Chapter 2: Direct Current Meters

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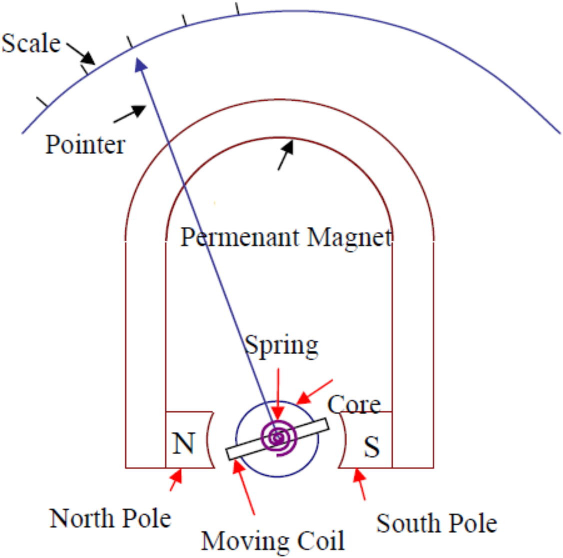
Contents

1. D'Arsonval Meter Movement

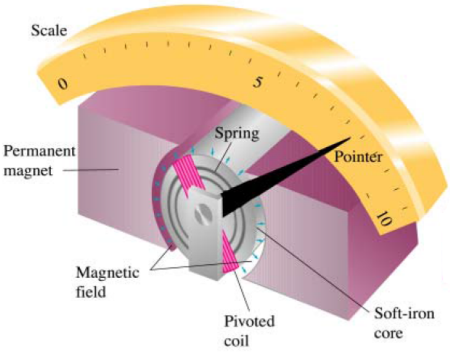
- Also called Permanent-Magnet Moving Coil (PMMC).
- Based on the moving-coil galvanometer constructed by d'Arsonval in 1881.
- Can be used to indicate the value of DC and AC quantity.
- Basic construction of modern PMMC can be seen in the Figure (see next slide).

D'Arsonval Meter Movement

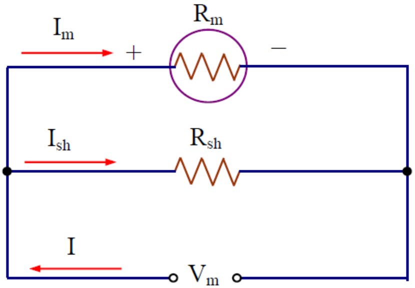


Operation D'Arsonval Meter

- When current flows through the coil, the core will rotate.
- Amount of rotation is proportional to the amount of current flows through the coil.
- The meter requires low current (50μA) for a full scale deflection.
- Its accuracy is about 2% - 5% of full scale deflection.

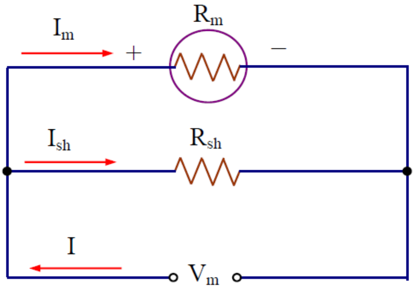


- The PMMC galvanometer constitutes the basic movement of a DC ammeter.
- The coil winding of a basic movement is small and light, so it can carry only very small currents.
- A low value resistor (shunt resistor) is used in DC ammeter to measure large current.
- Basic DC ammeter:



D'Arsonval as DC Ammeter

- R_{sh}: resistance of the shunt.
- R_m: internal resistance of the meter movement (resistance of the moving coil).
- I_{sh}: current through the shunt.
- I_m: full scale deflection current of the meter movement.
- I: full scale current of the ammeter + shunt (i.e. total current).



Example 1

Calculate the value of the shunt resistance required to convert a 1 mA meter movement, with a 100 Ω internal resistance, into 0 to 10 mA ammeter.

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Example 2

A 100 μA meter movement with an internal resistance of 800 Ω is used in a 0 to 100 mA ammeter. Find the value of the required shunt resistance?

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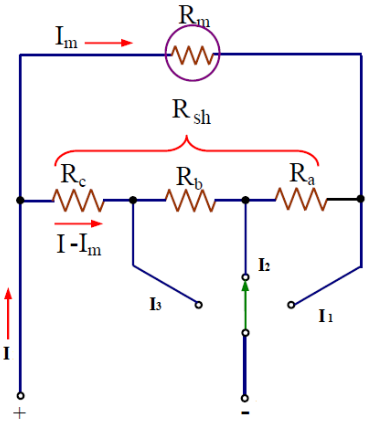
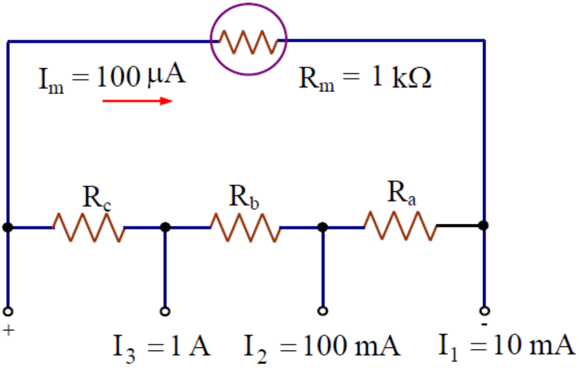
3. Multi-range Ammeter (The Ayrton Shunt)

- The shunt resistance works well enough on a single-range ammeter.
- On a multiple-range ammeter, the **Ayrton shunt** is frequently a more suitable design.
- The **Ayrton shunt** circuit is shown in the figure



Example 3

Compute the value of the shunt resistors for the circuit shown in the Figure.



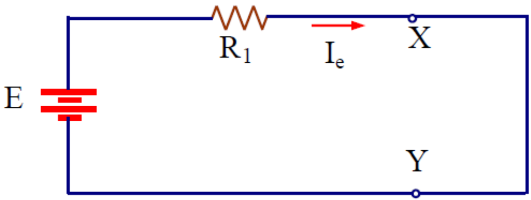
4. Ammeter Insertion Effect

- Inserting Ammeter in a circuit always increases the resistance of the circuit and, thus always reduces the current in the circuit. The expected current:

$$I_e = \frac{E}{R_1} \tag{1}$$

where;

I_e: the expected current, is the current **without** the ammeter in the circuit.



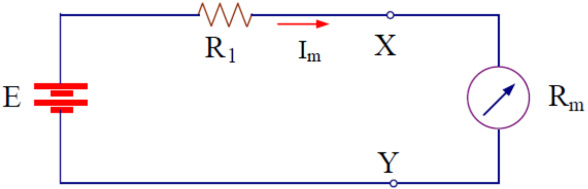
Ammeter Insertion Effect

- Placing the meter in series with R_1 causes the current to reduce to a value equal to:

$$I_m = \frac{E}{R_1 + R_m} \tag{2}$$

- Dividing equation (2) by (1) yields:

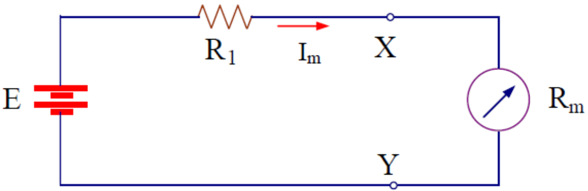
$$\frac{I_m}{I_e} = \frac{R_1}{R_1 + R_m} \tag{3}$$



Ammeter Insertion Effect

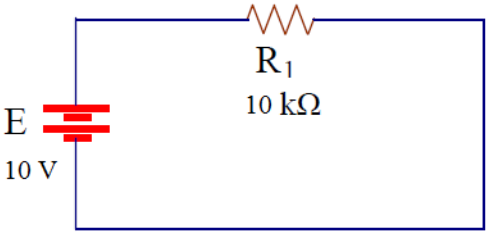
- The Ammeter insertion error is given by:

$$\text{Insertion Error} = \left(1 - \frac{I_m}{I_e}\right) \times 100\% \qquad (4)$$



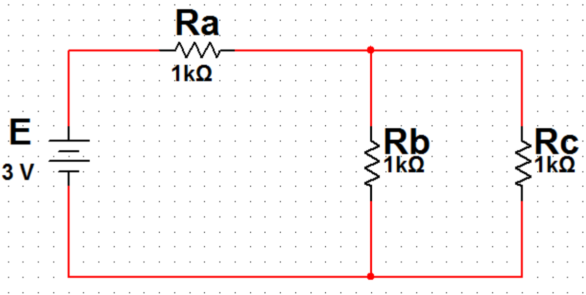
Example 4

A current meter that has an internal resistance of 2 kΩ is used to measure the current through R_1 in the following Figure. Determine the percentage of error of the reading due to ammeter insertion.



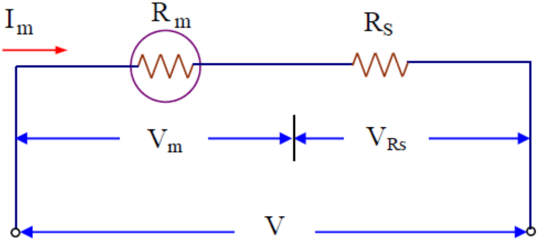
Example 5

A current meter that has an internal resistance of 78 Ω is used to measure the current through R_c in the following Figure. Determine the percentage of error of the reading due to ammeter insertion.



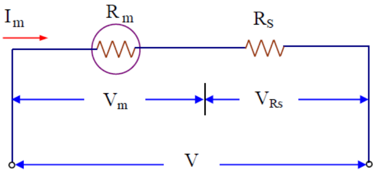
5. D'Arsonval Meter as DC Voltmeter

- The basic D'Arsonval meter movement can be converted to a **DC Voltmeter** by connecting a multiplier R_s is series with the meter movement as shown in Figure.
- The purpose of the multiplier:
  1. is to extend the voltage range of the meter.
  2. to limit current through the d'Arsonval meter movement to a maximum full-scale deflection current.



- To find the value of the multiplier resistor, first determine the **sensitivity, S**, of the meter movement.

$$S = \frac{1}{I_{fs}}(\Omega/V) \tag{5}$$



- where;
  I_m: full scale deflection current of the movement (I_{fs}).
  R_m: internal resistance of the movement.
  R_s: multiplier resistance.
  V: full range voltage of the instrument.

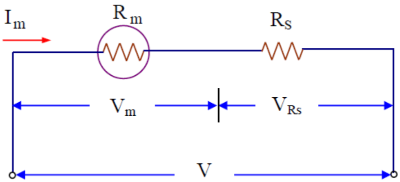
- From the circuit of Figure below

$$V = I_m(R_s + R_m) \tag{6}$$

$$R_s = \frac{V - I_m R_m}{I_m} = \frac{V}{I_m} - R_m \tag{7}$$

$$R_s = S.V - R_m \tag{8}$$

$$R_s = \text{Sensitivity . Range - Internal Resistance} \tag{9}$$



Example 6

Calculate the value of the multiplier resistance on the 50 V range of a DC voltmeter that used a 500 μA meter movement with an internal resistance of 1kΩ.

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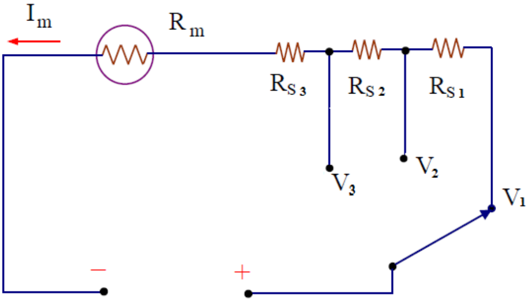
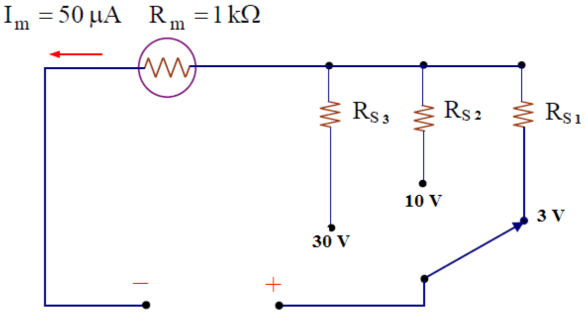
6. Multi-Range DC Voltmeter

- A DC voltmeter can be converted into a multi-range DC voltmeter by connecting a number of resistors (multipliers) in series with the meter movement.
- A practical multi-range DC voltmeter is shown in Figure.



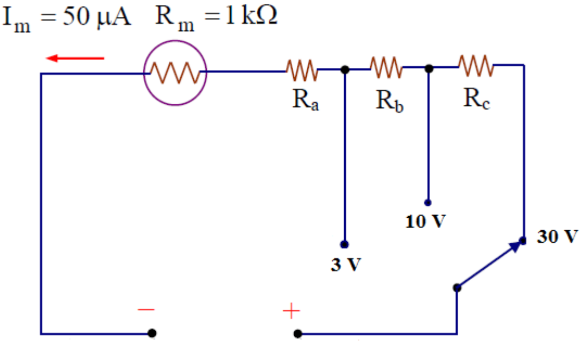
Example 7

Calculate the value of the multiplier resistance for the multiple-range DC voltmeter circuit shown in the Figure.



Example 8

Calculate the value of the multiplier resistance for the multiple-range DC voltmeter circuit shown in the Figure.



7. Voltmeter Loading Effects

- When a voltmeter is used to measure the voltage across a circuit component, the voltmeter circuit itself is in parallel with the circuit component.
- Total resistance will decrease, so the voltage across component will also decrease. This is called voltmeter loading.
- The resulting error is called a **loading error.**
- The voltmeter loading can be reduced by using a high sensitivity voltmeter.

$$\text{Voltmeter Error} = \frac{\text{Expected value - Measured value}}{\text{Expected value}} \times 100\% \tag{10}$$

Example 9

Two different voltmeters are used to measure the voltage across resistor R_B in the circuit of the Figure. The meters are as follows.
Meter A: S = 1kΩ/V, R_m = 0.2kΩ, range = 10V
Meter B: S = 20kΩ/V, R_m = 1.5kΩ, range = 10V
Calculate:

1. Voltage across R_B without any meter connected across it.
2. Voltage across R_B when meter A is used.
3. Voltage across R_B when meter B is used.
4. Error in voltmeter readings.

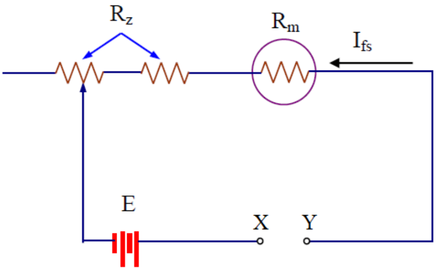
8. The Ohmmeter

- The ohmmeter consists of battery, resistor and meter movement.
- The full-scale deflection current is,

$$I_{fs} = \frac{E}{R_z + R_m} \tag{11}$$

where, R_z: variable resistor

- To determine the value of unknown resistor, R_x. The R_x is connected to terminal X and Y.



The Ohmmeter

- The circuit current is now expressed,

$$I = \frac{E}{R_z + R_m + R_x} \tag{12}$$

- The current I is less than the full-scale current I_{fs}, because of the addition resistance R_x
- If $R_x = R_z + R_m$

$$I = \frac{E}{2(R_z + R_m)} = \frac{1}{2} I_{fs} \tag{13}$$

- If $R_x = 2(R_z + R_m)$

$$I = \frac{E}{3(R_z + R_m)} = \frac{1}{3} I_{fs} \tag{14}$$

The Ohmmeter

- If $R_x = 3(R_z + R_m)$

$$I = \frac{E}{4(R_z + R_m)} = \frac{1}{4} I_{fs} \tag{15}$$

- The ratio of the current, I to the full-scale deflection current, I_{fs} is

$$\frac{I}{I_{fs}} = \frac{R_z + R_m}{R_z + R_m + R_x} \tag{16}$$

- If we let P represent the ratio of the current I to the full-scale deflection current, I_{fs}. We can say that

$$P = \frac{I}{I_{fs}} = \frac{R_z + R_m}{R_z + R_m + R_x} \tag{17}$$

Example 10

An ohmmeter uses a 1.5 V battery and a basic 50 μA movement and R_m of 100 Ω. Calculate

1. the value of R_z required
2. the value of R_x that would cause half-scale deflection in the circuit.

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Example 11

A 1 mA full-scale deflection current meter movement is to be used in an ohmmeter circuit. The meter movement has an internal resistance, R_m of 100 Ω and a 3 V battery will be used in the circuit. Mark off the meter face for reading resistance.

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