

PHYSICS 171

Experiment 3

Kirchhoff's Laws

Equipment: Digital Multimeter, Power Supply (0-20 V.).

Supplies: Three resistors (Nominally: 1 Kilohm, 2 Kilohm, 3 Kilohm).

A. Kirchhoff's Loop Law

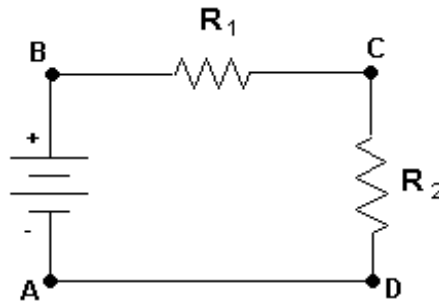
Suppose that a charged particle moves as shown below from point A to point B, then from point B to point C, and then from point C back to point A. Its potential energy will not have changed since it is back where it started.

Kirchhoff's loop law is an application of this idea: **The sum of voltage changes around a closed loop is zero.**

Symbolically, the potential changes for the path described are:

$$(V_B - V_A) + (V_C - V_B) + (V_A - V_C) = 0$$

As an example, consider a circuit consisting of a voltage source V and two resistors R_1 and R_2 in series.



Start from the negative side of the voltage source and traverse the circuit clockwise.

1. voltage gain $V_B - V_A = V$ (voltage of the source)
2. voltage loss $V_C - V_B = -IR_1$ (voltage drop across R_1)
3. voltage loss $V_A - V_C = -IR_2$ (voltage drop across R_2)

Kirchhoff's loop law states that

$$V - IR_1 - IR_2 = 0$$

Then

$$V = IR_1 + IR_2$$
$$V = I(R_1 + R_2)$$

The equivalent resistance of R_1 and R_2 in series is

$$V/I = R_1 + R_2 = R_s$$

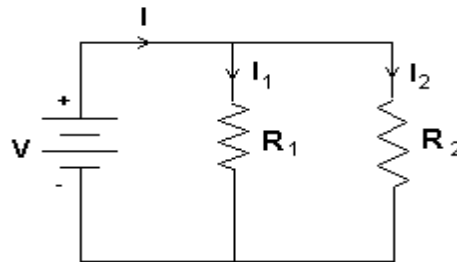
In general, if there are n resistors in series, then the equivalent resistance is given by

$$R_s = R_1 + R_2 + R_3 + \dots + R_n$$

B. Kirchhoff's Point Law

The conservation of electric charge, when applied to circuits, gives Kirchhoff's point of law: **The net current flowing into a junction equals the net current flowing out.**

As an example, consider a circuit consisting of a voltage source connected to two resistors in parallel.



Kirchhoff's current point states that:

$$I = I_1 + I_2$$

Kirchhoff's loop law applied to the two loops above states that

$$V = I_1R_1 \text{ and } V = I_2R_2$$

The equivalent resistance of R_1 and R_2 in parallel is

$$V/I = V/(I_1 + I_2) = 1/(1/R_1 + 1/R_2)$$
$$= (R_1R_2)/(R_1 + R_2) = R_p$$

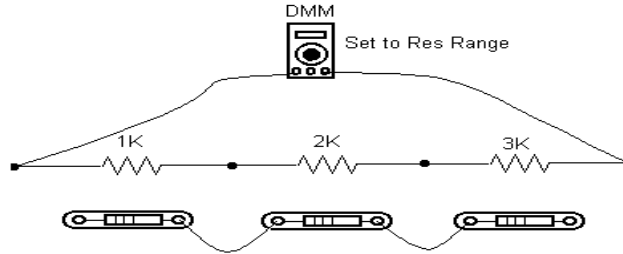
In general, if there are n resistors in parallel, then the equivalent resistance is given by

$$1/R_p = 1/R_1 + 1/R_2 + \dots + 1/R_n$$

Procedure - Experiment 2

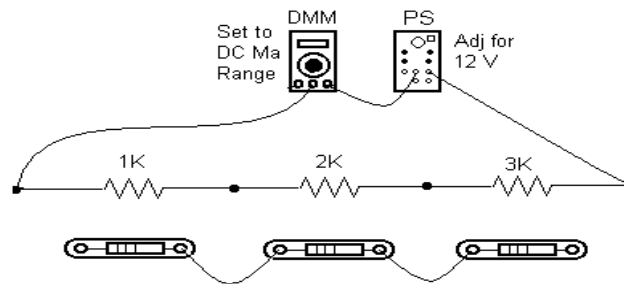
A. Resistors in Series

1. Measure the values of the three resistors using the digital ohmmeter.
2. Connect the three resistors in series, as shown.



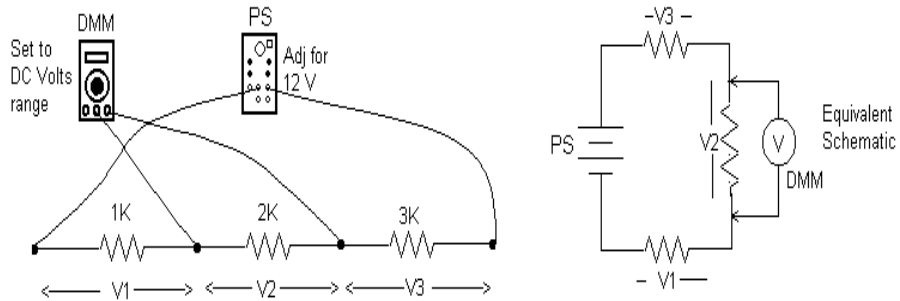
Measure the resistance of this series combination with the digital ohmmeter. Compare this measurement with the value computed from equivalent resistance equation for resistors in series.

3. Set up the circuit shown below and measure the current I. The power supply should be set to 12 volts.



Compute the resistance of the series combination of resistors from V/I .

4. Remove the digital milliammeter from the circuit and switch it to an appropriate voltage range. Measure the voltages V_1 , V_2 , V_3 across the three resistors. For example, the diagram below shows the measurement of V_2 .

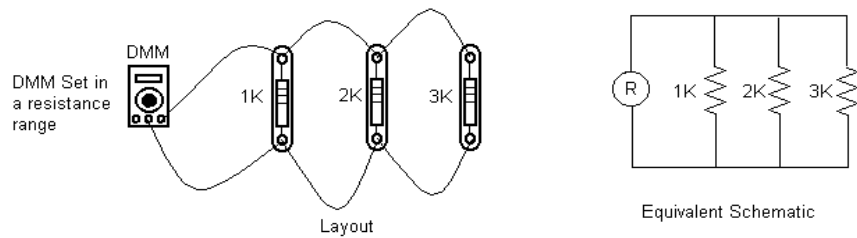


Verify Kirchoff's loop law: $V_1 + V_2 + V_3 = 12$ volts.

5. Compute the voltage drops across the three resistors by using the voltage divider equations:

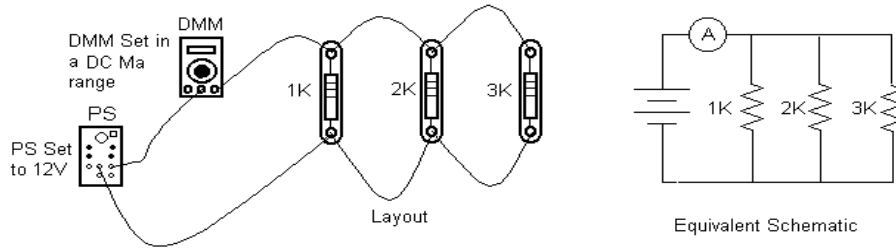
$$V_1 = 12 V(R_1/R_s) \quad V_2 = 12V(R_2/R_s) \quad V_3 = 12V(R_3/R_s)$$

- B. 1. Connect the three resistors in parallel, as shown.



Measure the resistance of this parallel combination with the digital ohmmeter. Compare this measurement with the value computed from the equivalent resistance equation for parallel resistors.

- Set up the circuit shown below and measure the total current I.



Compute the resistance of the parallel combination of resistors from V/I .
 Compute the resistance of the parallel combination of resistors from V/I .

- Put the digital milliammeter in each branch of the parallel resistor combination and measure the currents I_1 , I_2 , I_3 . Verify Kirchhoff's current law:

$$I_1 + I_2 + I_3 = I$$

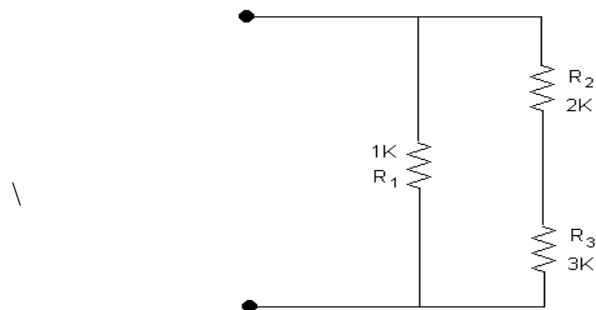
- Compute the three currents by using the current divider equations:

$$I_1 = I(R_p/R_1) \quad I_2 = I(R_p/R_2) \quad I_3 = I(R_p/R_3)$$

where R_p is the equivalent resistance of the parallel combination.

C. Resistors in a Series and Parallel Combination

- Connect the three resistors as shown below.

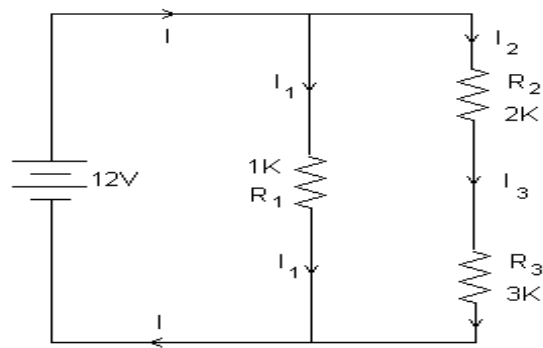


Measure the resistance of this combination with the digital ohmmeter. The equivalent resistance of this combination is given by:

$$1/R_{eq} = 1/R_1 + 1/(R_2+R_3)$$

Use this equation to compute R_{eq} and compare with the measured value.

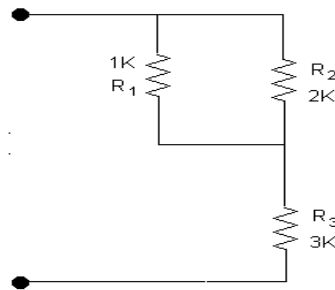
2. Set up the circuit shown below.



Compute the current delivered by the battery using $I = V/R_{eq}$.

Using the digital milliammeter measure I , I_1 , I_2 , and I_3 . Switch the meter to an appropriate voltage range and measure V_1 , V_2 , and V_3 .

3. Connect the three resistors as shown below.

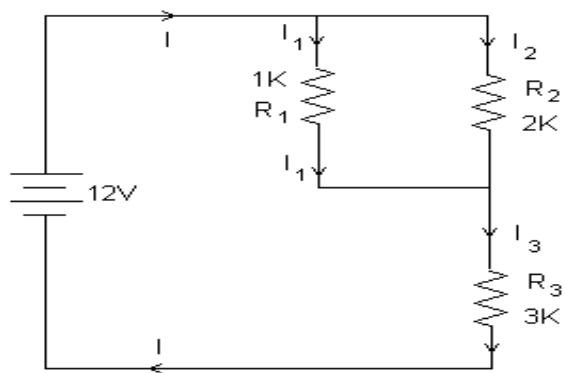


Measure the resistance of this combination with the digital ohmmeter. The equivalent resistance of this combination is given by:

$$R_{eq} = R_1 R_2 / (R_1 + R_2) + R_3$$

Use this equation to compute R_{eq} and compare with the measured value.

4. Set up the circuit shown below.



Compute the current delivered by the battery using $I = V/R_{eq}$.

Using the digital milliammeter measure I , I_1 , I_2 , and I_3 . Switch the meter to an appropriate voltage range and measure V_1 , V_2 , and V_3 .

A. Resistors in Series

1. Measured values of the three resistors

$R_1 = \text{_____ } k\Omega$ $R_2 = \text{_____ } k\Omega$ $R_3 = \text{_____ } k\Omega$

2. Measured value of the series combination

$R_s(\text{measured}) = \text{_____ } k\Omega$

3. Computed value of the series combination using V/I

$I = \text{_____ } mA.$ $(12 V.)/I = \text{_____ } k\Omega$

4. Measured values of V_1, V_2, V_3

$V_1 = \text{_____ } volts$ $V_2 = \text{_____ } volts$ $V_3 = \text{_____ } volts$

$V_1 + V_2 + V_3 = \text{_____ } volts$

5. Computed values of V_1, V_2, V_3

$V_1 = \text{_____ } volts$ $V_2 = \text{_____ } volts$ $V_3 = \text{_____ } volts$

B. Resistors in Parallel

1. Measured value of the parallel combination

$R_p(\text{measured}) = \text{_____ } k\Omega$

Computed value of the parallel combination

$R_p(\text{computed}) = \text{_____ } k\Omega$

2. Computed value of the parallel combination using V/I

$I = \text{_____ } mA.$ $(12 V.)/I = \text{_____ } k\Omega$

3. Measured values of I_1 , I_2 , I_3

$$I_1 = \text{_____ mA.} \quad I_2 = \text{_____ mA.} \quad I_3 = \text{_____ mA.}$$

$$I_1 + I_2 + I_3 = \text{_____ mA.}$$

4. Computed values of I_1 , I_2 , I_3

$$I_1 = \text{_____ mA.} \quad I_2 = \text{_____ mA.} \quad I_3 = \text{_____ mA.}$$

C. Resistors in a Series and Parallel Combination

1. Measured value of the combination

$$R_{\text{eq}} (\text{measured}) = \text{_____ k}\Omega$$

Computed value of the combination

$$R_{\text{eq}} (\text{computed}) = \text{_____ k}\Omega$$

2. Computed value of the current.

$$I = \text{_____ mA}$$

Measured values of I , I_1 , I_2 , I_3

$$I = \text{_____ mA} \quad I_1 = \text{_____ mA} \quad I_2 = \text{_____ mA} \quad I_3 = \text{_____ mA}$$

What relations do you see between these currents?

Measured values of V_1, V_2, V_3

$V_1 = \underline{\hspace{2cm}}$ Volts

$V_2 = \underline{\hspace{2cm}}$ Volts

$V_3 = \underline{\hspace{2cm}}$ Volts

What relations do you see between these voltages?

Would any readings change if R_1 and R_2 were interchanged?

3. Measured value of the combination

R_{eq} (measured) = $\underline{\hspace{2cm}}$ $k\Omega$

Computed value of the combination

R_{eq} (computed) = $\underline{\hspace{2cm}}$ $k\Omega$

4. Computed value of the current.

$I = \underline{\hspace{2cm}}$ mA

Measured values of I, I_1, I_2, I_3

$I = \underline{\hspace{2cm}}$ mA $I_1 = \underline{\hspace{2cm}}$ mA $I_2 = \underline{\hspace{2cm}}$ mA $I_3 = \underline{\hspace{2cm}}$ mA

What relations do you see between these currents?

Measured values of V_1 , V_2 , V_3

$V_1 =$ _____ Volts

$V_2 =$ _____ Volts

$V_3 =$ _____ Volts

What relations do you see between these voltages?

Would any readings change if R_1 and R_2 were interchanged?