

**Compute transformer calculations = Use reasoning to solve equations and justify the solution method**

**Program Task:** Identify the relationship between primary and secondary turns, primary and secondary voltage, and primary and secondary currents.

**Program Associated Vocabulary:**  
PRIMARY WINDING, SECONDARY WINDING, TURNS, CURRENT (or AMPERAGE), RATIO, VOLTAGE, VOLTAMPS (VA) RATING

**Program Formulas and Procedures:**  
A transformer is an electrical device that transforms an applied voltage to a higher or lower output voltage. The voltage in:out ratio is equal to the ratio of turns in the windings (primary:secondary).

V = Voltage N = Number of Turns

From Faraday's Law :  $V_2 = V_1 (N_2/N_1)$  – Direct Relation  
Transformers are rated in voltamps, or VA's (volts x amps).  
Input VA's equal output VA's, which means the output voltage is inversely proportional to the output current.  
Knowing these relationships makes calculating without formulas possible.

V = Voltage I = Current (amperes)

From conservation of energy:  $V_1 I_1 = V_2 I_2$   
Then:  $I_2 = I_1 (N_1/N_2)$  – Inverse Relation

**Example 1:** A transformer has 300 turns in the primary, 50 turns in the secondary, and 120 volts applied to the primary. What is the voltage of the secondary?

Step 1: Set up the proportion Step 2: Invert ratio?  
 $\frac{300 \text{ turns}}{50 \text{ turns}} = \frac{120 \text{ volts}}{x \text{ volts}}$  (No, it's a direct proportion.)

Step 3: Cross-multiply and divide to solve.  
 $50(120) = 300x, x = 20 \text{ volts}$

**Example 2:** A transformer has 300 turns in the primary, 50 turns in the secondary, and 1.2 amperes applied to the primary. What is the current of the secondary?

Step 1: Set up the proportion. Step 2: Invert ratio.  
 $\frac{300 \text{ turns}}{50 \text{ turns}} = \frac{1.2 \text{ Amperes}}{x \text{ Amperes}}$   $\frac{300 \text{ turns}}{50 \text{ turns}} = \frac{x \text{ Amperes}}{1.2 \text{ Amperes}}$

Step 3: Cross-multiply and divide to solve.  
 $300(1.2) = 50x, x = 7.2 \text{ Amperes}$

**PA Core Standard: CC.2.2.HS.D.9**

**Description:** Use reasoning to solve equations and justify the solution method.

**Math Associated Vocabulary:**  
INVERSE, RECIPROCAL, PROPORTION, CROSS MULTIPLICATION, RATIO, CONSTANT

**Formulas and Procedures:**  
**Direct Proportions**

**Two quantities, A and B, are directly proportional if by whatever factor A changes, B changes by the same factor.**

**Example 1:** Take the formula distance = rate x time. If the rate remains constant, 30 miles per hour, then the time and distance are directly proportional.

$d = 30t$   
when  $t = 2, d = 60$   
when  $t = 4, d = 120$

\*Note that when the time doubles, so does the distance.

**Example 2:** If speed is directly proportional to distance and a car can travel 100 miles at 50 miles per hour. How far can that car travel during the same time if it travels 70 mph?

Step 1: Set up proportion.

$$\frac{50 \text{ mph}}{70 \text{ mph}} = \frac{100 \text{ mi.}}{x}$$

Step 2: Cross multiply and divide to solve.

$$50x = 70(100) \rightarrow 50x = 7000 \rightarrow x = 140 \text{ miles}$$

**Inverse Proportions**

**Two quantities, A and B, are inversely proportional if by whatever factor A changes, B changes by the multiplicative inverse, or reciprocal of that factor.**

**Example 1:** Take the formula distance = rate x time. If the distance is constant, 100 miles, then as the rate increases the time decreases.

$100 = rt$   
When  $r = 100, t = 1$   
When  $r = 50, t = 2$

\*Note that when the rate doubles, the time is halved.

**Example 2:** If the time needed to complete a job is inversely proportional to the number of people working, how long would it take 4 people to paint a room if 1 person needs 8 hours?

Step 1: Set up the proportion.

$$\frac{1 \text{ person}}{4 \text{ people}} = \frac{8 \text{ hours}}{x \text{ hours}}$$

Step 2: Invert (flipA) one ratio.

$$\frac{1 \text{ person}}{4 \text{ people}} = \frac{x \text{ hours}}{8 \text{ hours}}$$

Step 3: Cross-multiply and divide to solve.

$$4x = 8, x = 2$$

4 people can paint the room in 2 hours.

### Instructor's Script - Comparing and Contrasting

Transformers provide a real-world example of direct and inverse proportional relationships at work.

### Common Mistakes Made By Students

When students compare direct and inverse proportional relationships, they may become confused and have difficulty differentiating one from the other. One way to keep them straight is to:

1. Set up one pair of values on the same line, e.g.,  $\frac{12}{24} = \frac{100 \text{ lbs.}}{x \text{ lbs.}}$ .
2. Beneath that line, place the other pair of values,  $\frac{12}{24} = \frac{100 \text{ lbs.}}{x \text{ lbs.}}$ .
3. Students need to be aware that direct proportions mean that as one variable increases so does the other variable. An inverse proportion means that one variable increases when the other one decreases. Students struggle with this concept.
4. If the problem is a direct proportion, students should cross multiply (24 times 100) and (12 times x) and then divide to solve the problem.
5. If an inverse relationship exists, then students should first invert one ratio before cross multiplying and dividing to solve the problem.
6. If need be, have the student set up the problem and do it both ways to see which answer makes sense! We know in problem #9, for example, that it won't take 5 rabbits more time than it took 1 rabbit to eat 20 carrots, so it must be an inverse proportion.

### CTE Instructor's Extended Discussion

# Electro Mechanical Mechatronics (15.0403) T-Chart

Problems	Occupational (Contextual) Math Concepts	Solutions
1. Given a primary input of 120 volts and 161 turns; the secondary is 88 turns, what is the secondary voltage?		
2. Given a primary voltage of 120 volts, a primary current of 7.5 Amperes, and a secondary voltage of 16, find the current.		
3. Given a primary voltage of 120 volts, a primary current of 7.5 Amperes, and secondary amperage of 45 amps, find the secondary voltage.		
Problems	Related, Generic Math Concepts	Solutions
4. If you need 5 pounds of chicken to serve 20 people, how many pounds will you need to serve 50 people?		
5. The pressure of a gas and its corresponding volume are inversely proportional. If the pressure of 0.24 m <sup>3</sup> is 0.5 atm (atmospheres), what would the pressure be of 0.060 m <sup>3</sup> of the same gas at the same temperature?		
6. If it takes 26 lbs. of metal to make 10 castings, how many pounds of metal will be needed to make 14 castings?		
Problems	PA Core Math Look	Solutions
7. Given that y and x are <b>directly</b> proportional and $y = 2$ when $x = 5$ , find the value of y when $x = 15$ .		
8. Given that y and x are <b>inversely</b> proportional and $y = 2$ when $x = 5$ , find the value of y when $x = 15$ .		
9. If one rabbit can chew 20 carrots in 15 hours, how long will it take 5 rabbits to chew the same number of carrots?		

# Electro Mechanical Mechatronics (15.0403) T-Chart

Problems	Occupational (Contextual) Math Concepts	Solutions
1. Given a primary input of 120 volts and 161 turns; the secondary is 88 turns, what is the secondary voltage?	<b>(Direct)</b> *turns and voltage are directly proportional	Step 1: Set up the proportion. $\frac{120 \text{ volts}}{x} = \frac{161 \text{ turns}}{88 \text{ turns}}$ Step 2: Cross-multiply and divide to solve. $120(88) = 161x \rightarrow x = 65.6 \text{ Volts}$
2. Given a primary voltage of 120 volts, a primary current of 7.5 Amperes, and a secondary voltage of 16, find the current.	<b>(Inverse)</b> *voltage and current are inversely proportional	Step 1: Set up the proportion. Step 2: Invert one ratio. $\frac{120 \text{ volts}}{16 \text{ volts}} = \frac{7.5 \text{ Amps.}}{x \text{ Amps.}} \quad \frac{120 \text{ volts}}{16 \text{ volts}} = \frac{x \text{ Amps.}}{7.5 \text{ Amps.}}$ Step 3: Cross-multiply and divide to solve. $120(7.5)=16x, x = 56.25 \text{ Amps}$
3. Given a primary voltage of 120 volts, a primary current of 7.5 Amperes, and secondary amperage of 45 amps, find the secondary voltage.	<b>(Inverse)</b> *voltage and current are inversely proportional	Step 1: Set up the proportion. Step 2: Invert one ratio. $\frac{120 \text{ volts}}{x \text{ volts}} = \frac{7.5 \text{ Amps.}}{45 \text{ Amps.}} \quad \frac{120 \text{ volts}}{x \text{ volts}} = \frac{45 \text{ Amps.}}{7.5 \text{ Amps.}}$ Step 3: Cross-multiply and divide to solve. $120(7.5)=45x, x = 20 \text{ volts}$
Problems	Related, Generic Math Concepts	Solutions
4. If you need 5 pounds of chicken to serve 20 people, how many pounds will you need to serve 50 people?	<b>(Direct)</b>	$\frac{5 \text{ pounds}}{20 \text{ people}} = \frac{x \text{ pounds}}{50 \text{ people}} \rightarrow 20x = 5(50) \rightarrow 20x = 250$ $x = 12.5 \text{ pounds}$
5. The pressure of a gas and its corresponding volume are inversely proportional. If the pressure of 0.24 m <sup>3</sup> is 0.5 atm (atmospheres), what would the pressure be of 0.060 m <sup>3</sup> of the same gas at the same temperature?	<b>(Inverse)</b>	$\frac{0.24\text{m}^3}{0.060\text{m}^3} = \frac{0.5 \text{ atm}}{x \text{ atm}} \quad (\text{Invert one ratio since it is an inverse proportion.})$ $\frac{0.24\text{m}^3}{0.060\text{m}^3} = \frac{x \text{ atm}}{0.5 \text{ atm}} \rightarrow 0.24(0.5) = 0.060x \rightarrow x = 2 \text{ atm}$
6. If it takes 26 lbs. of metal to make 10 castings, how many pounds of metal will be needed to make 14 castings?	<b>(Direct)</b>	$\frac{10 \text{ castings}}{14 \text{ castings}} = \frac{26 \text{ lbs}}{x \text{ lbs.}} \rightarrow 10x = 26(14) \rightarrow x = 36.4 \text{ lbs}$
Problems	PA Core Math Look	Solutions
7. Given that y and x are <b>directly</b> proportional and y = 2 when x = 5, find the value of y when x = 15.	<b>(Direct)</b>	$\frac{5}{15} = \frac{2}{y} \rightarrow 5y = 2(15) \rightarrow y = 6$
8. Given that y and x are <b>inversely</b> proportional and y = 2 when x = 5, find the value of y when x = 15.	<b>(Inverse)</b>	$\frac{5}{15} = \frac{y}{2} \rightarrow 15y = 2(5) \rightarrow y = 0.667$
9. If one rabbit can chew 20 carrots in 15 hours, how long will it take 5 rabbits to chew the same number of carrots?	<b>(Inverse)</b>	$\frac{1}{5} = \frac{x}{15} \rightarrow 5x = 1(15) \rightarrow x = 3 \text{ hours}$