GENERAL PHYSICS 2
2nd Semester - Module 4
CURRENT, RESISTANCE AND ELECTROMOTIVE FORCE
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What I Need to Know

This module will help you gain an understanding of current, resistance, and electromotive force. At the end of this module, you should be able to:

1. Distinguish between conventional current and electron flow
   STEM_GP12EM-IIIId-32
2. Apply the relationship charge = current x time to new situations or to
   solve related problems STEM_GP12EM-IIle-33
3. Describe the effect of temperature increase on the resistance of a metallic
   conductor STEM_GP12EM-IIle-35
4. Describe the ability of a material to conduct current in terms of
   resistivity and conductivity STEM_GP12EM-IIle-36
5. Apply the relationship of the proportionality between resistance and the
   length and cross-sectional area of a wire to solve problems
   STEM_GP12EM-IIle-37

What’s In

Have you seen the circuit board of a computer? It is composed of different components such as semiconductors, capacitors, and resistors where electric current flow and make the computers work. The computer is just one of the pieces of equipment students need these days especially with the distance learning modalities being implemented. It is a fact that we need various devices for a specific use or purpose to make our work easier, for our convenience, safety, and even comfort. Most of the equipment we have requires electricity. The flow of charges from one point to another has become too much involved in our practical lives.

Previously, we learned about the interaction of charges at rest and how these interactions produce phenomena that have entirely become essential in our daily activities. This time, we will be learning how these charges interact when they are in motion.

In the study of charges in motion, we will be dealing with circuits. Circuits are considered as the core element in communication, household appliances, power distribution grids, computers, and even in the nervous systems of living things. For this module, you will be able to describe the characteristics of conductors in terms of their resistivity and resistance.
Activity 1. How Much Do I Pay?

Objective: In this activity, you will determine the electrical energy consumption consumed by your household for the whole month.

Procedure:
1. Identify the appliances in your home and list them on the table.
2. Determine the power rating for each appliance. This is usually indicated in the seal at the back of the appliances.
3. Estimate the number of hours you are using this appliance in a month.
4. Calculate the energy consumed in each appliance and write the values in the table.
5. Calculate the energy cost per appliance using the cost of 1 kWh in your locality. You may ask your parent/guardian or check your electric bill.

<table>
<thead>
<tr>
<th>Appliances</th>
<th>Power Rating (W)</th>
<th>Number of hours used for the whole month (h)</th>
<th>Electrical energy consumed (P x h)</th>
<th>Energy Cost (pesos) (Electrical Energy consumed x cost per kWh)</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

(1)How much energy did you consume in a month? Is this consistent with the energy reflected in your electric bill for the month? If not, what do you think is the reason/s for the observed inconsistencies?

___________________________________________________

_____________________________________________________________________________
(2) What is the estimated cost of the use of this energy? Is this consistent with your electric bill for the month? If not, what do you think is the reason/s for inconsistencies?

(3) What would be your plans to reduce the energy consumption for the whole month? Complete the table below.

<table>
<thead>
<tr>
<th>Current Situation</th>
<th>Action Plan to Reduce the Electrical Energy Consumption</th>
<th>Expected Outcome (expected energy consumption and cost reduction)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Show this plan to your parents/guardian/household members and let them reflect on the next actions to be taken.

**What Is It**

**Current**

Current is the motion of charges from one point to another point in a conductor. When charges are at rest, the electric field at any point is zero. In ensuring a steady movement of electric charges, we need to have a constant force for these charges to move around the conductors. Suppose an electric field is present within the conductor, charge \( q \) experiences a force \( F = qE \).
Let us consider a cross-sectional area of a conductor as shown in figure 1.

![Figure 1](https://courses.lumenlearning.com/physics/chapter/20-1-current/)

**Figure 1. The moving charges passing through a cross-sectional area at a given time.**
*Image Source: https://courses.lumenlearning.com/physics/chapter/20-1-current/

We will define the current as the net charge flowing through the chosen area. Current is expressed as:

$$I = \frac{\Delta Q}{\Delta t}$$

where $I$ is current expressed as $\frac{C}{s}$ or Amperes (A), $\Delta Q$ is the net charge expressed as Coulombs (C) and $\Delta t$ is time expressed in seconds (s). The current flowing in radios and televisions is expressed as milliamperes, microamperes, or picoamperes.

When charges move in the conductor, it accelerates due to the presence of an electric field. It collides with other charges and transfers the kinetic energy to anything it collides with. This produces back-and-forth motion which causes random motion. Hence, it increases the temperature of the conductors.

![Figure 2](https://www.saburchill.com/physics/chapters/0037.html)

**Figure 2. The random motion of electric charges as they collide with other particles increases the random motion and the temperature of the conductor.**
*Image Source: https://www.saburchill.com/physics/chapters/0037.html

The current in the chosen cross-sectional area can also be expressed in terms of its drift velocity $\mathbf{v}$ of moving charges. Based on figure 3, the electric field is from left to right, there are $n$ particles within the cross-sectional area, the charges are positive $q$ and moving with drift velocity $\mathbf{v}$. 


The drift velocity of the charges has a magnitude of distance/time. The volume is given by the product of its cross-sectional area and the distance it traveled at some time.

In every time $\Delta t$, particles move at some distance $d = v\Delta t$. The volume of the cylinder is $Ad = Av\Delta t$ and the number of particles in the section is $nAv\Delta t$. Thus,

$$I = \frac{\Delta Q}{\Delta t} = \frac{nAv\Delta t}{\Delta t} \rightarrow I = nAv\Delta t$$

We can also express the current density $J$ in terms of current per unit area.

$$J = \frac{I}{A} = nv$$

Does this hold true for negatively charged particles? As shown in figure 4, the direction of the current is opposite to the direction of the charges. In this case, drift velocity is from right to left which is also opposite to the electric field. Still, the current moves in the same direction when positive charges travel in the conductor.

Moving charges of metals are always negative, both electrons and positively charged particles for ionized gas and plasma and electrons with a motion of vacancies which act as positive charges for semiconductors.
Example 1:
Find the current density and drift velocity of free electrons when the particles travel on a copper conductor with a square cross-section of 1.0 mm on the side and carries a current of 20 A to a 3 hp electric meter and its density of $8.0 \times 10^{28}$ electrons/m$^3$.

A What is/are given?
- $s = 1.0$ mm
- $I = 20$ A
- $n = 8.0 \times 10^{28}$ e$^-$/m$^3$

B What is asked?
- (a) $J =$ ?
- (b) $v =$ ?

C Are the units consistent with the formula?
- No, side must be converted from mm to m
- Thus, $1.0 \text{ mm} = 1.0 \times 10^{-3}$ m.

D What strategy must be employed?
- We use the formula for current density and solve for variable $v$ from $J = nqv$

E Solution

\[
(a) J = \frac{I}{s^2} = \frac{20 \text{ A}}{(1 \times 10^{-3} \text{ m})^2} = \frac{20 \text{ A}}{1 \times 10^{-9} \text{ m}^2} = 2 \times 10^6 \frac{\text{A}}{\text{m}^2}
\]

\[
(b) v = \frac{J}{nq} = \frac{2 \times 10^6 \frac{\text{A}}{\text{m}^2}}{8 \times 10^{-28} \text{e}/\text{m}^3} = 2.5 \times 10^{33} \frac{\text{A}}{\text{m}^3} \frac{\text{m}^3}{\text{e}} = 2.5 \times 10^{33} \frac{\text{C} \text{m}}{\text{s} \text{e}} = 2.5 \times 10^{33} \frac{\text{m}}{\text{s}}
\]

G What is the conclusion?
- Therefore, the current density is $2 \times 10^6$ A/m$^2$ while the drift velocity of the charges is $2.5 \times 10^{33}$ m/s

Resistivity
Since current density relies on the electric field $E$ and properties of a material, sometimes $J$ becomes directly proportional to the electric field. Thus, the ratio of $E$ to $J$ remains constant. We define this ratio as the resistivity of the material. The greater the resistivity, the greater the electric field needed to produce a current density. This is expressed as:

\[
\rho = \frac{E}{J}
\]

Table 1 shows the resistivities at room temperature.

<table>
<thead>
<tr>
<th>Substances</th>
<th>$\rho$, $\Omega$m</th>
<th>Substances</th>
<th>$\rho$, $\Omega$m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver</td>
<td>$1.47 \times 10^{-8}$</td>
<td>Carbon</td>
<td>$x \times 10^{-8}$</td>
</tr>
<tr>
<td>Copper</td>
<td>$1.72 \times 10^{-8}$</td>
<td>Germanium</td>
<td>0.60</td>
</tr>
<tr>
<td>Gold</td>
<td>$2.44 \times 10^{-8}$</td>
<td>Silicon</td>
<td>2300</td>
</tr>
<tr>
<td>Aluminum</td>
<td>$2.63 \times 10^{-8}$</td>
<td>Amber</td>
<td>$5 \times 10^{14}$</td>
</tr>
<tr>
<td>Tungsten</td>
<td>$5.51 \times 10^{-8}$</td>
<td>Glass</td>
<td>$10^{10} - 10^{14}$</td>
</tr>
<tr>
<td>Steel</td>
<td>$20 \times 10^{-8}$</td>
<td>Lucite</td>
<td>$&gt;10^{15}$</td>
</tr>
<tr>
<td>Lead</td>
<td>$22 \times 10^{-8}$</td>
<td>Mica</td>
<td>$10^{11} - 10^{15}$</td>
</tr>
<tr>
<td>Mercury</td>
<td>$95 \times 10^{-8}$</td>
<td>Quartz</td>
<td>$75 \times 10^{16}$</td>
</tr>
<tr>
<td>Manganin</td>
<td>$44 \times 10^{-8}$</td>
<td>Sulfur</td>
<td>$10^{15}$</td>
</tr>
<tr>
<td>Constantan</td>
<td>$49 \times 10^{-8}$</td>
<td>Reflon</td>
<td>$&gt;10^{15}$</td>
</tr>
<tr>
<td>Nichrome</td>
<td>$100 \times 10^{-8}$</td>
<td>Wood</td>
<td>$10^{8} - 10^{11}$</td>
</tr>
</tbody>
</table>

Source: Sears, F., Zemansky, M. and Young, H. College Physics 7th Edition
From the table, a perfect conductor has “zero” resistivity while a perfect insulator has an “infinitive resistivity”. Metals and alloys have the lowest resistance and are considered as best conductors while insulators have greater values by an enormous factor.

Good electrical conductors are usually good conductors of heat. On the other hand, poor electrical conductors are poor thermal conductors. Semiconductors have resistivities that are in the middle between metals and insulators. These components are very important since they are affected by the temperature and by impurities.

The proportionality of density and electric field obeys Ohm’s law ($V = IR$). There will be an in-depth application for this law in the succeeding module. A material is said to be an ohmic or linear conductor. The resistivity of the conductors increases with the temperature. This is represented approximately by:

$$\rho_T = \rho_0[1 + \alpha(T - T_0)]$$

where $\rho_0$ is the resistivity at a reference temperature $T_0$ (0°C or 20°C), $\rho_T$ is the resistivity at temperature $T$ and $\alpha$ is the temperature coefficient of resistivity. Table 2 shows the temperature coefficients of resistivity near room temperature.

<table>
<thead>
<tr>
<th>Material</th>
<th>$\alpha$, C°⁻¹</th>
<th>Material</th>
<th>$\alpha$, C°⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>0.0039</td>
<td>Lead</td>
<td>0.0043</td>
</tr>
<tr>
<td>Brass</td>
<td>0.0020</td>
<td>Manganin</td>
<td>0.00000000</td>
</tr>
<tr>
<td>Carbon</td>
<td>-0.0005</td>
<td>Mercury</td>
<td>0.000088</td>
</tr>
<tr>
<td>Constantan</td>
<td>+0.000002</td>
<td>Nichrome</td>
<td>0.0004</td>
</tr>
<tr>
<td>Copper</td>
<td>0.00393</td>
<td>Silver</td>
<td>0.0038</td>
</tr>
<tr>
<td>Iron</td>
<td>0.0050</td>
<td>Tungsten</td>
<td>0.0045</td>
</tr>
</tbody>
</table>

Source: Sears, F., Zemansky, M., and Young, H. College Physics 7th Edition

The negative value of carbon (nonmetal) shows that when the temperature increases, the resistivity decreases.

Figure 5 shows the comparison of the resistivity of metals, superconductors, and semiconductors. As shown in the graph, the resistivity of metals increases as temperature increases. Metallic conductors would always decrease their resistivity when the temperature decreases. For semiconductors, the resistivity decreases sharply with the increasing temperature while superconductors have a decreasing resistivity when the temperature decreases. However, at some transition temperatures known as $T_c$, the resistivity suddenly drops to zero.
Figure 5. The variation of resistivity with respect to temperature for metals, superconductors, and semiconductors.

Image source: https://pilgaard.info/Conductivity/ConductivityResistivity.htm

**Resistance**

Suppose our conductor is a wire with cross-sectional area $A$ and length $l$ as shown in the figure below. The total current is $I = JA$ and the potential difference is $V = EI$ (recall $V = Ed$ from the previous module). If $J$ and $E$ are uniform throughout the conductor, then

$$E = \rho J$$

$$\frac{V}{l} = \frac{\rho l}{A}$$

$$V = \frac{\rho ll}{A}$$

$$\frac{V}{I} = \frac{\rho l}{A}$$

Based on Ohm’s law, $V = IR$

$$R = \frac{\rho l}{A}$$

where $R$ is the resistance expressed in Ohms (Ω) or $\frac{V}{A}$. This should not be confused with resistivity since its SI unit is $\Omega\cdot m$.

Since resistivity varies with temperature, the resistance of the material also varies with the temperature. This is expressed as:

$$R_T = R_0[1 + \alpha(T - T_0)]$$

Where $R_0$ is the resistance at a reference temperature $T_0$ (0°C or 20°C), $R_T$ is the resistance at temperature $T$ and $\alpha$ is the temperature coefficient of resistivity. Table 2 shows the temperature coefficients of resistivity near room temperature.
Devices with a certain value of resistance are called a resistor. The resistors are usually marked with standard codes using three- or four-color bands. The first two bands are two digits and the third digit is a power of 10 multipliers. The fourth band is the precision value. If it has no fourth band, then it means it has a precision value of ± 20%. If the fourth band is silver, its precision is ± 10% and a gold band is ± 5%.

![Image of resistor bands](https://www.circuitbasics.com/what-is-a-resistor/)

**Figure 6. The four bands of a resistor representing its standard code.**

Table 3 shows the resistor codes.

<table>
<thead>
<tr>
<th>Colors</th>
<th>Digits</th>
<th>Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
<td>$10^0$</td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
<td>$10^1$</td>
</tr>
<tr>
<td>Red</td>
<td>2</td>
<td>$10^2$</td>
</tr>
<tr>
<td>Orange</td>
<td>3</td>
<td>$10^3$</td>
</tr>
<tr>
<td>Yellow</td>
<td>4</td>
<td>$10^4$</td>
</tr>
<tr>
<td>Green</td>
<td>5</td>
<td>$10^5$</td>
</tr>
<tr>
<td>Blue</td>
<td>6</td>
<td>$10^6$</td>
</tr>
<tr>
<td>Violet</td>
<td>7</td>
<td>$10^7$</td>
</tr>
<tr>
<td>Gray</td>
<td>8</td>
<td>$10^8$</td>
</tr>
<tr>
<td>White</td>
<td>9</td>
<td>$10^9$</td>
</tr>
</tbody>
</table>

Source: Sears, F., Zemansky, M., and Young, H. College Physics 7th Edition

You may also use this mnemonic to recall the sequence of colors:

**Big Boys Run Over Young Girls But Violeta Gave Way**

The significant role of a resistor is the highest power it can dissipate without damaging the other components or devices. Figure 6 shows an example of a resistor.
The graph of \((a)\) resistor following Ohm’s law is shown in the diagram below. The figure also compares the behavior of \((b)\) vacuum diode and \((c)\) semiconductor diode.

**Figure 6. Current-Voltage Relationship in Resistor, Vacuum Diode and Superconductor Diodes**

**Example 2:**
Suppose the resistance is 1.72 Ω at a temperature of 20°. Find the resistance at 0 and 100 degrees Celsius.

<table>
<thead>
<tr>
<th></th>
<th>What is/are given?</th>
<th>R = 1.72 Ω; (T_0) = 20°C; (T = 0°C) and 100°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>What is asked?</td>
<td>((a)) R at 0°C and 100°C</td>
</tr>
<tr>
<td>B</td>
<td>Are the units</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>consistent with the</td>
<td>formula?</td>
</tr>
<tr>
<td>C</td>
<td>What strategy must</td>
<td>We use the resistance formula expressed in terms</td>
</tr>
<tr>
<td></td>
<td>be employed?</td>
<td>of temperature.</td>
</tr>
</tbody>
</table>
Solution

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>(a)</td>
<td>( R_T = R_0[1 + \alpha(T - T_0)] = (1.72\Omega)[1 + \left(\frac{0.00393}{°C}\right)(0°C - 20°C)] = 1.58\ \Omega )</td>
</tr>
<tr>
<td>(b)</td>
<td>( R_T = R_0[1 + \alpha(T - T_0)] = (1.72\Omega)[1 + \left(\frac{0.00393}{°C}\right)(100°C - 20°C)] = 2.26\ \Omega )</td>
</tr>
</tbody>
</table>

What is the conclusion?

Therefore, the resistance is 1.58 Ω at 0°C and 2.26 Ω at 100°C

**Electromotive Force and Circuits**

To have a steady current in a circuit, the path should form a closed path or loop called a complete circuit. However, to complete the path we need the presence of decreasing potential energy since charges move towards this direction. Aside from decreasing potential energy, there should also be increasing potential energy.

This is similar to water fountains. When the fountain releases the water at the top, the water goes down the terraces and is collected at the bottom. Using a pump, the water is lifted back to the top for another cycle. The absence of a pump would make it difficult for the water to complete the cycle.

In a circuit, the electromotive force (emf) influences the “pushing” of charges from lower to a higher potential. This influence is called electromotive force abbreviated as emf is denoted as \( \varepsilon \). The sources of emf are batteries, generators, solar cells, and fuel cells. The ideal source of emf could maintain the difference of electric potential in opposite terminals.

The schematic diagram shows the source of emf with a potential difference in points \( a \) and \( b \). We call these points terminals. Terminal \( a \) has a plus sign which implies higher potential compared to potential in terminal \( b \). An electric field is produced inside the source. A force is produced in pushing charges from points \( b \) to \( a \) and points \( a \) to \( b \).

The potential difference is equal to the electromotive force:

\[ V_{ab} = \varepsilon \]

The SI unit of emf and the potential difference is Volts (V) or \( \frac{V}{C} \).
When a resistor is connected to the circuit, the terminals of the source produce an electric field causing the current to flow from points \( a \) to \( b \). This is expressed as:

\[
V_{ab} = \varepsilon = IR
\]

Real sources have different behavior from ideal sources. They encounter internal resistance within the source denoted by \( r \). If this behaves according to Ohm’s law, then we can express it under complete circuit conditions:

\[
V_{ab} = \varepsilon - IR
\]

\[
IR = \varepsilon - Ir
\]

\[
I = \frac{\varepsilon}{R + r}
\]

The current is equal to the source \( \text{emf} \) divided by the total circuit resistance (from the resistor and the real source).

**Example 3:**
A D cell of emf 1.5 V and internal resistance of 0.3 \( \Omega \) is connected to a flashlight which resistance is 3.0 \( \Omega \). Find the current in the circuit and the terminal voltage of the cell.

<table>
<thead>
<tr>
<th>A</th>
<th>What is/are given?</th>
<th>R = 3.00 ( \Omega ); r = 0.3 ( \Omega ) ( \varepsilon )=1.5 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>What is asked?</td>
<td>(a) I = ?  (b) V = ?</td>
</tr>
<tr>
<td>C</td>
<td>Are the units</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>consistent with the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>formula?</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>What strategy must</td>
<td>We use the current formula in terms of resistance</td>
</tr>
<tr>
<td></td>
<td>be employed?</td>
<td>and emf and the potential difference formula</td>
</tr>
<tr>
<td>F</td>
<td>Solution</td>
<td></td>
</tr>
</tbody>
</table>
What is the conclusion?

Therefore, the current is 0.45 A and the terminal voltage is 1.4 V.

**Circuit Diagrams**

In studying circuits, we use symbols and diagrams to represent the components.

- **Resistor**

- **Source of emf**
  - The longer vertical line means a positive terminal while a shorter vertical line means a negative terminal.

- **Ammeter**
  - Reads the current in the circuit.

- **Voltmeter**
  - Reads the voltage drops in the circuit.

- **Switch**
  - Closes or opens the circuit.

**Energy and Power in a Circuit**

The work done on the charge passing through the conductor is expressed as:

\[ W = V_{ab} \Delta Q = V_{ab} I \Delta t \]

The time rate of energy transfer is known as power, denoted by P.

\[ \frac{W}{\Delta t} = \frac{V_{ab} I \Delta t}{\Delta t} = V_{ab} I = P \]
Power is expressed as $\frac{I^2}{R}$ or Watt (W). Determining power includes (1) pure resistance and (2) power output of the source and (3) power input to a source.

1. For pure resistance, $P = V_{ab}I = I^2R = \frac{V_{ab}^2}{R} \rightarrow P = \frac{V_{ab}^2}{R}$
2. For power outputs of a source, $P = V_{ab}I = (\varepsilon - Ir)I = \varepsilon I - I^2r \rightarrow P = \varepsilon I - I^2r$
3. For power input to a source, $P = V_{ab}I = \varepsilon I + I^2r \rightarrow P = \varepsilon I + I^2r$

**Example 4:**
What is the rate of energy conversion and dissipation in the battery, net power output if the battery has an emf of 12 V, a current of 2 A, resistance of 4Ω and internal resistance of 2Ω?

<table>
<thead>
<tr>
<th>A</th>
<th>What is/are given?</th>
<th>$R = 4 , \Omega$; $r = 2 , \Omega$; $\varepsilon = 12 , V$; $I = 2 , A$</th>
</tr>
</thead>
</table>
| B | What is asked?   | (a) Energy conversion =?  
(b) Dissipation of energy =?  
(c) Electrical power output =? |
| C | Are the units consistent with the formula? | Yes |
| D | What strategy must be employed? | We use the formula for power |
| E | Solution        | 

\[
(a) P = I\varepsilon = (2A)(12 \, V) = 24 \, W  
(b) P = I^2R = (2A)^2(2\Omega) = 8 \, W  
(C) Power Output = 1V - I\varepsilon = 24 \, W - 8 \, W = 16 \, W  
\]

\[
\text{Therefore, the power for energy conversion is } 24 \, W, \text{ the power for energy dissipation is } 8 \, W \text{ and the net power output is } 16 \, W. 
\]

**Physiological Effects of Currents**

Table 4 below shows the effects of current to our body.

<table>
<thead>
<tr>
<th>Current (mA)</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Threshold</td>
</tr>
<tr>
<td>5</td>
<td>Harmless current</td>
</tr>
<tr>
<td>10–20</td>
<td>Muscular contraction and difficulty of breathing</td>
</tr>
<tr>
<td>50</td>
<td>Onset of pain</td>
</tr>
<tr>
<td>100–300+</td>
<td>Fibrillation</td>
</tr>
<tr>
<td>300</td>
<td>Burns</td>
</tr>
<tr>
<td>6000 (6 A)</td>
<td>Contraction and paralysis in respiratory system.</td>
</tr>
</tbody>
</table>

Activity 2: Qualitative Problems

Direction: Answer the following questions.

(1) Good thermal conductors are said to be good electrical conductors. If so, why is it that cords used to connect toasters, irons, and heat-producing appliances get hot by the conduction of heat from the heating element?

_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

(2) How would you expect the resistivity of a good insulator such as glass or polystyrene to vary with temperature?

_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

(3) A fuse is a device that is designed to break the circuit. It melts when the current exceeds its value. What characteristics should the material have?

_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
What I Have Learned

Activity 3: Quantitative Problem

**Direction:** Solve the problem as directed. Write your answers on a separate sheet of paper. You may also consult your Physics teacher.

(1) A silver wire 1.00 mm in diameter transfers a charge of 65.0 C in 1 hr. 15.0 min. Silver contains \(5.0 \times 10^{28}\) electrons per cubic meter. What is the current in the wire? What is the magnitude of the drift velocity of the electrons in the wire?

(2) An aluminum wire carrying a current has a diameter of 0.600 mm. The electric field in the wire is 0.640 V/m. What is the current carried by the wire? What is the potential difference between two points if the wires are 12.0 m apart? What is the resistance of a 12.0 m length of wire?

(3) The following measurements were made on a Thyrite resistor:

<table>
<thead>
<tr>
<th>Current</th>
<th>Potential Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.50</td>
<td>4.76</td>
</tr>
<tr>
<td>1.00</td>
<td>5.81</td>
</tr>
<tr>
<td>2.00</td>
<td>7.05</td>
</tr>
<tr>
<td>4.00</td>
<td>8.56</td>
</tr>
</tbody>
</table>

Make a graph of \(V_{ab}\) as a function of current. Does it obey Ohm’s law?

<table>
<thead>
<tr>
<th>Criteria</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics Approach</td>
<td>The approach is appropriate and complete</td>
<td>The approach contains minor errors</td>
<td>Some of the concepts and principles are missing or inappropriate</td>
<td>The solution doesn’t indicate an approach</td>
</tr>
<tr>
<td>Procedure</td>
<td>Mathematical and logical procedures are clear, complete, and connected</td>
<td>Mathematical and logical procedures are missing/contain errors</td>
<td>Most of the mathematical and logical procedures</td>
<td>All procedures are incomplete and contain errors</td>
</tr>
<tr>
<td>Description</td>
<td>Diagrams and symbols used are appropriate and complete</td>
<td>Parts of the diagrams and symbols contain errors</td>
<td>Most of the parts of the diagrams and symbols are not useful</td>
<td>The entire visualization is wrong or did not include visualization.</td>
</tr>
</tbody>
</table>
What I Can Do

Activity 4. Building Concept Map

**Direction:** Create a concept map out to demonstrate what you have learned from this module. You can use words, terms, phrases, or formulas in connecting the concepts. Refer to the scoring guide below:

<table>
<thead>
<tr>
<th>Legible (easy to read)</th>
<th>No (0-1)</th>
<th>Yes (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accurate (concepts were used accurately)</td>
<td>Many inaccuracies (0-2)</td>
<td>A few inaccuracies (3-4)</td>
</tr>
<tr>
<td>Complete (sufficient number of relevant concepts and relationships)</td>
<td>Limited use of concepts (0-2)</td>
<td>Some use of concepts (3-4)</td>
</tr>
<tr>
<td>Sophisticated (finding meaningful connections between relevant concepts)</td>
<td>Little or none (0-1)</td>
<td>Few meaningful connections made (2-4)</td>
</tr>
</tbody>
</table>

Mueller’s Classroom Concept Rubric

**Assessment**

**Direction:** Write the letter of your choice in the space provided.

____ 1. The resistance of a conductor is **not** dependent with
   a. mass
   b. area
   c. length
   d. resistivity

____ 2. A certain wire has a resistance $R$. The resistance of the other wire having twice its diameter is
   a. $\frac{1}{4}R$
   b. $2R$
   c. $\frac{1}{2}R$
   d. $4R$
3. Which of the combinations of length and area will cause the volume of copper to have the least resistance?
   a. L and A
   b. 2L and $\frac{1}{2}A$
   c. $\frac{1}{2}L$ and 2 A
   d. volume remains the same

4. The temperature of wire made from copper is increased. The resistance
   a. remains the same
   b. decreases
   c. increases
   d. depends on the temperature involved

5. Which of the following units is not equivalent to watt?
   a. $\frac{J}{s}$
   b. $A^2\Omega$
   c. AV
   d. $\frac{V^2}{A}$

6. A 200 mm length of copper wire has a resistance of 2.0 $\Omega$. The cross-sectional area is
   a. 0.0017 m$^2$
   b. 3.4 mm$^2$
   c. 1.7 mm$^2$
   d. 5.3 mm$^2$

7. An electric heater draws a current of 20 A when connected to a 120 V power source. The resistance is
   a. 0.17 $\Omega$
   b. 6 $\Omega$
   c. 8 $\Omega$
   d. 2400 $\Omega$

8. The 8.0 $\Omega$ coil of a loudspeaker carries a current of 0.80 A. The potential difference across the terminals is
   a. 5.2 V
   b. 2.3 V
   c. 6.4 V
   d. 11 V

9. When a 100 W, 240 V light bulb was operated at 200 V, the current flowing is
   a. 0.35 A
   b. 0.75 A
   c. 0.90 A
   d. 0.10 A
10. The energy content of a fully charged 12 V battery of capacity 50 A-h is
   a. 100 J  
   b. 3600 J  
   c. 0.78 J  
   d. 2.2 MJ

11. A battery of emf and internal resistance is connected to the resistance R. If R = r,
   a. there is a low current  
   b. there is a higher current  
   c. the power dissipated is lower  
   d. the power dissipated is higher

12. A battery is connected to the external circuit. The potential drop within the battery is directly proportional with
   a. emf of the battery  
   b. equivalent resistance of circuit  
   c. current in circuit  
   d. power distributed in circuit

13. What is the effect on the current in a simple circuit if both voltage and resistance are reduced by half?
   a. halved  
   b. stays the same  
   c. doubles  
   d. quadruples

14. If the switch in the figure below is open, the reading of voltmeter is ___.
   a. terminal voltage  
   b. EMF  
   c. current  
   d. power

15. Which of the following represents the current-voltage relation of a solid conductor at room temperature?
   a. 
   b. 
   c. 
   d. 

  [Diagram of a simple circuit with a battery, lamp, and switch]
Additional Activities

Activity 5. Social Context

Direction: The community is a rich source of learning opportunities of sources of magnetic forces and fields. Choose one from the following suggested activities in understanding the importance and utilization of electric potential in our daily lives:

1. Conduct simulations on electric current, resistance, and electromotive force. From this, write a short reflection. Scan the QR code to gain access to the simulations.
2. Ask an electrician or any household member who has experience in fixing electrical circuits in your home or appliances. Ask him the important reminders one should observe when dealing with electric circuits or appliances at home. From this, create simple infographics using pen and paper or coloring materials. You may also choose software that can help you prepare the infographics.
3. The Department of Energy is launching a campaign on how to become a responsible consumer. They have provided energy label guides that aim to identify the appliance’s energy efficiency ratio. Using the guide (shown below), consumers must choose appliances with higher EER which implies a lower cost of energy consumption. Check the appliances in your home and see if these stickers are available. Write a reflection on this activity.

Image Source:
Answer Key General Physics 2 Module 4

| 15°C | 10.1°C | 23°C |
| 14°F | 9.1°F | 4°F  |
| 13°F | 8°C  | 3°C  |
| 12°F | 7°C  | 2°C  |
| 11°F | 6°C  | 1.4°C|

Assessment
3. No
2. 12.2 A; 7.68 V; 0.628 Ω
1. 0.0144 A; 1.98 x 10⁻⁶ m/s

Activity 3: Quantitative Problems
3. How much point, higher resistance, 2. The resistivity decreases as the temperature increases.

Activity 2: Qualitative Problems
1. Heat is already dispersed in air when it reaches the device.

References

Printed Resources

Online References
Region IX: Zamboanga Peninsula Hymn – Our Eden Land

Here the trees and flowers bloom
Galant men And Ladies fair
Linger with love and care
Golden beams of sunrise and sunset
Are visions you’ll never forget
Oh! That’s Region IX
The liberty forever Stayed,
Here the Badjaos roam the seas
Hardworking people Abound,
Every valleys and Dale
Zamboangueños, Tagalogs, Bicolanos.

Cebuanos, Ilongos, Subanons, Boholanos, Ilongos,
All of them are proud and true
Region IX our Eden Land
Region IX
Our...
Eden...
Land...

My Final Farewell

Let the sun draw the vapors up to the sky,
And heavenward in purity bear my tardy protest
Let some kind soul o’er my untimely fate sigh,
And in the still evening a prayer be lifted on high
From thee, O my country, that in God I may rest.
Pray for all those that hapless have died,
For all who have suffered the unmeasured pain;
For our mothers that bitterly their woes have cried,
For widows and orphans, for captives by torture tormented
And then for thyself that redemption thou mayest gain
And when the dark night wraps the graveyard around
With only the dead in their vigil to see
Break not my repose or the mystery profound
And perchance thou mayest hear a sad hymn resound
’Tis I, 0 my country, raising a song unto thee.
And even my grave is remembered no more
Unmarked’by a cross nor a stone
Let the plow sweep through it, the spade turn it o’er
That my ashes may carpet earthly floor,
Before into nothingness at last they are blown.
Then will oblivion bring to me no care
As over thy vales and plains I sweep;
Throbbing and cleansed in thy space and air
With color and light, with song and lament I fare,
Ever repeating the faith that I keep.

My Fatherland ador’d, that sadness to my sorrow lends
Beloved Filipinas, hear now my last good-bye!
I give thee all: parents and kindred and friends
For I go where no slave before the oppressor kneels.
Where faith can never kill, and God reigns e’er on high!

Farewell to you all, from my soul torn away,
Friends in the home dispossessed!
Give thanks that I rest from the wearisome day!
Farewell to thee, too, sweet friend that lightened my way;
Beloved creatures all, farewell! In death there is rest!

I Am a Filipino, by Carlos P. Romulo

I am a Filipino-inheritor of a glorious past, hostage to the uncertain future. As such I must prove equal to a two-fold task—the task of meeting my responsibility to the past, and the task of performing my obligation to the future.

I sprang from a hardy race, child many generations removed of ancient Malayans. Across the centuries the memory comes rushing back to me: of brown-skinned men putting out to sea in ships that were frail as their hearts were stout. Over the sea I see them come, borne upon the billowing wave and the whispering wind, carried upon the mighty swell of hope—hope in the free abundance of new land that was to be their home and their children’s forever.

I am a Filipino. In my blood runs the immortal seed of heroes—seed that flowered down the centuries in deeds of courage and defiance.

In my veins yet pulses the same hot blood that sent Lapulapu to battle against the first invader of this land, that stirred Lakandula in the combat against the alien foe, that drove Diego Silang and Dagohoy into rebellion against the foreign oppressor.

The seed I bear within me is an immortal seed. It is the mark of my manhood, the symbol of dignity as a human being. Like the seeds that were once buried in the tomb of Tutankhamen many thousand years ago, it shall grow and flower and bear fruit again. It is the insignia of my race, and my generation is but a stage in the unending search of my people for freedom and happiness.

I am a Filipino, child of the marriage of the East and the West. The East, with its languor and mysticism, its passivity and endurance, was my mother, and my sire was the West that came thundering across the seas with the Cross and Sword and the Machine. I am of the East, an eager participant in its spirit, and in its struggles for liberation from the imperialist yoke. But I also know that the East must awake from its centuries sleep, shake off the lethargy that has bound his limbs, and start moving where destiny awaits.

I am a Filipino, and this is my inheritance. What pledge shall I give that I may prove worthy of my inheritance? I shall give the pledge that has come ringing down the corridors of the centuries, and it shall be compounded of the joyous cries of my Malayans forebears when first they saw the contours of this land loom before their eyes, of the battle cries that have resounded in every field of combat from Maanta to Tiral Pass, of the voices of my people when they sing:

“I am a Filipino born to freedom, and I shall not rest until freedom shall have been added unto my inheritance—for myself and my children and my children’s children—forever.”