

Sensor input / output as slope = Write functions or sequences that model relationships between two quantities

Program Task: Diagnose and operate digital and analog control devices.

PA Core Standard: CC.2.2.HS.C.3

Program Associated Vocabulary:
INPUT, OUTPUT, SIGNAL, RATE OF CHANGE

Description: Write functions or sequences that model relationships between two quantities.

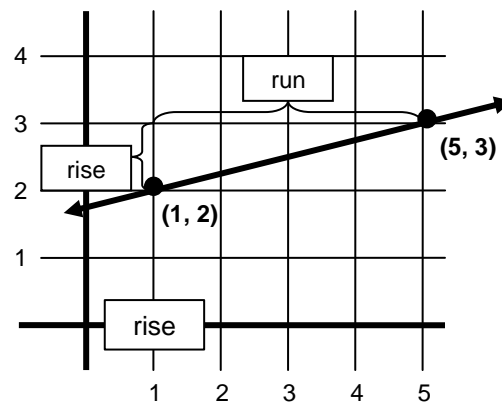
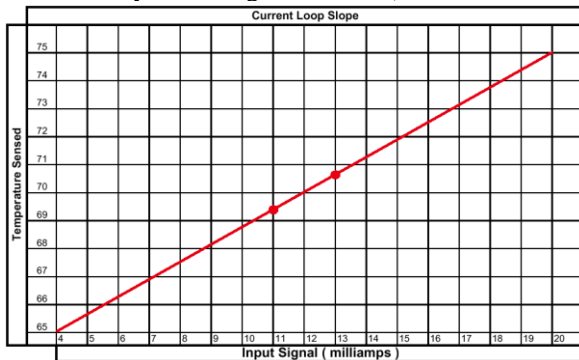
Math Associated Vocabulary:
SLOPE, RISE, RUN, RATE OF CHANGE, LINE, ΔX , ΔY

Program Formulas and Procedures:
HVAC systems utilize complex communication systems which allow HVAC components to interact with each other to provide optimum energy performance and comfort. Space sensors send climate information back to computer processors that interpret their signals and provide programmed responses to other pieces of equipment. In this way, temperature, humidity, CO₂ levels, and other conditions are controlled and monitored with a high degree of accuracy. The 4-20 milliamp sensor is used frequently in many computer based control systems.

Formulas and Procedures:

The 4-20 milliamp sensor is often preferred over voltage and resistance type sensors due to the fact that amperage does not vary within a given circuit (no loss / distance).

$$\text{slope} = \frac{Y_2 - Y_1}{X_2 - X_1} = \frac{\text{Rise}}{\text{Run}} = \frac{\Delta Y}{\Delta X}$$



In the graph above, a computer program interprets an input signal of 4 mA as 65 °F and 20 mA as 75 °F.

Example: To find the slope of the line above:

Find the slope of this sensor.
(4, 65), (20, 75)

Step1: Label your coordinates (x₁, y₁) and (x₂, y₂).

$$\text{slope} = \frac{Y_2 - Y_1}{X_2 - X_1} = \frac{75 - 65}{20 - 4} = \frac{10}{16} = \frac{0.625}{1}$$

Note: It does not matter which coordinate you select to represent (x₁, y₁) and (x₂, y₂)

For our example, we'll make (x₁, y₁) = (1,2) and (x₂, y₂) = (5,3)

Step 2: Substitute values into the formula and solve.

$$\text{slope} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{3 - 2}{5 - 1} = \frac{1}{4}$$

In other words, every 0.625 °F change produces a 1mA change.

Note: Slope is written as a fraction in simplest form

Another way to determine this would be to use the formula:
(Temp Range / Current Range)
(75 °F -65 °F) / (20mA - 4mA) which = 0.625.

HVAC (47.0201) T-Chart

Instructor's Script - Comparing and Contrasting

Many CTC program areas use the concept of slope without ever realizing it. Every time a student looks at a graph of a line and has to evaluate the rate of change, he/she is using the formula for slope. It is very important for an HVAC technician to be able to determine the rate of change when looking at a graph.

Common Mistakes Made By Students

Students will often not subtract consistently among y and x values. For instance, for the slope of a line passing through the points (3, 5) and (-1,7):

(3, 5) and (-1,7)

$$\frac{7-5}{3-(-1)} \quad \text{or} \quad \frac{5-7}{-1-3}$$

INCORRECT

instead of the correct answer:

(3, 5) and (-1,7)

$$\frac{7-5}{-1-3} \quad \text{or} \quad \frac{5-7}{3-(-1)}$$

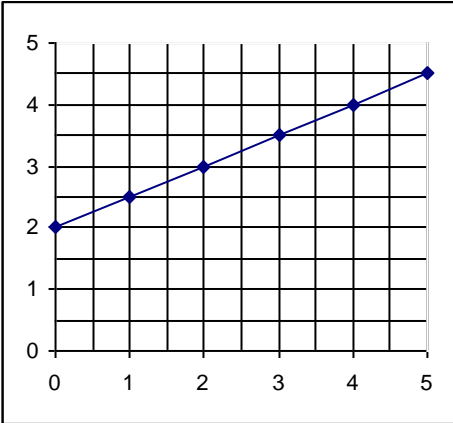
CORRECT

(3, 5) and (-1,7)

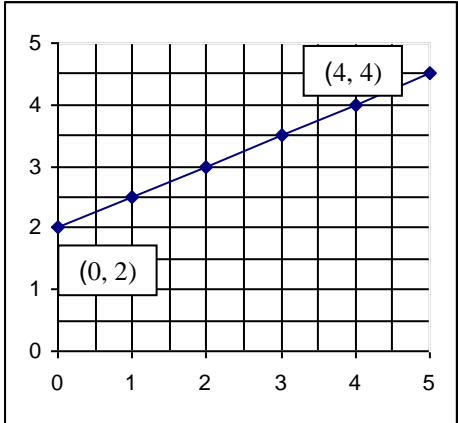
(3, 5) and (-1,7)

CTE Instructor's Extended Discussion

There are many other examples in the field of HVAC that might have been used to demonstrate this math concept. HVAC professionals are concerned with rate of change and the control of mediums that affect the desired change (outcome). Peruse any good HVAC text and you will see many graphs displaying the relationship between an X and a Y coordinates.

Problems	Occupational (Contextual) Math Concepts	Solutions
1. Determine the slope of a steam pressure sensor where 9 mA = 12 psi and 12 mA = 15 psi. (mA = X, psi = Y)		
2. Determine the slope of a walk-in freezer temperature sensor where 8 mA = -18° F and 13 mA = -9° F. (mA = X, temp = Y)		
3. Determine the slope of a CO ₂ sensor where 7 mA = 800 parts per million (ppm) 14 mA = 1200 ppm. (mA = X, CO ₂ ppm = Y)		
Problems	Related, Generic Math Concepts	Solutions
4. A ramp increases from ground level to a height of 5 feet over a span of 20 feet. What is the slope (rate of change) of the ramp?		
5. Determine the slope of the line graphed at the right:		
6. A sidewalk increases from ground level to a height of 3 feet over a span of 40 feet. What is the slope (rate of change) of the sidewalk?		
Problems	PA Core Math Look	Solutions
7. Find the slope of a line passing through the points (3, 5) and (2, 1).		
8. Find the slope of a line passing through the points (-2, 1) and (4, -5).		
9. Find the slope of a line passing through the points (4, 2) and (-5, 6)		

Problems	Occupational (Contextual) Math Concepts	Solutions
1. Determine the slope of a steam pressure sensor where 9 mA = 12 psi and 12 mA = 15 psi. (mA = X, psi = Y)		$\text{slope} = \frac{Y_2 - Y_1}{X_2 - X_1} = \frac{15 - 12}{12 - 9} = \frac{3}{3} = 1$ <p>A change of 1mA will produce a change of 1 psi.</p>
2. Determine the slope of a walk-in freezer temperature sensor where 8 mA = -18° F and 13 mA = -9° F. (mA = X, temp = Y)		$\text{slope} = \frac{Y_2 - Y_1}{X_2 - X_1} = \frac{(-9) - (-18)}{13 - 8} = \frac{9}{5} = 1.8$ <p>A change of 1mA will produce a change of 1.8°F.</p>
3. Determine the slope of a CO ₂ sensor where 7 mA = 800 parts per million (ppm) and 14 mA = 1200 ppm. (mA = X, CO ₂ ppm = Y)		$\text{slope} = \frac{Y_2 - Y_1}{X_2 - X_1} = \frac{1200 - 800}{14 - 7} = \frac{400}{7} \approx \frac{57.14}{1}$ <p>A change of 1mA will produce a change of 57.14 ppm.</p>

Problems	Related, Generic Math Concepts	Solutions
4. A ramp increases from ground level to a height of 5 feet over a span of 20 feet. What is the slope (rate of change) of the ramp?		$\frac{5}{20} = \frac{1}{4}$
5. Determine the slope of the line graphed at the right:		 $m = \frac{4 - 2}{4 - 0}$ $m = \frac{2}{4} = \frac{1}{2}$
6. A sidewalk increases from ground level to a height of 3 feet over a span of 40 feet. What is the slope (rate of change) of the sidewalk?		$\frac{3}{40}$

Problems	PA Core Math Look	Solutions
7. Find the slope of a line passing through the points (3, 5) and (2, 1).		$\frac{5 - 1}{3 - 2} = \frac{4}{1} = 4 \quad \text{or} \quad \frac{1 - 5}{2 - 3} = \frac{-4}{-1} = 4$
8. Find the slope of a line passing through the points (-2, 1) and (4, -5).		$\frac{-5 - 1}{4 - (-2)} = \frac{-6}{6} = -1 \quad \text{or} \quad \frac{1 - (-5)}{-2 - 4} = \frac{6}{-6} = -1$
9. Find the slope of a line passing through the points (4, 2) and (-5, 6).		$\frac{6 - 2}{-5 - 4} = \frac{4}{-9} = -\frac{4}{9} \quad \text{or} \quad \frac{2 - 6}{4 - (-5)} = \frac{-4}{9} = -\frac{4}{9}$