Math Skills Laboratory

Lab 4 MS 3

MATH ACTIVITIES

Activity 1:** **Rearranging Symbols in Resistance Equations to Isolate Certain Unknowns

Activity 2:** **Solving Electrical Resistance Problems

MATH SKILLS LAB OBJECTIVES

When you've completed these activities, you should be able to do the following:

1. ***Isolate the change in voltage (ΔV), or the current (I), by rearranging Ohm's law given in the form, $R_E = \Delta V/I$.***
2. ***Isolate the resistivity (ρ), the length of the wire (ℓ), or the cross-sectional area (A), by rearranging the equation, $R_E = \rho\ell/A$.***
3. ***Find the resistance of a resistor using a table of resistor color codes.***
4. ***Substitute correct numerical values and units in resistance equations. Solve the equations for a numerical value with the proper units.***

LEARNING PATH

1. ***Read the Math Skills Lab. Give particular attention to the Math Skills Lab Objectives.***
2. ***Study the equations.***
3. ***Work the problems for Activities 1 and 2.***

ACTIVITY 1

Rearranging Symbols in Resistance Equations To Isolate Certain Unknowns

MATERIALS

For this activity, you'll need pencil and paper.

From previous math labs, you know that equations and formulas express a relationship between several physical quantities. Equation 1 shows the relationship between (1) electrical resistance, (2) voltage difference and (3) current. Equation 1 is a form of Ohm's law and is stated as follows:

$$\text{Electrical Resistance} = \frac{\text{Voltage Difference}}{\text{Current}}$$

This relationship can help you find the value of one physical quantity if you know the value and units of the other two physical quantities. The relationship is often written with symbols, as follows:

$$R_E = \frac{\Delta V}{I} \qquad \textbf{\textit{Equation 1}}$$

where: R_E = electrical resistance measured in ohms (Ω)
ΔV = voltage measured in volts (V)
I = current measured in amperes (A)

(Recall that 1 ohm = 1 volt/1 amp.)

Equation 1 describes resistance in terms of voltage difference (ΔV) and current flow (I). We can also describe ***resistance*** in terms of (1) length, (2) cross-sectional area, and (3) resistivity of the material, as follows:

$$\text{Resistance} = \frac{\text{Resistivity of Material} \times \text{Length of Material}}{\text{Cross-sectional Area of the Material}}$$

This relationship is written with symbols as follows:

$$R_E = \frac{\rho \ell}{A} \qquad \textbf{\textit{Equation 2}}$$

where: R_E = resistance in ohms (Ω)
ρ = resistivity in ohm·cm or microhm·cm (or ohm·in.)
ℓ = length in cm (or in.)
A = cross-sectional area in cm^2 (or in^2)

WHAT'S THE RESISTOR COLOR CODE?

Electronics industries have a specific color-coding system for resistors. Coding is based on the use of four bands of color. The position and color of each band have a specific meaning. Figure 1 shows a fixed, tubular-shaped resistor. The color bands are painted on it. The meaning of each band is explained.

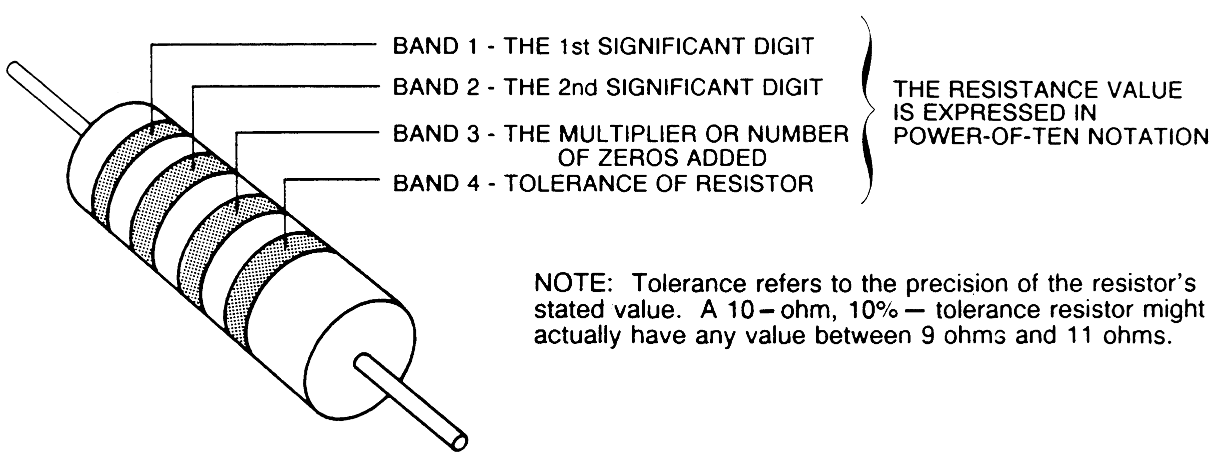

Fig. 1 Resistor color-coding.

Table 1 shows the colors used in resistor coding and explains what each color means with respect to the band.

TABLE 1. RESISTOR COLOR CODES

	Value in Band			
	Band 1	Band 2	Band 3	Band 4
Color	First Significant Digit	Second Significant Digit	Multiplier	Tolerance
Black	0	0	10^0	—
Brown	1	1	10^1	—
Red	2	2	10^2	—
Orange	3	3	10^3	—
Yellow	4	4	10^4	—
Green	5	5	10^5	—
Blue	6	6	10^6	—
Violet	7	7	10^7	—
Gray	8	8	10^8	—
White	9	9	10^9	—
Gold	—	—	10^{-1} or $\frac{1}{10}$	±5%
Silver	—	—	10^{-2} or $\frac{1}{100}$	±10%
No Color	—	—	—	±20%

For example, suppose the four color bands are *orange*, *green*, *red*, and *silver*.

Band 1:	orange	→	*First* digit is 3.
Band 2:	green	→	*Second* digit is 5.
Band 3:	red	→	*Multiplier* is 10^2.
Band 4:	silver	→	*Tolerance* is 10%.

The value of this resistor is 35×10^2 or 3500 Ω ±10% of 3500. (The symbol "±" means "plus or minus.") A tolerance of ±10% means the manufacturer "guarantees" the resistance value to be 3500 Ω ±350 Ω. So the true value can be anywhere between 3150 Ω and 3850 Ω. Study Table 1. Refer to it as needed when you have to determine resistor values from the color code.

Table 2 summarizes the units used with the physical quantities given in Equations 1 and 2. The table is meant to help you learn the units. Study Table 2.

TABLE 2. ELECTRICAL RESISTANCE UNITS

		System of Units	
		English	SI
Equation 1: $R_E = \frac{\Delta V}{I}$	R_E	—	ohms (Ω)
	ΔV	—	volts (V)
	I	—	amperes (A)
Equation 2: $R_E = \frac{\rho \ell}{A}$	R_E	—	ohms (Ω)
	ρ	ohm·in.	ohm·cm
	ℓ	in.	cm
	A	in^2	cm^2

Values of resistivity (ρ) are given for some common conductors in Table 3. Remember: 1 microhm·centimeter = 10^{-6} Ω·cm.

TABLE 3. RESISTIVITY OF COMMON CONDUCTORS

Material	Resistivity ($\mu\Omega$·cm)	Material	Resistivity ($\mu\Omega$·cm)
Glass	10^{20}	Lead	22
Silicon *	10^{6}	Aluminum	2.824
Germanium *	10^{6}	Gold	2.44
Carbon	10^{5}	Copper	1.724
Nichrome Wire	112	Silver	1.59

* The resistivity of semiconductors—like silicon and germanium—is very sensitive to temperature.

LET'S REVIEW UNITS!

Before starting your Practice Exercises, answer the following questions on units for electrical resistance. Complete the sentences with the correct word or words.

a. An electrical voltage in SI units is measured in ______ (volts, amperes, ohms).

b. An electrical current in SI units is measured in ______ (volts, amperes, ohms).

c. An electrical resistance in SI units is measured in ______ (volts, amperes, ohms).

d. Another expression of units for ohms is ______ (volts/amps, volts·amps).

e. Resistivity of electrical conductors ______ (may, may not) be measured in ohm·cm or ohm·inches.

f. The cross-sectional area of electric conductors ______ (may, may not) be measured in cm^2 or in^2.

LET'S REVIEW RESISTOR COLOR CODE!

a. The first color band tells the ______ (first, second) significant digit of the resistor value.

b. The second color band tells the ______ (first, second) significant digit of the resistor value.

c. The third color band tells the ______ (third significant digit, number of zeros) added to the resistor value.

d. The fourth color band is a ______ (multiplier, tolerance) band.

e. If the first three colors are brown-green-brown, the resistance (according to the color code) is ______ (15, 150, 1.5).

PRACTICE EXERCISES FOR ACTIVITY 1

Problem 1: Given: $R_E = {}^{\Delta V}\!/\!{}_{I}$ (Equation 1).

Find: ΔV. (Rearrange the equation and isolate ΔV.)

Solution: Step 1: First, write down the equation.

$$R_E = \frac{\Delta V}{I}$$

Step 2: Multiply both sides by I.

$$R_E \times I = \left(\frac{\Delta V}{\cancel{I}}\right) \times \cancel{I} \qquad \text{(Cancel I's on right side.)}$$

Step 3: Rewrite the equation without the I's that were canceled.

$R_E \times I = \Delta V$ (ΔV is isolated.)

Step 4: Reverse the order of the equation with (ΔV) on the left side.

$\Delta V = R_E \times I$

The problem has been solved. The equation, $R_E = \Delta V / I$, has been rearranged. ΔV has been isolated.

Problem 2: Given: $R_E = \rho\ell / A$ (Equation 2).

Find: ρ. (Rearrange the equation and isolate ρ.)

Solution: (***Hint:*** Examination of the right side of the equation indicates that multiplying both sides by the inverse of ℓ / A, which is A / ℓ, will isolate ρ on the right side when terms cancel out.)

Step 1: First, write down the equation.

$$R_E = \frac{\rho\ell}{A}$$

Step 2: Multiply both sides by A / ℓ (the inverse of ℓ / A).

$$R_E \times \left(\frac{A}{\ell}\right) = \left(\frac{\rho\cancel{\ell}}{\cancel{A}}\right) \times \left(\frac{\cancel{A}}{\cancel{\ell}}\right)$$

(Cancel A's and ℓ's on the right side.)

Step 3: Rewrite the equation without the A's and ℓ's that you canceled.

$$R_E \times \left(\frac{A}{\ell}\right) = \rho$$

(The "ρ" is isolated.)

Step 4: Reverse the order of the equation with ρ on the left side.

$$\rho = R_E \times \left(\frac{A}{\ell}\right)$$

The problem has been solved. Equation 2 has been rearranged, and ρ has been isolated.

Problem 3: Given: $R_E = \Delta V / I$ (Equation 1).

Find: I.

Solution: (Rearrange the equation and isolate I.)

Problem 4: Given: $R_E = \rho\ell / A$ (Equation 2).

Find: ℓ.

Solution: (Rearrange the equation and isolate ℓ. ***Hint:*** Multiply both sides by A / ρ.)

Problem 5: Given: $R_E = \rho\ell / A$ (Equation 2).

Find: A.

Solution: (Rearrange the equation and isolate A. ***Hint:*** First multiply both sides by A. This gets A in the numerator. Then divide both sides by R_E.)

ACTIVITY 2

Solving Electrical Resistance Problems

Electrical resistance problems in Activity 2 involve Equations 1 and 2 from Activity 1. If the equation isn't in the correct form, first rearrange the equation. Isolate the symbol that represents the physical quantity you want to find. Then solve this equation for the unknown value.

Your final answer should include a correct numerical answer with the proper units. Use Tables 1, 2 and 3 to help you solve the problems and check the units in your answer.

PRACTICE EXERCISES FOR ACTIVITY 2

Problem 6: Given: An electrical circuit with a 6-V battery operates a floodlight that has 3 A of current flowing through it.

Find: The resistance of the floodlight.

Solution:

Problem 7: Given: A current of 6 A flows through an electrical device. Resistance is 16.67 ohms.

Find: The voltage difference causing the current.

Solution:

Problem 8: Given: A voltage difference of 50 V causes current in an electrical circuit. Series resistance in the circuit is 20 ohms.

Find: The current in the circuit.

Solution:

Problem 9: Given: The resistivity of copper wire is $\rho = 1.724 \times 10^{-6}\ \Omega\cdot\text{cm}$. A copper wire has a cross-sectional area of 0.077 cm^2 and is 120 cm long.

Find: The resistance of this piece of wire.

Solution:

Student Challenge

Problem 10: Given: A resistor has the following color code: 1st band = blue, 2nd band = black, 3rd band = brown, 4th band = gold.

Find: The *length* in cm of a piece of nichrome wire that has the same resistance value as the resistor. The wire has a cross-sectional area of 0.04 cm^2.

Solution: (***Hint:*** First use Figure 1 and Table 1 to find the correct resistance for the given resistor.)

Problem 11: Given: A circuit must be made from a 6-V battery, conducting wire, a switch, a miniature lamp base, and a single 1.5-V miniature lamp. When the voltage across the lamp is 1.5 volts, the current through it is 1 ampere. If more than one ampere flows, the lamp's life expectancy is severely reduced.

Find: The amount of resistance needed to limit the voltage across the miniature lamp to 1.5 V and limit the current through it to 1 A.

Solution: (***Hint:*** Draw a schematic of the circuit. Find the lamp resistance. Subtract it from the total resistance in the circuit. The difference is the amount of fixed resistance you must add in series with the lamp to avoid rapid burnout.)