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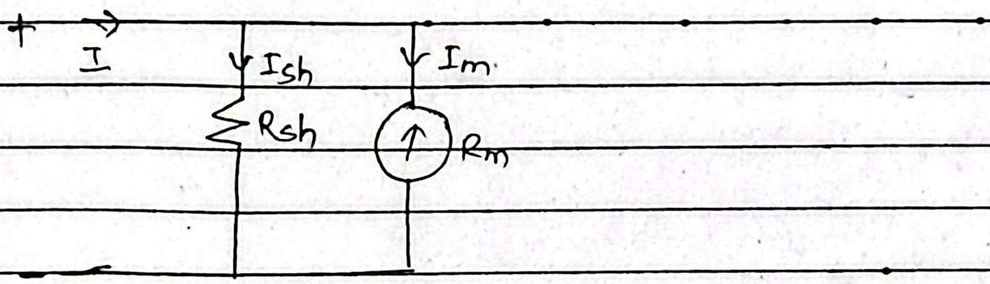
Extension of Range of Ammeter (upto 50A)

The amount of current that can be passed to moving coil is limited to (20 mA) due to weight constraints. weight of moving part should be minimum to decrease the friction effect.

→ To increase the range of ammeter, a low value of resistance must be connected in parallel with the meter called shunt. The shunt by passes the extra current & allows only safe current to flow through ammeter.

When heavy currents are to be measured, the major part of current if bypassed through a low resistance called shunt.



let, R_m = Internal resistance of the meter (Ω)

R_{sh} = shunt resistance (Ω)

$I = I_{sh} + I_m \Rightarrow I_{sh} = (I - I_m)$

By current division rule,

$$I_m = I \frac{R_{sh}}{R_{sh}+R_m} \Rightarrow \frac{R_{sh}+R_m}{R_{sh}} = \frac{I}{I_m} = m$$

multiplication factor

$\Rightarrow I_m (R_{sh} + R_m) = I R_{sh}$

$\Rightarrow R_{sh} (I - I_m) = I_m R_m$

$$\Rightarrow R_{sh} = \frac{I_m R_m}{I - I_m} = \frac{R_m}{\left(\frac{I}{I_m} - 1\right)} = \frac{R_m}{m-1} \quad \text{—— (A)}$$

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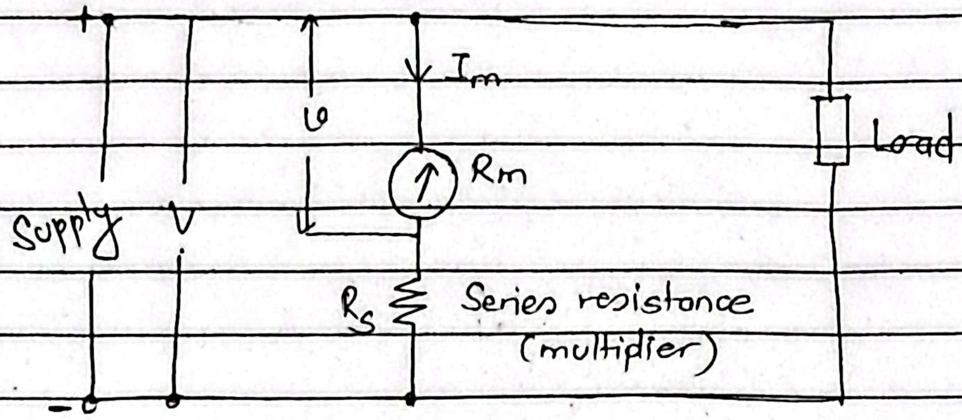
Extension of the range of voltmeters (upto 500V)

→ To extend the range of voltmeter, a series resistance of manganin or constantan is used to limit the current to a safe value. ~~The mut~~ This series resistance is called multiplier. Multiplier limits the current through the meter so that it doesnot exceed the value for full scale deflection & thus prevents the movement (meter) from being damaged.



Let,

I_m = full scale deflection current of meter

R_m = Internal resistance of meter

R_s = multiplier resistance

v = voltage across the meter movement

V = full range voltage of instrument

From fig,

$$v = I_m R_m$$

$$V = I_m (R_m + R_s)$$

$$\therefore R_s = \frac{V - I_m R_m}{I_m} = \frac{V}{I_m} - R_m$$

Multiplying factor for multiplier,

$$m = \frac{V}{v} = \frac{I_m (R_m + R_s)}{I_m R_m} = 1 + \frac{R_s}{R_m}$$

$$\therefore R_s = (m - 1) R_m$$

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Multirange Ammeter:-

The current range of DC ammeter may be further extended by a number of shunts, selected by a range switch, such ammeter is called multirange ammeter.

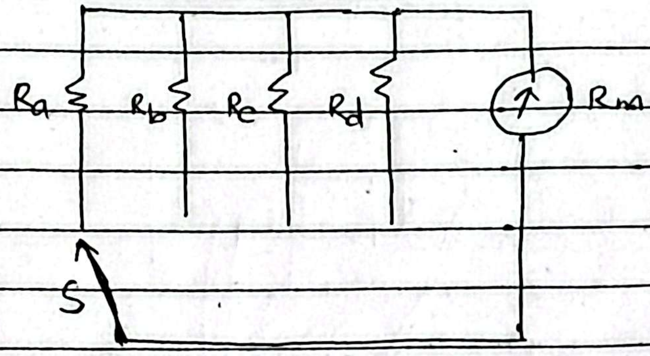

Fig. Schematic diagram of simple multirange ammeter.

Multirange Voltmeter:-

The addition of a number of multiplies together with range switch is known as multirange voltmeter. The voltmeter provides the facility to work with number of voltage range. Fig. below shows schematic diagram of multirange voltmeter having 4 multipliers R_1, R_2, R_3 & R_4.

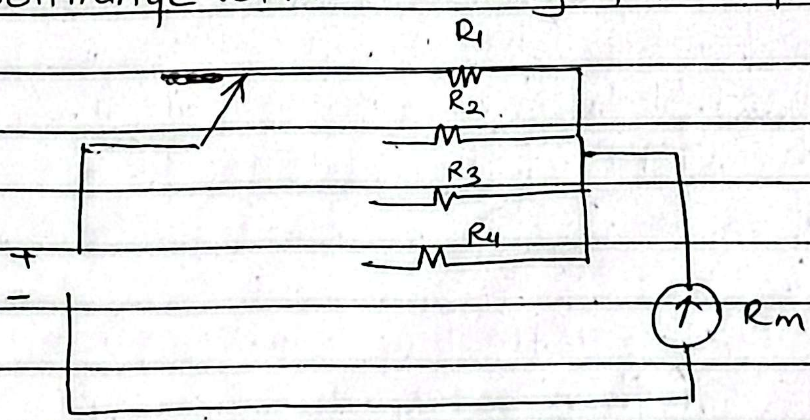

Fig. Schematic diagram of simple multirange voltmeter.

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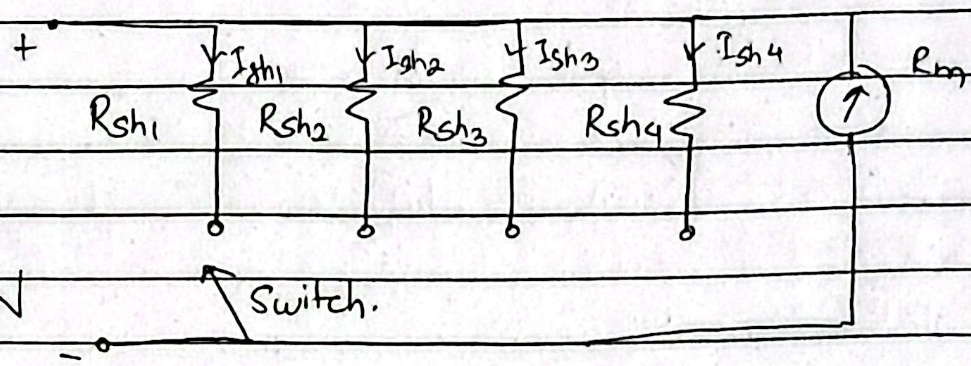
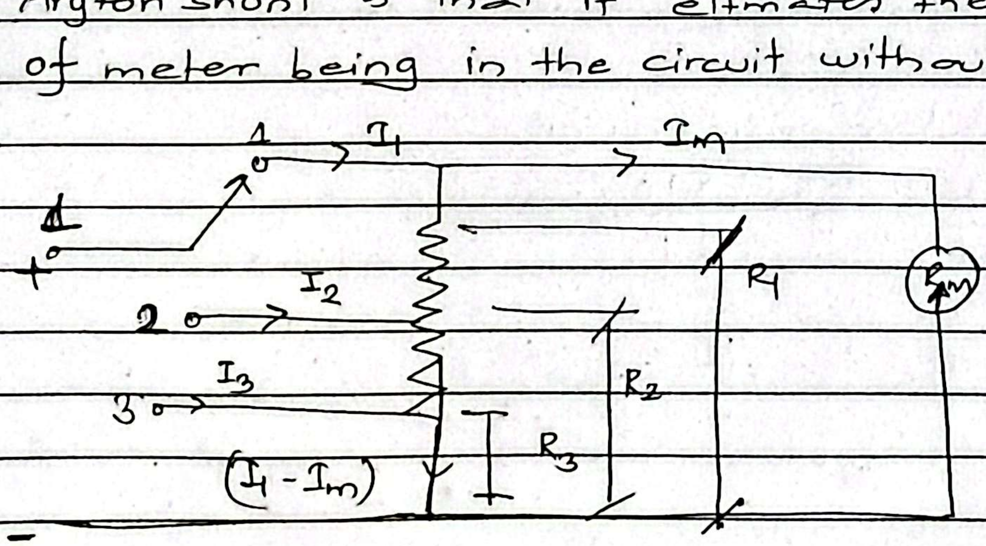
Multi-Range Ammeters

The current range of dc ammeter may be further extended by a no. of shunts, selected by a range switch. which is called as multi-range ammeter.



$$\therefore \; R_{sh1} = R_m/(m_1 - 1)$$
$$R_{sh2} = R_m/(m_2 - 1)$$
$$R_{sh3} = R_m/(m_3 - 1)$$
$$R_{sh4} = R_m/(m_4 - 1)$$
$(1 - 50A)$

The universal shunt or Ayrton shunt is also used for multirange ammeter. The advantages of an Aryton shunt is that it elimates the possibility of meter being in the circuit without a shunt.



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For switch at position 1

$I_m R_m = (I_1 - I_m) R_1 \Rightarrow R_1 = \frac{I_m R_m}{I_1 - I_m}$

$$\boxed{\begin{aligned} m_1 &= \frac{I_1}{I_m} \\ &= 1 + \frac{R_m}{R_1} \end{aligned}}$$

$= \frac{R_m}{\frac{I_1}{I_m} - 1}$

$R_1 = R_m/(m-1)$

For switch at 2

$$I_m (R_1 - R_2 + R_m) = (I_2 - I_m) R_2$$

$$R_2 = (R_1 + R_m)/m_2$$

For switch at position 3,

$$I_m (R_1 - R_3 + R_m) = (I_3 - I_m) R_3$$

$\Rightarrow I_3 R_3 = I_m (R_m + R_1) \Rightarrow R_3 = \frac{R_m + R_1}{m_3}$; $m_3 = I_3 / I_m$.

$R_1 - R_2$, $R_1 - R_3$ & R_3 may be found.

Q) Design a multi-range dc milli-ammeter using a basic movement with an internal resistance $R_m = 50\,\Omega$ & a full deflection current $I_m = 1\,mA$.

The range required are $0-10\,mA$, $0-50\,mA$.

Soln For $(0-10)\,mA$ range

Multiplying power,

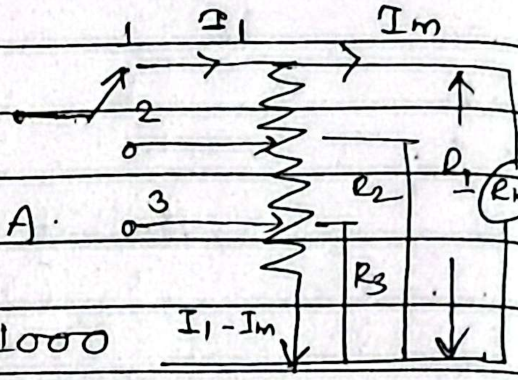
$$m = \frac{I}{I_m} = \frac{10}{1} = 10$$

Resistance of shunt

$$R_{sh1} = R_m/(m-1) = \frac{50}{10-1} = 5.55\,\Omega.$$

Q) Design an aryton shunt to provide an ammeter with current ranges of 1A, 5A & 10 A. A basic meter with an internal resistance of 50Ω & a full scale deflection current of 1mA is to be used.

Solⁿ.



$I_m = 1\,mA$, $R_m = 50\Omega$

$I_1 = 1A$, $I_2 = 5A$, $I_3 = 10A$.

Thus

$$m_1 = 1/(1\times10^{-3}) = 1000$$

$$m_2 = 5/(1\times10^{-3}) = 5000$$

$$m_3 = 10/(1\times10^{-3}) = 10{,}000.$$

Thus

$$R_1 = \frac{R_m}{(m_1-1)} = \frac{50}{1000-1} \approx 0.05\Omega$$

$$R_2 = \frac{R_1+R_m}{m_2} = \frac{0.05+50}{5000} \approx 0.01\Omega$$

$$R_3 = \frac{R_1+R_m}{m_3} = \frac{0.05+50}{10{,}000} = 0.005\Omega$$

i.e. Resistance at various section of the universal shunt are:-

$R_1 - R_2 = 0.040\Omega$

$R_2 - R_3 = 0.005\Omega$

$R_3 = 0.005\Omega$

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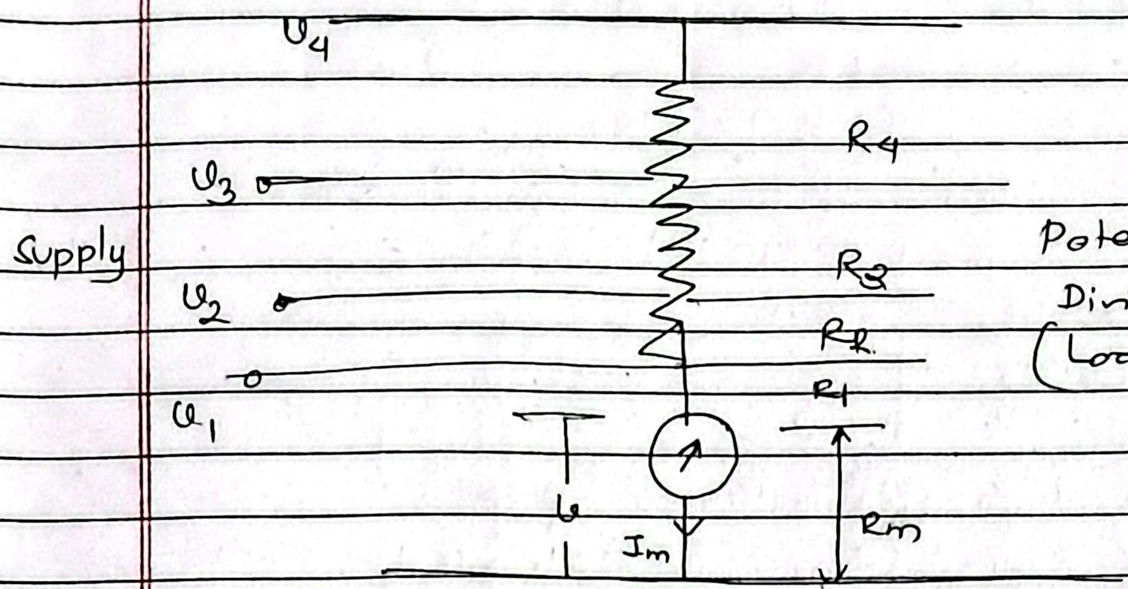
Potential Divider arrangement for extension of Voltmeter



Voltage across the meter $v = I_m R_m$

Voltage multiplying factor:-

$m_1 = V_1/v$, $m_2 = V_2/v$, $m_3 = V_3/v$,

$m_4 = V_4/v$

$R_1 = (m_1 - 1) R_m$

$R_2 = (m_2 - m_1) R_m$

$R_3 = (m_3 - m_2) R_m$

& $R_4 = (m_4 - m_3) R_m$

Q) A d' Arsonval meter movement with an internal resistance $R_m = 100\Omega$ & full scale current of $I_m = 1mA$ is to be converted into a multi-range dc voltmeter with range of 0-10V, 0-50V, 0-250V, 0-500 V. find the values of various resistance using the potential divider arrangement.

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Soln Voltage across the meter movement,

$$v = I_m R_m = 1 \times 100 = 100\,mV$$

The voltage multiplying factors are:-

$$m_1 = \frac{10}{(100 \times 10^{-3})} = 100$$

$$m_2 = \frac{50}{(100 \times 10^{-3})} = 500$$

$$m_3 = 2500$$

$$m_4 = 5000$$

The values of resistances are:-

$$R_1 = (m_1 - 1) R_m = (100 - 1) \times 100 = 9900\,\Omega$$

$$R_2 = (m_2 - m_1) R_m = (500 - 100) \times 100 = 40\,k\Omega.$$

$$R_3 = (m_3 - m_2) R_m = (2500 - 500) \times 100 = 200\,k\Omega$$

& $R_4 = (m_4 - m_3) R_m = (5000 - 2500) \times 100 = 250\,k\Omega.$