Machine Tool Technology (48.0501) T-Chart

Determine required material & time needed to complete a job	=	Use reasoning to solve equations and justify the solution method

Program Task: Perform job planning & bench work.

Program Associated Vocabulary:
RATIO, PROPORTION

Program Formulas and Procedures:
Planning a machining project involves determining how much material is needed and the time required to perform the operations.

Each of these situations can be calculated using proportions.

Example 1:
A machining contract is for 150 parts from 1/16" square mild steel. Each part sawn from a bar of material uses .23". How much material will be needed?

This is an example of a **direct proportion**. As the number of parts increases, the length of material needed increases at the same rate.

$$\frac{.23\text{ in.}}{\text{x in.}} = \frac{1\text{ part}}{150\text{ parts}}$$

$$x = .23 \cdot 150$$

$$x = 34.5 \text{ inches}$$

Example 2:
A dedicated CNC milling operation is being run on two VMC's. Combined, they fill the customer's order in 60 hours. How long will it take to fill the order if three machines were running the same operation at the same rate?

$$\frac{2\text{ machines}}{3\text{ machines}} = \frac{60\text{ hours}}{\text{x hours}}$$

This is an example of an **inverse proportion**. As the number of machines increases, the time decreases inversely, so one ratio must be inverted before solving.

$$\frac{2\text{ machines}}{3\text{ machines}} = \frac{\text{x hours}}{60\text{ hours}}$$

$$3x = 120$$

$$x = 40\text{ hours}$$

If the proportion were solved as originally set up, the answer would be 90 hours. That answer doesn't make sense because three machines can finish the job more quickly than two machines.

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, at 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 at 70 mph?

Step 1: Set up proportion.

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

Step 2: Cross multiply and divide to solve.

$50x = 70(100) \rightarrow 50x = 7000 \rightarrow x = 140$ 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, 100 miles is constant, 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: The time needed to complete a job is inversely proportional to the number of people working. If it takes one person 8 hours to pain the room alone, how long would it take 4 people to paint a room?

Step 1: Set up the proportion.

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

Step 2: Invert (flip) one ratio.

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

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

These are excellent examples for direct and inverse proportions. It is important when working with direct and inverse proportions that you check your solutions to see that they make sense. Read the problem carefully and think about the answer. It may be helpful to try to get an estimate of the answer prior to your calculations.

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,
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.

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

As in many machining topics, conversion of units may need to be performed.

There are many areas in machining where proportions are used. Here are two more examples.

Direct proportions are used is in blueprint reading when referring to scale.

Sample question:

If a blueprint's scale is 4:1 and one of the part's dimensions is 1.255", how large will it be shown on the blueprint?

$$\frac{4 \text{ in.}}{x \text{ in.}} = \frac{1 \text{ in.}}{1.255 \text{ in.}}$$

$$x = 5.020 \text{ inches}$$

Tapers are direct proportions.

Sample question:

If a taper's diameter changes .015" per inch of length (.015" taper per inch), what is the difference between the two end diameters if the part is 6.25" long?

$$\frac{.015 \text{ in.}}{x \text{ in.}} = \frac{1 \text{ in.}}{6.25 \text{ in.}} \rightarrow x = .09375 \text{ inches}$$

If the TPI is still .015", and the diameter was changed by .040", by how much would the length of the tapered section change?

$$\frac{.015 \text{ in.}}{.040 \text{ in.}} = \frac{1 \text{ in.}}{x \text{ in.}} \rightarrow .015x = .040 \rightarrow x = 2.667 \text{ inches}$$

Problems	Career and Technical Math Concepts	Solutions
1. As shift leader you must order material for the jobs being run in your department. A new contract awarded to your company is for 500 parts made from 1" x 2.5" 6061 T6 aluminum bar stock. Each part will use 6 1/8" from the bar. How many feet of material will you need to order?		
2. Three students are machining parts to give away at the open house. In a 2 hour daily session the three can produce 24 parts. How many parts can be made in a session if one more student works on the same operation?		
3. How far will a 16 TPI nut travel along a lead screw when the lead screw makes 60 revolutions?		
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^3 is 0.5 atm, what would the pressure be of 0.060 m^3 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 **directly** proportional, and y = 2 when x = 5, find the value of y when x = 15.		
8. Given that y and x are **inversely** 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 20 carrots?		

Problems	Career and Technical Math Concepts	Solutions
1. As shift leader you must order material for the jobs being run in your department. A new contract awarded to your company is for 500 parts made from 1" x 2.5" 6061 T6 aluminum bar stock. Each part will use 6 1/8" from the bar. How many feet of material will you need to order?	$\frac{6.125\text{ in.}}{\text{x ft.}} = \frac{1\text{ part}}{500\text{ parts}}$ Must convert inches to feet $\frac{1\text{ ft.}}{12\text{ in.}} x \frac{6.125\text{ in.}}{\text{x ft.}} = .510\text{ ft.}$ $\frac{.510\text{ ft.}}{\text{x ft.}} = \frac{1\text{part}}{500\text{ parts}}$ x = 255 feet	
2. Three students are machining parts to give away at the open house. In a 2 hour daily session the three can produce 24 parts. How many parts can be made in a session if one more student works on the same operation?	$\frac{3\text{ students}}{4\text{ students}} = \frac{2\text{ hours}}{\text{x hours}} \rightarrow \text{inverse} \rightarrow \frac{3\text{ students}}{4\text{ students}} = \frac{\text{x hours}}{2\text{ hours}}$ $4x = 6$ x =1.5 hours	
3. How far will a 16 TPI nut travel along a lead screw when the lead screw makes 60 revolutions?	$\frac{\frac{1}{16}\text{in.}}{\text{x in.}} = \frac{1\text{ rev.}}{60\text{ rev.}}$ $x = \frac{1}{16} x\ 60 \rightarrow x = \frac{60}{16} \rightarrow x = 3\frac{12}{16} \rightarrow x = 3\frac{3}{4}$ inches	
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?	**(Direct)** $\frac{5\text{ pounds}}{20\text{ people}} = \frac{\text{x pounds}}{50\text{ people}} \rightarrow 20x = 5(50) \rightarrow 20x = 250$ $x = 12.5\text{ pounds}$	
5. The pressure of a gas and its corresponding volume are inversely proportional. If the pressure of 0.24 m^3 is 0.5 atm, what would the pressure be of 0.060 m^3 of the same gas at the same temperature?	**(Inverse)** $\frac{0.24\text{ m}^3}{0.060\text{ m}^3} = \frac{0.5\text{ atm}}{\text{x atm}}$ (Invert one ratio since it is an inverse proportion.) $\frac{0.24\text{ m}^3}{0.060\text{ m}^3} = \frac{\text{x atm}}{0.5\text{ atm}}$ $\rightarrow 0.24(0.5) = 0.060x \quad x = 2\text{ atm.}$	
6. If it takes 26 lbs. of metal to make 10 castings, how many pounds of metal will be needed to make 14 castings?	**(Direct)** $\frac{10\text{ castings}}{14\text{ castings}} = \frac{26\text{ lbs.}}{\text{x lbs.}} \rightarrow 10x = 26(14) \rightarrow x = 36.4\text{ lbs.}$	
Problems	**PA Core Math Look**	**Solutions**
7. Given that y and x are **directly** proportional, and y = 2 when x = 5, find the value of y when x = 15.	**(Direct)** $\frac{5}{15} = \frac{2}{y} \rightarrow 5y = 2(15) \rightarrow y = 6$	
8. Given that y and x are **inversely** proportional, and y = 2 when x = 5, find the value of y when x = 15.	**(Inverse)** $\frac{5}{15} = \frac{y}{2} \rightarrow 15y = 2(5) \rightarrow y = 0.667$	
9. If one rabbit can chew 20 carrots in 15 hours, how long will it take 5 rabbits to chew the same 20 carrots?	**(Inverse)** $\frac{1}{5} = \frac{x}{15} \rightarrow 5x = 1(15) \rightarrow x = 3\text{ hours}$	