DEPARTMENT OF ELECTRNICS & COMMUNICATION ENGINEERING, KITSW

COURSE: **U14EI 205 - BASIC ELECTRONICS ENGINEERING**	**ECE-I, Semester-II, 2015-16**

ASSIGNMENT-7 HINTS &SOLUTIONS (PART-3 –of- 3)

6. The true value of the voltage across a resistor is 80V. However, when a 0-100V meter is employed, the measurement reading obtained is 79V. Calculate:

- **(i) absolute error**
- **(ii) relative error as function of measured value**
- **(iii) relative error as function of fsd**

Solution:

Given data: True voltage = 80V,
Measured voltage = 79 V
Voltmeter fsd = 100V

(i) Absolute error (e) = Measured value- True value = 79-80= -1V

(ii) Relative error is % error.

Relative error as a function of measured value = $\frac{\text{Measured value-True value}}{\text{Measured value}} \times 100\%$

$$= \frac{79-80}{79} \times 100\% \quad = -1.266\ \%$$

(iii) Relative error as a function of fsd = $\frac{\text{Measured value-True value}}{\text{fsd}} \times 100\%$

$$= \frac{79-80}{100} \times 100\% \quad = -1\ \%$$

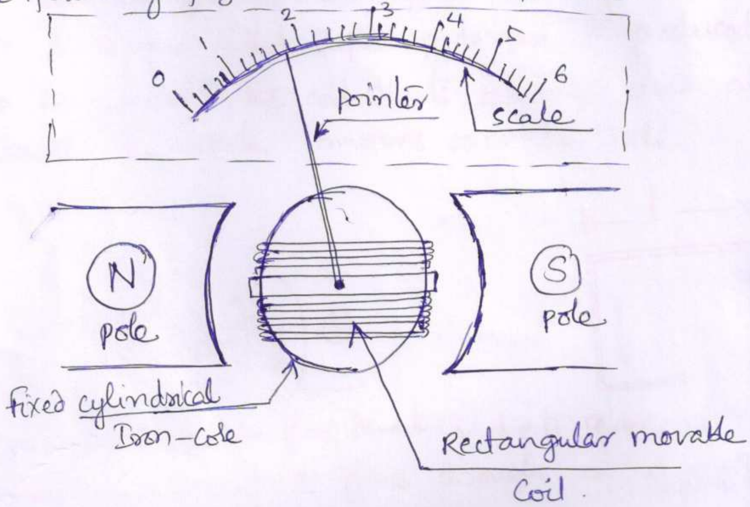
7. With a neat sketch, explain the principle of permanent magnet moving coil (PMMC) instrument and discuss briefly the errors in PMMC.

Permanent Magnet Moving Coil (PMMC) Instruments

→ PMMC meter is the most accurate type for d.c measurements. PMMC meters are also referred to as the d'Arsonval Movement meters.

→ The PMMC instrument is an Ammeter.

→ The following figure illustrates the constructional features



→ It consists of a rectangular coil wound round a soft iron core which is suspended in the field of a permanent magnet.

→ The rectangular coil is mounted on jewel bearings so that it is free to move.

→ An Aluminium pointer is attached to the moving Coil.

→ When coil rotates, the pointer moves on a graduated Scale.

→ Two spiral springs are attached to the coil assembly — one at the top and the other at the bottom.

For deflection type instruments, three operating forces are required.

(i) Deflecting force (ii) controlling force & (iii) Damping force.

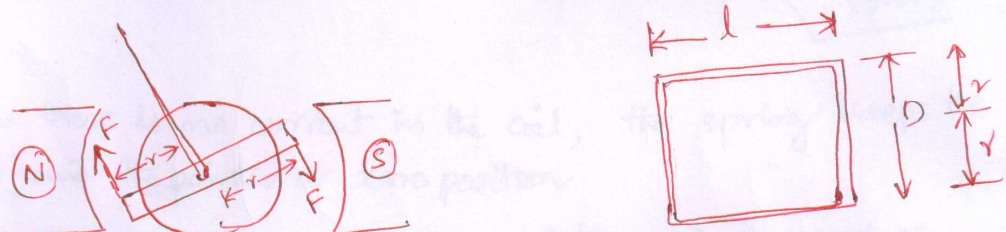
Deflecting force :

→ When a current flows the coil, a magnetic flux is produced

→ This electro-magnetic flux interacts with the flux due to permanent magnet

→ A torque called deflecting torque is produced.

→ As a result, the coil starts rotating and along with it, the pointer moves over the scale.



let B = Magnetic flux density (T) due to permanent magnet

when a current I flows through a one-turn coil, ~~the force~~ of length (l), then the force F exerted on each side of the coil is

$$F = BIl \text{ Newtons}$$

Then total force acting on both sides of the coil of 'N' turns

$$F = 2BIl \cdot N$$

The deflecting torque $T_d = 2BIlN \cdot r$ (N-m)

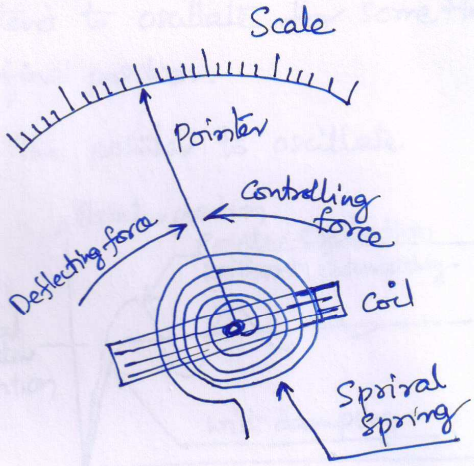
$$T_d = BIlN(2r)$$

$$\boxed{T_d = BIlND.} \quad D \rightarrow \text{dia of coil.}$$

$$\boxed{T_d = NABI} \; ; A \rightarrow \text{effective coil area.}$$

Controlling force

The controlling force in PMMC instrument is provided by spiral springs.



→ Spring material must be non-magnetic to avoid any magnetic field influence on controlling force

→ springs are made of phosphor Bronze

→ When there is no current in the coil, the spring keeps the coil and the pointer at zero position

→ when current flows, the coil rotates and the springs "wind up".

→ As the coil rotates, the restoring force (torque) provided by the ~~spiral~~ spiral springs goes on increasing.

→ The coil and pointer stop rotating at a point where deflecting torque (T_d) = controlling torque (T_c)

$$BINA = K\theta$$

Here K = spring constant (Nm/deg)

θ = angular deflection of the pointer (deg)

$$\theta = \frac{BINA}{K}$$

$$\Rightarrow \boxed{\theta \propto I}$$

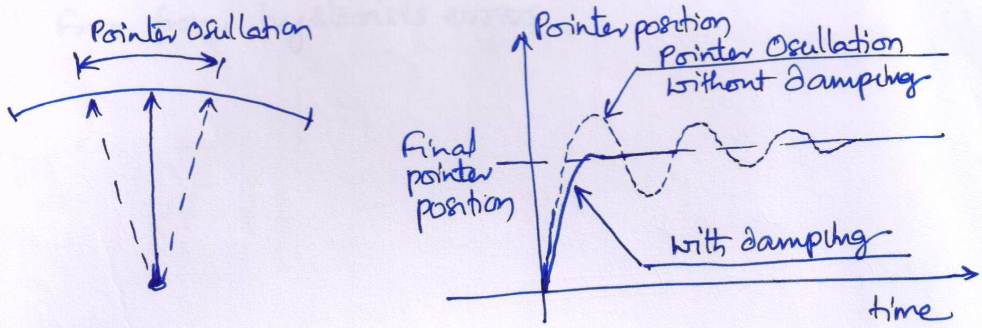
i.e, the pointer deflection is always proportional to the coil current (I) and hence scale is linear or uniformly divided //

Damping force or Torque

→ The pointer deflects to a position where $T_c = T_d$

→ The pointer and the coil tend to oscillate for some time before settling down at final position.

→ Lack of damping causes the pointer to oscillate



→ In PMMC instruments, the damping force is normally provided by eddy currents

→ The coil former (core) is constructed of Aluminium, a non-magnetic conductor.

→ Eddy currents are introduced in the coil former set up a magnetic flux that opposes the coil motion and thus damps the oscillations of the coil.

Specifications: The d'Arsonval movement (or meter) or PMMC instrument is specified in terms of its "current sensitivity" or full scale deflection current and the coil resistance.

→ The most sensitive d'Arsonval meter gives f.s.d with a coil current of 25 μA

Advantages of PMMC instruments:

1. Linear scale (the scale is uniformly divided)
2. High torque –to- weight ratio (high accuracy can be achieved)
3. Very low power consumption (25 μW -200 μW)
4. Free from hysteresis errors
5. Wide range of currents can be measured with the help of shunts
6. Wide range of voltages can be measured with the help of series multipliers

Disadvantages of PMMC instruments:

Suitable for dc measurements only
Aging of permanent magnet and control springs introduces errors
Friction due to jewel-pivot suspension
Instrument cost is high

Errors in PMMC instruments:

- Errors due to friction:
    - To reduce errors due to friction, the torque-to-weight ratio is made high
- Errors due to temperature: Basic PMMC is sensitive to temperature.
    - The magnetic field strength decreases with increase in temperature
    - The spring tension decreases with increase in temperature
    - The coil resistance increases with increase in temperature
- Errors due to aging:
    - Weakening of permanent magnet causes less deflection for a given current
    - Weakening of control spring causes more deflection for a given current

8. With the help of circuits explain how PMMC can be used as

(i) an ammeter
(ii) multirange ammeter using Aryton shunt with necessary equations
(iii) voltmeter
(iv) multirange voltmeter with necessary equations

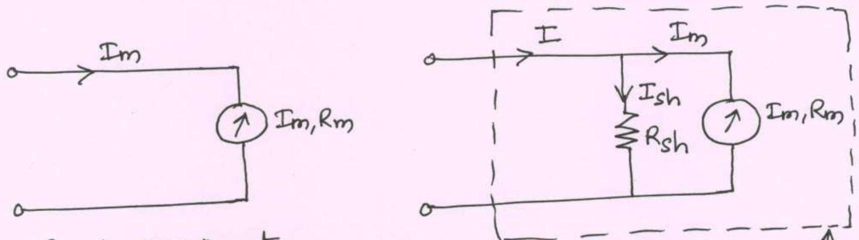
(refer to class notes….)
Those who missed regular classes are advised to take notes from their friends who attended.

9. With required circuits and necessary computations, explain how a PMMC movement of range 0-25mA, with an internal resistance of 20 Ω, can be

(i) extended to a range of 0-100mA; and

(ii) converted into an Voltmeter of range 0-10V.

Sol: (i) A PMMC (d'Arsonval movement) meter range can be extended by connecting a low resistance, called shunt, across the basic meter movement.



Basic PMMC meter

Range extended ammeter

We need to calculate R_{sh} to extend the range of 0-25mA to 0-100mA.

Given: $I_m = 25\,mA$, $R_m = 20\,\Omega$

Range to be extended to $I = 100\,mA$.

(a) $I = I_{sh} + I_m \Rightarrow I_{sh} = I - I_m = 100\,mA - 25\,mA$

$I_{sh} = 75\,mA$.

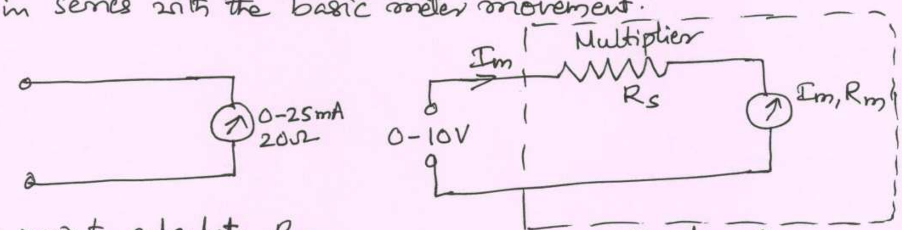
(b) Drop across shunt = Drop across meter

$I_{sh} \cdot R_{sh} = I_m R_m \Rightarrow R_{sh} = \frac{I_m R_m}{I_{sh}}$

$$R_{sh} = \frac{25\,mA \times 20\,\Omega}{75\,mA} = 6.66\,\Omega$$

∴ The Range of 0-25mA meter can be extended to 0-100mA meter by connecting a shunt resistance of 6.66Ω across Rm //

(ii) The PMMC meter can be converted into a voltmeter by connecting a high resistance, called 'Multiplier' in series with the basic meter movement.



Voltmeter

→ We need to calculate R_s.

$V = I_m (R_s + R_m)$

$10\,V = 25\,mA\,(R_s + R_m) \Rightarrow R_s + R_m = 400\,\Omega \Rightarrow R_s = 400\,\Omega - 20\,\Omega$

$\Rightarrow R_s = 380\,\Omega$

The PMMC of 0-25mA can be converted into 0-10V Voltmeter by connecting a multiplier of 380Ω in series with the meter //

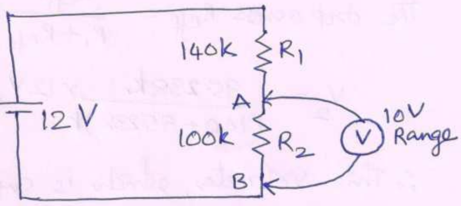
10. Two resistors R_1=140kΩ and R_2=100kΩ are connected in series across 12V supply. A voltmeter on a 10V range is connected to measure the voltage across the resistor 'R_2'. Calculate

(i) actual value of voltage across R_2 , (ii) measured voltage across R_2 with voltmeter having sensitivity of 20kΩ/V , (iii) measured voltage across R_2 with voltmeter having sensitivity 200kΩ/V , (iv) % error in both the above cases

What is your comment on the result with reference to sensitivity of the voltmeters used?

Solution:

(i) Actual voltage across R_2



$$V_0 = \frac{R_2}{R_1+R_2} \times V = \frac{100k}{(100k+140k)} \times 12V$$

$$= \frac{100}{240} \times 12 = 5V$$

Actual voltage across R_2 is $V_0 = 5V$

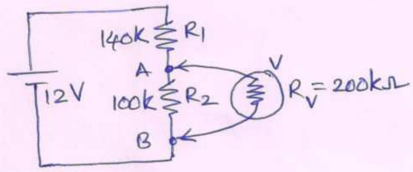
Any voltmeter is supposed to read 5V when connected across R_2

(ii) Measured voltage across R_2, when a voltmeter of $S = 20\,k\Omega/V$ is connected:

→ The resistance offered by the voltmeter comes in parallel with the R_2.

→ Resistance offered by voltmeter $= R_V =$ Sensitivity × Range

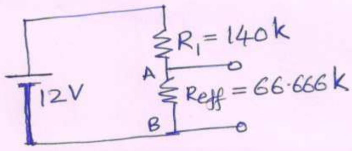
$$R_V = 20\frac{k\Omega}{V} \times 10V = 200k\Omega$$



→ ∴ The effective resistance across points A & B is

$$R_{eff} = \frac{R_2 R_V}{R_2+R_V} = \frac{100k\Omega \times 200k\Omega}{100k\Omega+200k\Omega}$$

$$R_{eff} = 66.666\,k\Omega$$



∴ The Reading that will be shown by the voltmeter = Drop across R_{eff}

$$V_1 = \frac{R_{eff}}{R_1+R_{eff}} \times 12V = \frac{66.666k}{(140+66.666)k} \times 12V = 3.871V$$

This voltmeter, which is supposed to read 5V, reads 3.87V.

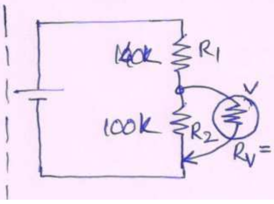
∴ Error in voltmeter reading $(e) = \frac{\text{measured} - \text{true}}{\text{True}} \times 100$

$$e = \frac{3.871-5}{5} \times 100 = -22.58\%$$

(iii) Measured voltage across R_2, when a voltmeter of $S = 200k\Omega/V$ is connected:

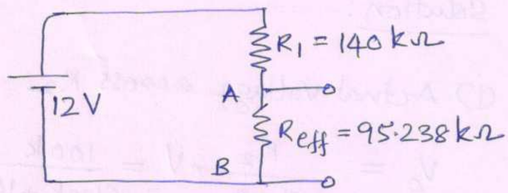
$$R_V = S \times Range = 200\frac{k\Omega}{V} \times 10V$$

$$R_V = 2000k\Omega$$



$$R_{eff} = R_2 \| R_V = \frac{R_2 R_V}{R_2+R_V} = 95.238\,k\Omega$$

The drop across $R_{eff} = \frac{R_{eff}}{R_1 + R_{eff}} \times 12\,V$



$$V_2 = \frac{95.238k}{(140 + 95.238)k} \times 12\,V = \underline{\underline{4.858V}}$$

∴ This voltmeter, which is supposed to read 5 V, reads 4.858V.

Hence error in voltmeter reading (e) = $\frac{\text{measured} - \text{True reading}}{\text{True reading}} \times 100\,\%$

$$e = \frac{4.858 - 5}{5} \times 100 = \underline{\underline{-2.84\%}}$$

Comment :

* Voltmeter with $S = 20k\Omega/V$, reads voltage across R_2 with -22.58% error
* Voltmeter with $S = 200k\Omega/V$, reads voltage across R_2 with -2.84% error

→ Higher the meter sensitivity ($k\Omega/V$), more accurate is the meter reading.

→ Loading effect is caused by meters with low sensitivity //.