

ELECTROTECHNOLOGY
ELTK1100
ASSIGNMENT #8
SOLUTIONS

1.

$$F_M = N I = 300t * 200mA = 60A \cdot t$$

2.

$$\phi = \frac{F_M}{R_M}$$

$$\therefore F_M = \phi R_M = 120\mu Wb * 225 * 10^5 \frac{A \cdot t}{Wb} = 2700A \cdot t$$

3.

$$F_M = N I = 2000t * 2A = 4000 A \cdot t$$

$$\phi = \frac{F_M}{R_M} = \frac{4000A \cdot t}{2000000 \frac{A \cdot t}{Wb}} = 2mWb$$

4.

$$\phi = \frac{F_M}{R_M}$$

$$\therefore F_M = \phi R_M = 0.033Wb * 2.7 * 10^4 \frac{A \cdot t}{Wb} = 891 A \cdot t$$

$$F_M = N I$$

$$\therefore I = \frac{F_M}{N} = \frac{891A \cdot t}{300t} = 2.97A$$

5.

$$F_M = N I = 60t * 5A = 300A \cdot t$$

6. Resistance is the opposition of an electric circuit to electric current flow and reluctance is the opposition of a magnetic circuit to the production of flux. Therefore resistance and reluctance provide the opposition in Ohm's Law and Magnetic Ohm's Law, respectively.

$$I = \frac{V_T}{R_T}$$

$$\phi = \frac{F_M}{R_M}$$

7. (a)

For 10 mA range

$I_{FSD} = 20 \mu A$ when 10 mA is input

$$V_{SH} = V_{MM} = I_{MM} * R_{MM} \\ = 20 \mu A * 2500 \Omega = 0.05 V \quad 1$$

$$I_{SH} = I_T - I_{MM} = 10 mA - 20 \mu A = 9.98 mA \quad 2$$

$$R_{SH} = \frac{V_{SH}}{I_{SH}} = \frac{0.05 V}{9.98 mA} = 5.01 \Omega \quad 3$$

For 25 mA range

$I_{FSD} = 20 \mu A$ when 25 mA is input

$$V_{SH} = 0.05 V$$

$$I_{SH} = I_T - I_{MM} = 25 mA - 20 \mu A = 24.98 mA$$

$$R_{SH} = \frac{V_{SH}}{I_{SH}} = \frac{0.05 V}{24.98 mA} = 2.002 \Omega$$

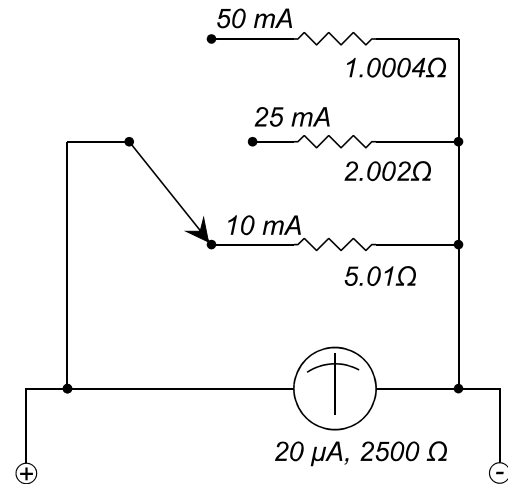
For 50 mA range

$I_{FSD} = 20 \mu A$ when 50 mA is input

$$V_{SH} = 0.05 V$$

$$I_{SH} = I_T - I_{MM} = 50 mA - 20 \mu A = 49.98 mA$$

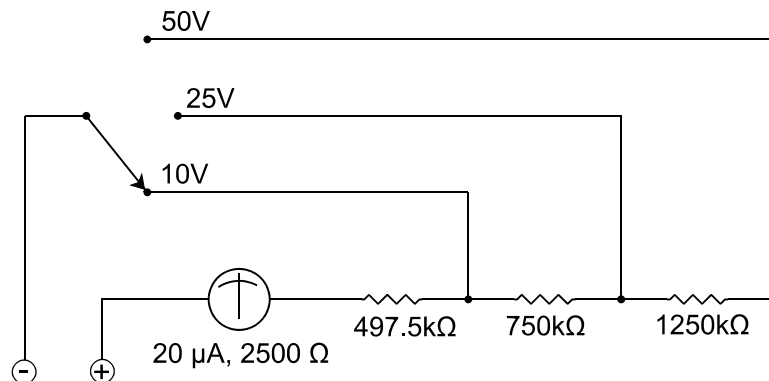
$$R_{SH} = \frac{V_{SH}}{I_{SH}} = \frac{0.05 V}{49.98 mA} = 1.0004 \Omega$$



| | V (V) | I | R(Ω) |
|----|-------------------|----------------------|-------------------|
| T | 0.05 ¹ | 10 mA | 5 |
| MM | 0.05 ¹ | 20 μA | 2500 |
| SH | 0.05 ¹ | 9.98 mA ² | 5.01 ³ |

For 10mA range

(b)



For 10 V range

$I_{FSD} = 20 \mu A$ when 10 V is input

$$R_T = \frac{V_T}{I_T} = \frac{10 V}{20 \mu A} = 500 k\Omega$$

$$R_{S1} = R_T - R_{MM} \\ = 500 k\Omega - 2500 \Omega \\ = 497.5 k\Omega$$

For 25 V range

$I_{FSD} = 20 \mu A$ when 25 V is input

$$R_T = \frac{V_T}{I_T} = \frac{25 V}{20 \mu A} = 1250 k\Omega$$

$$R_{S2} = R_T - R_{MM} - R_{S1} \\ = 1250 k\Omega - 2500 \Omega - 497.5 k\Omega \\ = 750 k\Omega$$

For 50 V range

$I_{FSD} = 20\mu A$ when 50V is input

$$R_T = \frac{V_T}{I_T} = \frac{50V}{20\mu A} = 2500k\Omega^1$$

$$\begin{aligned} R_{S3} &= R_T - R_{MM} - R_{S1} - R_{S2} \\ &= 2500k\Omega - 2500\Omega - 497.5k\Omega - 750k\Omega \\ &= 1250k\Omega^2 \end{aligned}$$

| | V (V) | I (μA) | R(k Ω) |
|----|-------|---------------|-------------------|
| T | 50 | 20 | 2500 ¹ |
| MM | | 20 | 2.5 |
| S1 | | 20 | 497.5 |
| S2 | | 20 | 750 |
| S3 | | 20 | 1.25 ² |

8.

For $I_{FSD} = 500\mu A$

$$R_T = \frac{V_T}{I_{FSD}} = \frac{1.5V}{500\mu A} = 3000\Omega$$

$$R_{INT} = R_T - R_{MM} = 3000\Omega - 2000\Omega = 1000\Omega$$

For half-scale $I_{HSD} = 250\mu A$

$$R_T = \frac{V_T}{I_{HSD}} = \frac{1.5V}{250\mu A} = 6000\Omega$$

$$\begin{aligned} R_{EXT} &= R_T - R_{MM} - R_{INT} \\ &= 6000\Omega - 2000\Omega - 1000\Omega \\ &= 3000\Omega \end{aligned}$$

For quarter-scale $I_{QSD} = 125\mu A$

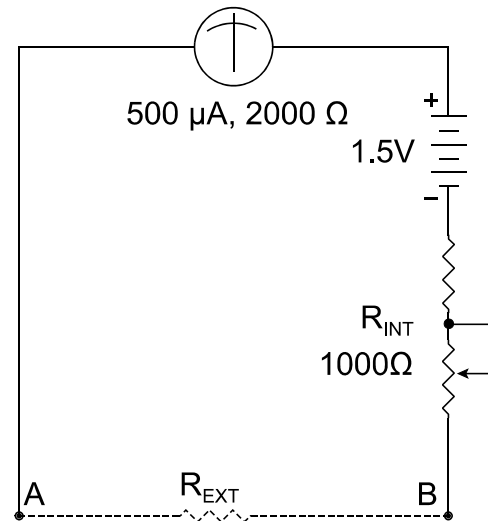
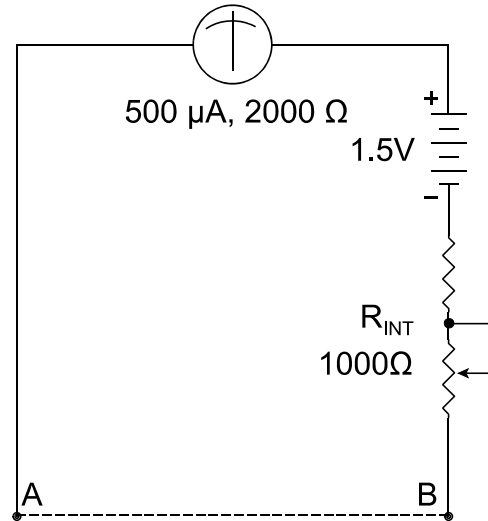
$$R_T = \frac{V_T}{I_{QSD}} = \frac{1.5V}{125\mu A} = 12000\Omega^1$$

$$\begin{aligned} R_{EXT} &= R_T - R_{MM} - R_{INT} \\ &= 12000\Omega - 2000\Omega - 1000\Omega \\ &= 9000\Omega^2 \end{aligned}$$

| | V (V) | I (μA) | R(Ω) |
|-----|-------|---------------|--------------------|
| T | 1.5 | 500 | 12000 ¹ |
| MM | | 500 | 2000 |
| INT | | 500 | 1000 |
| EXT | | 500 | 9000 ² |

For quarter-scale position

For 50V range

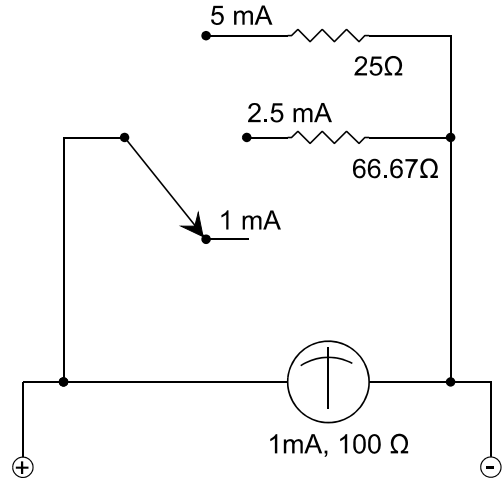


9. Multirange Ammeter.

For the 1st range, there is no shunt resistor.
 ∴ The range is the meter movement's sensitivity $I_{FSD} = 1 \text{ mA}$.

For the 2nd range.

$$\begin{aligned} \text{Maximum} \rightarrow \text{FSD} \rightarrow I_{MM} &= 1 \text{ mA} \\ V_{SH2} = V_{MM} &= I_{MM} * R_{MM} = 1 \text{ mA} * 100 \Omega = 0.1 \text{ V} \\ I_{SH2} &= \frac{V_{SH2}}{R_{SH2}} = \frac{0.1 \text{ V}}{66.67 \Omega} = 1.5 \text{ mA} \\ I_T = I_{MM} + I_{SH2} &= 1 \text{ mA} + 1.5 \text{ mA} = 2.5 \text{ mA} \end{aligned}$$



For the 3rd range.

$$\begin{aligned} \text{Maximum} \rightarrow \text{FSD} \rightarrow I_{MM} &= 1 \text{ mA} \\ V_{SH3} = V_{MM} &= I_{MM} * R_{MM} = 1 \text{ mA} * 100 \Omega = 0.1 \text{ V} \\ I_{SH3} &= \frac{V_{SH3}}{R_{SH3}} = \frac{0.1 \text{ V}}{25 \Omega} = 4 \text{ mA} \\ I_T = I_{MM} + I_{SH3} &= 1 \text{ mA} + 4 \text{ mA} = 5 \text{ mA} \end{aligned}$$

| | V (V) | I (mA) | R(Ω) |
|----|------------------|----------------|------|
| T | 0.1 ¹ | 5 ³ | 20 |
| MM | 0.1 ¹ | 1 | 100 |
| SH | 0.1 ¹ | 4 ² | 25 |

For 3rd range

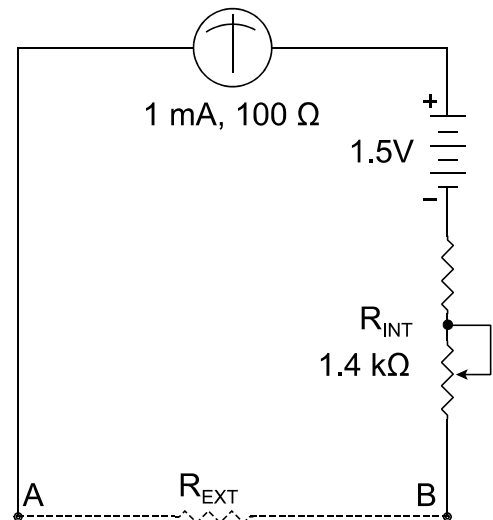
10. Ohmmeter.

For quarter-scale $I_{QSD} = \frac{1}{4} I_{FSD} = 0.25 \text{ mA}$

$$\begin{aligned} R_T &= \frac{V_T}{I_{QSD}} = \frac{1.5 \text{ V}}{0.25 \text{ mA}} = 6000 \Omega \\ R_{EXT} &= R_T - R_{MM} - R_{INT} \\ &= 6000 \Omega - 100 \Omega - 1400 \Omega \\ &= 4500 \Omega \end{aligned}$$

| | V (V) | I (mA) | R(Ω) |
|-----|-------|--------|-------------------|
| T | 1.5 | 1 | 6000 ¹ |
| MM | | 1 | 100 |
| INT | | 1 | 1400 |
| EXT | | 1 | 4500 ² |

For quarter-scale position



11. Single-range Ammeter

½ scale reading should be 25mA if 50mA scale.

$$\text{Maximum} \rightarrow \text{FSD} \rightarrow I_{MM} = 1 \text{ mA}$$

$$V_{SH} = V_{MM} = I_{MM} * R_{MM} = 1 \text{ mA} * 100 \Omega = 0.1 \text{ V} \quad 1$$

$$I_{SH} = \frac{V_{SH}}{R_{SH}} = \frac{0.1 \text{ V}}{2.041 \Omega} = 49 \text{ mA} \quad 2$$

$$I_T = I_{MM} + I_{SH} = 1 \text{ mA} + 49 \text{ mA} = 50 \text{ mA} \quad 3$$

You should prove it.

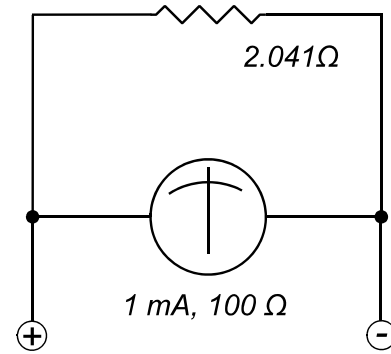
$$I_{MM} = \frac{1}{2} I_{FSD} = 0.5 \text{ mA}$$

$$V_{SH} = V_{MM} = I_{MM} * R_{MM} \\ = 0.5 \text{ mA} * 100 \Omega = 0.05 \text{ V}$$

$$I_{SH} = \frac{V_{SH}}{R_{SH}} = \frac{0.05 \text{ V}}{2.041 \Omega} = 24.5 \text{ mA}$$

$$I_T = I_{MM} + I_{SH} = 0.5 \text{ mA} + 24.5 \text{ mA} = 25 \text{ mA}$$

If $I_{FSD} = 1 \text{ mA}$, then $I_{MM} = 0.5 \text{ mA}$ is half scale deflection (I_{HSD}). If the scale is set up so that I_{FSD} points to 50 mA, then I_{HSD} must point to $50 \text{ mA} / 2 = 25 \text{ mA}$, which is the correct reading.



| | V (V) | I (mA) | R(Ω) |
|----|------------------|-----------------|-------|
| T | 0.1 ¹ | 50 ³ | 2 |
| MM | 0.1 ¹ | 1 | 100 |
| SH | 0.1 ¹ | 49 ² | 2.041 |

For calculating Ammeter range

12. Single-range voltmeter.

$$\text{Maximum} \rightarrow \text{FSD} \rightarrow I_{MM} = 20 \mu\text{A}$$

$$R_T = R_{MM} + R_S = 2500 \Omega + 4997.5 \text{ k}\Omega = 5000 \text{ k}\Omega \quad 1$$

$$V_T = I_T R_T = 20 \mu\text{A} * 5000 \text{ k}\Omega = 100 \text{ V} \quad 2$$

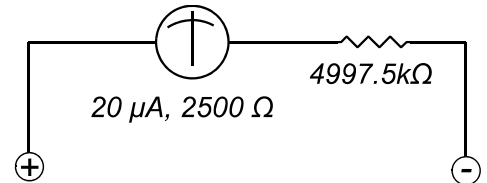
¾ scale reading should be 75V if 100V scale.

You should prove it.

$$I_{MM} = \frac{3}{4} I_{FSD} = 15 \mu\text{A}$$

$$R_T = R_{MM} + R_S = 2500 \Omega + 4997.5 \text{ k}\Omega = 5000 \text{ k}\Omega$$

$$V_T = I_T R_T = 15 \mu\text{A} * 5000 \text{ k}\Omega = 75 \text{ V}$$



| | V (V) | I (μA) | R(kΩ) |
|----|------------------|--------|-------------------|
| T | 100 ² | 20 | 5000 ¹ |
| MM | 0.05 | 20 | 2.5 |
| S | 99.95 | 20 | 4997.5 |

For calculating Voltmeter range

If $I_{FSD} = 20 \mu\text{A}$, then $I_{MM} = 15 \mu\text{A}$ is three-quarter scale division. If the scale is set up so that I_{FSD} points to 100V, then $I_{MM} = 15 \mu\text{A}$ must point to 75V, which is the correct reading.

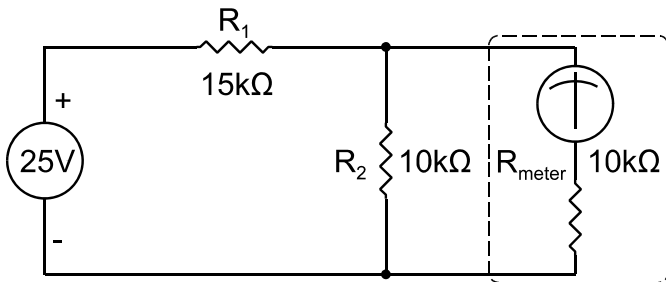
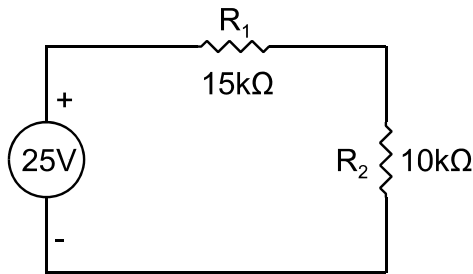
13. (a)

For 10 V range

$I_{FSD} = 1 \text{ mA}$ when 10 V is input

$$R_T = \frac{V_T}{I_T} = \frac{10 \text{ V}}{1 \text{ mA}} = 10 \text{ k}\Omega$$

$$R_{MU} = R_T - R_{MM} = 10 \text{ k}\Omega - 100 \Omega = 9.9 \text{ k}\Omega$$



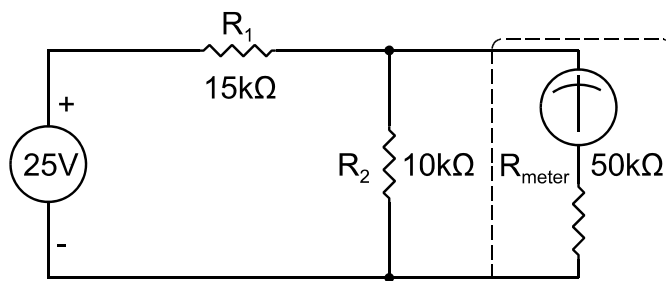
(b)

For 10 V range

$I_{FSD} = 0.2 \text{ mA}$ when 10 V is input

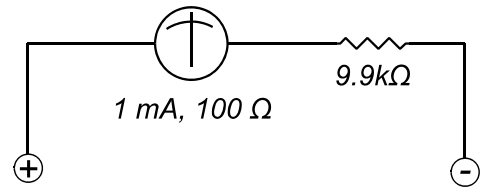
$$R_T = \frac{V_T}{I_T} = \frac{10 \text{ V}}{0.2 \text{ mA}} = 50 \text{ k}\Omega$$

$$R_{MU} = R_T - R_{MM} = 50 \text{ k}\Omega - 500 \Omega = 49.5 \text{ k}\Omega$$



(c)

The voltmeter steals current from the circuit, therefore the resistance of the voltmeter must be high as compared to the resistance the meter is measuring ($R_{\text{meter}} \gg R_{\text{measured}}$). So the part (b) voltmeter (10.7% error) is better than the part (a) voltmeter (37.5% error).



$$R_T = 15 \text{ k}\Omega + 10 \text{ k}\Omega = 25 \text{ k}\Omega$$

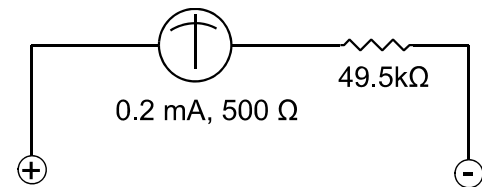
$$V_2 = \frac{10 \text{ k}\Omega}{25 \text{ k}\Omega} * 25 \text{ V} = 10 \text{ V}$$

$$10 \text{ k}\Omega \parallel 10 \text{ k}\Omega = 5 \text{ k}\Omega$$

$$R_T = 15 \text{ k}\Omega + 5 \text{ k}\Omega = 20 \text{ k}\Omega$$

$$V_2 = \frac{5 \text{ k}\Omega}{20 \text{ k}\Omega} * 25 \text{ V} = 6.25 \text{ V}$$

$$\begin{aligned} \% \text{ error} &= \left| \frac{\text{actual} - \text{measured}}{\text{actual}} \right| * 100\% \\ &= \left| \frac{10 \text{ V} - 6.25 \text{ V}}{10 \text{ V}} \right| * 100\% \\ &= 37.5\% \end{aligned}$$



$$50 \text{ k}\Omega \parallel 10 \text{ k}\Omega = 8.33 \text{ k}\Omega$$

$$R_T = 15 \text{ k}\Omega + 8.33 \text{ k}\Omega = 23.33 \text{ k}\Omega$$

$$V_2 = \frac{8.33 \text{ k}\Omega}{23.33 \text{ k}\Omega} * 25 \text{ V} = 8.93 \text{ V}$$

$$\begin{aligned} \% \text{ error} &= \left| \frac{\text{actual} - \text{measured}}{\text{actual}} \right| * 100\% \\ &= \left| \frac{10 \text{ V} - 8.93 \text{ V}}{10 \text{ V}} \right| * 100\% \\ &= 10.7\% \end{aligned}$$