Moving Coil Instruments

There are two types of moving coil instruments namely, the ***permanent magnet moving coil*** type which can only be used for ***direct*** current, voltage measurements, and the ***dynamometer*** type which can be used on either ***direct or alternating*** current, voltage measurements.

Permanent Magnet Moving Coil Mechanism (PMMC)

In PMMC meter or (D'Arsonval) meter or galvanometer, all are the same instrument, a coil of fine wire is suspended in a magnetic field produced by a permanent magnet. According to the fundamental law of electromagnetic force, the coil will rotate in the magnetic field when it carries an electric current by electromagnetic (EM) torque effect. A pointer attached to the movable coil will deflect according to the amount of current to be measured which is applied to the coil. The (EM) torque is counterbalanced by the mechanical torque of control springs attached to the movable coil also. When the torques are balanced the moving coil will be stopped and its angular deflection represents the amount of electrical current to be measured against a fixed reference, called a scale. If the permanent magnet field is uniform and the spring linear, then the pointer deflection is also linear.

Mathematical Representation of PMMC Mechanism

Assume there are (N) turns of wire and the coil is (L) in long by (W) in wide. The force (F) acting perpendicular to both the direction of the current flow and the direction of a magnetic field is given by:

$F = N \cdot B \cdot I \cdot L$

where N: turns of wire on the coil I: current in the movable coil

B: flux density in the air gap

L: vertical length of the coil

Electromagnetic torque is equal to the multiplication of force with distance to the point of suspension

$T_{I1} = NBIL\frac{W}{2}$ in one side of cylinder $T_{I2} = NBIL\frac{W}{2}$ in the other side of cylinder

The total torque for the two cylinder sides

$$T_I = 2\left(NBIL\frac{W}{2}\right) = NBILW = NBIA$$ where A: effective coil area

This torque will cause the coil to rotate until an equilibrium position is reached at an angle θ with its original orientation. At this position

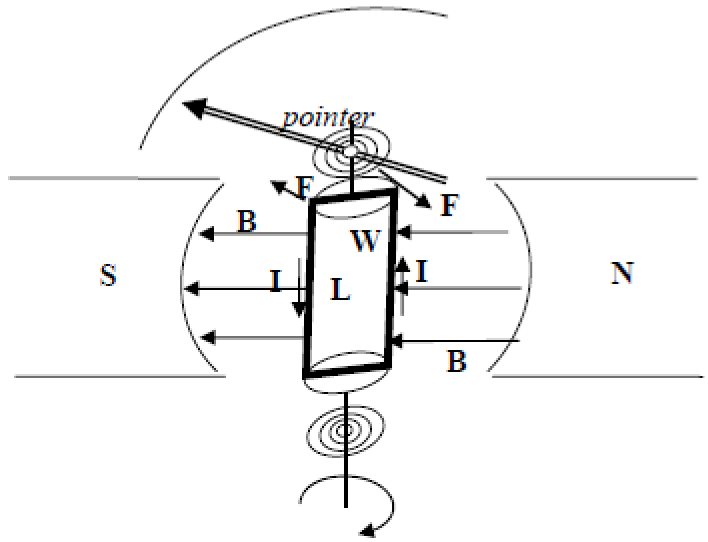
Electromagnetic torque = control spring torque

$$T_I = T_s$$

Since $T_s = K\theta$

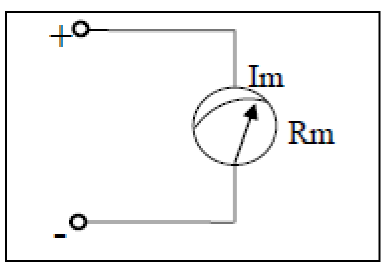
So $\theta = \frac{NBA}{K} I$ where $C = \frac{NBA}{K}$ Thus $\theta = CI$

The angular deflection is proportional linearly with applied current



1- *D.c Ammeter:*

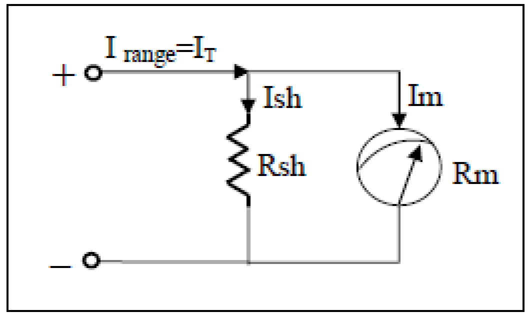
An Ammeter is always connected in series with a circuit branch and measures the current flowing in it. Most d.c ammeters employ a d'Arsonval movement, an ideal ammeter would be capable of performing the measurement without changing or distributing the current in the branch but real ammeters would possess some internal resistance.



Extension of Ammeter Range:

Since the coil winding in PMMC meter is *small and light*, they can carry only small currents (μA-1mA). Measurement of large current requires ***a shunt external resistor*** to connect with the meter movement, so only a fraction of the total current will passes through the meter.

$$Vm = Vsh$$
$$Im\,Rm = Ish\,Rsh$$
$$Ish = I_T - Im$$
$$\boxed{Rsh = \frac{Im\,Rm}{I_T - Im}}$$



Example:

If PMMC meter has an internal resistance of 10Ω and a full-scale range of 1mA.

Assume we wish to increase the meter range to 1A.

Sol.

So we must connect shunt resistance with the PMMC meter of

$$R_{Sh} = \frac{I_m R_m}{I_T - I_m}$$

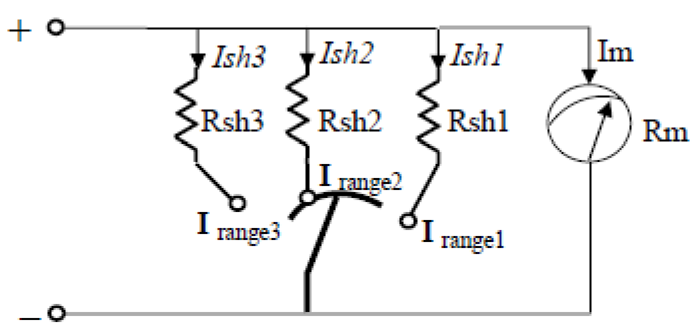
$$R_{Sh} = \frac{1\times10^{-3}\times10}{1-1\times10^{-3}}$$

$$R_{Sh} = 0.01001\ \Omega$$

a) *Direct D.c Ammeter Method (Ayrton Shunt):*

The current range of d.c ammeter can be further extended by several shunts selected by a range switch; such ammeter is called a multirange ammeter.

$$\boxed{Rsh_* = \frac{Im\,Rm}{Ir_* - Im}}$$

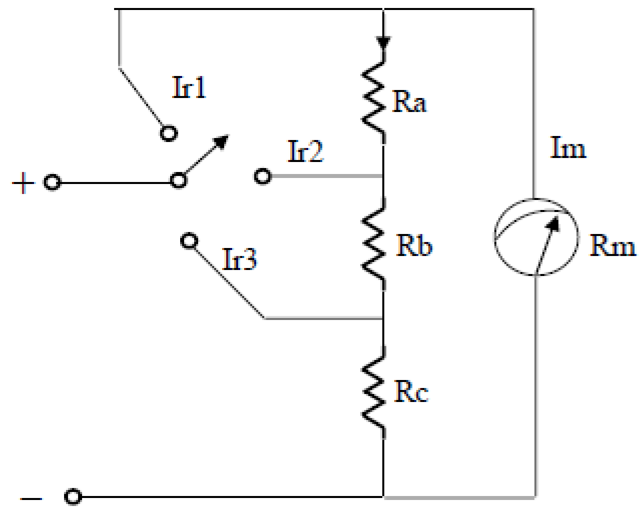


b) *Indirect D.C Ammeter Method:*

$$\frac{I_{r*}}{I_m} = \frac{R_m + R}{r_*}$$

Where $R = R_a + R_b + R_c$

And r = parallel resistors branch with the meter



Example (1):

Design a multirange ammeter by using the ***direct method*** to give the following ranges 10mA, 100mA, 1A, 10A, and 100A. If d'Arsonval meter has an internal resistance of 10Ω and full-scale current of 1mA.

Sol:

$R_m = 10\Omega$

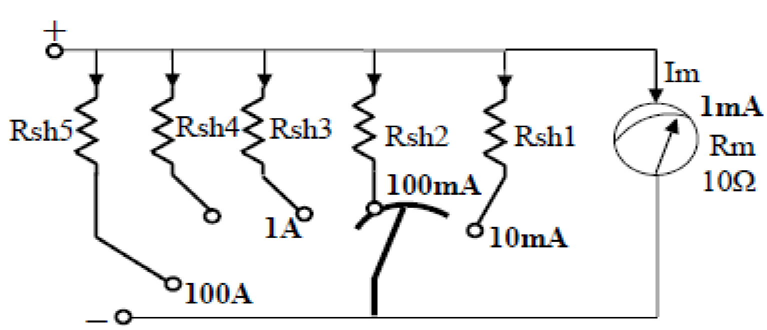
$I_m = 1mA$

$$\boxed{Rsh_* = \frac{\mathrm{Im}\,Rm}{Ir_* - \mathrm{Im}}}$$

$$Rsh1 = \frac{1\times10^{-3}\cdot 10}{(10-1)\times10^{-3}} = 1.11\Omega$$

$$Rsh2 = \frac{1\times10^{-3}\cdot 10}{(100-10)\times10^{-3}} = 0.101\Omega \qquad Rsh3 = \frac{1\times10^{-3}\cdot 10}{1-10\times10^{-3}} = 0.0101\Omega$$

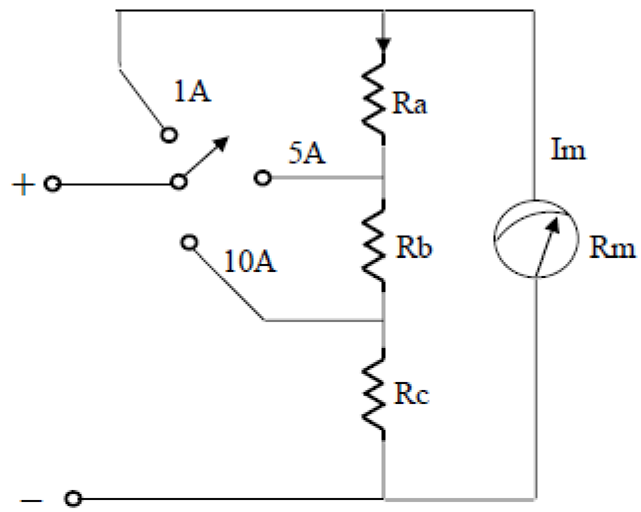
$$Rsh4 = \frac{1\times10^{-3}\cdot 10}{10-1\times10^{-3}} = 0.0011\Omega \qquad Rsh5 = \frac{1\times10^{-3}\cdot 10}{100-1\times10^{-3}} = 0.00011\Omega$$



Example (2):

Design an Ayrton shunt by ***indirect method*** to provide an ammeter with current ranges 1A, 5A, and 10A, if PMMC meter has an internal resistance of 50Ω and full-scale current of 1mA.

Sol.:



R_m=50Ω I_{FSD}=I_m=1mA

$$\frac{I_{r*}}{I_m} = \frac{R_m+R}{r_*}$$

Where R=R_a+ R_b+ R_c

And r = parallel resistors branch with the meter

1- *For 1A Range:*

$$\frac{I_1}{I_m} = \frac{R_m+R}{R}$$

$$\frac{1\ A}{1\ mA} = \frac{50+R}{R}$$

R= 0.05005 Ω

2- *For 5A Range:*

$$\frac{I1}{I_m} = \frac{R_m+R}{R_b+R_c}$$

r =R_b+R_c

$$\frac{5\ A}{1\ mA} = \frac{50+0.05005}{R_b+R_c}$$

R_b+R_c= 0.01001 Ω

R_a=R- (R_b+R_c)

R_a=0.05-0.01001=0.04004 Ω

3- *For 10A Range:*

$\frac{I3}{I_m} = \frac{R_m+R}{R_c}$

$r=R_c$

$\frac{10\ A}{1\ mA} = \frac{50+0.05005}{R_c}$

$\mathbf{R_c}=5.005\text{x}10^{-3}\ \Omega$

$\mathbf{R_b}=0.01001-5.005\text{x}10^{-3}= 5.005\text{x}10^{-3}\ \Omega$