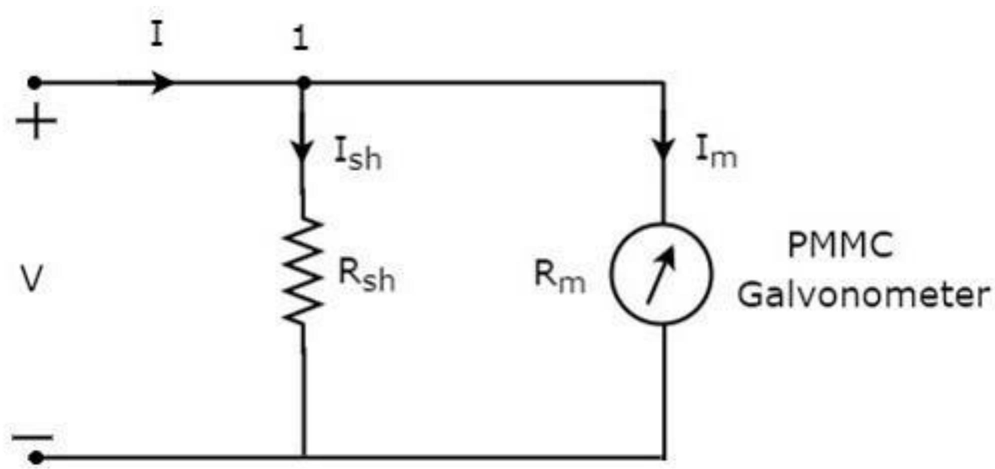
Moving coil instrument (DC AMMETER)

Current is the rate of flow of electric charge. If this electric charge flows only in one direction, then the resultant current is called Direct Current (DC). The instrument, which is used to measure the Direct Current called **DC ammeter**.

If we place a resistor in parallel with the Permanent Magnet Moving Coil (PMMC) galvanometer, then the entire combination acts as DC ammeter. The parallel resistance, which is used in DC ammeter is also called shunt resistance or simply, **shunt**. The value of this resistance should be considered small in order to measure the DC current of large value.

The **circuit diagram** of DC ammeter is shown in below figure.



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We have to place this **DC ammeter** in series with the branch of an electric circuit, where the DC current is to be measured. The voltage across the elements, which are connected in parallel is same. So, the voltage across shunt resistor Rsh and the voltage across galvanometer resistance, Rm is same, since those two elements are connected in parallel in above circuit.

Mathematically, it can be written as

$$I_{sh}R_{sh} = I_m R_m$$

$$\Rightarrow R_{sh} = \frac{I_m R_m}{I_{sh}} \qquad \text{(Equation 1)}$$

The **KCL equation** at node 1 is

$$-I + I_{sh} + I_m = 0$$

$$\Rightarrow I_{sh} = I - I_m$$

Substitute the value of I_{sh} in Equation 1.

$$R_{sh} = \frac{I_m R_m}{I - I_m} \qquad \text{(Equation 2)}$$

Take, I_m as common in the denominator term, which is present in the right hand side of Equation 2

$$R_{sh} = \frac{I_m R_m}{I_m(\frac{1}{I_m} - 1)}$$

$$\Rightarrow R_{sh} = \frac{R_m}{\frac{I}{I_m} - 1} \qquad \text{(Equation 3)}$$

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Where,

R_{sh} is the shunt resistance

R_m is the internal resistance of galvanometer

I is the total Direct Current that is to be measured

I_m is the full scale deflection current

The ratio of total Direct Current that is to be measured, I and the full scale deflection current of the galvanometer, I_m is known as **multiplying factor, m**. Mathematically, it can be represented as

$$m = \frac{I}{I_m} \quad \text{(Equation 4)}$$

$$R_{sh} = \frac{R_m}{m-1} \quad \text{(Equation 5)}$$

We can find the **value of shunt resistance** by using either Equation 2 or Equation 5 based on the available data.

1- DC Ammeter:

An Ammeter is always connected in series with a circuit branch and measures the current flowing in it. Most dc 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 pass through the meter.

Example:

If PMMC meter have internal resistance of 10Ω and 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

$$\boxed{Rsh = \frac{\text{Im}\, Rm}{I_T - \text{Im}}}$$

$$Rsh = \frac{1\times10^{-3}\cdot 10}{1-1\times10^{-3}} = 0.01001\Omega$$

Multi Range DC Ammeter

In previous section, we discussed about DC ammeter which is obtained by placing a resistor in parallel with the PMMC galvanometer. This DC ammeter can be used to measure a **particular range** of Direct Currents.

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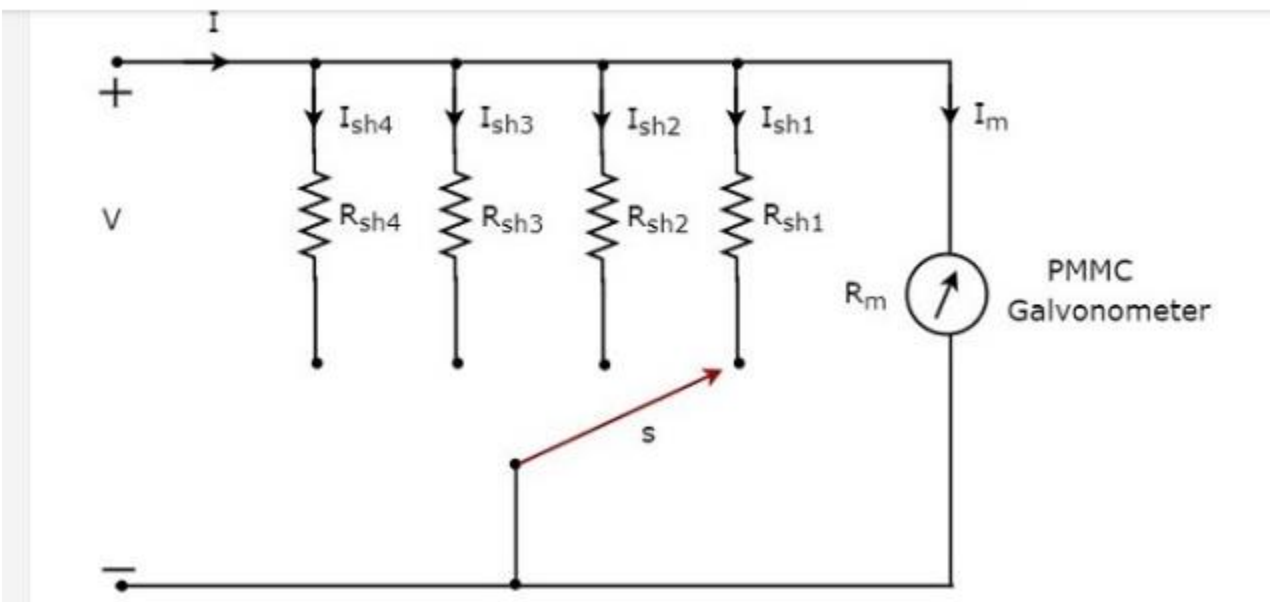
If we want to use the DC ammeter for measuring the Direct Currents of **multiple ranges**, then we have to use multiple parallel resistors instead of single resistor and this entire combination of resistors is in parallel to the PMMC galvanometer. The **circuit diagram** of multi range DC ammeter is shown in below figure.



a) Direct Dc Ammeter Method (Ayton Shunt):
The current range of dc ammeter can be further extended by a number of shunts selected
by a range switch; such ammeter is called a multirange ammeter.

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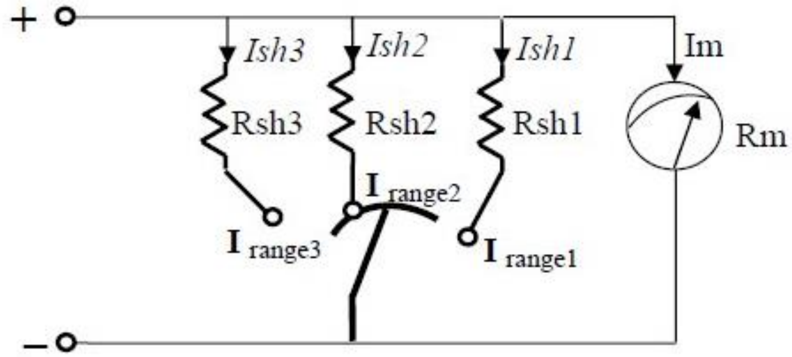
$$Rsh_* = \frac{\text{Im}\, Rm}{Ir_* - \text{Im}}$$



Example (1):

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

Sol:

Rm=10Ω Im=1mA

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

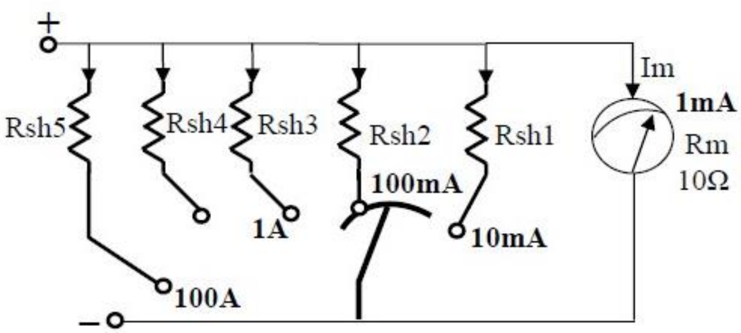
$$Rsh1 = \frac{1\times10^{-3}\cdot 10}{(10-1)\times10^{-3}} = 1.11\Omega$$

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

$$Rsh3 = \frac{1\times10^{-3}\cdot 10}{1-10\times10^{-3}} = 0.0101\Omega$$

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

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



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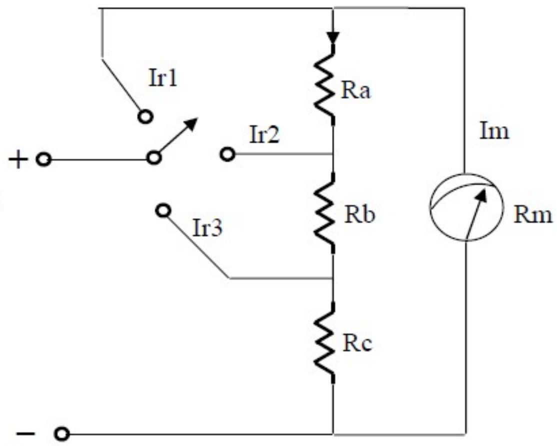
b) ***Indirect D.C Ammeter Method:***

$$\frac{Ir_*}{Im} = \frac{Rm + R}{r_*}$$

Where R=Ra+ Rb+ Rc
And r = parallel resistors branch with the meter



Example (2):

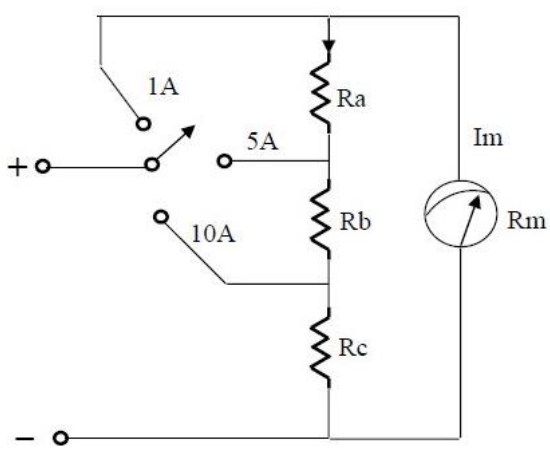
Design an Ayrton shunt by ***indirect method*** to provide an ammeter with current ranges 1A, 5A, and 10A, if PMMC meter have internal resistance of 50Ω and full scale current of 1mA.

Sol.:

Rm=50Ω I_{FSD}=Im=1mA

$$\frac{Ir_*}{Im} = \frac{Rm + R}{r_*}$$

Where R=Ra+ Rb+ Rc
And r = parallel resistors branch with the meter



1- *For 1A Range:*

$$\frac{I1}{Im} = \frac{Rm + R}{R}$$

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$$\frac{1A}{1mA}=\frac{50+R}{R}$$ R=0.05005Ω

2- *For 5A Range:*

$$\frac{I2}{\text{Im}}=\frac{Rm+R}{Rb+Rc}$$ r =Rb+Rc

$$\frac{5A}{1mA}=\frac{50+0.05005}{Rb+Rc}$$ Rb+Rc= 0.01001Ω

Ra=R-(Rb+Rc) **Ra**=0.05-0.01001=0.04004 Ω

3- *For 10A Range:*

$$\frac{I3}{\text{Im}}=\frac{Rm+R}{Rc}$$ r =Rc

$$\frac{10A}{1mA}=\frac{50+0.05005}{Rc}$$ **Rc**=5.005×10^{-3} Ω

Rb=$0.01001-5.005\times10^{-3}=5.005\times10^{-3}$ Ω