Lecture-6

DC Ammeters and Voltmeters

6.1 Introduction

Most of the electrical measuring instruments have an output in the form of current and voltage level.

For some purpose it is necessary to have a visual indication of the signal level when monitoring the output of the measuring instrument, while for other purpose there is a requirement to record the output signal continuously in a form that can be recorded and saved for future work.

6.2 DC Galvanometers

A galvanometer is an electromechanical instrument used for detecting and measuring small electric currents. Galvanometers were first developed in the early 19th century. It is named after professor Galvani of Italy. Galvanometers operate on the principle of electromagnetism. When an electric current passes through a coil placed in a magnetic field, a torque is generated due to the interaction between the current and the magnetic field. This torque causes a deflection in the coil, which is proportional to the strength of the current passing through it.

The main applications of the DC galvanometers are in DC bridges and potentiometers measurements as a null detector.

1. Types of DC galvanometers

(1) Moving-Coil Galvanometer

This is the most common type, where the coil is free to rotate within a magnetic field. The common features of this type include: high sensitivity and linear response to current.

(2) Moving-Magnet Galvanometer

Here, the magnet moves while the coil remains stationary. It is less sensitive than the moving-coil type but is mechanically simpler and more robust.

(3) Ballistic Galvanometer

Designed to measure the quantity of charge passing through it in a short interval of time. Commonly used in experiments to determine the capacitance of a capacitor or the magnetic flux linkage.

2. Applications of galvanometers

- **Electrical Circuit Testing**: Detecting and measuring small currents in circuits.
- **Laboratory Experiments**: Used in educational and research laboratories to study electromagnetic principles.
- **Calibration**: Serves as a reference instrument to calibrate other measuring devices.
- **Ballistic Measurements**: Determines magnetic flux or charge in transient phenomena.

3. Advantages of galvanometers

- High sensitivity to small currents.
- Can measure both direct and alternating currents with modifications.
- Compact and relatively inexpensive.

4. Limitations of galvanometers

- Limited to low current measurements.
- Sensitive to mechanical vibrations and external magnetic fields.
- Requires frequent calibration for accurate readings.

6.3 Ammeters and Voltmeters

Fundamentally there is no essential difference in principle between ammeters and voltmeters. In general, the operating torque is produced by the current which is proportional to the voltage to be measured in case of voltmeters and to the current to be measured in case of ammeters.

An ammeters and voltmeters may come under any one of the fallowing classes :

1. Moving-coil instruments.
   a. Permanent magnet moving-coil instruments.
   b. Dynamometer moving-coil instruments.
2. Moving-iron instruments.
   a. Attraction type moving-iron instruments.
   b. Repulsion type moving-iron instruments.
3. Thermal instruments.
4. Electrostatic instruments.
5. Rectifier instruments.
6. Digital instruments

All the above instruments, except the permanent magnet moving-coil instrument can be used for both direct and alternating current measurement. The permanent magnet moving-coil type can be used only for direct current measurement.

6.4 Permanent Magnet Moving-Coil Instruments

The Permanent-Magnet Moving Coil (PMMC) instruments are used for D.C. work only. Their operation based on the principal that when a current–carrying conductor is placed in a magnetic field it is affected by a force which tends to move it to one side and out of the field.

The PMMC instruments consist essentially of a pointer which moves on a calibrated scale or dial and is attached to a moving system pivoted in jeweled bearings as shown in figure 6.1.

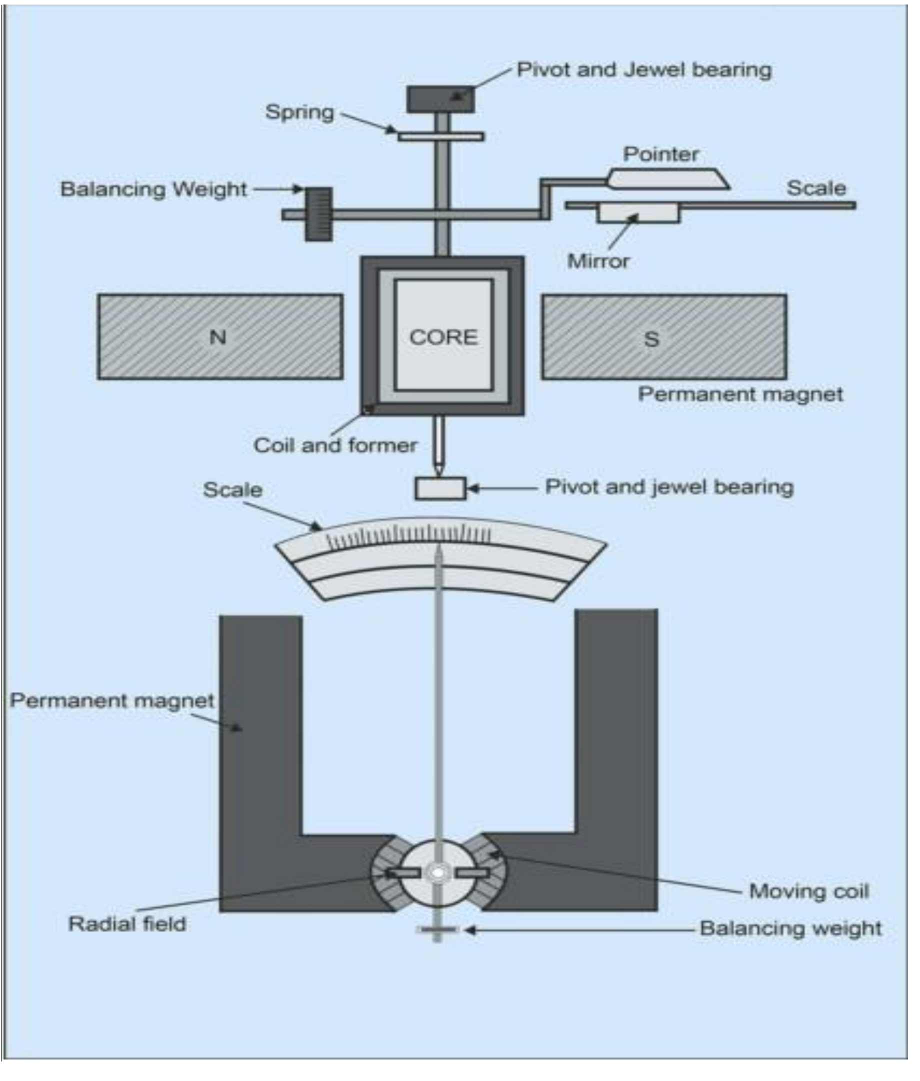


Figure 6.1 Permanent magnet moving-coil instrument

The moving system is statically balanced for all deflection position by one or more of balance weight. The pointer, spring and pivots are assembled to the coil by means of pivot bases. Jewel bearings are used in precision instruments where low friction, long life, and dimensional accuracy are important. Figure 6.2 shows some of ring jewel bearings. Ring jewel bearings featuring a circular or ring-shaped configuration, offering a smooth surface for the pivot to rotate within, minimizing wear and enhancing overall performance.

Figure 6.2 Some types of jewel bearings

Specially protected instruments use the spring-back jewel bearding, whose construction is shown in Figure 6.3. It is located in the normal position by the spring and is free to move axially when the shock to the mechanism becomes severe.

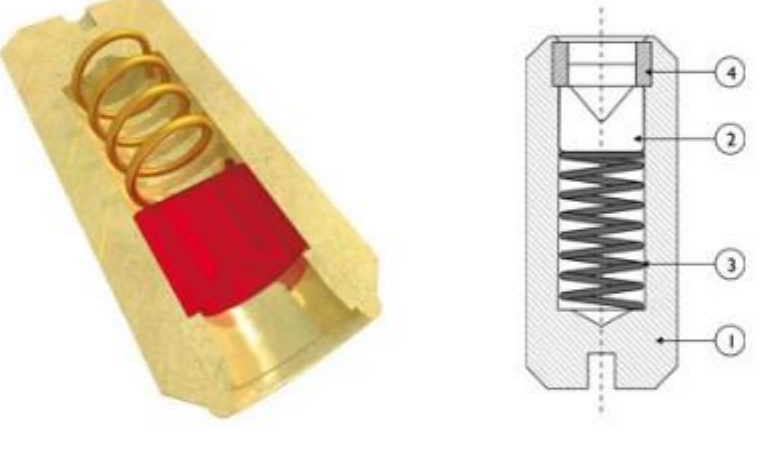


Figure 6.3 Spring-back jewel bearing

Other types of jewel bearings are:

1. **V-shaped Jewel:** Characterized by a groove or indentation in the shape of a “V” providing stability and reduced friction for the rotating pivot.
2. **Cap Jewel:** Designed as small, capped structures enclosing the pivot, providing additional protection and stability for precise and reliable functioning.
3. **Hole Jewel:** This type consists of a simple, smooth hole through which the pivot passes, offering a straightforward yet effective design for supporting rotation.
4. **Cone Jewel:** Shaped like a cone, this design allows for a gradual contact point with the pivot, promoting stability and minimizing friction in mechanical movements.

6.5 Torques Affecting the moving system

The moving system of the indicating instruments is subjected to three torques:

1. Deflecting Torque

Deflecting torque (T_d) is produced by utilizing the electromagnetic effect. The deflecting torque causes the moving system, and hence the pointer attached to it to move from zero position to indicate the value of the measured quantity. The deflecting torque is also known as the "operating torque".

When the current is passing through the coil, a forces (F) act on the both sides of the coil as shown in Figure 6.4.

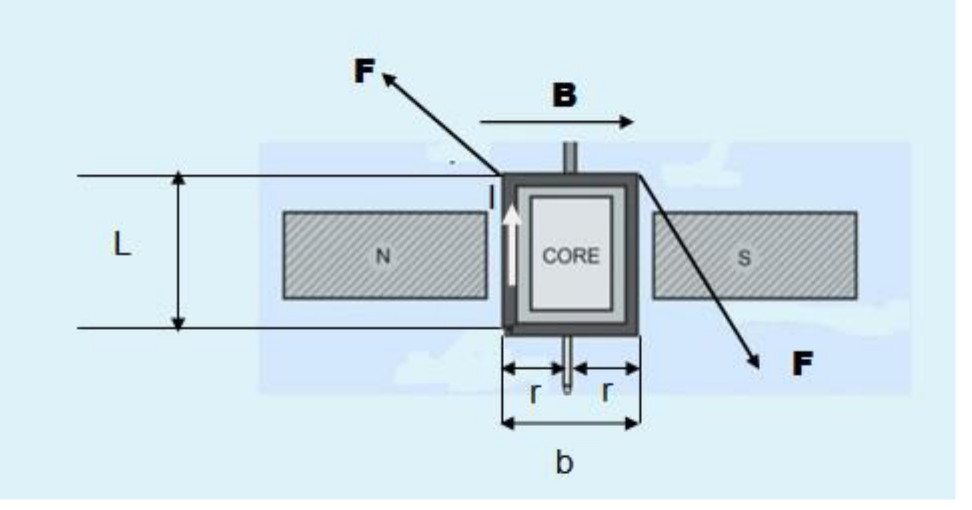


Figure 6.4 Forces acting on the coil of the PMMMC instrument

The force is giving by :

$$F = NBLI$$

Where,

F = is the force acting on one side of the coil in N.

N = number of turns of conductor.

B = flux density in Wb\m^2

L = the length or the height of the coil.

I = the current passing through the coil .

Since, we have two forces acting on both sides of the coil, then the above equation can be rewritten as :

$$2F = 2NBLI$$

If the two forces act at a distance (r) from the pivot, then the deflecting torque T_d will be:

$$2F\,r = 2\,r\,NBLI$$

But,

$$2r = b$$

Therefore, the equation can be written as :

$$F\,b = NBbLI$$

Thus,

$$T_d = NBbLI$$

Or,

$$T_d = NBA\,I$$

Where,

A = is the area of the coil face.

Since N, B and A are constants, then

$$T_d \propto I$$

2. Controlling Torque

Controlling torque (T_c) is also known as restoring torque. The controlling torque opposes the deflecting torque and increases with increasing of deflection of the moving system. Without the controlling torque, the deflection of the moving system would be indefinite.

The controlling torque (T_c) in the indicating instruments is obtained by two methods:

(i) Spring Control

In this method, the spring is attached to the moving system of the instrument as shown in Figure 6.1. When the pointer is deflected, the spring is twisted in the opposite direction. The twist produces the controlling (restoring) torque which is directly proportional to the angle of deflection θ, of the moving system.

The deflecting torque is proportional to current passing through the coil, i.e

$$T_d \; \alpha \; I$$

And the controlling torque is proportional to the angle of deflection of the moving system, i.e,

$$T_c \; \alpha \; \theta$$

The pointer comes to a position of rest when the deflecting torque (T_d) and the controlling torque (T_c) are equal, i.e,

$$T_c = T_d$$

Therefore,

$$\theta \; \alpha \; I$$

From the last equation, we can conclude that , since θ is proportional to the current passing through that coil, the spring-controlled instruments have a uniform scale.

The spring should have large number of turns so that angular deformation pre unit length on full-scale deflection is small. The stress on the spring should be restricted to such a value that it does not produce a permanent set in it.

Springs are made of phosphor-bronze or phosphor-silicon alloys, which have the following features:

1. Are non-magnetic.
2. Are not subjected to much fatigue.
3. Have low specific resistance.
4. Have low temperature-resistance coefficient.

(ii) Gravity Control

Gravity control can be obtained by attaching a small adjustable weight to some part of the moving system as shown in Figure 6.5.a.

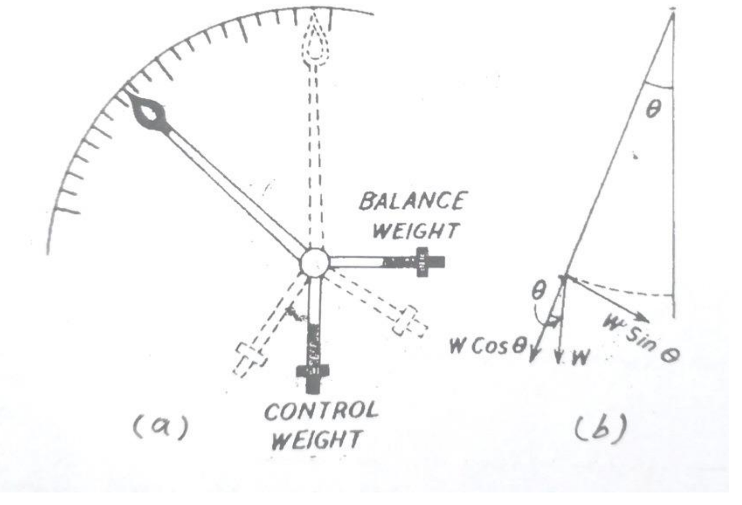


Figure 6.5 The gravity control (a) the deflection of the control weight (b) the control torque is function of sin θ.

It can be seen from Figure 6.5.b that the controlling torque is proportional to the sine of the angle of deflection, i.e,

$$T_c \ \alpha \ sin\theta$$

And we have that,

$$T_d \ \alpha \ I$$

At rest,

$$T_c = T_d$$

Therefore,

$$sin\theta \ \alpha \ I$$

From the last equation, we can see that the gravity-controlled instruments have a scale which are not uniform and crowded at their lower ends.

The advantages of the gravity control are :

1. It is cheap.
2. It is unaffected by temperature.
3. It is not subjected to fatigue with time.

But , the gravity control has some disadvantages such as:

1. It gives crowded scale .
2. The instruments have to be kept vertical.

3. Damping Torque

The damping torque is necessary to bring the pointer to rest quickly, otherwise due to inertia of the moving system, the pointer will oscillate about its final position for some time before coming to rest .

The damping torque can be achieved by:

(i) Air friction damping

There are two methods of obtaining the air friction damping :

- The first method is achieved by a light aluminum piston attached to the moving system of the instrument as shown in Figure 6.6.a.. The piston is arranged to travel with a very small clearance in a fixed air chamber closed at one end.
- The second method is achieved by one or two light aluminum vanes which are mounted on the spindle of the moving system as shown in Figure 6.6.b.

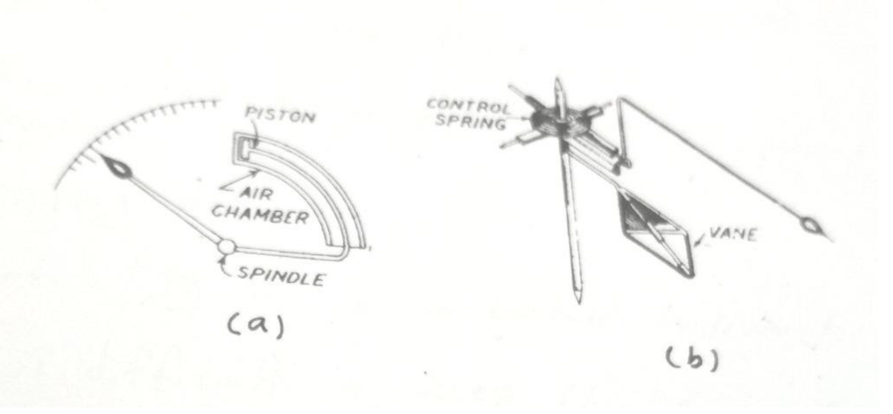


Figure 6.6 The air friction damping.

(ii) Fluid friction damping

Fluid friction damping is similar in action to air friction . In this method of damping, the vanes attached to the spindle move in a damping oil. Due to the greater viscosity of oil, the damping will be more effective . The oil used for this purpose must fulfill the following requirements:

1. It should not evaporate quickly.
2. It should not have any corrosive action upon metal.
3. Its viscosity should not change with temperature.
4. It should be good insulator.

However, oil damping is not much used because of several disadvantages:

1. The instrument must be kept in vertical position .
2. Creeping of oil .
3. Unsuitability for use in portable instruments.
4. It is difficult to keep this type of instruments clean due to the leakage of the oil.

(iii) Eddy currents damping

Eddy currents damping is the most efficient form of damping. As shown in Figure 6.7.a, the essential components in this method are a permanent magnet and a light disc of conducting material, mostly of aluminum. It is more convenient if either the permanent magnet or moving metal is a part of the instrument . The permanent magnet induces an e.m.f in the disc when it moves and hence an eddy currents circulate in the disc as shown in Figure 6.7.b. The eddy currents act in such direction that their reactions with the magnetic field of the permanent magnet producing a torque opposing the motion. The damping torque is proportional to the velocity of the disc . This method of damping is used in the instruments where the permanent magnet does not influence the operating flux.

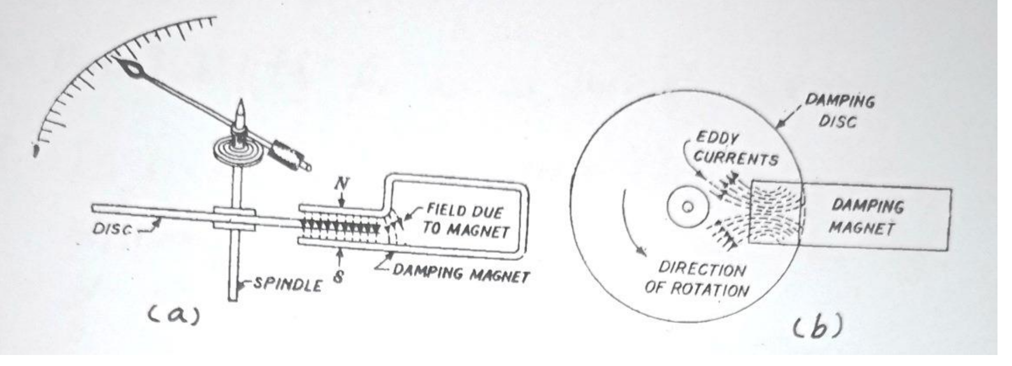


Figure 6.7 The eddy currents damping.

The instrument consists of a permanent magnet and a rectangular coil inside which an iron core is placed as shown in Figure 6.8.

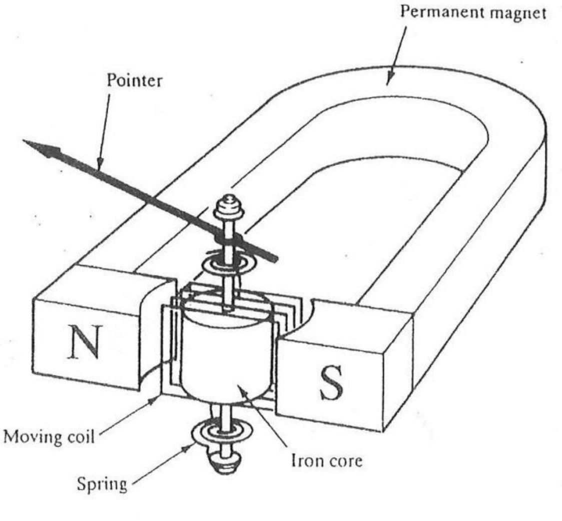


Figure 6.8 The permanent-magnet type moving–coil instrument

As shown in Figure 6.8, the permanent magnet has a U shape and has a soft iron pieces of a cylindrical form at its ends. The functions of the soft iron cylinders are:

1. To make the field to be uniform.
2. To reduce the reluctance of the air–gap between the poles.
3. To increase the magnetic flux.

Surrounding the core is a rectangular coil of many turns wound on a light aluminum frame. The functions of the aluminum frame are :

1. Provides a support for the coil.
2. Provides a damping work by eddy currents induced in it.

The instrument is equipped with two phosphor–bronze hair springs one above and the other below. These two springs are used to:

1. Provide the control of the coil movement.
2. Serve in leading the current in and out of the coil.
3. They are spiraled in opposite direction in order to neutralize the effect of temperature change.

The electric circuit of the PMMC coil instrument is shown in Figure 6.9.

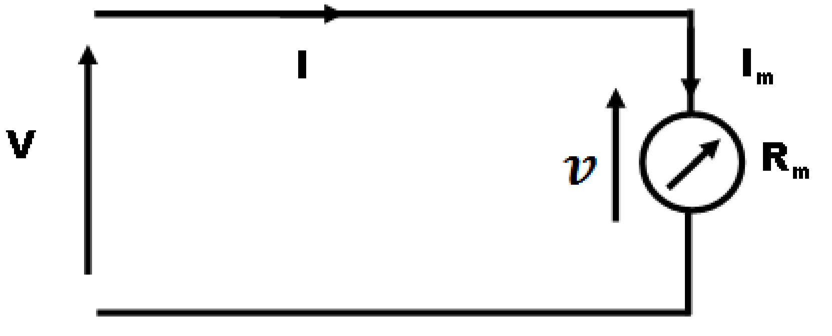


Figure 6.9 The electric circuit Of the PMMC instrument

6.6 Using the Instrument as an Ammeter

The permanent magnet moving-coil instrument described by the electric circuit shown in Figure 6.9 is designed for full-scale deflection current from 5 µA to 100 mA. Therefore, the range of this type of instruments can be extended by using a low shunt resistance as shown in Figure 6.10.

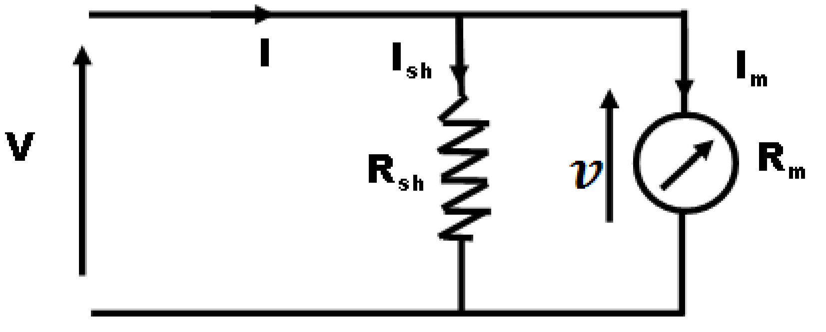


Figure 6.10 Using the PMMC instrument as an ammeter

Where,

R_m = the resistance of the moving coil.

I_m = the current passing through the coil to give full-sscale.

I = the extended range of the instrument.

R_{sh} = the shunt resistance used to extend the range.

As shown from Figure 6.10,

$$V = v$$

Or

$$I_{sh}R_{sh} = I_mR_m$$

But,

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

Therefore,

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

Or

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

From which, we can get the following equations:

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

And

$$I = I_m \left(\frac{R_{sh} + R_m}{R_{sh}}\right)$$

And

$$R_{sh} = R_m \left(\frac{I_m}{I - I_m}\right)$$

The ratio $\frac{I}{Im}$ is known as the current multiplying factor.

Shunts are used for the extension of range of ammeters should have the following properties:

1. The temperature coefficient of shunt should be low.
2. Resistance of shunt should not vary with time.
3. They should carry current without excessive temperature rise.
4. They should have thermal electromotive force with copper.

To measure the current passing through a circuit, the ammeter is connected as shown in Figure 6.11.

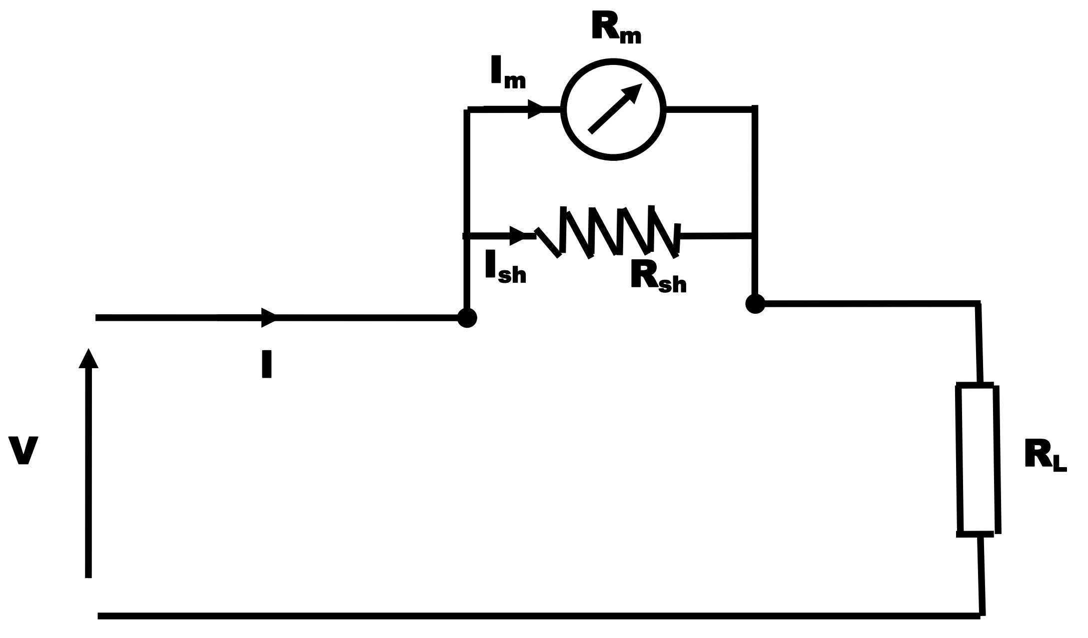


Figure 6.11 The method of connecting the ammeter in the circuit

6.7 Multi- Ranges Ammeters

DC ammeter can be used to measure a particular range of direct currents. 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 with the moving-coil.

In this section, two methods of extension the range of ammeters are presented:

1. Using a multi-position make–before-break switch

The current range of DC ammeter may be further extended by a number of shunts selected by a range switch. Figure 6.12 illustrates the multi-range ammeter. The circuit has three shunts R_{sh1}, R_{sh2} and R_{sh3} which can be placed in parallel with the moving-coil to give four different current range. The range can be selected by a switch S, which is a multi-position make–before-break type switch, so that the moving-coil will not be damaged or unprotected as the range is changed.

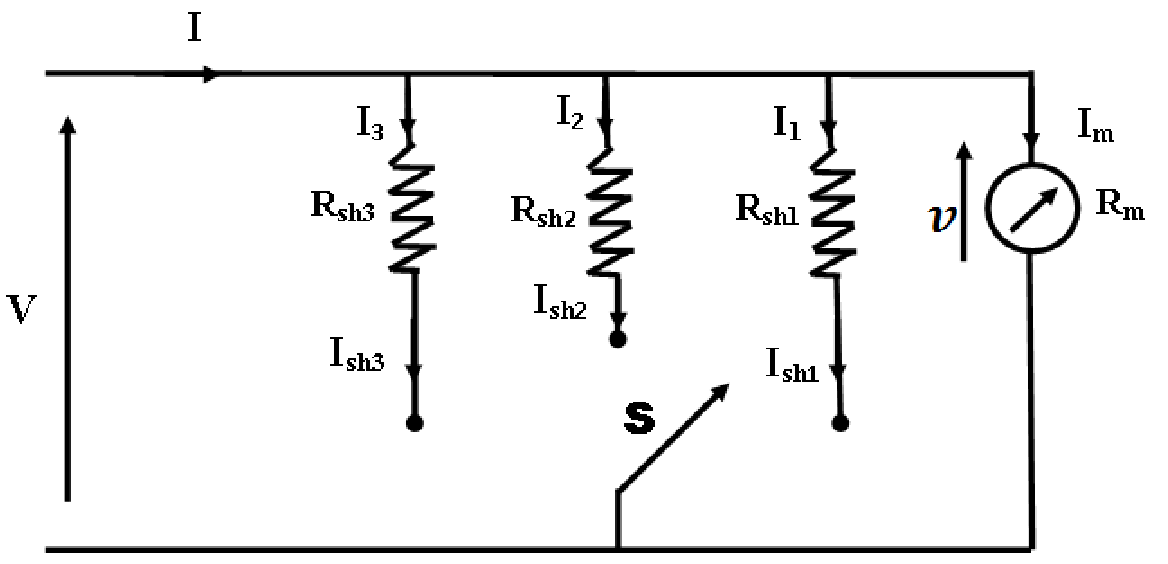


Figure 6.12 The connection of a multi-range ammeter

The three shunting resistances can be calculated as follows:

$$R_{sh1} = R_m \frac{I_m}{I_1 - I_m}$$

$$R_{sh2} = R_m \frac{I_m}{I_2 - I_m}$$

and

$$R_{sh3} = R_m \frac{I_m}{I_3 - I_m}$$

2. Using Ayrton Shunt

Ayrton shunt is also known as universal shunt. The advantage of the Ayrton shunt is that it eliminates the possibility of the meter being in the circuit without a shunt, but this advantage will be against increasing the resistance of the moving coil and the cost of the instrument. The construction of the Ayrton shunt is shown in Figure 6.13.

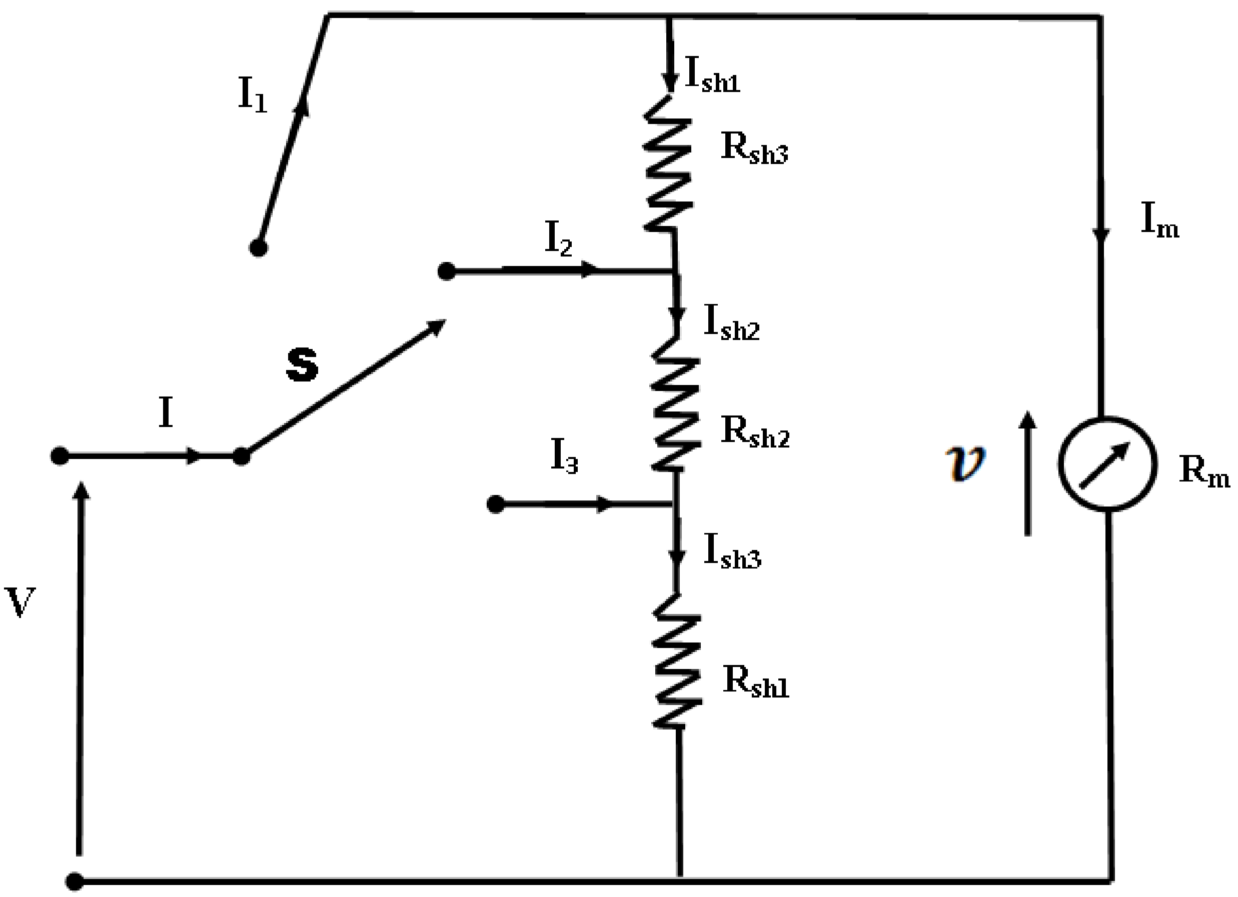


Figure 6.13 The construction of Ayrton shunt

According to the number of shunt resistances (ranges) a simultaneous equations can be used to determine the values of shunt resistances as illustrated below:

- On the range of I_1 :

$$R_{sh1} + R_{sh2} + R_{sh3} = R_m \frac{I_m}{I_1 - I_m}$$

- On the range of I_2 :

$$R_{sh1} + R_{sh2} = (R_{sh3} + R_m)\frac{I_m}{I_2 - I_m}$$

- On the range of I_3 :

$$R_{sh1} = (R_{sh2} + R_{sh3} + R_m)\frac{I_m}{I_3 - I_m}$$

By solving the above simultaneous equations the values of shunt resistances can be determined.

6.8 Using the instrument as a voltmeter

When the permanent magnet type moving–coil instrument is used as a voltmeter, its range can be extended by using a high resistance in series with the moving-coil, as shown in Figure 6.14.

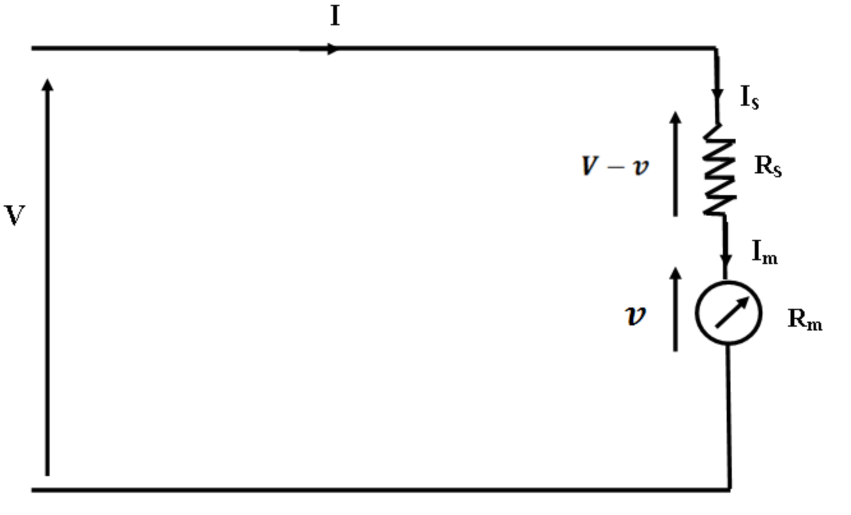


Figure 6.14 The PMMC instrument when used as a Voltmeter

As shown from Figure 6.14,

$$I_m = I_S$$

or

$$\frac{v}{R_m} = \frac{V - v}{R_S}$$

Or

$$v\, R_S = R_m(V - v)$$

Or

$$(R_m + R_S)\, v = R_m V$$

From which, we can get the following equations:

$$\frac{V}{v} = \frac{R_m + R_s}{R_m}$$

And

$$V = v \left(\frac{R_m + R_s}{R_m}\right)$$

And

$$R_s = R_m \frac{V - v}{v}$$

Where,

$\frac{V}{v}$ = is the voltage multiplying factor.

R_S = the series resistance used to extend the range of the voltmeter.

From the last equation, we can conclude that greater the value of R_S greater the range of the voltmeter. The simplest way of increasing the series resistance of the voltmeter is either by increasing the number of turns of the coil or by constructing the same number of coil turns with a higher resistance material. Either of these solutions decrease the current in the coil, and giving less deflecting torque and thus decreasing the measurement sensitivity of the instrument. This problem can be overcome by changing the spring constant of instrument, but this however, reduces the ruggedness of the instrument and also demands better pivot design to reduce the friction.

When the voltmeter is used to measure a voltage across a load or circuit, it is connected as shown in Figure 6.15.

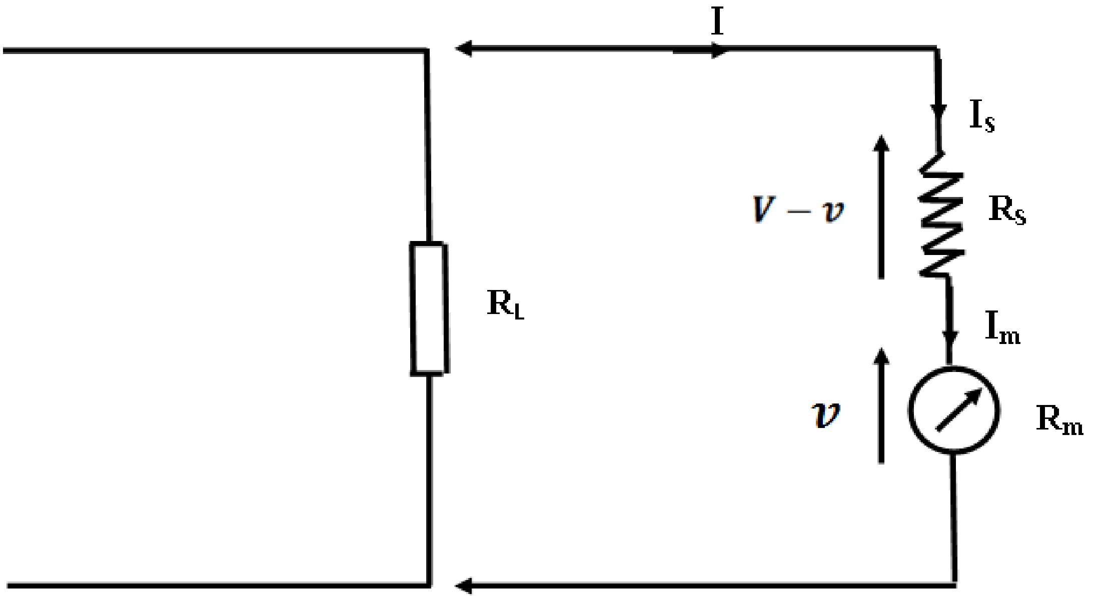


Figure 6.15 The method of connecting the voltmeter in the circuit

6.9 Multi- Ranges Voltmeters

1. Using individual multiplier with a selector range switch

The addition of a number of multipliers (series resistors) , together with a selector range switch, provides the instrument with a number of voltage ranges. Figure 6.16 shows a multi-range voltmeter using three individual multipliers R_{s1}, R_{s2} and R_{s3} for the voltage ranges V_1, V_2 and V_3 respectively.

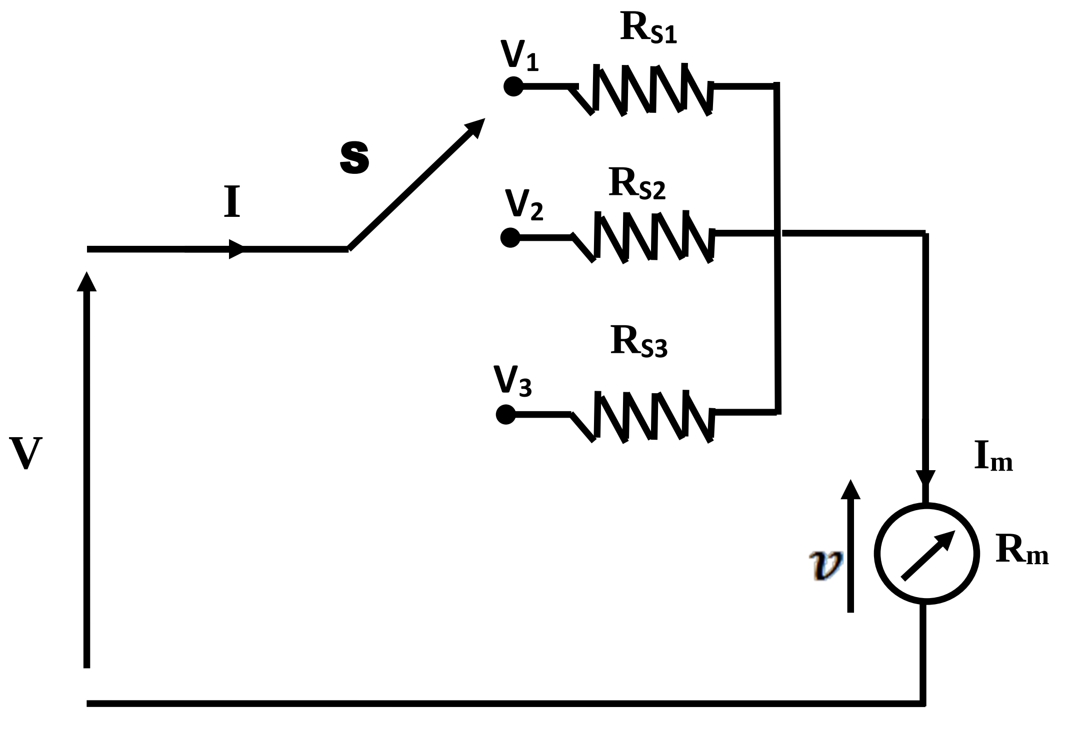


Figure 6.16 Multi-range voltmeter with individual resistances and a selector range switch

The series resistance corresponding to the selecting range can be found as follows:

- on the range of V_1:

$$R_{s1} = R_m \frac{V_1 - v}{v}$$

- on the range of V_2:

$$R_{s2} = R_m \frac{V_2 - \nu}{\nu}$$

- on the range of V_3:

$$R_{s3} = R_m \frac{V_3 - \nu}{\nu}$$

2. When all the multiplier in series with the moving-coil

Another method can be used to extend the range of the voltmeter. In this method the multipliers are connected all in series with the moving coil. The desired range can be selected by using a range switch as shown in Figure 6.17.

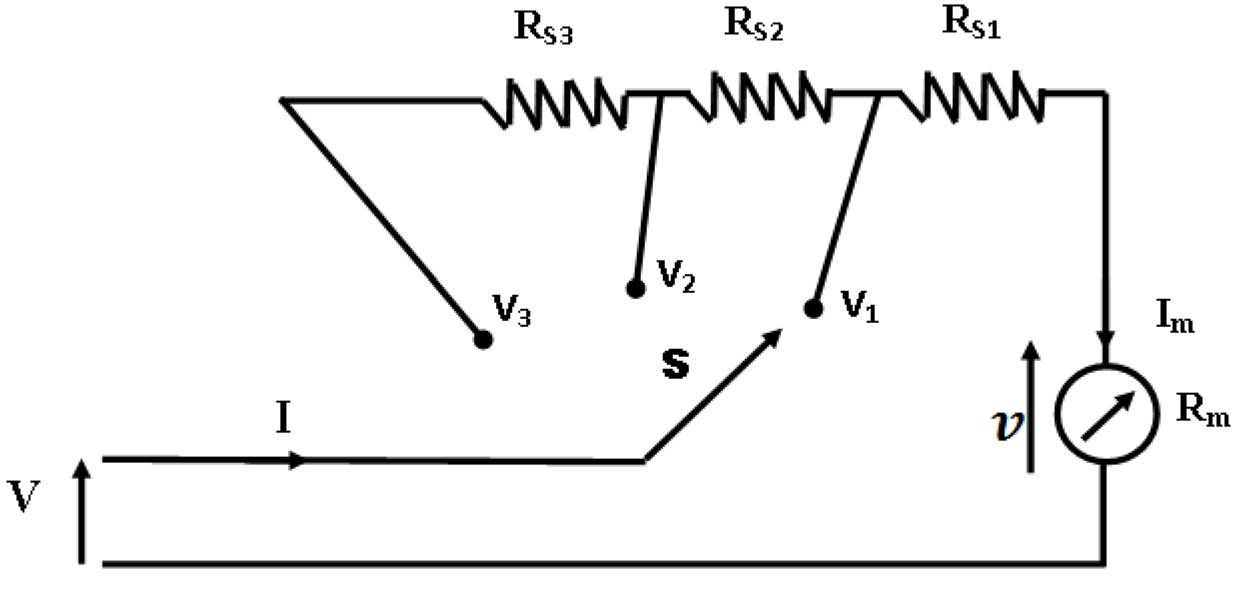


Figure 6.17 Multi-range voltmeter with all multipliers are connected in series with the moving coil

The series resistances (multipliers) can be determined as follows:

- on the range of V_1:

$$R_{s1} = R_m \frac{V_1 - v}{v}$$

- on the range of V_2 the resistance R_{s2} can be determined as follows:

$$R_{s1} + R_{s2} = R_m \frac{V_2 - v}{v}$$

From which we can get:

$$R_{s2} = R_m \frac{V_2 - v}{v} - R_{s1}$$

- on the range of V_3 the resistance R_{s3} can be determined as follows:

$$R_{s1} + R_{s2} + R_{s3} = R_m \frac{V_3 - v}{v}$$

From which we can get:

$$R_{s3} = R_m \frac{V_3 - v}{v} - R_{s1} - R_{s2}$$

Examples – L6

Ex6.1 List the types of DC galvanometers.

Sol. The main types of galvanometers are
1. Moving-coil galvanometers.
2. Moving-magnet galvanometers.
3. Ballistic galvanometers.

Ex6.2 List the types of ammeters and voltmeters

Sol.
1. Moving-coil instruments.
   a. Permanent magnet moving-coil instruments.
   b. Dynamometer moving-coil instruments.
2. Moving-iron instruments.
   a. Attraction type moving-iron instruments.
   b. Repulsion type moving-iron instruments.
3. Thermal instruments.
4. Electrostatic instruments.
5. Rectifier instruments.
6. Digital instruments

Ex6.3 List the types of torques that affect the moving system of the indicating measuring instruments.

Sol. The moving system of the indicating instruments is subjected to three torques:
1. Deflecting torque.
2. Controlling torque.
   a. Spring control.
   b. Gravity control.
3. Damping torque.
   a. Air friction damping.
   b. Fluid friction damping.
   c. Eddy currents damping.

Ex6.4 A permanent-magnet moving-coil instrument has a moving coil of 4 cm height, 8 cm width, 3000 turns and internal resistance of 100 Ω. The magnetic flux density is 0.25 Wb/m^2.

(1) Calculate the deflecting torque required to give a full-scale deflection current of 100 mA.
(2) Design the instrument with the following ranges:
(i) An ammeter with current range of 5 A.
(ii) A voltmeter with voltage range of 250 V .
(3) Plot the electric circuit diagram of the designed instrument.

Sol. **(1)**

T_d = NBA I

Or

T_d = (3000) × (0.25) × (0.04) ×(0.08) × (0.1)
= 0.24 N.m

(2)
(i) Ammeter with current of range 5 A.

To increase the ammeter range to 5 A, a resistance must be connected in shunt with the moving coil. This resistance is given as:

$$R_{sh} = R_m \frac{I_m}{I - I_m}$$

Or

$$R_{sh} = 100 \frac{0.1}{5 - 0.1}$$

Or

$$R_{sh} = 2 \ \Omega$$

(ii) Voltmeter with voltage of range 250 V.

To increase the voltmeter range to 250 V, a resistance must be connected in series with the moving coil. This resistance is given as:

$$R_s = R_m \frac{V - v}{v}$$

Where,

$$v = I_m R_m$$

Thus,

$$v = 0.1 \times 100 = 10\,V$$

Therefore,

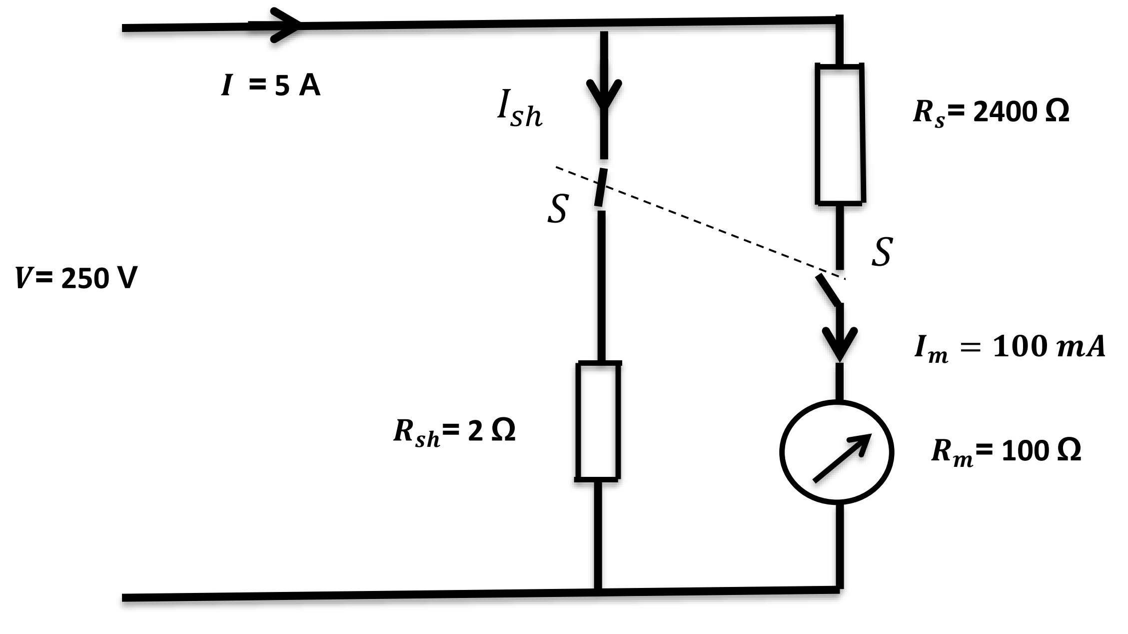
$$R_s = 100\ \frac{250 - 10}{10}$$

Or

$$R_s = 2400\,\Omega$$

(3)

The circuit diagram of the designed instrument is given below:



Ex6.5 By using a D'Arsonval movement with 200 Ω internal resistance and 100 mA FSD current, design an ammeter with a current ranges of 0.5 A, 3 A, and 5 A by using a make-before-switch. Plot the electric circuit diagram of the designed instrument.

Sol.

$$R_{sh1} = R_m \frac{I_m}{I_1 - I_m}$$

Or

$$R_{sh1} = 200 \frac{0.1}{0.5 - 0.1}$$

Therefore,

$$R_{sh1} = 50\ \Omega$$

also

$$R_{sh2} = R_m \frac{I_m}{I_2 - I_m}$$

or

$$R_{sh2} = 200 \frac{0.1}{3 - 0.1}$$

Therefore,

$$R_{sh2} = 6.89\ \Omega$$

and

$$R_{sh3} = R_m \frac{I_m}{I_3 - I_m}$$

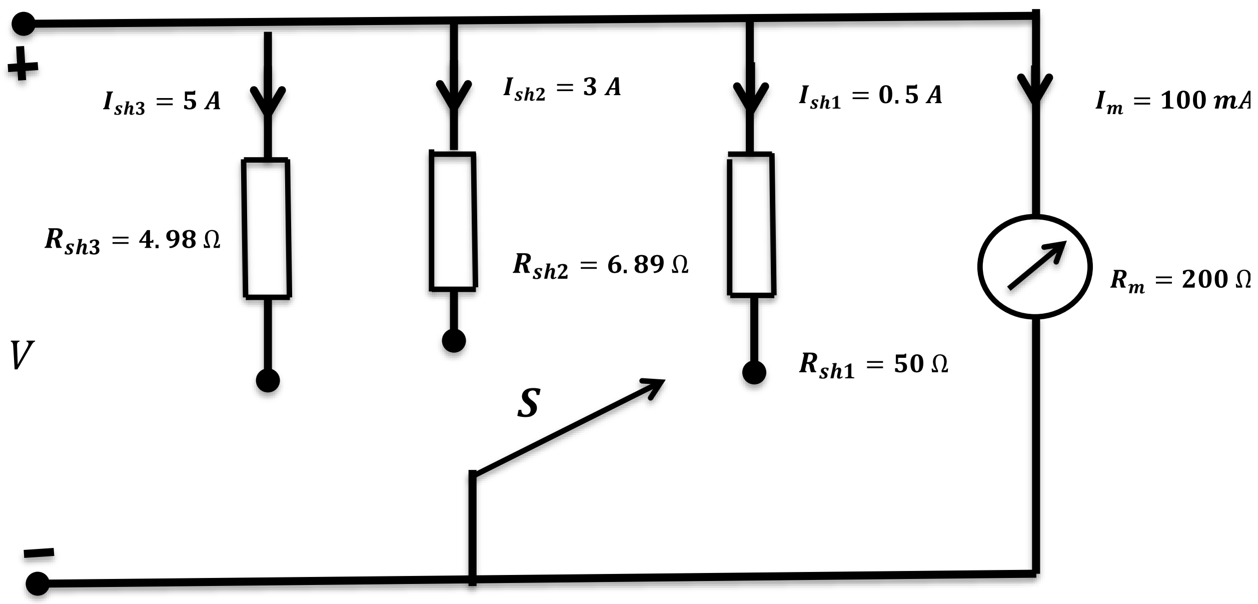
or

$$R_{sh3} = 200 \frac{0.1}{5 - 0.1}$$

Therefore,

$$R_{sh3} = 4.98\ \Omega$$

The circuit diagram of the designed instrument is shown below:



Ex6.6 By using a D'Arsonval movement with 200 Ω internal resistance and 100 mA FSD current, design an ammeter with a current ranges of 0.5 A, 3 A, and 5 A by using an Ayrton shunt. Plot the electric circuit diagram of the designed instrument.

Sol.

- On the range of 0.5 A :

$$R_{sh1} + R_{sh2} + R_{sh3} = R_m \frac{I_m}{I_1 - I_m}$$

Or

$$R_{sh1} + R_{sh2} + R_{sh3} = 200 \frac{0.1}{0.5 - 0.1}$$

Or

$$R_{sh1} + R_{sh2} + R_{sh3} = 50 \ldots\ldots\ldots\ldots\ldots(1)$$

- On the range of 3 A :

$$R_{sh1} + R_{sh2} = (R_{sh3} + R_m)\frac{I_m}{I_2 - I_m}$$

Or

$$R_{sh1} + R_{sh2} = (R_{sh3} + 200)\frac{0.1}{3 - 0.1}$$

Or

$$R_{sh1} + R_{sh2} = (0.0344827\, R_{sh3} + 6.896551)$$

Or

$$R_{sh1} + R_{sh2} - 0.0344827\, R_{sh3} = 6.896551 \ldots\ldots\ldots\ldots(2)$$

- On the range of 5 A :

$$R_{sh1} = (R_{sh2} + R_{sh3} + R_m)\frac{I_m}{I_3 - I_m}$$

Or

$$R_{sh1} = (R_{sh2} + R_{sh3} + 200)\frac{0.1}{5 - 0.1}$$

Or

$$R_{sh1} = (0.0204081\, R_{sh2} + 0.0204081\, R_{sh3} + 4.081632)$$

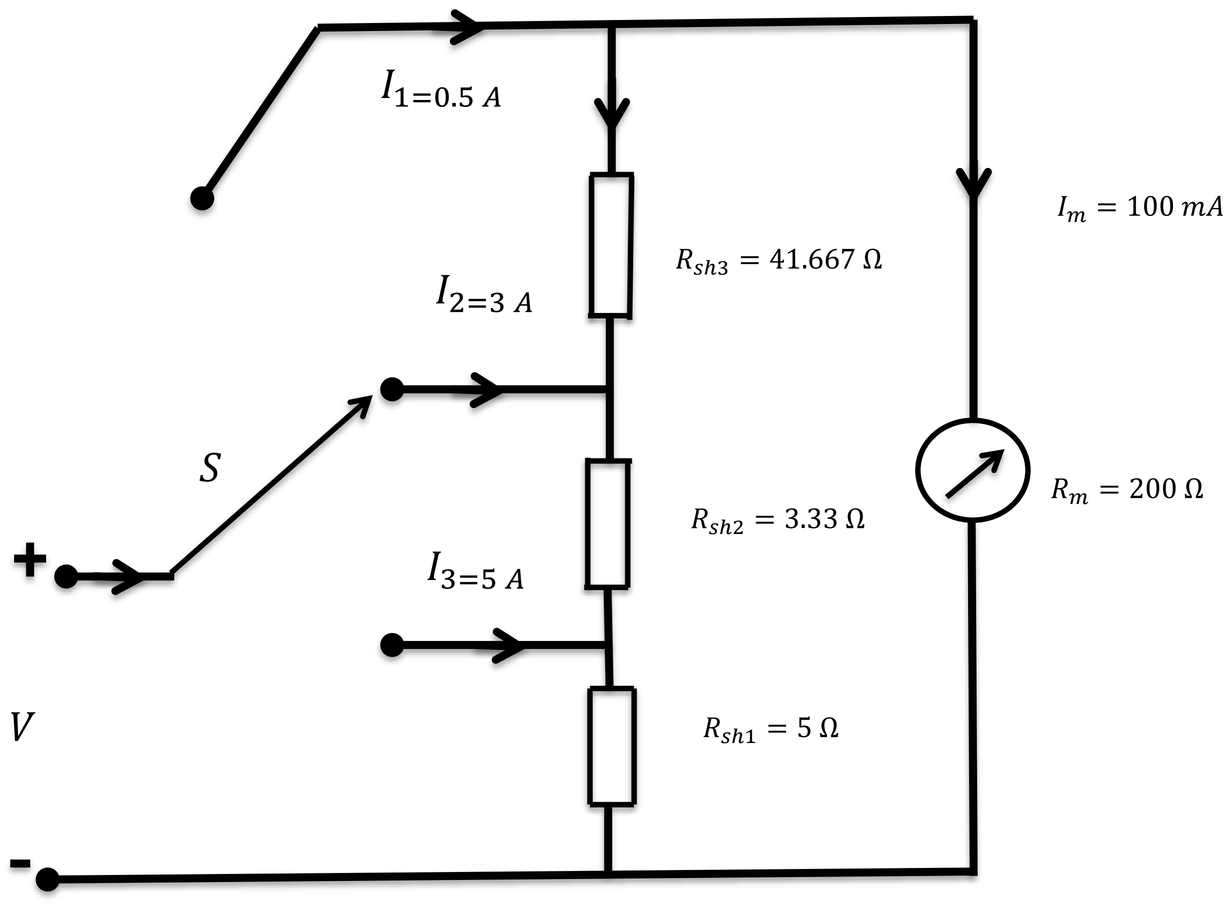
Or

$$R_{sh1} - 0.0204081\, R_{sh2} - 0.0204081\, R_{sh3} = 4.081632 \ldots\ldots\ldots(3)$$

By solving the above three simultaneous equations we can obtain:

$$R_{sh1} = 5\ \Omega$$
$$R_{sh2} = 3.333\ \Omega$$
$$R_{sh3} = 41.667\ \Omega$$

The circuit diagram of the designed instrument is shown below:



Ex6.7 By using a D'Arsonval movement with 100 Ω internal resistance and 1 mA FSD current, design a multi-range voltmeter with a voltage ranges of 10 V, 50 V and 250 V by using individual multipliers with a selector range switch. Plot the electric circuit diagram of the designed instrument.

Sol. - on the range of 10 V:

$$R_{s1} = Rm\frac{V1 - v}{v}$$

where,

$$v = Im \times R_m$$

or,

$$v = 0.001 \times 100$$
$$v = 0.1\ V$$

Therefore,

$$R_{s1} = 100\frac{10 - 0.1}{0.1}$$

or

$$R_{s1} = 9.9\ K\Omega$$

- on the range of 50 V:

$$R_{s2} = Rm\frac{V2 - v}{v}$$

or

$$R_{s2} = 100\frac{50 - 0.1}{0.1}$$

Therefore,

$$R_{s2} = 49.9\ K\Omega$$

- on the range of 250 V:

$$R_{s3} = Rm\frac{V3 - v}{v}$$

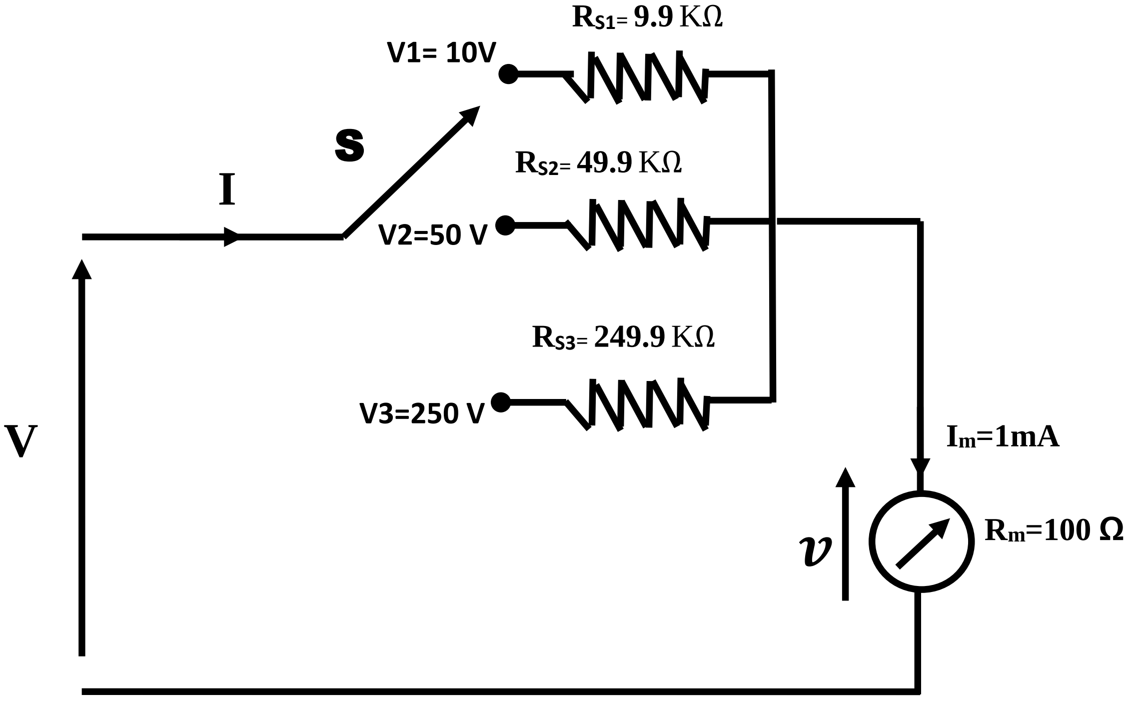
or

$$R_{s3} = 100\frac{250 - 0.1}{0.1}$$

Therefore,

$$R_{s3} = 249.9\ K\Omega$$

The circuit diagram of the designed instrument is shown below:



Ex6.8 By using a D'Arsonval movement with 100 Ω internal resistance and 1 mA FSD current, design a multi-range voltmeter with a voltage ranges of 10 V, 50 V and 250 V by using all the multipliers connected in series with the moving coil. Plot the electric circuit diagram of the designed instrument.

Sol.

- on the range of 10 V:

$$R_{s1} = Rm\frac{V1-\nu}{\nu}$$

Or

$$R_{s1} = 100\frac{10-0.1}{0.1}$$

Therefore,

$$R_{s1} = 9.9\ K\Omega$$

- on the range of 50 V:

$$R_{s1} + R_{s2} = Rm\frac{V2-\nu}{\nu}$$

from which we can get:

$$R_{s2} = Rm\frac{V2-\nu}{\nu} - R_{s1}$$

or,

$$R_{s2} = 100\frac{50-0.1}{0.1} - 9900$$

or,

$$R_{s2} = 40\ K\Omega$$

- on the range of 250 V:

$$R_{s1} + R_{s2} + R_{s3} = Rm\frac{V3-\nu}{\nu}$$

from which we can get:

$$R_{s3} = Rm\frac{V3-\nu}{\nu} - R_{s1} - R_{s2}$$

or,

$$R_{s3} = 100\frac{250 - 0.1}{0.1} - 9900 - 40000$$

or,

$$R_{s3} = 200\ K\Omega$$

The circuit diagram of the designed instrument is shown below: