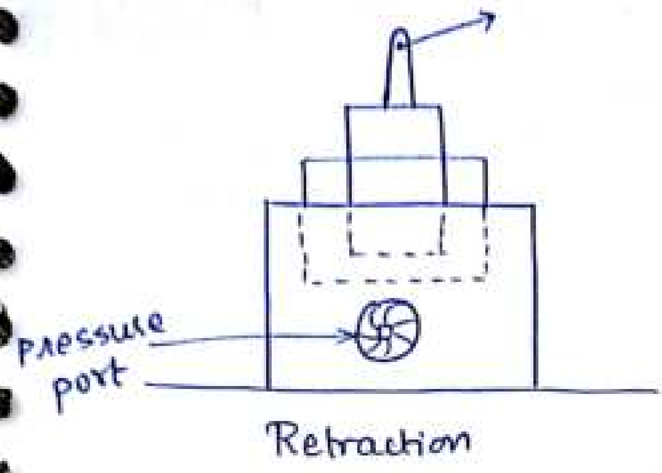
② 0.174 m³/sec

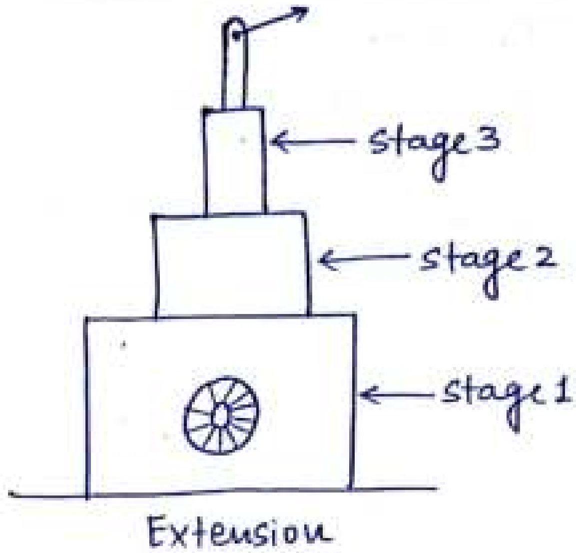
* Telescopic Cylinders :- Telescopic cylinders are used when there is a requirement of large stroke length during extension stroke and small stroke length during retraction stroke.

Telescopic cylinders are available with single side rod as well as double side Rod.

In this actuators, extension as well as retraction both will be done stage by stage.

The diameter of the last stage is smaller than all remaining stages, the velocity of a Rod will be maximum at the final stage.





Q1 A 3 stage telescopic cylinder is used to tilt the Body of a truck when the truck is fully loaded, the cylinder has to exert a force equivalent to 4000 Kg at all points on its stroke. the outside diameters of the 3 stages are 60, 80, 100 mm respectively. If the pump powering the cylinder delivers ~~than~~ 10 LPM, Calculate the velocity of the rod and the pressure required to be applied for each stage during extension.

$M = 4000\,kg$

$D_1 = 60\,mm$

$D_2 = 80\,mm$

$D_3 = 100\,mm$

$Q = 10$ LPM (litres/min)

Ans → 1st stage

$V = 1.27\,m/min$

$P = 50 \times 10^5\,N/m^2$ (pressure)

Ans → 2nd stage

$V = 1.99\,m/min$

$P = 78.1 \times 10^5\,N/m^2$

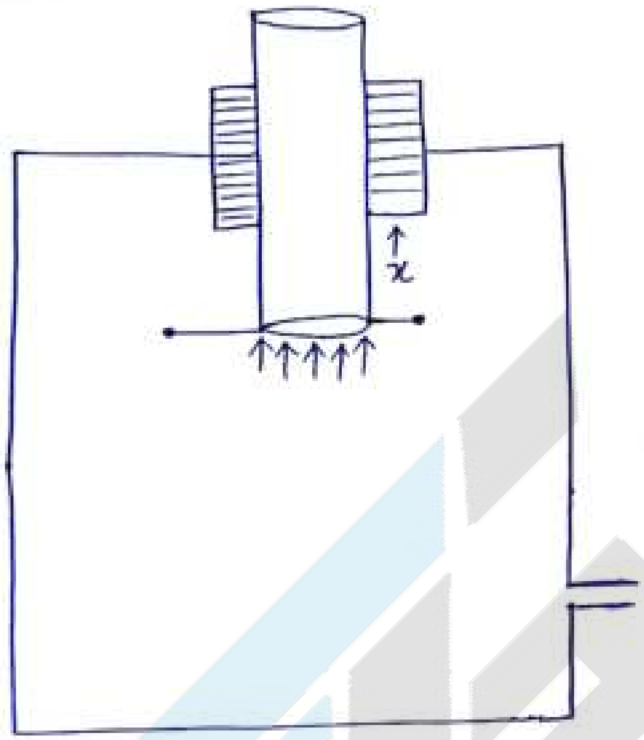
Ans → 3rd stage

$V = 3.54\,m/min$

$P = 139 \times 10^5\,N/m^2$

* Tandem Type cylinders → These actuators are used to lift the weight in vertical direction.

These actuators consist of freely moving cylindrical rod which is placed vertically as shown in the figure.



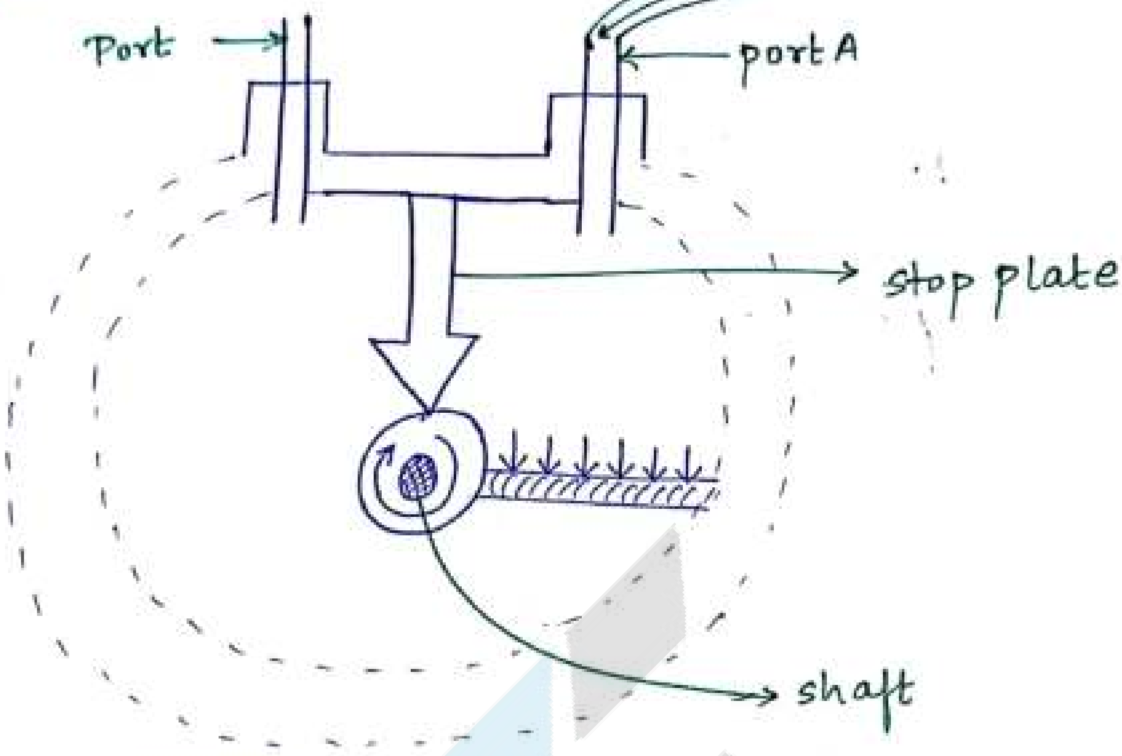
up - thrust force (F) = $P \times A_r$

Velocity of rod = $\frac{Q}{A_r}$

* Rotatory Actuators/ Hydraulic Motors :- H.M. are used to provide angular rotation to the shaft., hydr. Motors are also called Rotatory actuators. hydraulic motors are bydefault double acting type actuators. Hydraulic motors are divided into two types → ⓐ Single vane type actuator.

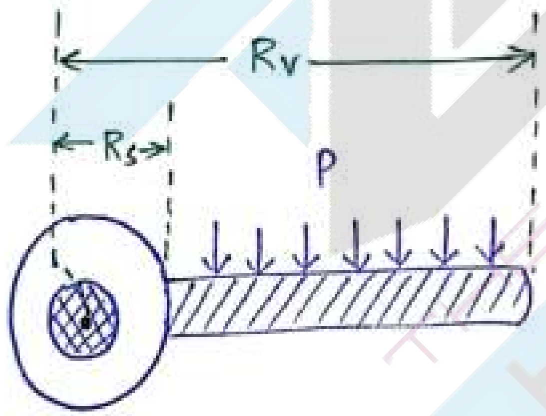
ⓑ Double Vane type actuator.

* Single Vane Type Actuator :-



statement

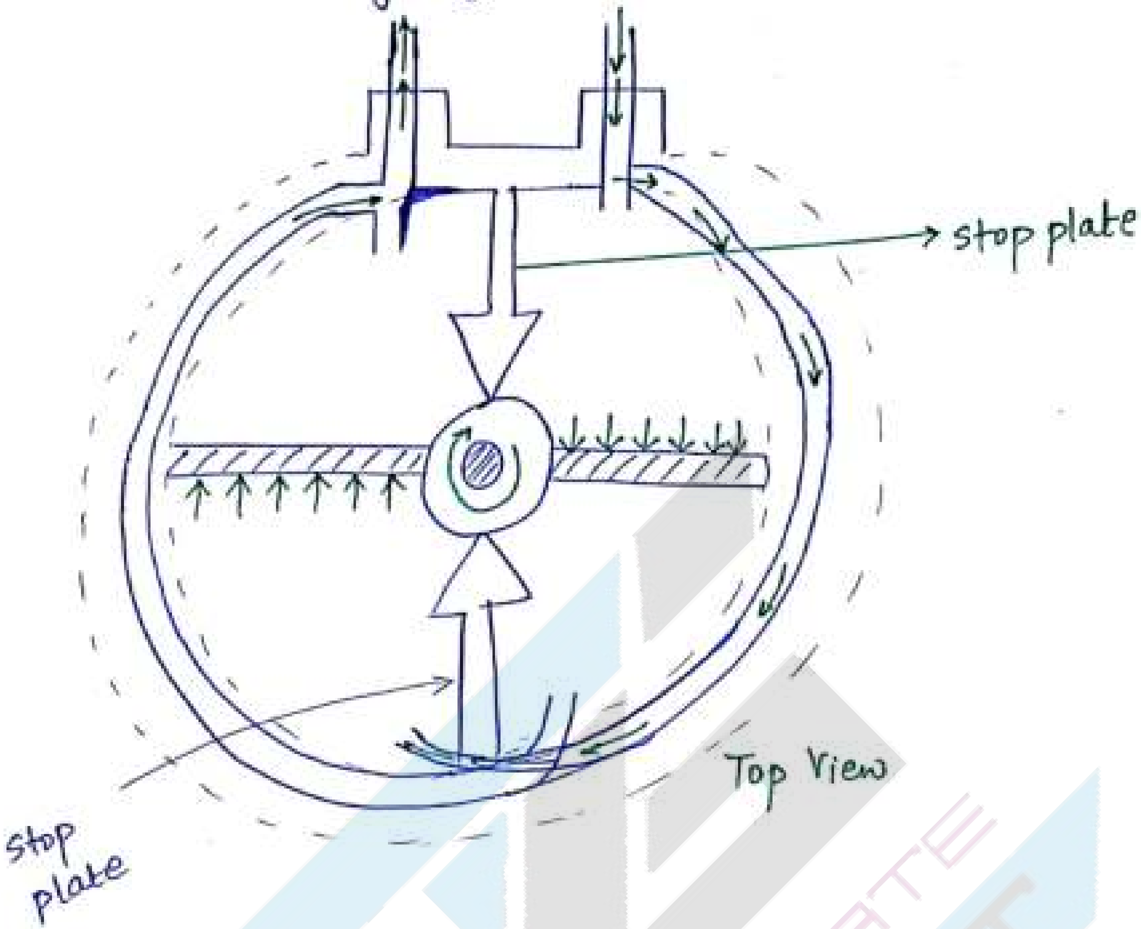
Top View



Force acting on vane = $P \times (R_v - R_s) \times L$

The angular rotation of shaft in single vane type actuator is limited to less than 360°.

* Double Vane Type Actuator In this actuator, the rotation is limited to less than 180°. Double vane type actuator are also double acting type actuators.



08144829925 ← phanendra sir