Diagnose mechanical & electrical system problems =	**Apply properties of rational and irrational numbers to solve real-world or mathematical problems**

Program Task: Diagnose electrical circuit, HVAC cooling and engine drivability problems.

PA Core Standard: CC.2.1.HS.F.2

Description: Apply properties of rational and irrational numbers to solve real-world or mathematical problems.

Program Associated Vocabulary:
SQUARE ROOT, RESISTANCE, COFFICIENT OF DRAG

Math Associated Vocabulary:
SQUARE ROOT

Program Formulas and Procedures:
It is important for automotive technicians to properly diagnose fluid and gaseous (i.e. air conditioning, emissions) system problems. Many devices change size in diameter, altering the amount of pressure or volume of fluid/gas in the system. They must be diagnosed to determine the root cause of a malfunction. Here we'll learn how to diagnose an air conditioning system.

If a particular liquid enters the 1" diameter inlet with 10 lbs. of force and exits the outlet with 2.5 lbs. of force, what is the radius of the outlet?
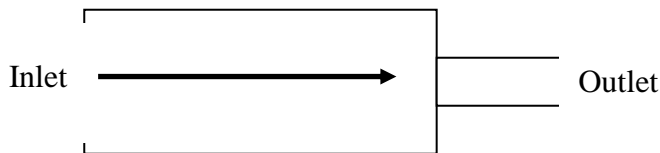
Inlet → Outlet

ILLUSTRATION IS **NOT** TO SCALE

Find the cross-sectional area of the Inlet (A_{inlet}).

r = d/2 = 0.5"

$$A_{inlet} = \pi r^2 = \pi(0.5)^2 = .784 \text{ in.}^2$$

$$\frac{F_{inlet}}{A_{inlet}} = \frac{F_{outlet}}{A_{outlet}}$$

$$\frac{10 \text{ lbs.}}{.784 \text{ sq.in.}} = \frac{2.5 \text{lbs.}}{A_{outlet}} \quad \text{Cross-multiply}$$

$$A_{outlet} = \frac{(2.5\text{lbs.})(.784 \text{ sq.in.})}{10 \text{ lbs.}} = .196 \text{ sq.in.}$$

To find the radius of the outlet:

$A=\pi r^2$

$.196 \text{ sq.in.} = \pi r^2$

$$r = \sqrt{\frac{.196 \text{sq.in.}}{\pi}} = \sqrt{.0624} = .25 \text{ in.}$$

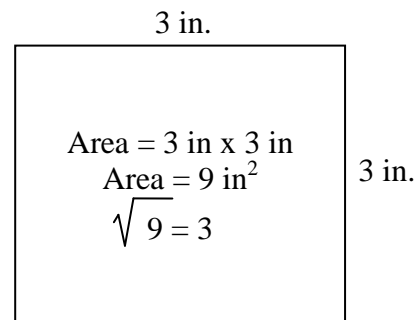Note: While the radius of the outlet is half the radius of the inlet, the force and area decreases by a factor of 4.

Formulas and Procedures:

Find Square Roots:

3 in.

Area = 3 in x 3 in
Area = 9 in^2
$\sqrt{9} = 3$

3 in.

Nearest Estimation Method to find Square Root:
**Example:** Estimate the square root of 7.

1. Pick two perfect squares closest to the number you want to find the square root of; choose one perfect square greater than the number you want to find the square root of and one perfect square less than the number you want to find the square root of. Two perfect squares below and above 7 are 4 and 9.

2. Since 7 is closer to 9 than it is to 4, then $\sqrt{7}$ must be between $\sqrt{4} = 2$ and $\sqrt{9} = 3$ but closer to $\sqrt{9} = 3$.

3. An estimate around 2.6 to 2.7 would be fine.

Instructor's Script – Comparing and Contrasting

When taking the square root of a number, the answer can actually be + or -. So the square root of 4 is actually ±2 because square root answers the question "What number do I multiply by itself to get the number under the root?" In this case "2 times 2 = 4 AND -2 times -2 = 4". In automotive and most real life applications of square root, the value needed is a measurement so we only concern ourselves with the positive value.

When computing formulas involving square roots, it is good practice to compute all math within the square root before using the square root key. For example, when using the Pythagorean formula with a right triangle, be sure to square and add the 2 sides before using square root:

If a = 5, b = 12, then what is **c**?   Since $c^2 = a^2 + b^2$,
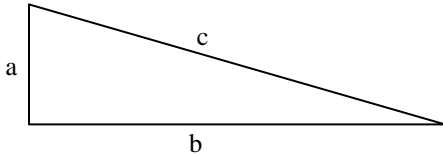
$$c = \sqrt{a^2 + b^2}$$
$$= \sqrt{5^2 + 12^2}$$
$$= \sqrt{169}$$
$$= 13$$

This is NOT $\sqrt{5^2} + \sqrt{12^2}$!!
Calculate $5^2 + 12^2 = 169$ first

When using a calculator for these problems, you probably want to break the problem into 2 steps – the inside math followed by square root of that answer. If you insist on trying it in a single step, be sure to use parentheses for the inside math to avoid making an error. **Formulas for problems on page 3:**
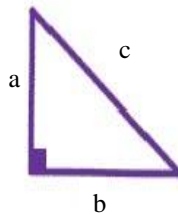
1. $\dfrac{F}{a} = \dfrac{F}{A}$ $\rightarrow$ $\dfrac{300\,\text{lbs. of Force}}{\pi r^2} = \dfrac{15\,\text{lbs. of Force}}{A}$

2. $a = \pi r^2$ $\rightarrow$ $a = \pi r^2 \times 2$ $\rightarrow$ $r = \sqrt{\dfrac{a}{\pi}}$

3. $a = \sqrt{c^2 - b^2}$

5. $\sqrt{30 \times .35 \times 175}$

6. $\sqrt{(\dfrac{5280}{2}+1)^2 - (\dfrac{5280}{2})^2}$

Common Mistakes Made By Students

Unfamiliar with the calculator: Students who borrow calculators or keep switching between styles and models have to continually determine how to enter the square root of a number. Suggestion: Ask students to find the square root of 4 using their calculator. Some calculators require the student to press the number then the square root button; others require the square root button before the number. Whichever order of entry gives the correct answer of 2 is the correct choice.

Estimation: Most errors from estimation without a calculator will come from not knowing perfect squares or not being able to find the middle between other values quickly and easily.

Students often think that finding the square root means dividing by two.

CTE Instructor's Extended Discussion

Technical tasks are usually not presented using this model. Therefore, it is important that technical instructors demonstrate to students how these math concepts link to and are relevant in their technical training and that the math is presented in a way which shows a relationship to the math which CTE students use in their academic school settings.

Automotive Technology (47.0604) T-Chart

	Problems	Career and Technical Math Concepts	Solutions
1.	Fifteen pounds of force is needed to open the wastegate on a particular turbocharger. If the inlet has a diameter of three inches with 250 lbs. of force, find the area and the radius of the wastegate tube outlet.		
2.	To improve air conditioning cooling, a TSB (Technical Service Bulletin) states to replace the air intake duct with one twice the area. What diameter line will you need to install if the installed duct is 2.5" diameter?		
3.	A customer complains his car pulls after an accident. All wheel alignment measurements are within spec. According to the service manual you must measure the frame at three specific points to determine if the frame is twisted. If b = 36" & c = 48" what must a = for the frame to be in spec?		

	Problems	Related, Generic Math Concepts	Solutions
4.	You want to draw a square box and fill it with 144 one-inch squares, how many inches must each side of your square measure?		
5.	Skid marks are used to determine the maximum speed of a car in an accident. If a car leaves skid marks of 175' with a coefficient of drag of 35%, its approximate speed, in MPH, can be determined. Use the formula provided on page 2.		
6.	The Golden Gate Bridge is about one mile long. On a warm day it expands about 2'. If there were no expansion joints to compensate for expansion, how high a bulge would be produced? Use the formula provided on page 2.		

	Problems	PA Core Math Look	Solutions
7.	Find $\sqrt{324}$ a) +- 16 b) +- 17 c) +- 18 d) +- 19		
8.	Which of the following is the approximate value of $\sqrt{5}$? a) +- 3.4 b) +- 2.5 c) +- 2.2 d) +- 1.8		
9.	$Z = \sqrt{31.25}$ Solve for Z. a) +- 31.25 b) +- 5.6 c) +- 6.6 d) +- 5.1		

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Problems	Career and Technical Math Concepts	Solutions
1. Fifteen pounds of force is needed to open the wastegate on a particular turbocharger. If the inlet has a diameter of three inches with 250 lbs. of force, find the area and the radius of the wastegate tube outlet.	$A_{inlet} = \pi(1.5)^2 = 7.07\,cu.in.$ $\dfrac{250}{7\,cu.in} = \dfrac{15}{A} \rightarrow \dfrac{7 \times 15}{250} = \dfrac{105}{250} = 0.42\,cu.in.$ $A = .42\,in.cu.$ $r = \sqrt{\dfrac{.42}{\pi}}$ $r = 0.37\,in.$	
2. To improve air conditioning cooling, a TSB (Technical Service Bulletin) states to replace the air intake duct with one with twice the area. What diameter line will you need to install if the installed duct is 2.5" diameter?	Installed Duct $A = \pi r^2$ $a = \pi(1.25^2) = 4.91\,in.^2$ Doubled $a = 9.82\,in.^2$ $r = \sqrt{\dfrac{9.82}{\pi}}$ $r = 1.77$ $d = 1.77 \times 2$ $d = 3.54\,in.$	
3. A customer complains his car pulls after an accident. All wheel alignment measurements are within spec. According to service manual you must measure the frame at 3-specific points to determine if the frame is twisted. If b = 36" & c = 48" what must a = for the frame to be in spec?	$a = \sqrt{c^2 - b^2}$ $a = \sqrt{48^2 - 36^2}$ $a = 31.75\,in.$	

Problems	Related, Generic Math Concepts	Solutions
4. You want to draw a square box and fill it with 144 one-inch squares, how many inches must each side of your square measure?	Find the square root of 144 (inches). Answer: The box should be 12 inches on all sides.	
5. Skid marks are used to determine the maximum speed of a car in an accident. If a car leaves skid marks of 175' with a coefficient of drag of 35%, its approximate speed, in MPH, can be determined. Use the formula provided on page 2.	$MPH \approx \sqrt{30 \times .35 \times 175}$ $MPH \approx 43$	
6. The Golden Gate Bridge is about one mile long. On a warm day it expands about 2'. If there were no expansion joints to compensate for expansion, how high a bulge would be produced? Use the formula provided on page 2.	$H = \sqrt{(\dfrac{5280}{2}+1)^2 - (\dfrac{5280}{2})^2}$ $H = \sqrt{(5280 \div 2 + 1)^2 - (5280 \div 2)^2}$ $H = \sqrt{5281} = 73'\,(rounded)$	

Problems	PA Core Math Look	Solutions
7. Find $\sqrt{324}$ a) +- 16 b) +- 17 c) +- 18 d) +- 19	c) +- 18	
8. Which of the following is an approximate value of $\sqrt{5}$? a) +- 3.4 b) +- 2.5 c) +- 2.2 d) +- 1.8	c) +- 2.2	
9. $Z = \sqrt{31.25}$ Solve for Z. a) +- 31.25 b) +- 5.6 c) +- 6.6 d) +- 5.1	b) +-5.6	