COMMON CORE MATHEMATICS

Integration Activity

Pathway: Mechanical Systems and Technology

Lesson: AMT A4–3: Measuring and Calculating Electricity

Common Core State Standards for Mathematics: 9-12.A-CED.1, 9-12.A-CED.4

Domain: Creating Equations A-CED

Cluster: Create equations that describe numbers or relationships.

Standard: 1. Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.

Standard: 4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V = IR to highlight resistance R.

Student Objective: Students will be able to manipulate the Ohm's law formula and the power equation to solve for the desired quantity.

BACKGROUND KNOWLEDGE for Teachers and Students

Math Concepts:

Expression: A statement of value using numbers, variables, and operators. Ex: $(2x + 5)/y$.

Equation: A statement showing two expressions as equal using an equal sign.

Ex: To solve for x, you must isolate the variable x on one side by using basic operations.

In an equation, you must perform the same operation to both sides.

Ex: Solving for the variable x:

$$\begin{array}{rcl} 4y + 6 & = & 2x - 4 \\ +\ 4 & & +\ 4 \end{array}$$

$$4y + 10 = 2x$$
$$/2 \qquad\quad /2$$

$$2y + 5 = x$$

The two equations $4y + 6 = 2x - 4$ and $x = 2y + 5$ describe the same relationship, but the second has been rearranged to show the x value in terms of y.

Solving for a variable:

Khan Academy—Video

(http://www.khanacademy.org/math/algebra/solving-linear-equations-and-inequalities/More-equation-practice/v/solving-for-a-variable)

Agriculture Concepts:

Electricity is a staple of the agricultural industry, supplying the majority of fixed building power for animal and crop production. Electricity is the flow of electrons in a conductor. The electrons must have a path to and from their source, a circuit. Ohm's law describes the relationship between voltage, amperage, and resistance within a circuit. It states that Amps (I) = Volts (E) / Ohms (R). *I* designates the rate of electrical flow per second across a certain point. *E* designates electromotive force, voltage, which is the measure of electrical pressure. *R*, resistance, measured in ohms, quantifies a material's opposition to the flow of electricity. The power equation describes the relationship between watts, amperage, and voltage. It states that Watts (P) = Amps (I) × Volts (E). *P* denotes wattage, or electrical power.

Guided Practice Exercises: ANSWER KEY

1. $P = I \times E$
2. $I = P/E$
3. $I = (12 \times 60)/120 = 6$ amps
4. $I = E/R$
5. $R = E/I$
6. $R = 120/6 = 20$ ohms*

*Some students may ask why the resistance is lower but there are more lights (loads) on the circuit between #6 and #8. This gives the current more ways to move through the circuit, reducing the resistance. Just as with a river and small streams, as more streams are added, even though the resistance for each individual stream is the same, more water will be able to travel through the system. This is also reflected in the relationship between P, I, and R.

7. $P = I \times E$
   $I = P/E$
   $I = (40 \times 60 + 30 \times 100)/120$
   $I = 45$ amps

8. $R = E/A$
   $R = 120/45 = 2.66$ ohms*

9. $P = I \times E$ $\qquad\qquad$ $E = I \times R$
   Substitute $(I \times R)$ for E so that $P = I \times (I \times R)$
   $\mathbf{P = I^2 \times R}$

10. The answer is I. It will cause P to increase at a rate equal to the square of the increase in I, while an increase in R will cause only P to increase at the same rate as R.

Independent Practice Exercises: ANSWER KEY

1. Motor hp = Auger length (ft) × 1.5 hp/8 ft
   $M = L \times 1.5/8$

2. a. 12 ft—$12ft/8ft \times 1.5hp = 2.25hp \sim 2.5hp$
   b. 24 ft—$24ft/8ft \times 1.5hp = 4.5hp$
   c. 30 ft—$30ft/8ft \times 1.5hp = 5.625hp \sim 6hp$
   d. 40 ft—$40\ ft/8ft \times 1.5hp = 7.5hp$

3. a. 2.5-hp motor = $P = E \times I$ $\quad I = P/E$ $\quad I = (2.5 \times 746)/120$ $\quad$ 15.54A
   b. 4.5-hp motor = $P = E \times I$ $\quad I = P/E$ $\quad I = (4.5 \times 746)/120$ $\quad$ 27.975A
   c. 6-hp motor = $P = E \times I$ $\quad I = P/E$ $\quad I = (6 \times 746)/120$ $\quad$ 37.3A
   d. 7.5-hp motor = $P = E \times I$ $\quad I = P/E$ $\quad I = (7.5 \times 746)/120$ $\quad$ 46.625A

4. No. He will be using a total of 127.44 amps, more than allowed from his panel.
   15.54 + 27.975 + 37.3 + 46.625 = 127.44A

5. a. 2.5-hp motor = $P = E \times I$ $\quad I = P/E$ $\quad A = (2.5 \times 746)/240$ $\quad$ 7.77A
   b. 4.5-hp motor = $P = E \times I$ $\quad I = P/E$ $\quad A = (4.5 \times 746)/240$ $\quad$ 13.988A
   c. 6-hp motor = $P = E \times I$ $\quad I = P/E$ $\quad A = (6 \times 746)/240$ $\quad$ 18.65A
   d. 7.5-hp motor = $P = E \times I$ $\quad I = P/E$ $\quad A = (7.5 \times 746)/240$ $\quad$ 23.31A

6. Yes. Now he is using only 63.72 amps, well under the 100-amp maximum.
   7.77 + 13.988 + 18.65 + 23.31 = 63.72A

*Some students may ask why the resistance is lower but there are more lights (loads) on the circuit between #6 and #8. This gives the current more ways to move through the circuit, reducing the resistance. Just as with a river and small streams, as more streams are added, even though the resistance for each individual stream is the same, more water will be able to travel through the system. This is also reflected in the relationship between P, I, and R.

Name: _____

Guided Practice Exercises:

Use Ohm's law and the power equation to determine the proper amperage for a breaker for a machine shed lighting circuit that will run twelve 60-watt bulbs on a 120-volt power source.

1. Write the relationship between watts, amps, and volts.

2. Rearrange the variables in the above equation to solve for amps.

3. How many amps are needed to power the lighting circuit?

4. Write the relationship between ohms, amps, and volts.

5. Rearrange the variables in the above equation to solve for ohms.

6. How many ohms of resistance will this lighting circuit have?

7. The machine shed has a need for a total of seventy light bulbs—forty 60-watt bulbs and thirty 100-watt bulbs. How many amps will be needed to provide power to all of them on one circuit?

8. How many ohms of resistance will this lighting circuit have?

9. Using the power equation and Ohm's law, create an equation that shows watts in terms of amps and ohms.

10. Which variable, amps (I) or ohms (R), will cause a larger change in wattage (P) when it changes? Why?

Name: _____

Independent Practice Exercises:

Mike needs to estimate his overall electrical service requirements for his new wet grain handling system, which includes three wet bins and four augers of differing lengths: 12 feet, 24 feet, 30 feet, and 40 feet. Every 8 feet of auger needs to be turned by 1.5 horsepower (hp) of motor under a full load. One horsepower is equal to 746 watts of power. Each auger motor will be run on a separate 120-volt circuit.

1. Write a relationship between auger length and motor hp.

2. What hp motor should Mike buy to run each auger (sized in $^1/_2$-hp increments)?

3. How many amps of electricity are needed to run each motor? (Use Watts = Volts × Amps and 1 hp = 746 watts.)

4. Mike's electrical panel can supply only 100 amps of total power safely. Can he use all of his motors at the same time with this power supply?

5. Mike wants to install his motors on a 240-volt circuit. Show what will happen to the amps flowing through each motor.

6. Can Mike use his 100-amp service with motors wired for 240 volts?