MADE EASY

Electrical Engineering

Toppers Handwritten Notes

E.M.I

BY Balaji Sir

:- Measurement and Instrument :-

Electrical :-

- Current
- Voltage
- Power
- Energy
- Power factor
- Resistance
- Inductor
- Capacitor
- Instrument T/F

Electronics :-

- Digital multimeter
- CRO
- Q-meter
- Frequency counter
- Analysers (IES)
- Error Analysis

Transducer :-

- Measurement of Non-electrical Quantities like temperature, pressure, force etc.

- Thermo couple
- LVDT
- Piezo-electrical crystal
- Thermistor
- Strain-gauge

Analog Meters

- Quantity to be measured
  - → Current
  - → Voltage
  - → Power
  - → Energy
  - → Power factor
  - → Resistance
  - → Inductor
  - → Capacitor
- Principles
  - → Electromagnetic
  - → Induction
  - → Electrostatic
  - → Thermal
- Representation
  - Indicating
    - → Ammeter
    - → Voltmeter
    - → Wattmeter
  - Null detector
  - Integrating
    - → Energy meter
    - → A-hr meter
  - Recording
    - → Galvanometer
    - → Potentiometric

Order of Instruments :-

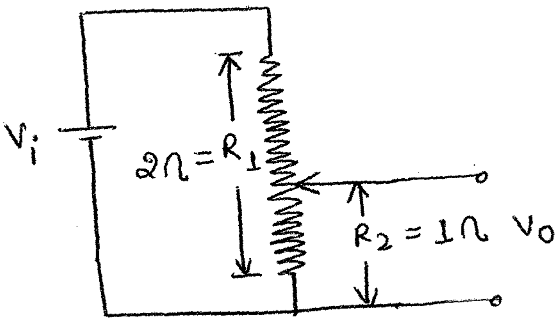
- The instrument should behaves similar to the quantity to be measured is called order of the instrument.

(i) zero order instrument

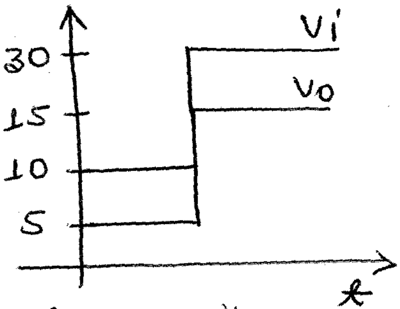
- If the o/p follows the i/p without any time delay is called zero order instrument.

Ex :- Potentiometer

$$T(S) = \frac{C(S)}{R(S)} = K = \text{constant}$$



$$V_o = V_i \times \frac{R_2}{R_1} = \frac{V_i}{2}$$



Here o/p follows i/p without any time delay.

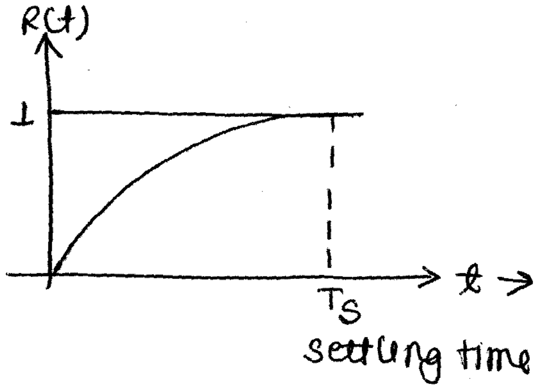
(ii) First ~~zero~~ order instrument :-

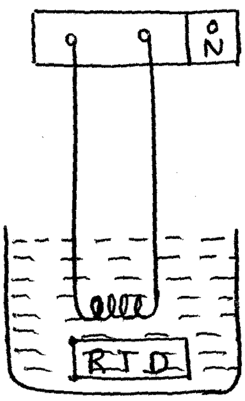
If the o/p follows the i/p with time delay without oscillations.

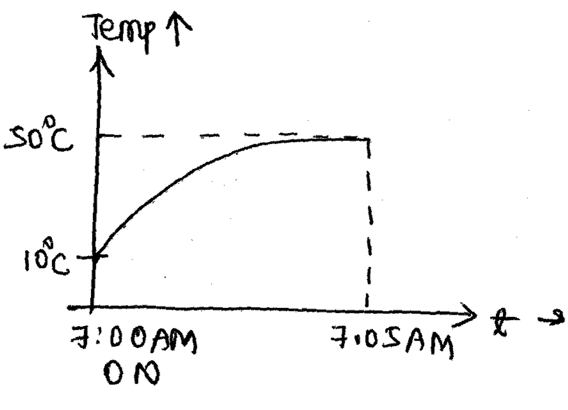
Ex :- Temperature measuring instrument like thermometer, thermocouple, MCB, bimetallic strip etc.

Temperature measuring transducer like RTD, thermocouple bimetallic strip of first order instrument and this will respond slowly the change in its input and hence the temperature of human body can not equal to measure instantaneous continuously.

$$T(S) = \frac{C(S)}{R(S)} = \frac{K}{(1+TS)}$$







$$R_2 = R_1 [1 + \alpha (T_2 - T_1)]$$

(iii) Second order system :-

Indicating meters are of 2nd order instrument like Ammeter, voltmeter, wattmeter with damping factor between 0.62 to 0.8 having undamped response.

$$T(s) = \frac{C(S)}{R(S)} = \frac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$$

$$1 + GH = s^2 + 2\xi\omega_n s + \omega_n^2 = 0$$ where ξ = Damping factor

$\xi = 0 \Rightarrow$ undamped

$\xi = 1 \Rightarrow$ critical damped

$\xi > 1 \Rightarrow$ overdamped

$0 < \xi < 1 \Rightarrow$ underdamped

Types of torques in indicating meters :-

(i) Damping torque
(ii) Deflecting or operating torque (T_d)
(iii) control or Restraining torque (T_c)

Meter	T_d	T_c	T_c	Damping	Applications
PMMC	NBIA	$K\theta$	spring	Eddy current	DC I, V
MI	$\frac{1}{2}I^2\frac{dL}{d\theta}$	$K\theta$	spring	Air friction	DC, AC(RMS) I, V
EMMC|EDM	$I^2\frac{dM}{d\theta}$	$K\theta$	spring	Air friction	DC, AC(RMS) I, V
ES	$\frac{1}{2}V^2\frac{dC}{d\theta}$	$K\theta$	spring	Air or Fluid friction	DC, AC(RMS) V

(i) Damping torque :-

a. The torque response of a system depends on damped oscillation exist in the system.

b. If the damped oscillations are more then it requires more time for the system to settle at final steady state

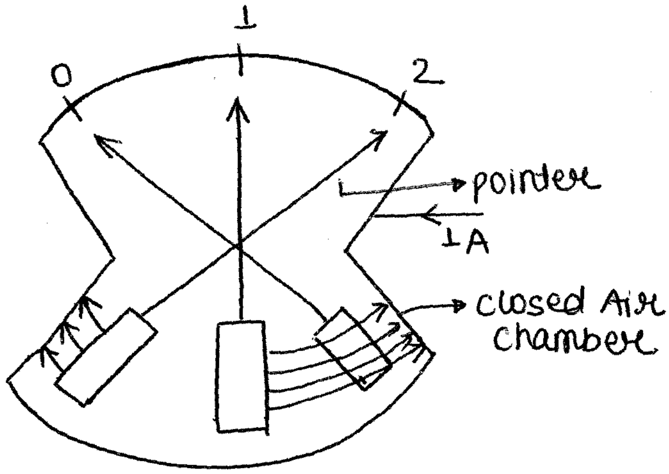
c. Damping torque is used to bring the system (pointer of instrument) to the final steady state position within a minimum time.

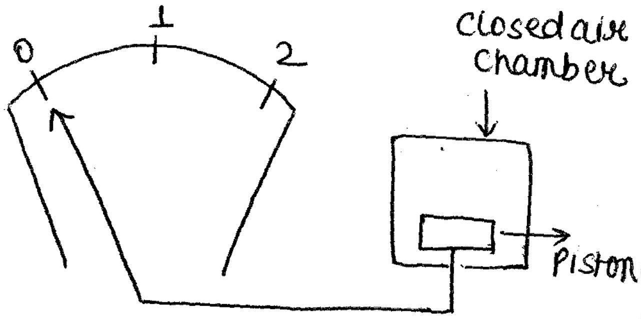
Damping torque types :-

(i) Air friction Damping :-

a. In this method air is used to bring the pointer to the final steady state position so that damped oscillations are reduced.

b. This method is used in moving iron (MI) and electromagnetic moving coil (EMMC) or electro dynamometer (EDM).





c. used in MI, EMMC, EDM

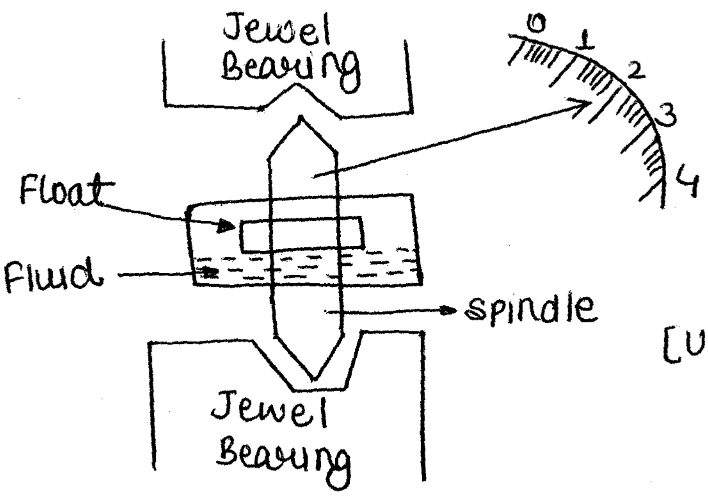
(ii) Fluid Friction Damping :-

a. This type of damping is used where the operating torque is very small. Ex : Electrostatic meters.

b. The instruments must have high value of torque to weight ratio so that friction errors are minimised and hence sensitivity improves.

c. In electrostatic meters, operating torque is less, the friction between the fluid and the float is used to reduce damped oscillations.

d. Jewel bearing are used to minimize the wear & tear (maintenance of instrument)



[used in electrostatic meter]

Torque to weight ratio (T_w) :-

$$T_w = \frac{\text{operating torque}}{\text{weight of moving system}}$$

NOTE-: $T_w >> 1 \Rightarrow$ Frictional errors are less so that sensitivity is improved higher

c. The moving system like spindle & pointer are made up of Al which has less weight so that torque to weight ratio improved.

Types of Damping		Application
Air friction	→	MI, EMMC
Fluid friction	→	ES (Electrostatic)
Eddy current	→	PMMC
Electromagnetic	→	Galvanometer

operating torque or Deflecting torque (T_d) :-

a. T_d is proportional to quantity to be measured i.e; current, voltage etc. Depending on the magnitude of quantity operating torque is produced which is used to move or drive the pointer from initial position to the final position.

b. The driving torque is produced by applying different principles like electromagnetic, electrostatic, thermal etc.

controlling torque or Restraining torque (T_c) :-

a. T_c is used to produce a torque opposite to the T_d so that keep the pointer at the final steady state position where $T_c = T_d$

b. In the absence of T_d, it will bring the pointer to the zero initial position.

(i) spring control:-

spring control is the most practical one used because $T_c \propto \theta$ which has linear response.

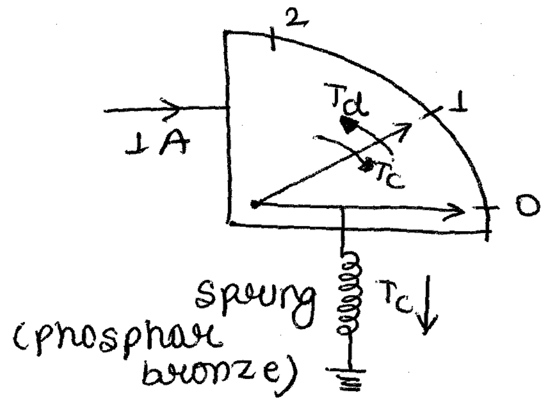
$$T_c \propto \theta$$

$$\boxed{T_c = K\theta}$$

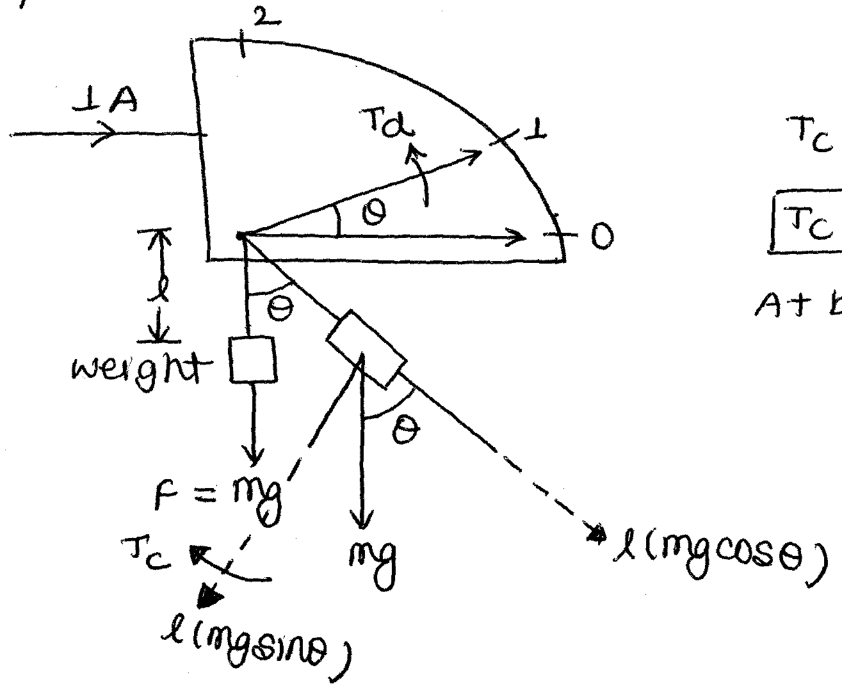
K = spring constant N-m/rad

θ = Deflection Angle Rad or Degree

At balance $T_c = T_d$



(ii) Gravity control :-
Gravity control produces $T_c \propto \sin\theta$ which has non-linear response and hence it is used in specific applications for vertically mounted instruments it is used.

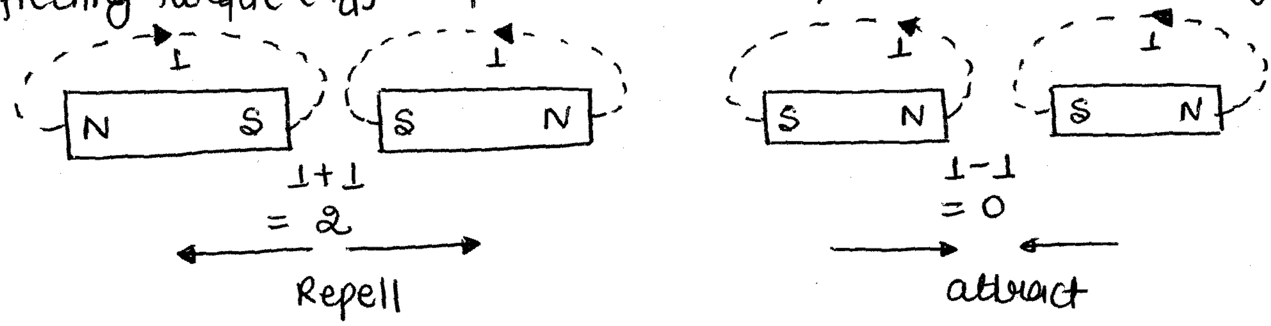


$T_c = (mgl)\sin\theta$

$$\boxed{T_c \propto \sin\theta}$$

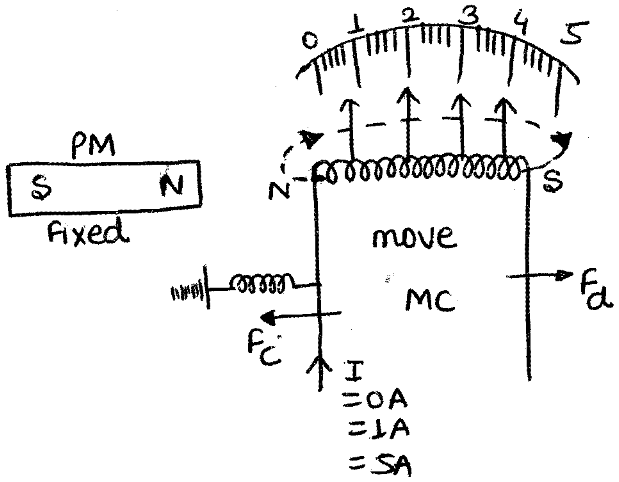
At balance : $T_c = T_d$

Electromagnetic meters :-
Deflecting torque (T_d) is produced on the principle of electromagnetic.

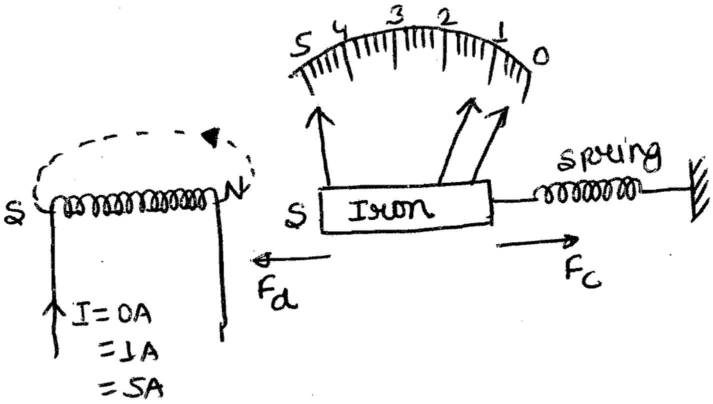


The instrument like PMMC, MI & EMMC are working on the principle of electromagnetic used to measure voltage current power, power factor depending on the arrangement of the instrument.

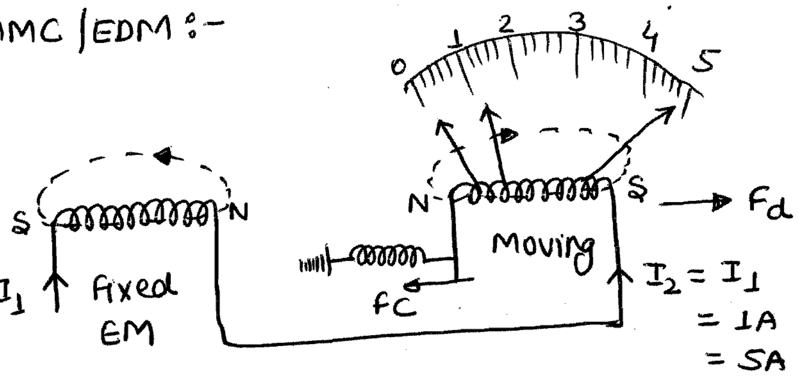
(i) PMMC:



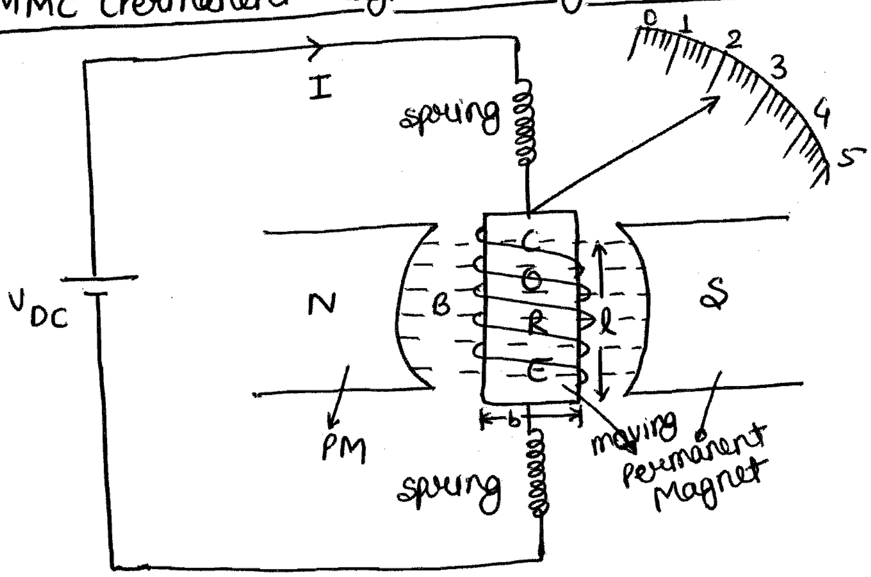
(ii) MI (moving iron):-



(iii) EMMC / EDM:-



(i) PMMC (Permanent Magnet Moving coil):-



Lorentz force $\vec{F} = I(\vec{l} \times \vec{B})$

Deflection torque (T_d):- $F = NBIl\sin\theta$

phase $\theta = 90°$

$T_d = F \times b$

$= NBI(l \times b)$

$T_d = NBIA$

$$\boxed{T_d = (NBA)I = GI}$$

$$\boxed{T_d \propto I}$$

G = constant of PMMC

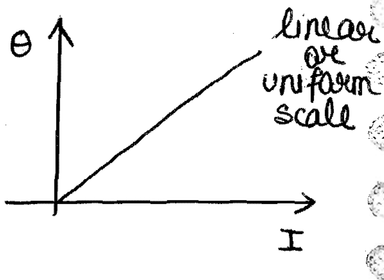
where
N = No. of turns of coil
$l \times b$ = Area of coil
B = Magnet flux density $= Wb/m^2$
I = Test current in Amp.

At balance, $T_c = T_d$

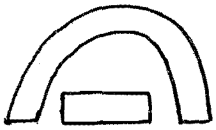
$K\theta = GI$

$\theta = \left(\frac{G}{K}\right) \cdot I$

$\boxed{\theta \propto I \text{ linear scale}}$



Symbol of PMMC:



Features of PMMC:-

a. PMMC is working on the principle of Fleming's left hand rule.

b. The current flowing through the coil interacts with the permanent magnetic flux density produces deflecting torque.

c. Spring provides controlling torque.

d. If one of the spring has broken or snaped the pointer comes to zero initial position because T_d become zero. (no current passing)

e. Eddy current damping is used.

f. Scale has linear or uniform because $\theta \propto I$

g. The core or former is made of Al and pointer is also made of Al which has less weight and due to permanent magnet operating torque is more so that torque to weight ratio is higher and hence sensitivity is more.

h. PMMC is used to measure DC or average quantity of current or voltages.