BENHA UNIVERSITY
FACULTY OF ENGINEERING (SHOUBRA)
ELECTRONICS AND COMMUNICATIONS ENGINEERING

CCE 304

Measurements and Instrumentations

(2022 - 2023) term 231

Lecture 3: Electromechanical Instruments (part2).

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Chapter Outline:

1) Permanent Magnet Moving Coil (PMMC).
2) Galvanometer.
3) DC Ammeters
4) **DC Voltmeters**
5) Ohmmeters
6) AC Voltmeters
7) AC Ammeters

3.4 DC Voltmeter: Voltmeter Circuit

- The scale of the PMMC meter can be calibrated to **indicate voltage** since the **current through the coil is proportional to the voltage**.
- The PMMC is modified by adding a **series resistance** to measure higher voltmeter range.
- Because it increases the range of the voltmeter, the series resistance is termed a multiplier resistance.
- A multiplier resistance that is nine times the coil resistance will increase the voltmeter range by a factor of 10.

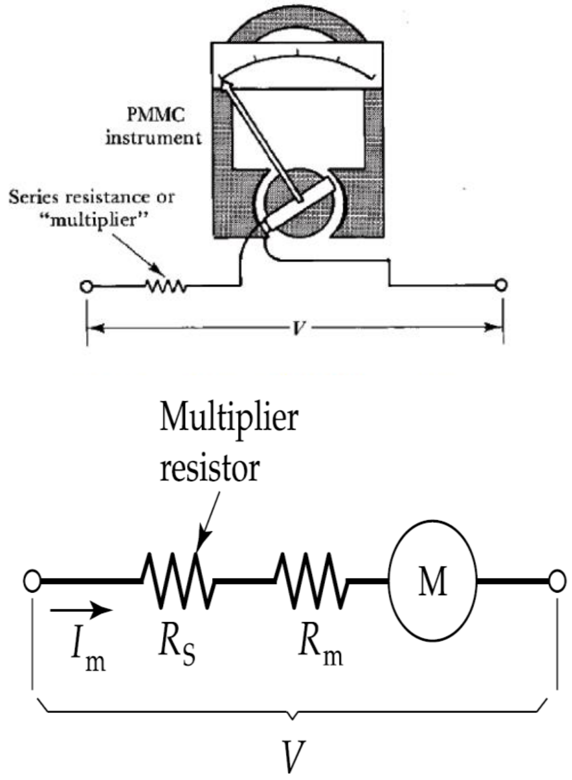


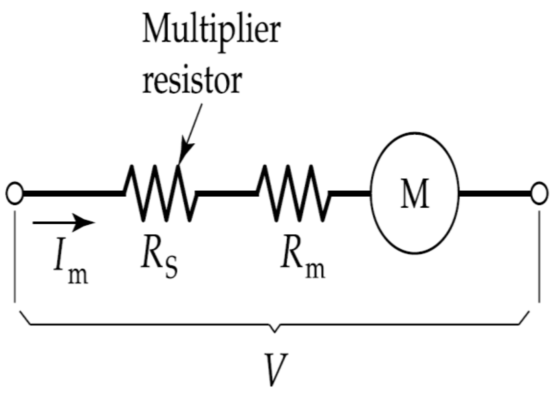
Figure 4-5 A dc voltmeter is made up of a PMMC instrument and a series multiplier resistor. The meter current is directly proportional to the applied voltage, so that the meter scale can be calibrated to indicate the voltage.

3.4 DC Voltmeter (Cont.):

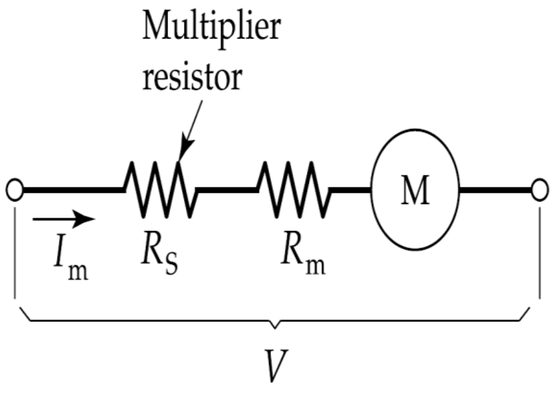
Example 3.6:

- A PMMC instrument with FSD of 100 μA and a coil resistance of 1 kΩ is to be converted into a voltmeter. ***Determine*** the required multiplier resistance if the voltmeter is to measure 50 V at full scale.

  Also ***calculate*** the applied voltage when the instrument indicates 0.8, 0.5, and 0.2 of FSD.



Solution



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

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

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

For $V = 50$ V *FSD,* $\quad I_m = 100\ \mu A$

$$R_s = \frac{50\ V}{100\ \mu A} - 1\ k\Omega$$

$$= 499\ k\Omega$$

At 0.8 FSD: $\quad I_m = 0.8 \times 100\ \mu A$

$$= 80\ \mu A$$

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

$$= 80\ \mu A(499\ k\Omega + 1\ k\Omega)$$

$$= 40\ V$$

At 0.5 FSD: $\quad I_m = 50\ \mu A$

$$V = 50\ \mu A(499\ k\Omega + 1\ k\Omega)$$

$$= 25\ V$$

At 0.2 FSD: $\quad I_m = 20\ \mu A$

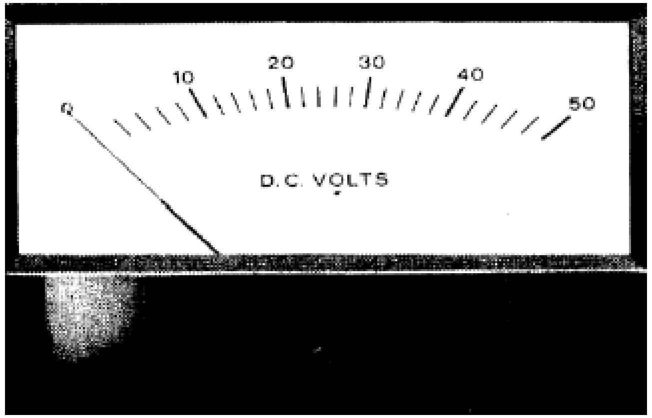
$$V = 20\ \mu A(499\ k\Omega + 1\ k\Omega)$$

$$= 10\ V$$

3.4 DC Voltmeter: Voltmeter Sensitivity:

The sensitivity of a voltmeter is equal to the resistance per volt:

$$S_v = \frac{R_m + R_s}{FSD} \qquad \Omega/V$$



- The voltmeter sensitivity is always specified by the manufacturer.
- If the sensitivity is known, the total voltmeter resistance is easily calculated as (sensitivity x range).
- Ideally, a voltmeter should have an extremely high resistance.
- If the voltmeter resistance is **too low**, it can alter the circuit voltage. This is known as **voltmeter loading effect.**

3.4 DC Voltmeter: Multirange Voltmeter

- It consists of a deflection instrument, several multiplier resistors, and a selector switch.
- Two possible circuits are proposed.
- Only one of the three multiplier resistors is connected in series with the meter at any time.
- The range of this voltmeter is

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

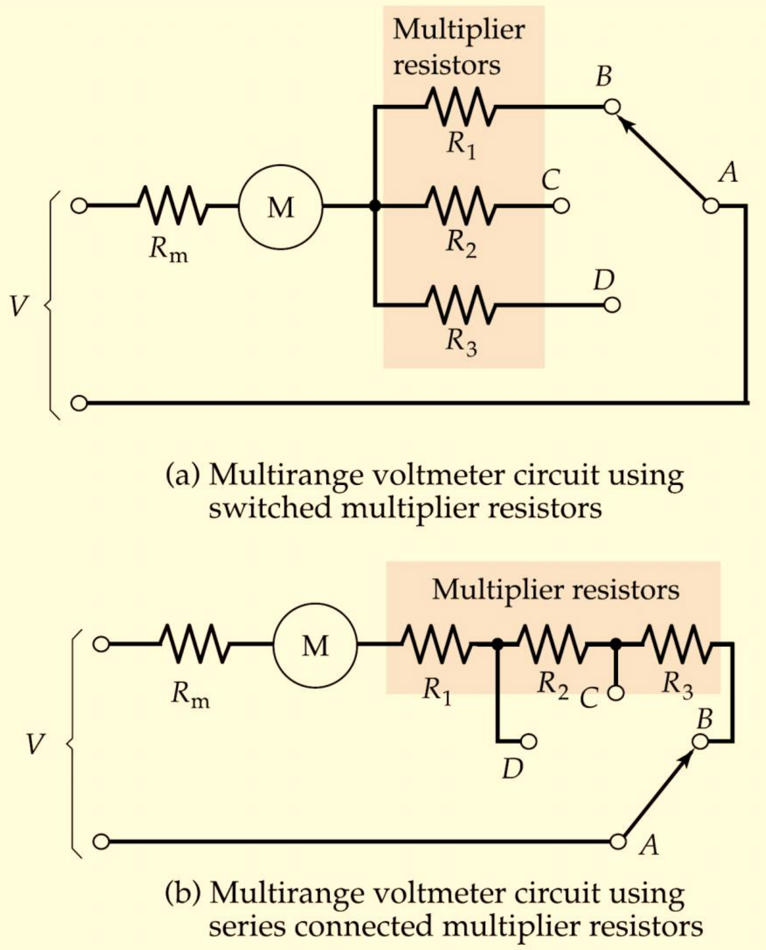
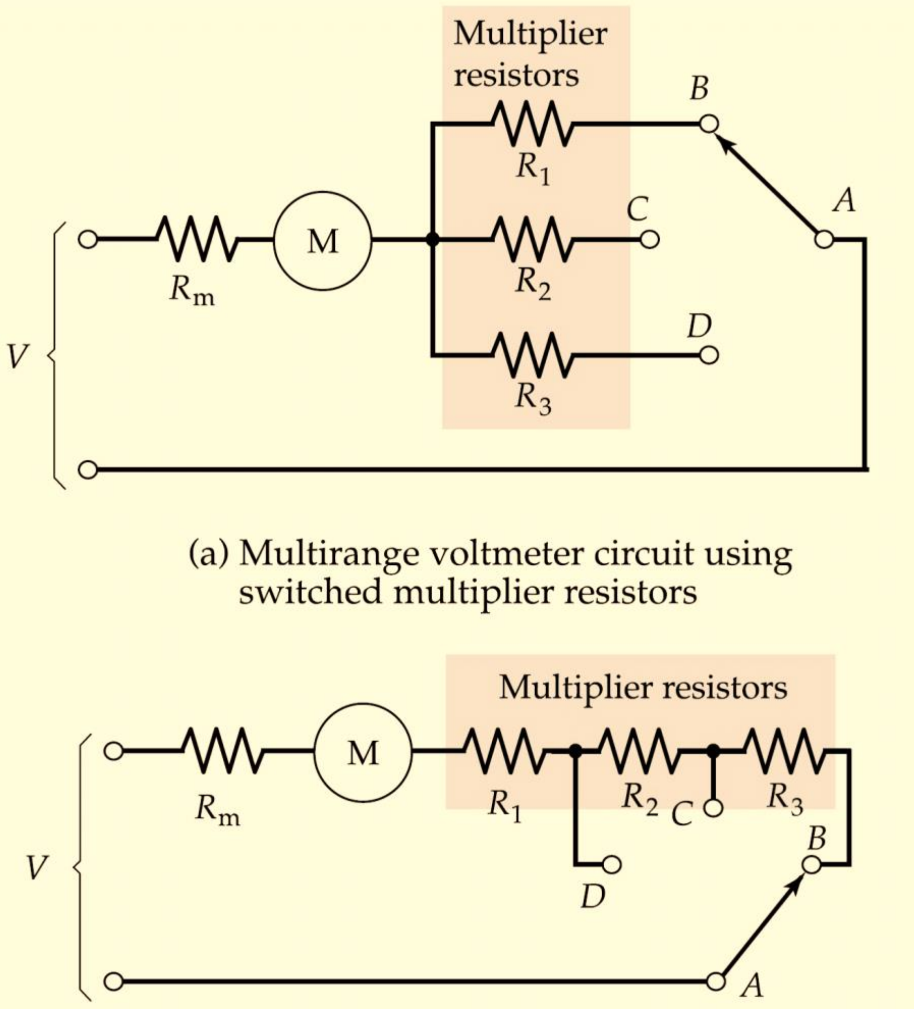


Figure 4-6 A multirange voltmeter consists of a PMMC instrument, several multiplier resistors, and a switch for range selection. Individual or series-connected resistors may be used.

Example 3.7:

A PMMC instrument with FSD = 50 μ A and R_m = 1700 Ω is to be employed as a voltmeter with ranges of 10 V, 50 V, and 100 V. ***Calculate*** the required values of multiplier resistors for the two circuits



(a) Multirange voltmeter circuit using switched multiplier resistors

(b) Multirange voltmeter circuit using series connected multiplier resistors

Solution:

Solution (Cont.)

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

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

$$= \frac{10\ \text{V}}{50\ \mu\text{A}} - 1700\ \Omega$$

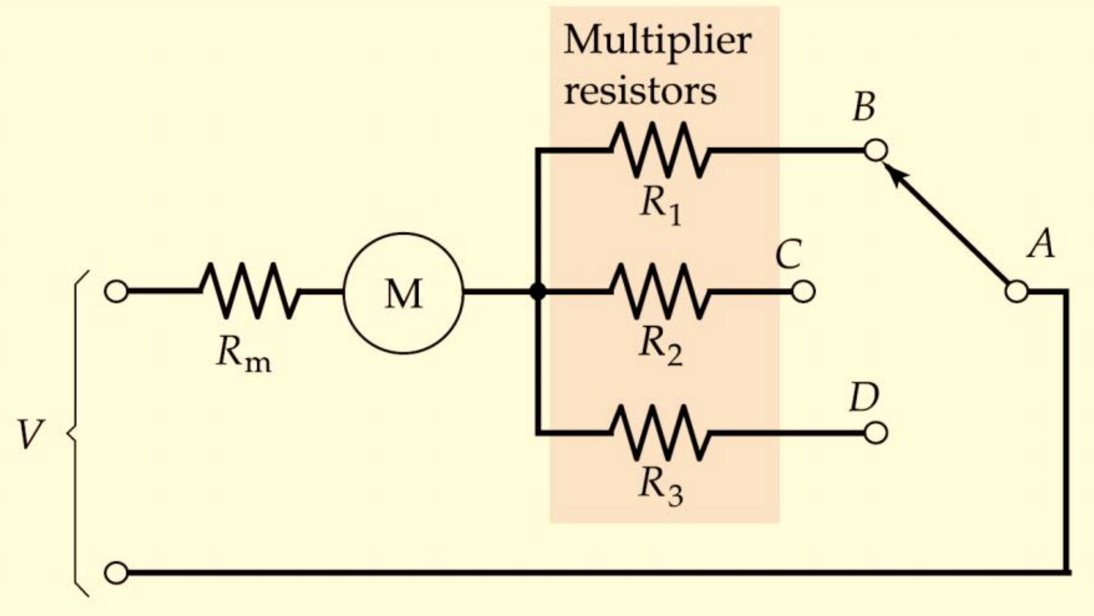
$$= 198.3\ \text{k}\Omega$$

$$R_2 = \frac{50\ \text{V}}{50\ \mu\text{A}} - 1700\ \Omega$$

$$= 998.3\ \text{k}\Omega$$

$$R_3 = \frac{100\ \text{V}}{50\ \mu\text{A}} - 1700\ \Omega$$

$$= 1.9983\ \text{M}\Omega$$



(a) Multirange voltmeter circuit using switched multiplier resistors

Solution (Cont.)

$$R_m + R_1 = \frac{V_1}{I_m}$$

$$R_1 = \frac{V_1}{I_m} - R_m$$

$$= \frac{10\ \text{V}}{50\ \mu\text{A}} - 1700\ \Omega$$

$$= 198.3\ \text{k}\Omega$$

$$R_m + R_1 + R_2 = \frac{V_2}{I_m}$$

$$R_2 = \frac{V_2}{I_m} - R_1 - R_m$$

$$= \frac{50\ \text{V}}{50\ \mu\text{A}} - 198.3\ \text{k}\Omega - 1700\ \Omega$$

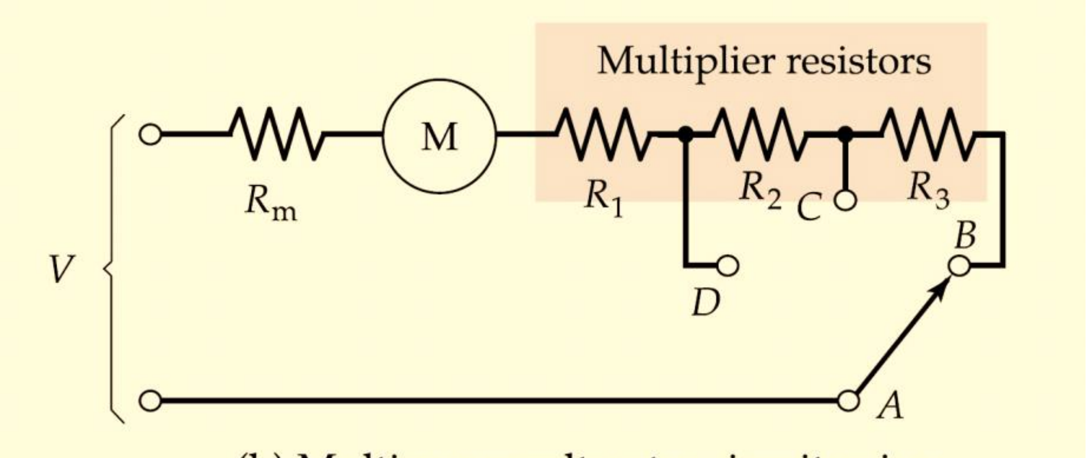
$$= 800\ \text{k}\Omega$$

$$R_m + R_1 + R_2 + R_3 = \frac{V_3}{I_m}$$

$$R_3 = \frac{V_3}{I_m} - R_2 - R_1 - R_m$$

$$= \frac{100\ \text{V}}{50\ \mu\text{A}} - 800\ \text{k}\Omega - 198.3\ \text{k}\Omega - 1700\ \Omega$$

$$= 1\ \text{M}\Omega$$



(b) Multirange voltmeter circuit using series connected multiplier resistors

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3.5 Ohmmeter: Basic Circuit: Series Ohmmeter:

- The series ohmmeter consists of a PMMC with a battery voltage Eb connected in series.
- The unknown resistance is connected between terminals, A and B.
- A standard (known) resistance R1 is connected to protect the device from high current when low resistance is connected.

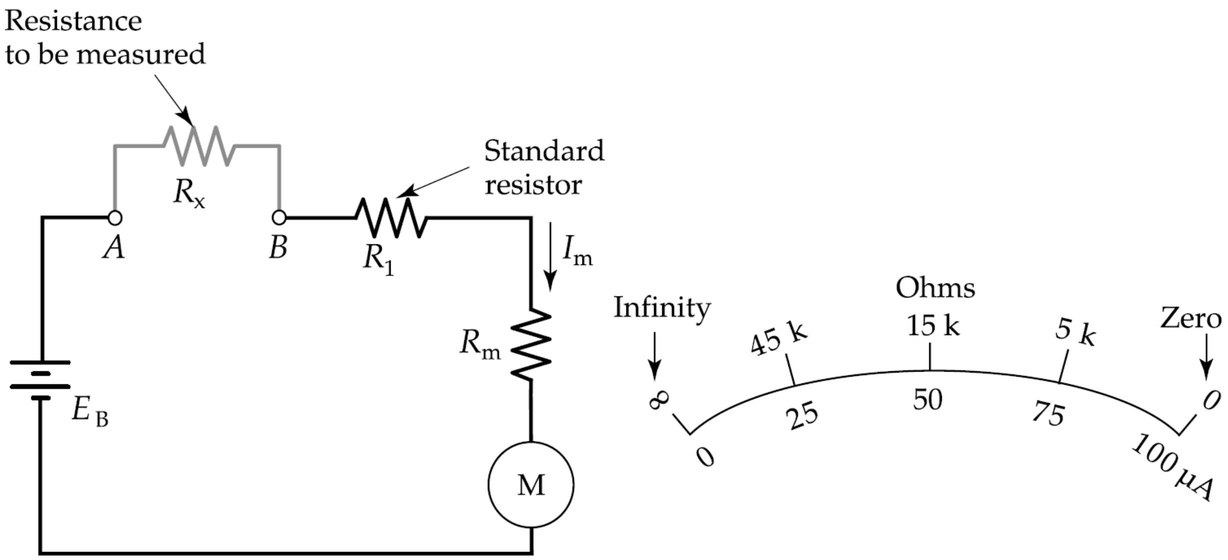


Figure 4-11 Basic series ohmmeter circuit consisting of a PMMC instrument and a series-connected standard resistor (R_1). When the ohmmeter terminals are shorted (R_x = 0) meter FSD occurs. At half-scale deflection $R_x = R_1$, and at zero deflection the terminals are open-circuited.

$$I_m = \frac{E_b}{R_1 + R_x + R_m}$$

If $R_x = 0$, $I_m = FSD$ and if $R_x = \infty$, $I_m = 0$.

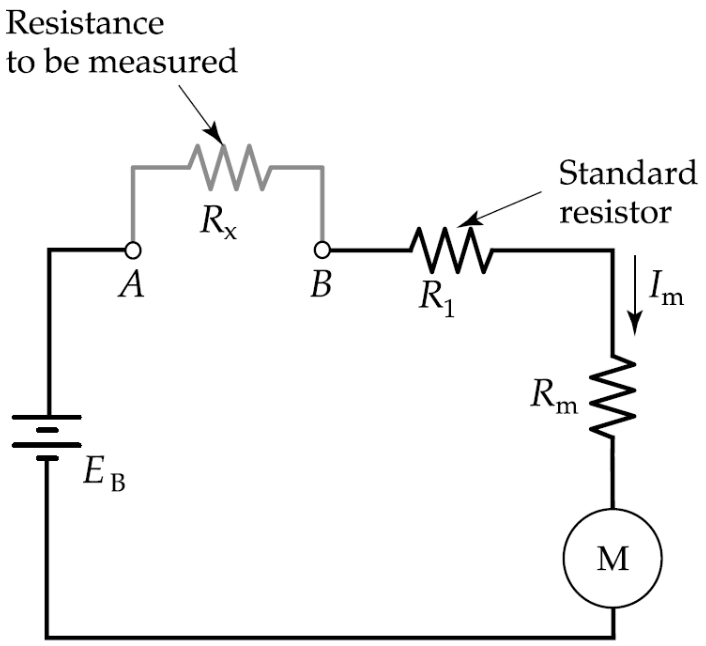
If $0 < R_x < \infty$, $FSD < I_m < 0$

Example 3.8:

Series ohmmeter shown in the figure is made up of a 1.5 V battery and $(R_1 + R_m) = 15\ k\Omega$.

(a) Determine the instrument indication when $R_X = 0$. .

(b) Determine how the resistance scale should be marked at 0.5 FSD, 0.25 FSD, and 0.75 FSD.



Solution

(a) $I_m = \frac{E_b}{R_x + R_1 + R_m} = \frac{1.5\ \text{V}}{0 + 15\ \text{k}\Omega}$

$= 100\ \mu\text{A (FSD)}$

(b) At 0.5 FSD:

$I_m = \frac{100\ \mu\text{A}}{2} = 50\ \mu\text{A}$

$R_x + R_1 + R_m = \frac{E_b}{I}$

$R_x = \frac{E_b}{I_m} - (R_1 + R_m)$

$= \frac{1.5\ \text{V}}{50\ \mu\text{A}} - 15\ \text{k}\Omega$

$= 15\ \text{k}\Omega$

(c) At 0.25 FSD: $I_m = \frac{100\ \mu\text{A}}{4} = 25\ \mu\text{A}$

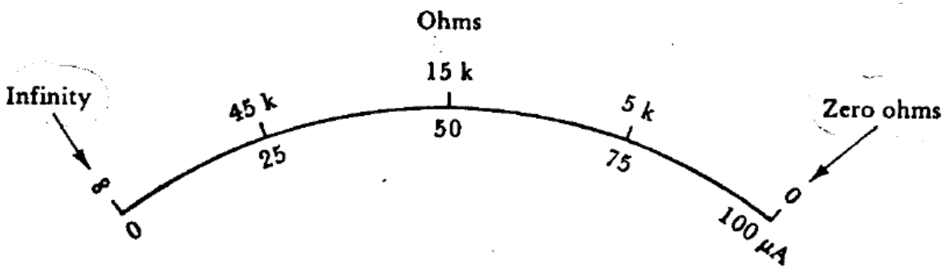
$R_x = \frac{1.5\ \text{V}}{25\ \mu\text{A}} - 15\ \text{k}\Omega$

$= 45\ \text{k}\Omega$

(d) At 0.75 FSD: $I_m = 0.75 \times 100\ \mu\text{A} = 75\ \mu\text{A}$

$R_x = \frac{1.5\ \text{V}}{75\ \mu\text{A}} - 15\ \text{k}\Omega$

$= 5\ \text{k}\Omega$



3.5 Ohmmeter:
Ohmmeter with Zero Control:

- In the series ohmmeter, if the battery voltage drops, the instrument scale no longer gives correct reading.
- An adjustable resistor R2 is connected in parallel with the meter to adjust the falling battery voltage.
- Ohmmeter is calibrated by making Rx = 0 and adjusting R2 to give FSD (0)

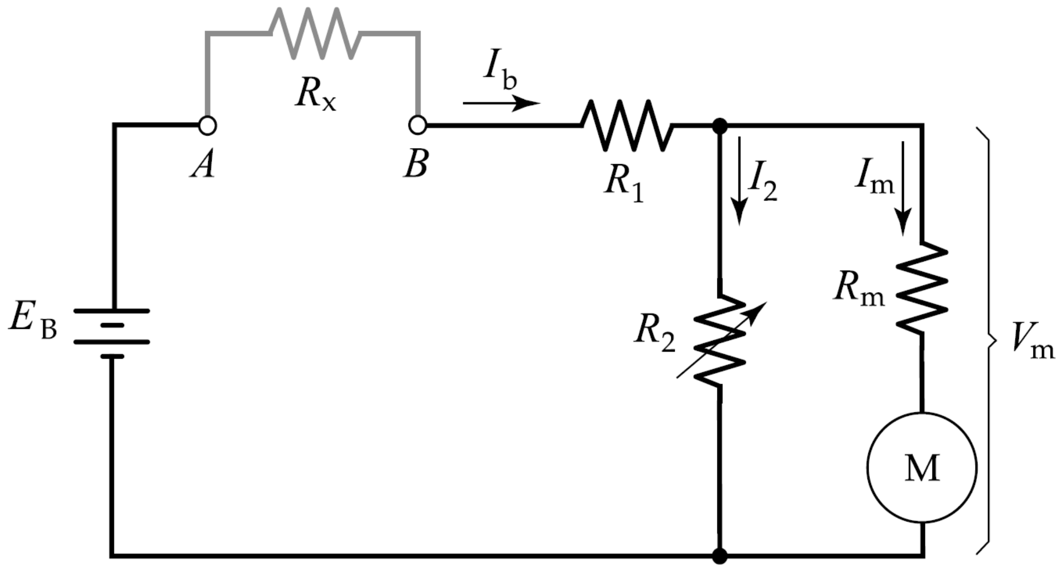


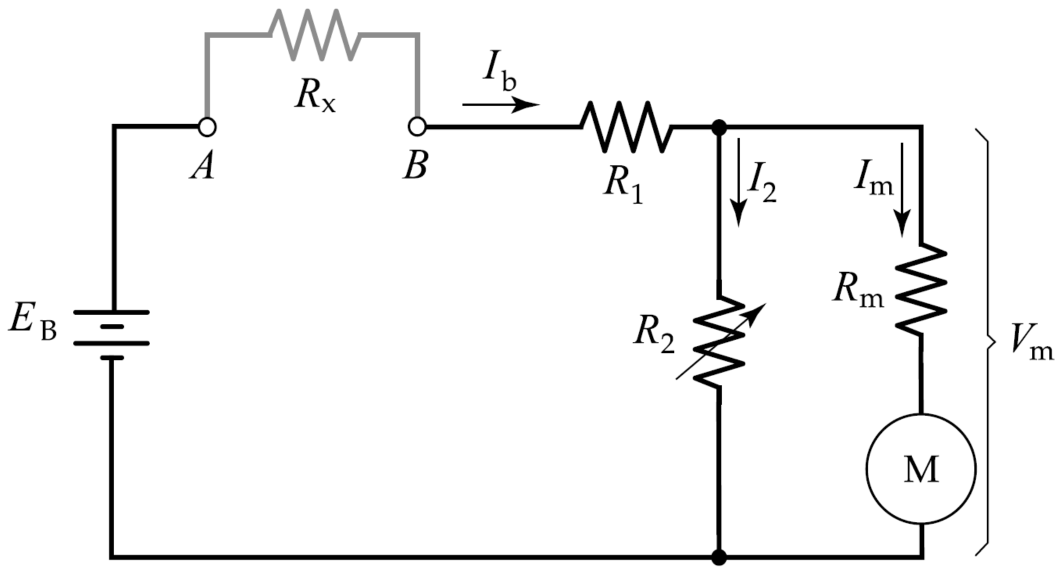
Figure 4-12 An adjustable resistor (R_2) connected in parallel with the meter provides ar ohmmeter zero control. The ohmmeter terminals are initially short-circuited and the zero control is adjusted to give a zero-ohm reading. This eliminates errors due to variations in the battery voltage.

$$I_m = V_m / R_m, \quad V_m = I_b.(R_2 // R_m)$$

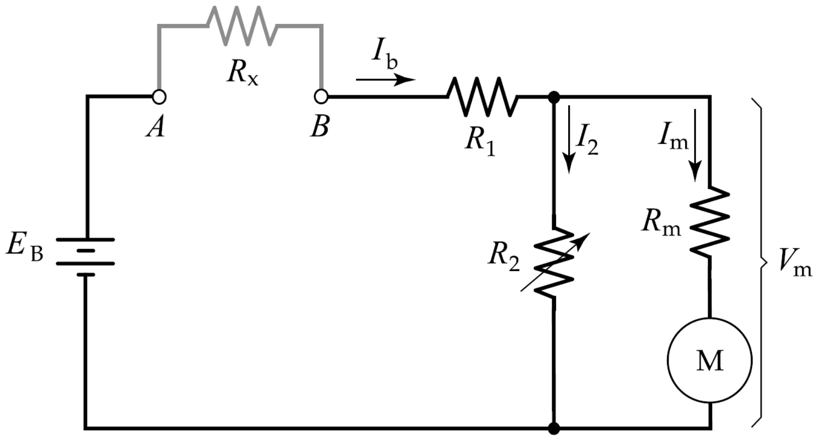
$$I_m = I_b.\frac{R_2//R_m}{Rm}$$

Example 3.8:

The ohmmeter circuit in the figure has E_b = 1.5 V, R_1 = 15 kΩ, R_m=R_2= 50 Ω, and meter FSD = 50 μA. ***Determine*** the ohmmeter scale reading at 0.5 FSD, and ***determine*** the new resistance value that R_2 must be adjusted to when E_b falls to 1.3 V. Also, recalculate the value of R_X at 0.5 FSD when E_b = 1.3 V.



Solution



At 0.5 FSD, with $E_b = 1.5$ V,

$$V_m = I_m \times R_m = 25\ \mu A \times 50\ \Omega$$

$$= 1.25\ mV$$

$$I_2 = \frac{V_m}{R_2} = \frac{1.25\ mV}{50\ \Omega}$$

$$= 25\ \mu A$$

$$I_b = I_2 + I_m = 25\ \mu A + 25\ \mu A$$

$$= 50\ \mu A$$

$$R_x + R_1 \approx \frac{E_b}{I_b} = \frac{1.5\ V}{50\ \mu A}$$

$$= 30\ k\Omega$$

$$R_x = 30\ k\Omega - R_1 = 30\ k\Omega - 15\ k\Omega$$

$$= 15\ k\Omega$$

With $R_x = 0$ and $E_b = 1.3$ V,

$$I_b \approx \frac{E_b}{R_x + R_1} = \frac{1.3\ V}{0 + 15\ k\Omega}$$

$$= 86.67\ \mu A$$

$$I_2 = I_b - I_{m(FSD)} = 86.67\ \mu A - 50\ \mu A$$

$$= 36.67\ \mu A$$

$$V_m = I_m R_m = 50\ \mu A \times 50\ \Omega$$

$$= 2.5\ mV$$

$$R_2 = \frac{V_m}{I_2} = \frac{2.5\ mV}{36.67\ \mu A}$$

$$= 68.18\ \Omega$$

END OF LECTURE

BEST WISHES