D'ARSONVAL METER MOVEMENT

Also called Permanent-Magnet Moving Coil (PMMC).

Based on the moving-coil galvanometer constructed by Jacques 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 Figure 1.0.

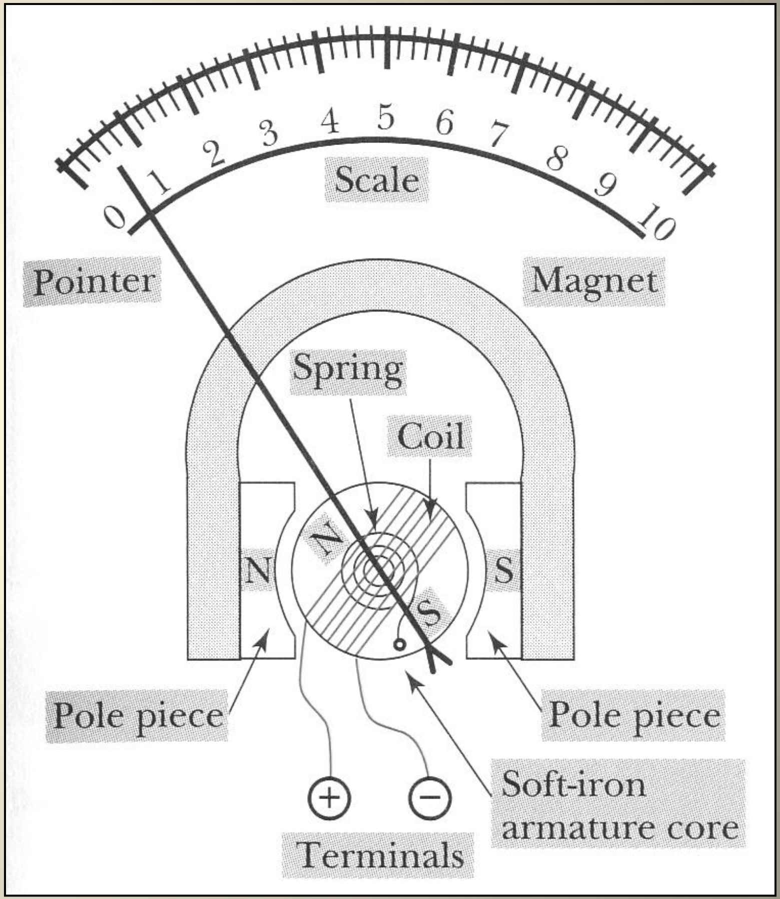
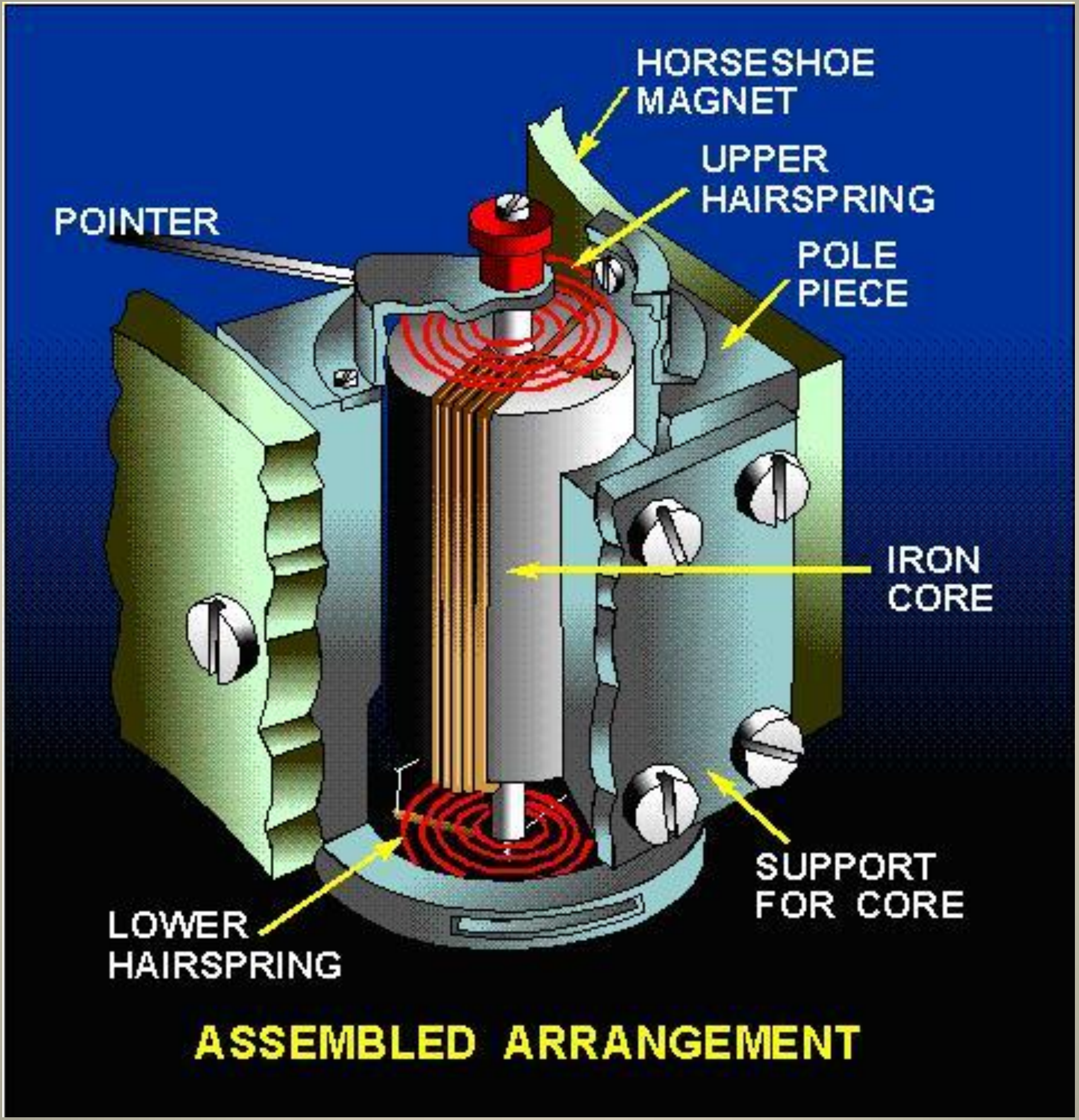


Figure 1.0.


HORSESHOE MAGNET
UPPER HAIRSPRING
POINTER
POLE PIECE
IRON CORE
SUPPORT FOR CORE
LOWER HAIRSPRING
ASSEMBLED ARRANGEMENT

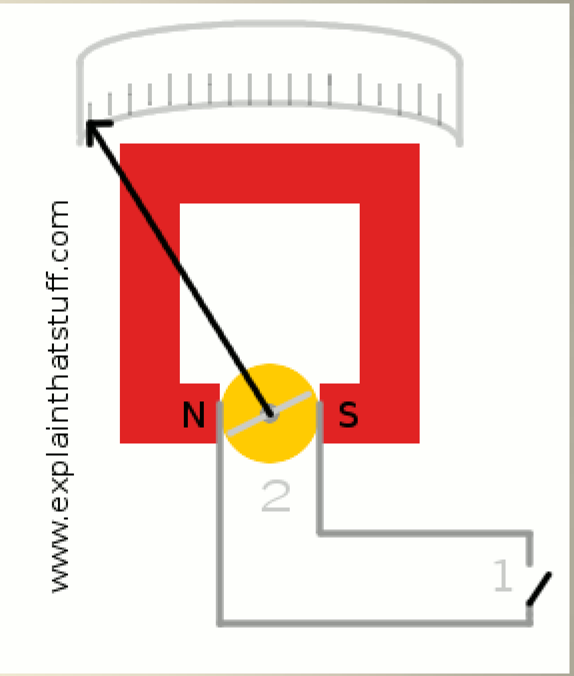
1 When current flows through the coil, the core will rotate.

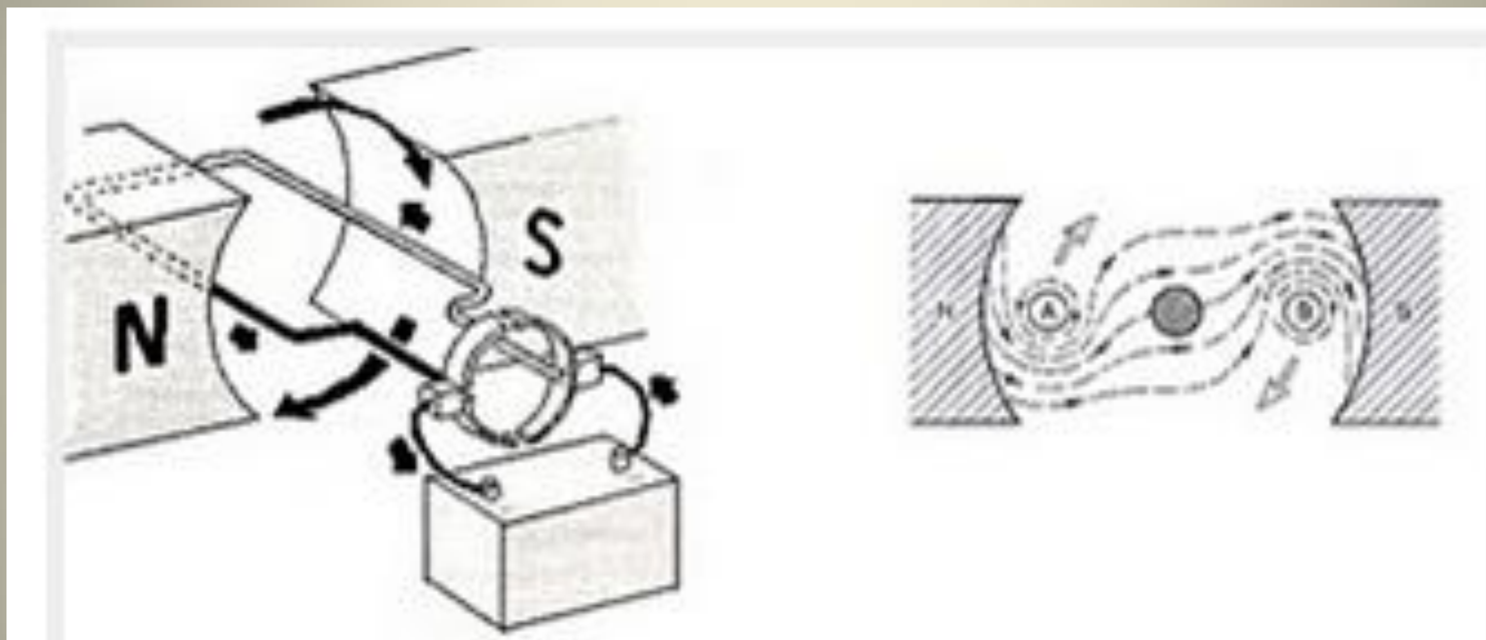
2 The poles of EMT interact with the poles of PM, causing the coils to rotate.

3 Amount of rotation is proportional to the amount of current flows through the coil.

4 The meter requires low current (~50uA) for a full scale deflection, thus consumes very low power (25-200 Uw).

5 Its accuracy is about 2% -5% of full scale deflection.

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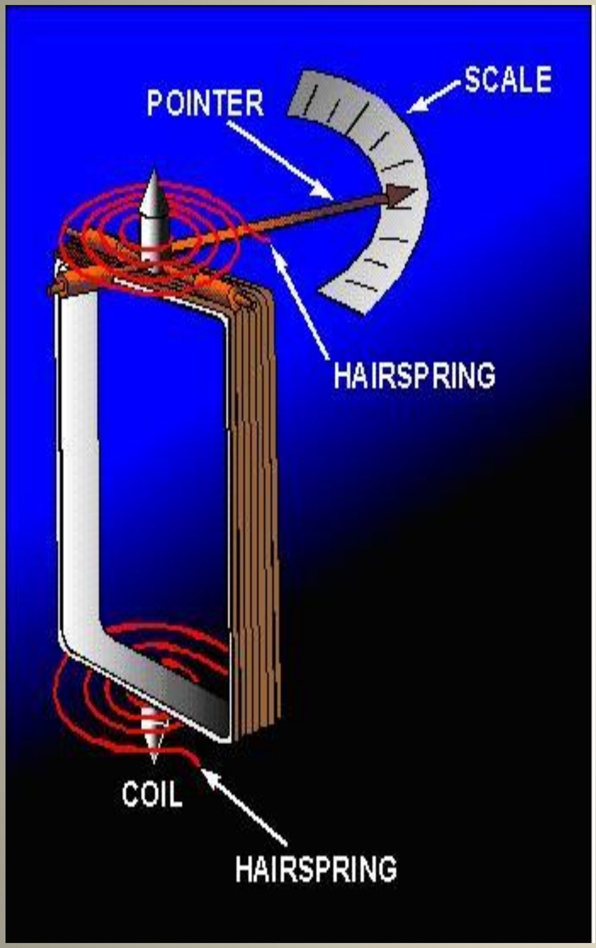


How to return the coil to its original position when there is no current through the coil?

- Use of hairsprings attached to each end of the coil.
- With the hairsprings, the coil will return to its initial position when there is no current.

The springs will also tend to resist the movement of the coil when there is current through the coil.

- An indicating instrument is generally subjected to THREE Types of TORQUEs

1. Deflecting Torque

2. Controlling Torque

3. Damping Torque

DEFLECTION TORQUE

The deflection torque causes the moving system to move from zero position when the instrument is connected to the circuit to measure the given electrical quantity.

Torque , T = BINA

T = Torque in unit Newton meter(Nm)

B = Flux density in unit Tesla(T) or wb/m^2

I = Current through coil in unit Ampere (A)

N = Numbers of coil

A = Area (length x wide), m^2

Eg:

Given frame of permanent moving coil is $6m^2$.
The number of winding around coil is 50 and flux $0.12wb/m^2$. If 1mA current through the coil, calculate the deflection torque.

A meter PMMC with dimension 4cmx2cm has 60 turns and its flux density is 0.3T. The resistance of the meter is 20kΩ. Calculate the Deflection Torque, Td produced by the meter when the voltage is 315V.

A meter PMMC with dimension 3cmx2cm has 40 turns and its flux density is 0.2T. The resistance of the meter is 15kΩ. Calculate the Deflection Torque, Td produced by the meter when the voltage is 215V.

The d'Arsonval meter movement is very widely used.

Regardless of the units (volt, ohm,, etc) for which the scale is calibrated, the moving coil responds to the amount of current thru its winding.

Figure 1: A typical 0 to 1mA ammeter.

DC VOLTMETER (single range)

A basic D'Arsonval movement can be converted into a DC voltmeter by adding a series resistor (multiplier).

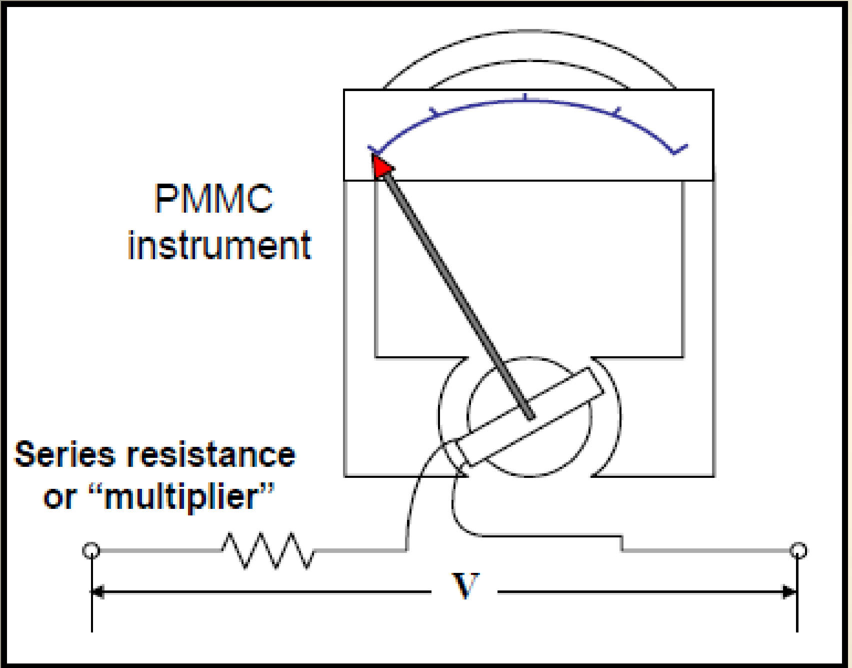


Figure 1

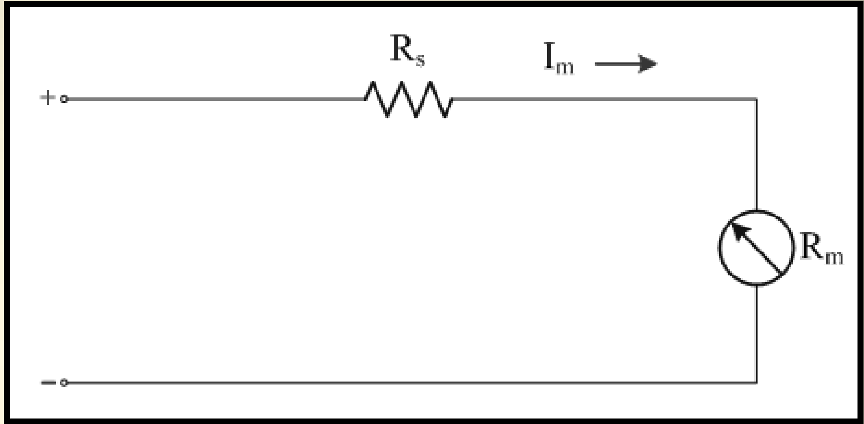


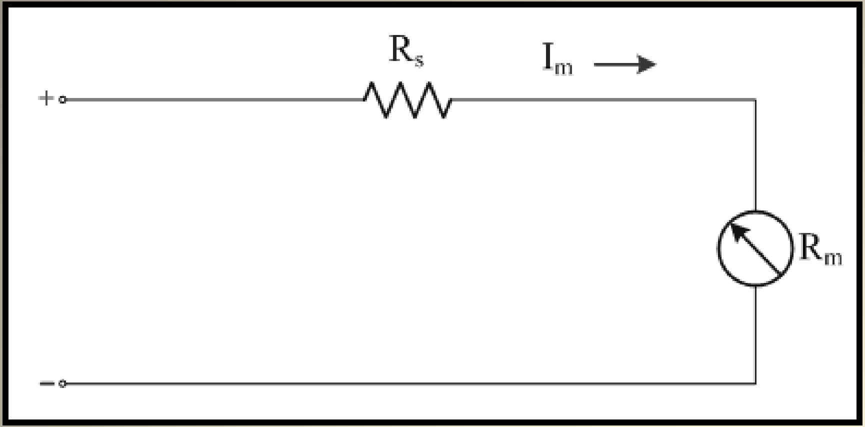
Figure 2

I_m = full scale deflection current of the movement (I_{fsd}).

R_m = internal resistance of the movement.

R_s = multiplier resistance

V = full range voltage of the instrument.



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

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

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

Sensitivity of meter;

$$S = \frac{1}{I_{fsd}} = \frac{1}{I_m}$$

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

Example 1:
Find the value of the multiplier resistor to convert a 50µA meter into a voltmeter having a full-scale voltage of 5volts. The resistance of the meter movement is 1800Ω.

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

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

$$R_s = \frac{5V}{50\mu} - 1800\Omega$$

$$= \underline{98.2k\ \Omega}$$

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

$$= \underline{20k\Omega/V}$$

EXERCISE 1:
A basic D'Arsonval movement with a full-scale deflection of 50μA and internal resistance of 500Ω is used as a DC voltmeter. Determine the value of the multiplier resistance needed to measure a voltage range of 0-10V.

Solution:

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

$$R_s = \frac{10V}{50\mu} -$$

$$= \underline{199.5k\ \Omega}$$

$$S = \frac{R_s + R_m}{V} = \frac{1}{I_m}$$

$$= \underline{20k\Omega/V}$$

DC VOLTMETER (multi-range)

A DC voltmeter can be converted into a multirange voltmeter by connecting a number of resistors(multipliers) in series with the meter movement.

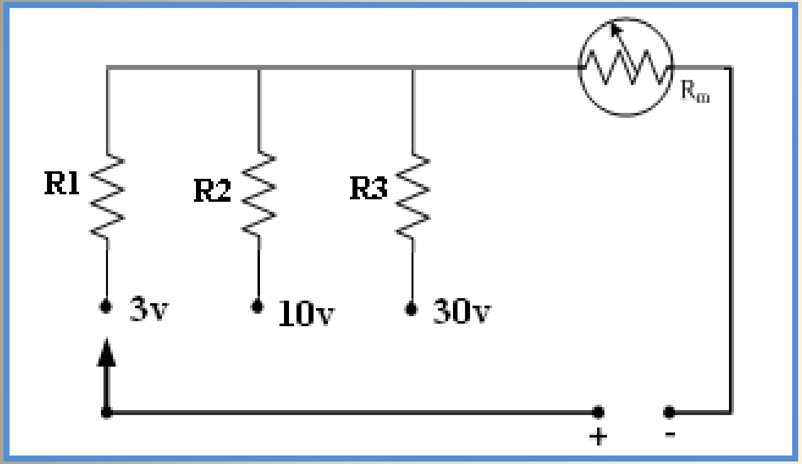


Figure 3

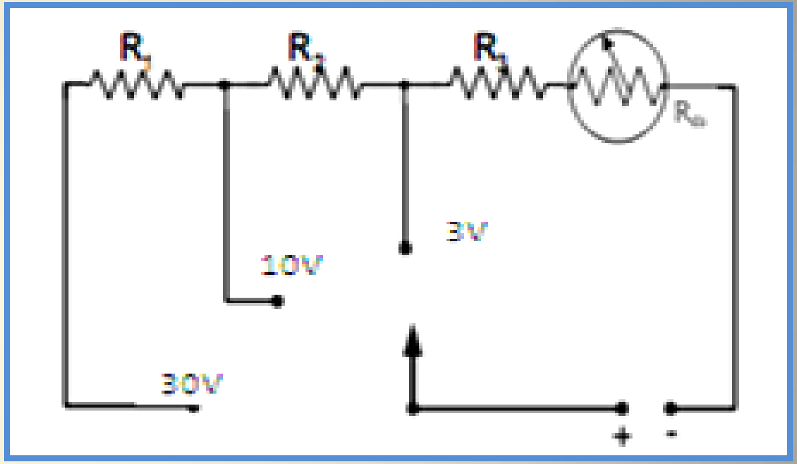


Figure 4

A practical multi-range DC voltmeter is shown in Figure 4.

Example 2:
Calculate the value of the multiplier resistance value in multiple range dc voltmeter circuit shown in Figure 3 if I_{fsc} = 50μA and R_m = 1kΩ.

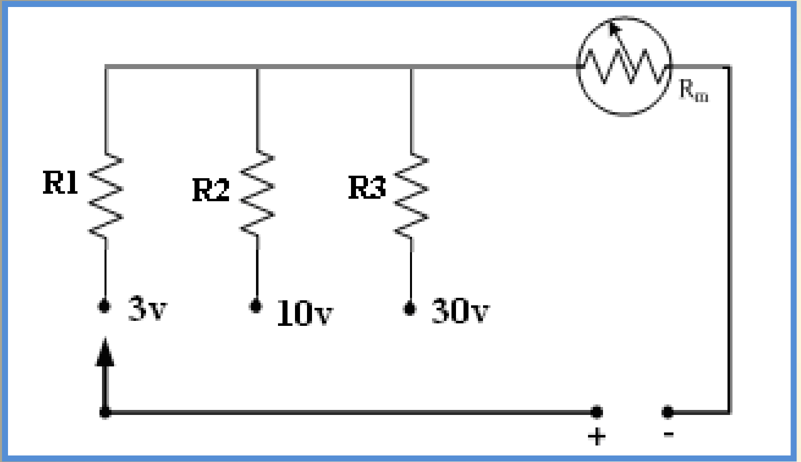


Figure 3

For range (1-3V);

$$R_1 = \frac{V}{I_m} - R_m$$

$$R_1 = \frac{3V}{50\mu A} - 1k\Omega$$

$$= \underline{59k\Omega}$$

For range (1-10V);

$$R_2 = \frac{V}{I_m} - R_m$$

$$R_2 = \frac{10V}{50\mu A} - 1k\Omega$$

$$= \underline{199k\Omega}$$

For range (1-30V);

$$R_3 = \frac{V}{I_m} - R_m$$

$$R_3 = \frac{30V}{50\mu A} - 1k\Omega$$

$$= \underline{599k\Omega}$$

Example 2:

Calculate the value of the multiplier resistance value in multiple range dc voltmeter circuit shown in Figure 4 if I_{fsc} = 50µA and R_m = 1kΩ.

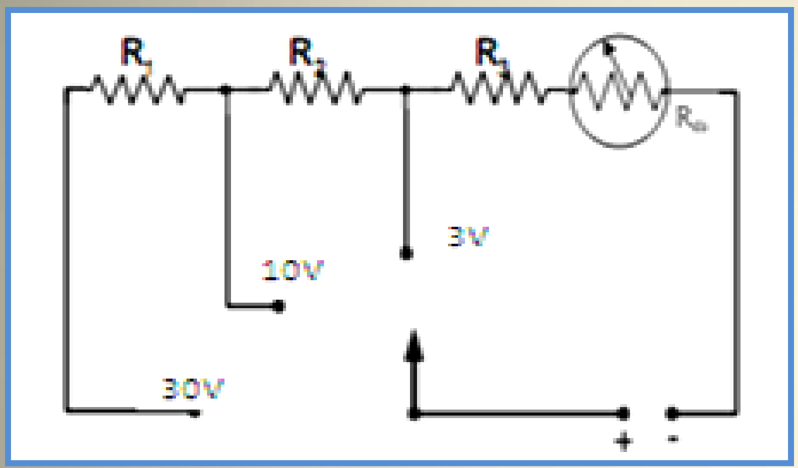


Figure 4

For range (1-10V);

$$R_3 + R_2 = \frac{V}{I_m} - R_m$$

$$R_2 = \frac{10V}{50\mu A} - 1k\Omega - 59k\Omega$$

$$= \underline{140k\Omega}$$

For range (1-3V);

$$R_3 = \frac{V}{I_m} - R_m$$

$$R_3 = \frac{3V}{50\mu A} - 1k\Omega$$

$$= \underline{59k\Omega}$$

For range (1-30V);

$$R_1 + R_2 + R_3 = \frac{V}{I_m} - R_m$$

$$R_1 = \frac{30V}{50\mu A} - 1k\Omega - 140k\Omega - 59k\Omega$$

$$= \underline{400k\Omega}$$

EXERCISE 2:

A basic D'Arsonval movement with a full scale deflection of 50μA and an interval resistance of 1800Ω is available. Its is to be converted into a 0-1V, 0-5V, 0-25V and 0-255V multirange voltmeter using individual multipliers for each range. Calculate the values of the individual resistors.

ANSWERS:

R1 = 18.2kΩ (0-1V)

R2 = 98.2kΩ (0-5V)

R3 = 498.2kΩ (0-25V)

R4 = 5.098M Ω (0-255V)

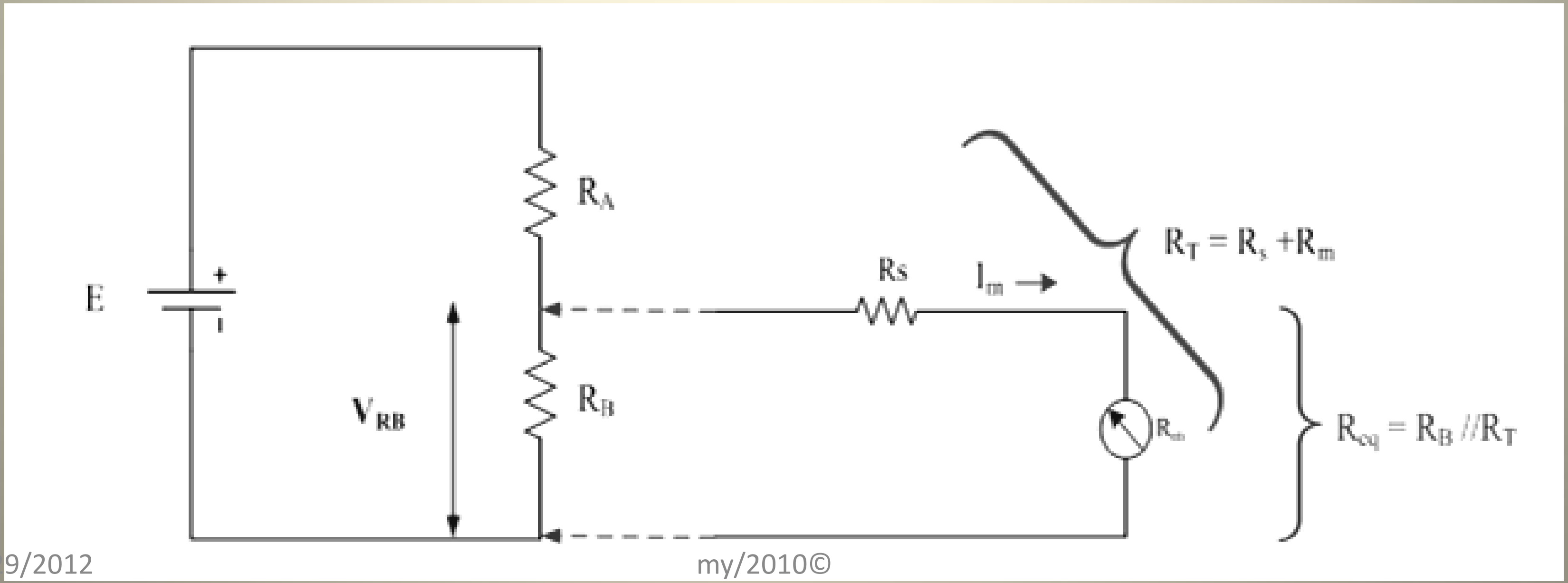
LOADING EFFECT DC VOLTMETER

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.



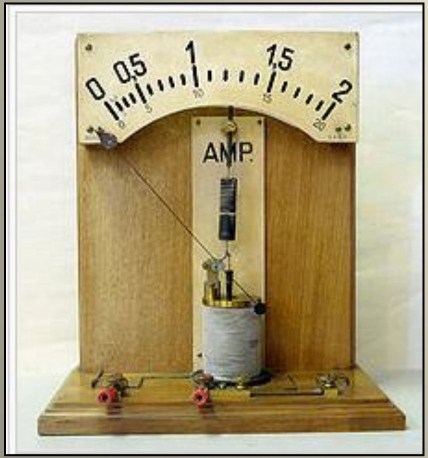
Example 3:

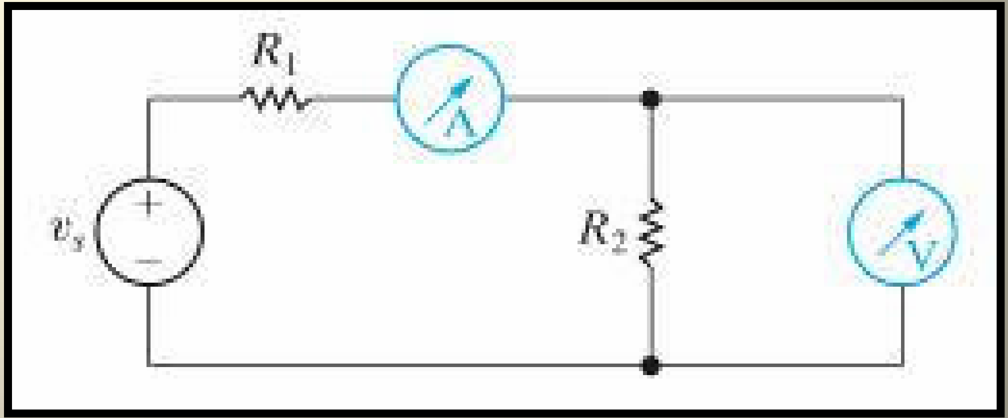
A series circuit of two resistors Ra = 25kΩ and Rb = 10kΩ is supplied by a 30V voltage supply. A voltmeter is used to measure VRb . The sensitivity of meter is 1k Ω/V.
The meter is used on 10 range. Find the %error due to its loading effect .

DC AMMETER

An ammeter is an instrument for measuring the electric current in amperes in a branch of an electric circuit.

It must be placed in series with the measured branch.





DC AMMETER DESIGN (SINGLE RANGE)

An analog ammeter consist of a d'Arsonval movement in parallel with a resistor.

The purpose of the parallel resistor is to limit the amount of current in the movement's coil.

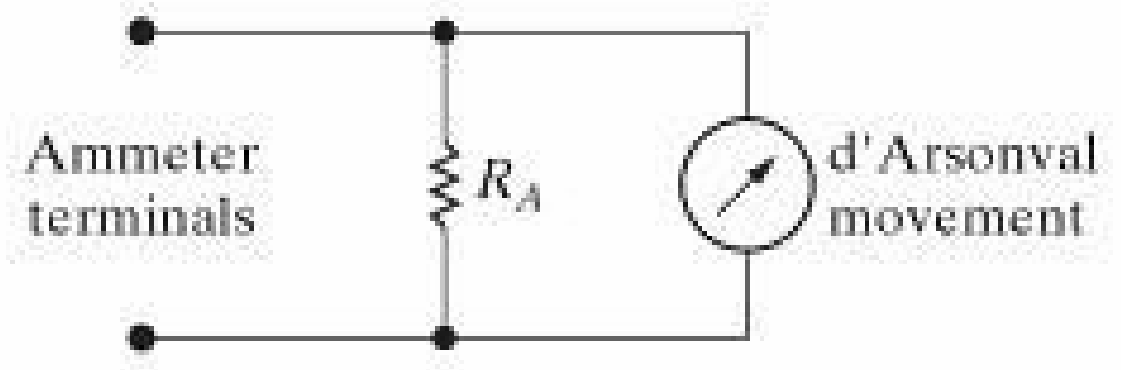
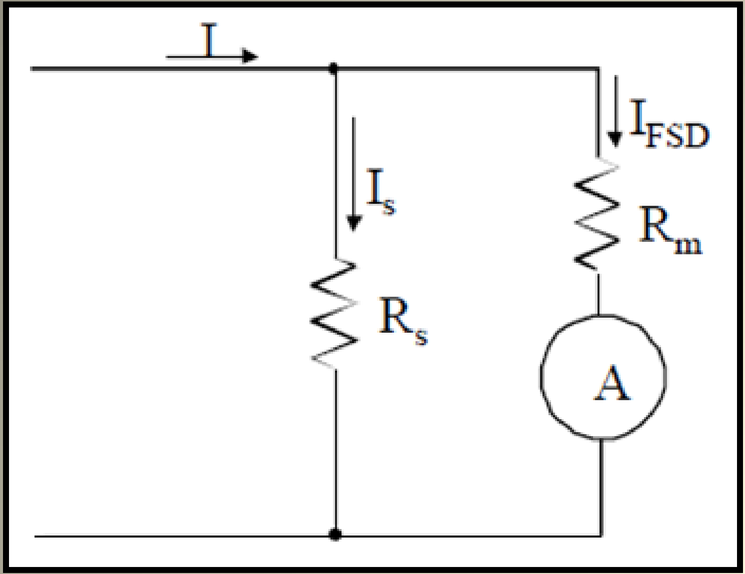


Figure 3.24 A dc ammeter circuit.



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

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

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

R_m = internal resistance of the movement.

R_{sh} = shunt resistance

I_{sh} = shunt current

I_m = full scale deflection current of the movement

I = full scale current of the ammeter + shunt

Example 1:

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

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

$$R_{sh} = \frac{(1mA)(100\Omega)}{100mA - 1mA}$$

$$= \underline{1.01\ \Omega}$$

EXERCISE 1:

Design an ammeter to measure 100mA using a 50µA PMMC meter movement with internal resistance 3k Ω. (ans: 1.5Ω)

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

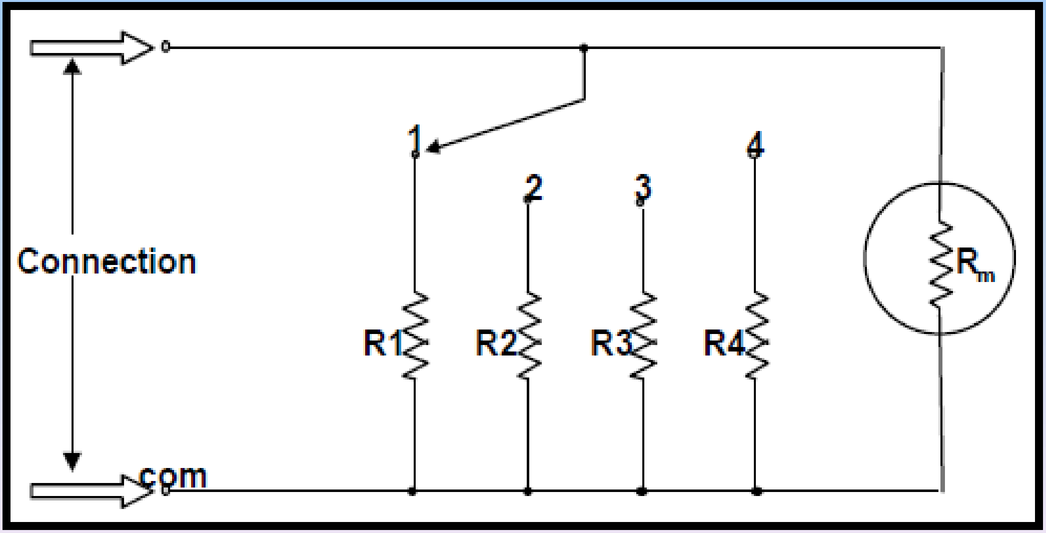
$$R_{sh} = \frac{(50\mu A)(3k\Omega)}{100mA - 50\mu A}$$

$$= \underline{1.5\ \Omega}$$

DC AMMETER DESIGN (MULTI RANGE)

The range of DC ammeter is extended by a number of shunts, selected by a range switch.

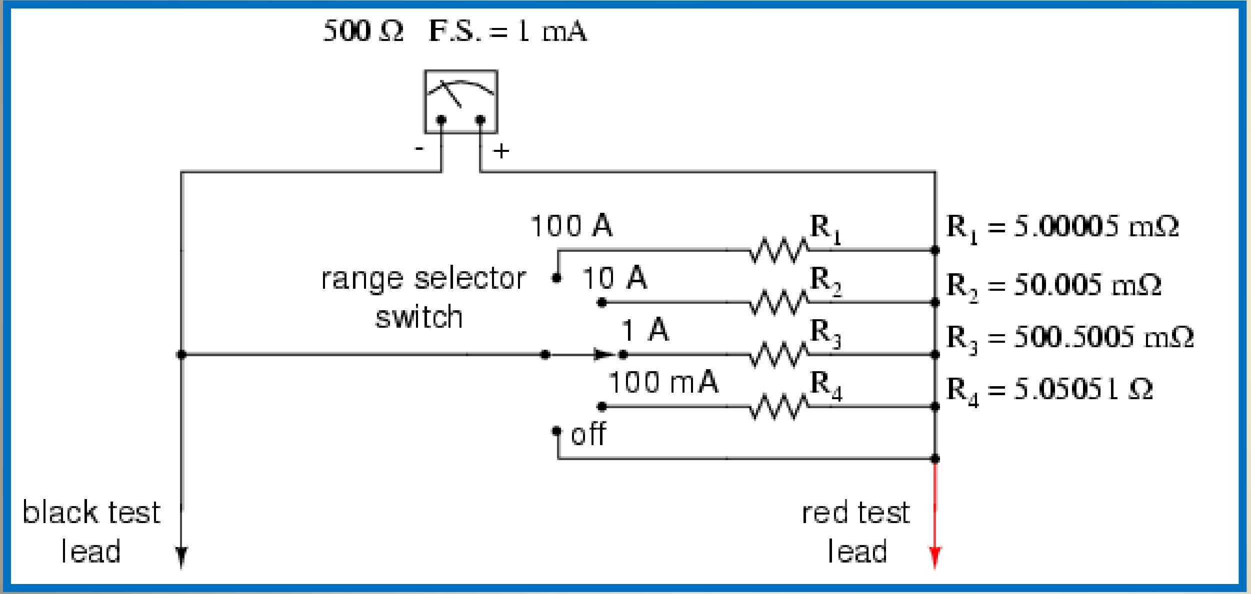
The resistors are placed in parallel o give diferent current ranges.



Switch S (multiposition switch) protects the meter movement from being damage during range changing.

EXAMPLE 1:

For ammeter ranges of 100mA, 1A, 10A, and 100A, the shunt resistances would be as such:



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

$$R_1 = \frac{(1mA)(500\Omega)}{100A - 1mA}$$

$$= \underline{5.00005m\Omega}$$

Exercise 1:

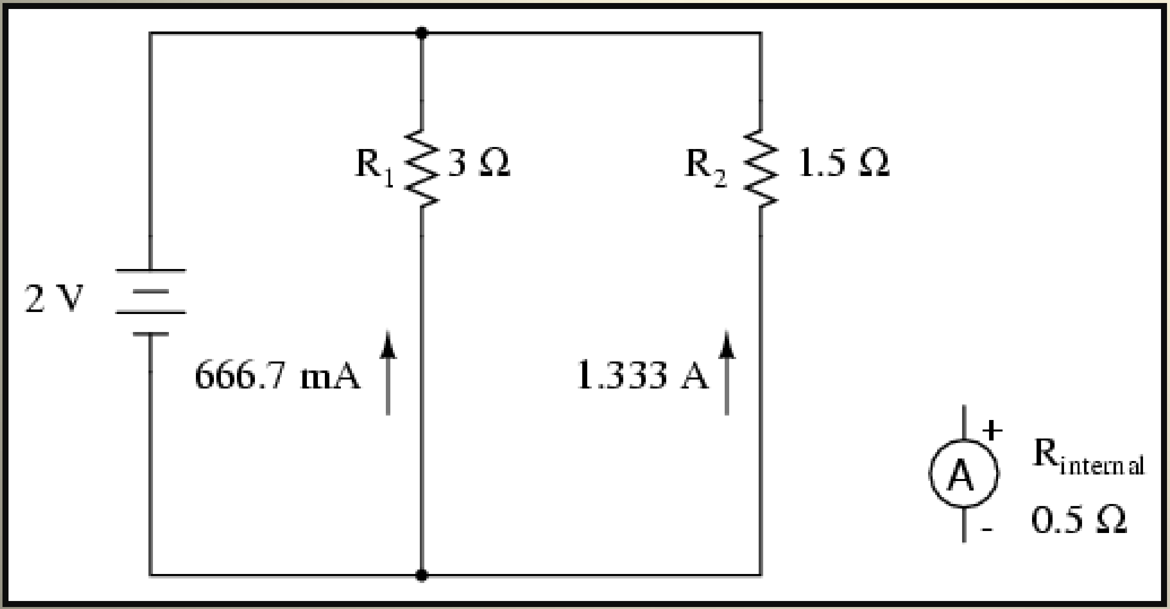
Design a multirange ammeter to provide an ammeter with a current range of 0-1mA, 0-10mA, 0-50mA and 0-100mA. A d'Arsonval movement with an internal resistance of 100Ω and full scale current of 50μA is used.

(ans: 5.26Ω, 0.51Ω, 0.1Ω, 0.05Ω)

AMMETER IMPACT ON MEASURED CIRCUIT

Just like voltmeters, ammeters tend to influence the amount of current in the circuits they're connected to.

Here is an extreme example of an ammeter's effect upon a circuit:



$$I = V/R$$

$$I = V/R_1$$

$$I = V/(R_1 + R_2)$$