This part of the experiment is prepared with Online LaTeX Editor Overleaf, and the circuits are drawn in LTspice. Visit the website for the code here:

https://www.overleaf.com/read/ttjwtvcwwgyq#14ff29

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2. PRELIMINARY WORK

2.1 Explain why the adjusted value of R_2 is equal to the internal resistance of the basic meter in Fig. 4.

Answer: When the switch is open, the current is that the ammeter measures when it deflects full-scale. After the switch is closed, the current splits equally and the ammeter deflects half-scale. From Kirchhoff's Voltage Law, the voltage across the ammeter and R_2 must be equal. Since they have the same magnitude of current, from Ohm's Law, they have equal magnitudes of resistance. Therefore, the resistance of the ammeter equals the resistor's.

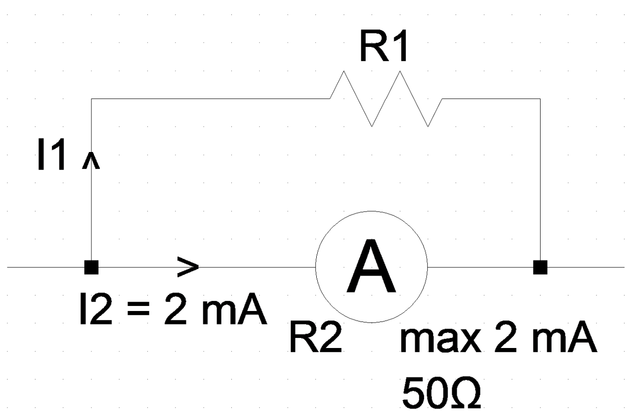
2.2 Assume that we are given a basic meter having an internal resistance of 50 Ω and a full scale deflection of 2 mA

a) Design an ammeter having a full scale deflection of 20 mA.

b) Design a voltmeter to measure a full scale voltage of 20 V.

Answer:

a)

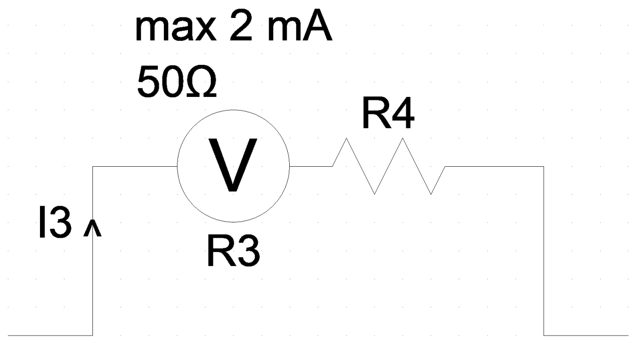


$\mathrm{I_1} = 20\ \mathrm{mA} - \mathrm{I_1} = 20\ \mathrm{mA} - 2\ \mathrm{mA} = 18\ \mathrm{mA}$

$$\mathrm{I_1} \cdot \mathrm{R_1} = \mathrm{I_2} \cdot \mathrm{R_2} \ \rightarrow\ \mathrm{R_1} = \frac{\mathrm{I_2} \cdot \mathrm{R_2}}{\mathrm{I_1}} = \frac{2\ \mathrm{mA} \cdot 50\ \Omega}{18\ \mathrm{mA}} = \frac{50}{9}\ \Omega \approx 5.56\ \Omega$$

$\boxed{\mathrm{I_1} = 18\ \mathrm{mA},\ \mathrm{R_1} = 5.56\ \Omega}$

b)



$$V_{max} = I_3 \cdot R_3 + I_3 \cdot R_4 = I_3 \cdot (R_3 + R_4)$$

$$R_4 = \frac{V_{max}}{I_3} - R_3 = \frac{20\ V}{2\ mA} - 50\ \Omega = 9950\ \Omega \ \rightarrow \ \boxed{R_4 = 9950\ \Omega}$$

2.3 Consider the circuit diagram in Fig. 3 and $V_{DC} = 3$ V
a) When a-b are short-circuited, determine the value of R_v for full-scale deflection.
b) Find the value of the unknown resistor R_x, if the meter current is 0.33 mA.

Answer:

a) $R_v = R_T - R_m = \dfrac{3\ V}{1\ mA} - 100\ \Omega = 2900\ \Omega \ \rightarrow \ \boxed{R_v = 2900\ \Omega}$

b) $R_x = R_T - R_v - R_m = \dfrac{3\ V}{0.33\ mA} - 2900\ \Omega - 100\ \Omega \approx 6091\ \Omega \ \rightarrow \ \boxed{R_x = 6091\ \Omega}$

2.4 For the given circuit in Fig. 7, the voltage across the element R_L is required to be measured using two voltmeters whose internal resistances are 300 kΩ and 6 MΩ.

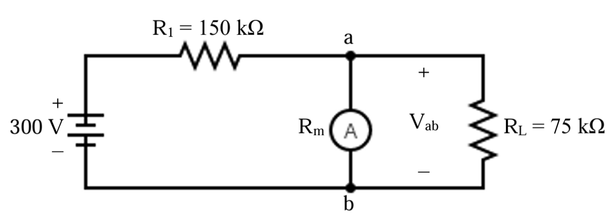


Figure 7.

a) Calculate the correct value.
b) Calculate the values measured by each voltmeter and corresponding errors.

Answer:

a) $V_{R_L} = \dfrac{75}{75 + 150} \cdot 300 = 100\ V \ \rightarrow \ \boxed{V_{R_L} = 100\ V}$

b) With 300 kΩ,

$R_{ab} = 75\ k\Omega\ //\ 300\ k\Omega = 60\ k\Omega$

$$V_{ab} = \frac{60\ k\Omega}{60\ k\Omega + 150\ k\Omega} \cdot 300\ V = \frac{600}{7}\ V \approx 85.71\ V$$

Error: $V_{R_L} - V_{ab} \approx 14.29\ V$

With 6 MΩ,

$R_{ab} = 75\ k\Omega\ //\ 6\ M\Omega \approx 74.07\ k\Omega$

$$V_{ab} = \frac{74.07\ k\Omega}{74.07\ k\Omega + 150\ k\Omega} \cdot 300\ V \approx 99.17\ V$$

Error: $V_{R_L} - V_{ab} \approx 0.83\ V$