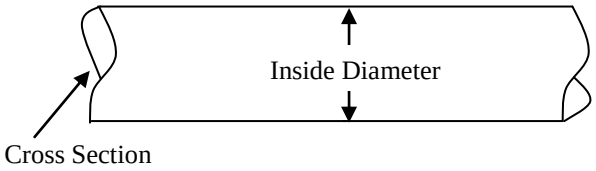
HVAC (47.0201) T-CHART

Determine volume of airflow	Apply geometric concepts to model and solve real world problems.

Program Task: Determine volume of airflow

Program Associated Vocabulary:
FORMULAS, EQUATIONS, RULES OF THUMB

Ductwork – Cross Sectional Area



Cross Section

Program Formulas and Procedures:
HVAC technicians must be proficient with mathematical formulas in order to be successful. When determining system performance, for instance, it must be known whether or not the designed volume of air is flowing throughout the duct system. To accomplish this, a multi-step mathematical process is used.

Air Volume is measured as a rate, in units of cubic feet per minute (CFM). HVAC technicians routinely calculate CFM rates. To determine CFM, technicians implement a process that first involves finding two other system values (air velocity and the cross sectional area of the duct in question).

We use this formula to calculate the cross sectional area of round ducts and pipes:
Area = πr^2

We use this formula to calculate the cross sectional area of rectangular ducts:
Area = lw

Finally, we use this formula to determine air flow volume in cubic feet per minute:
CFM = Area x Velocity

Example: Determine CFM where the Velocity = 900 feet per minute and the rectangular duct measures 24" X 36".
CFM = Velocity × Area ($ft.^2$)
CFM = 900 x ((24 × 36)/144)) (convert to sq. ft.)
CFM = 900 × 6
CFM = 5,400

PA Core Standard: CC.2.3.HS.A.14

Description: Apply geometric concepts to model and solve real world problems.

Math Associated Vocabulary:
LENGTH, HEIGHT, BASE, WIDTH, DIAMETER, RADIUS, HYPOTENUSE, AREA, PERIMETER, CIRCUMFERENCE

Formulas and Procedures:
Rectangle: $A = lw$ $P = 2l + 2w$

Trapezoid: $A = \frac{h(a+b)}{2}$

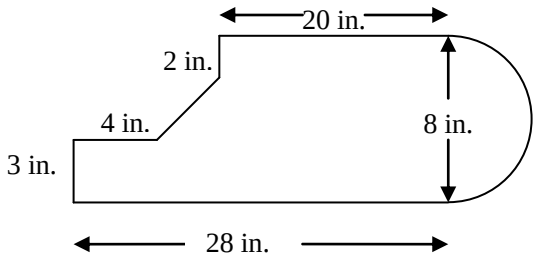
Circle: $A = \pi r^2$ $C = 2\pi r$ or πd
(Circumference = circle perimeter)

Triangle: $A = \frac{1}{2}bh$

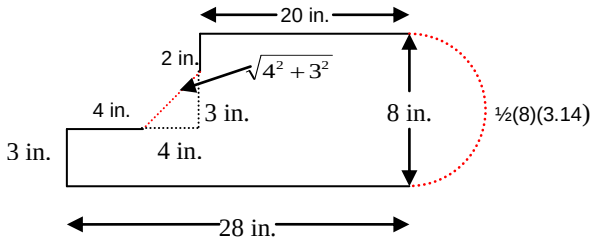
Pythagorean Theorem: $c^2 = a^2 + b^2$
An irregular figure can be broken down into two or more regular shapes, such as triangles, circles, trapezoids or rectangles.

To find the **perimeter** around irregular figures, add the lengths of the sides. If the sides of the figures include circles, use the circumference formula to calculate the length of that portion of the figure and add it to the total of the other sides.

Example 1: To find the **area** of an irregular figure, separate the figure into shapes for which you can calculate the area. The sum of the areas of each smaller figure is the area of the irregular figure.



Example 2: To find the **perimeter** of the figure above, use the Pythagorean theorem and circumference formula to find the missing lengths:



To find the **area** of the same figure, divide the figure into one triangle, two rectangles, and one semi-circle.

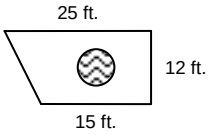
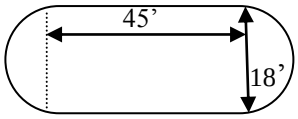
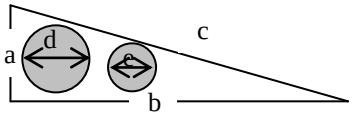
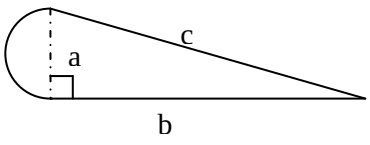
Instructor's Script - Comparing and Contrasting
It is important for HVAC technicians to not only be able to use formulas but also be able to manipulate them for another variable for trouble shooting purposes.

Example:
The free air flow velocity delivered by a fan is given as 80 CFM and the area of the airflow passage is 6 $in.^2$. What is the Velocity (LFM)?

$$\text{CFM} = \text{Velocity x Area}\left(\text{ft.}^2\right)$$
$$80 = \text{Velocity} \times \left(6\,\text{in.}^2 / 144\right)$$
$$80 = \text{Velocity} \times 0.04167$$
$$\frac{80}{0.04167} = \frac{\text{Velocity} \times 0.04167}{0.04167}$$
$$1919.8 = \text{Velocity}$$

Common Mistakes Made By Students
HVAC technicians must be able to calculate airflow volumes in cubic feet per minute (CFM). The area of a duct's cross section, in units of square feet, must be determined in order to make the calculation. Students often measure the outside of a rectangular duct in inches, and multiply the length by the width to determine the cross sectional area in square inches. This is acceptable, but they must convert those square inches to square feet, and this is where many go wrong. Students often divide the square inch value by 12, giving them the incorrect number of square feet. Be sure to reinforce that one square foot is equal to 144 square inches, and not 12 square inches. Many high school students can be counted on to make this mistake if they are not trained to avoid the error.
Square inches divided by 144 equals square feet!

CTE Instructor's Extended Discussion
This T-Chart focuses on airflow calculations as an example of formulas used by HVAC professionals. See T-Chart. CC.2.1.HS.F.2 (Find square root), for details on using the square root function to calculate air flow velocity.

Problems	Occupational (Contextual) Math Concepts	Solutions
1. What is the rate of air flow CFM in a duct if the velocity pressure is 900 fpm and the diameter of the circular duct is 8 inches?		
2. To limit whistling noises in a duct, you design for a velocity of 1,000 fpm. If you need 400 CFM delivered at 1,000 fpm, what is the area of the cross section of duct you will need?		
3. In the previous problem, it was determined that a duct needs to be 0.4 square feet in order to carry the proper air flow at the proper velocity. If a rectangular duct is used, and one side of the duct measures 6 inches, what should the other side measure?		
Problems	**Related, Generic Math Concepts**	**Solutions**
4. A health club has a circular jogging track with an outside diameter of 200 feet and the track is 15 feet wide. What is the area of the track?		
5. Your goal is to paint a mural that depicts a large yellow image of the Sun, risen half-way above the Eastern horizon. You buy a gallon of yellow paint and read that the manufacturer claims it will cover a 200 square foot wall. What is the diameter of the largest Sun you can paint?		
6. The installer plans to build a new patio with a 6 ft. (d) round hot tub in the center. What is the area of material needed around the hot tub pictured in the patio?		
Problems	**PA Core Math Look**	**Solutions**
7. Find the area of the figure pictured.		
8. Find the area of the figure pictured.		
9. Find the perimeter of the figure if c = 37 and b = 24.		

Problems	Occupational (Contextual) Math Concepts	Solutions
1.	What is the rate of air flow CFM in a duct if the velocity pressure is 900 fpm and the diameter of the circular duct is 8 inches?	$CFM = V \times Area \rightarrow CFM = V \times (\pi r^2) / 144$ $CFM = 900 \times (\pi 4^2) / 144$ $CFM = 900 \times (16\pi) / 144$ $CFM = 14400\pi / 144$ $CFM = 100\pi \rightarrow CFM = 314$
2.	To limit whistling noises in a duct, you design for a velocity of 1,000 fpm. If you need 400 CFM delivered at 1,000 fpm, what is the area of the cross section of duct you will need?	If CFM = Velocity x Area, then Area = CFM / Velocity. Area = 400 CFM / 1000 fpm Area = 0.4 square feet (4/10 of 1 square foot)
3.	In the previous problem, it was determined that a duct needs to be 0.4 square feet in order to carry the proper air flow at the proper velocity. If a rectangular duct is used, and one side of the duct measures 6 inches, what should the other side measure?	Hint: first convert the 0.4 ft.^{2} into square inches by multiplying by 144. $0.4 \times 144 = 57.6$ in.^{2} $A = L \times W \rightarrow 57.6\,\text{in}^2 = 6W$ $\frac{57.6}{6} = \frac{6W}{6} \rightarrow 9.6\,\text{inches} = W$
Problems	**Related, Generic Math Concepts**	**Solutions**
4.	A health club has a circular jogging track with an outside diameter of 200 feet and the track is 15 feet wide. What is the area of the track?	The diameter of the smaller circle is (200 - (15 + 15)) feet Large circle area = π (100 x 100) Large circle area = 3.14 x 10,000, or 31,400 ft.^{2} Small circle area = 3.14 x 85 x 85, or 22,687 ft.^{2} Area of the track = Large Circle Area (31,400) - Small Circle Area (22,687), or 8,718 ft^2.
5.	Your goal is to paint a mural that depicts a large yellow image of the Sun, risen half-way above the Eastern horizon. You buy a gallon of yellow paint and read that the manufacturer claims it will cover a 200 square foot wall. What is the diameter of the largest Sun you can paint?	Base your estimations on a semi-circle whose area is 200 sq. ft. A full circle size would be 400 sq. ft. Area of a semi-circle: $\frac{1}{2}\pi r^2 = 200$ $2 \times \frac{1}{2}\pi r^2 = 2 \times 200$ Multiple both sides by 2. $\pi r^2 = 400$ $\frac{\pi r^2}{\pi} = \frac{400}{\pi}$ Divide both sides by π. $r^2 = \frac{400}{\pi}$ $\sqrt{r^2} = \sqrt{\frac{400}{\pi}}$ Square root both sides. r = 11.28 Diameter = r (11.28) x 2 Diameter = 22.5’
6.	The installer plans to build a new patio with a 6 ft. (d) round hot tub in the center. What is the area of material needed around the hot tub pictured in the patio?	Area of patio = area of a trapezoid (patio shape) – area of the circle (hot tub shape) Area = $\frac{h(a+b)}{2} - \pi r^2$ $A = \frac{12(15+25)}{2} - \pi 3^2$ A= 240 – 28.26 = 211.74 ft.^{2}
Problems	**PA Core Math Look**	**Solutions**
7.	Find the area of the figure pictured.	Area = Area Rectangle + Area one full circle = $lw + \pi r^2$ (l=45, w=18, r = radius = ½ × 18 = 9’) = $(45)(18) + \pi(9)^2$ = 810 + 254.3 = 1064.3 ft.^{2}
8.	Find the area of the figure pictured.	Area = Area triangle – Area circle 1 – Area circle 2 = ½ bh – πr^2 - πr^2 (radius circle 1 = ½ × 3 = 1.5, radius circle 2 = ½ × 1 = 0.5) = ½ (18)(5) – $\pi(1.5)^2$ - $\pi(0.5)^2$ = 45 – 7.1 - .8 = 37.1 units^2
9.	Find the perimeter of the figure if c = 37 and b = 24.	Perimeter = c + b + semicircle with diameter a. $a^2 + b^2 = c^2$ $a^2 + 24^2 = 37^2$ $a^2 + 576 = 1369$ $a^2 + 576 - 576 = 1369 - 576$ $a^2 = 793$ $\sqrt{a^2} = \sqrt{793}$ a = 28.2 = diameter of semicircle circumference of semicircle =1/2 dπ = ½ (28.2)(3.14) = 44.3 Total perimeter = 37 + 24 + 44.3 = 105.3 units