Sample Needed Math Project Scenario

Breaker Testing

Award # 2100062

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PROBLEM STATEMENT

A technician needs to test the critical design components of a medium to large circuit breaker to determine if all the manufacturing design specifications are met.

SCENARIO DESCRIPTION–SPECIFIC EXAMPLE

Circuit breakers are simple machines that cut the electrical power going to a circuit. Cutting the power is a needed safety feature that can prevent fires and other damage. In manufacturing plants, medium and high voltage (V) circuits are used that require large breakers. Low voltage, like in your home, has 120 V or 240 V circuits. Medium voltage circuits are defined as voltages between 600 V and 69 kV. High voltage circuits are defined as being from 115 kV to 230 kV, and extra-high volage is defined as 345 kV to 765 kV. The pictures below show a breaker that could be used in your home and one that is used in a medium voltage circuit. Every breaker is tested for multiple specifications such as the time to open, velocity of opening, and distance that one of the contacts moves. A breaker testing machine (shown in Figure 3) forces the breaker through various combinations of closing and opening the circuit. Data and graphics are generated that measure various parameters of the breaker. Each parameter is measured to determine if the breaker meets design specifications.

Fig 1. Low Voltage Breaker

Fig.2 Medium Voltage Breaker

Fig 3. Breaker being Tested (Rear of Breaker)

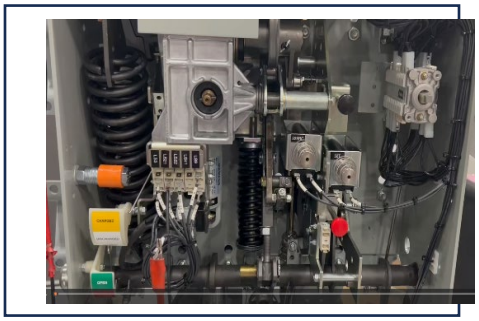


Fig. 4. Breaker being Tested (Front of Breaker)

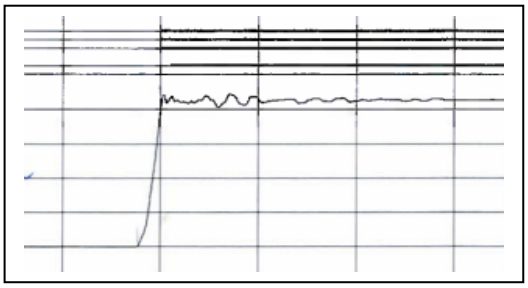
ISSUES TO BE ADDRESSED

As with any manufactured component, high standards are set to assure the breaker will work precisely as designed. A faulty breaker for a medium to high voltage circuit could be dangerous and cause serious harm or damage. These breakers must be tested and held to very high standards. A technician will use a breaker tester that runs the breaker through the operations it is designed to perform. Data and graphics are generated by the tester, and the technician will utilize the data and graphics to determine if the breaker meets specifications. Each breaker type has it's own specifications. Below is a short table showing 4 breaker types and seven of the requirements that need to be met. The technician will use the data generated, compare measured values, determine if each particular specification is met, and if any are not met, trouble shoot the potential problem and make adjustments until the breaker operates within all required specifications.

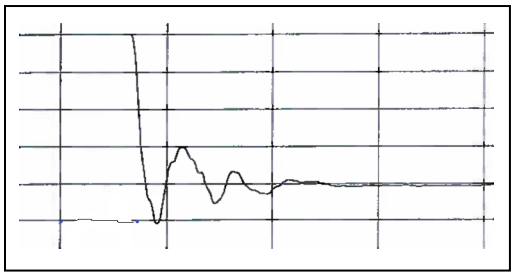
Type	H (mm)	Vc (m/s)	Vo (m/s)	C Time (ms)	O Time (ms)	OC (ms)	CO (ms)
B16-A-1200	5-7	0.4-0.8	0.6-1.2	62-85	24.8-41.6	130 max	140 max
C1-A-2000	10-12	0.8-1.3	1.0-1.8	51-77	24.8-41.6	130 max	140 max
E1-B-2000	7-9	0.4-1.1	0.7-1.4	51-77	24.8-41.6	130 max	140 max
D21-A-3000	18-22	1.1-1.7	1.3-1.8	63.8-83.8	24.8-41.6	130 max	140 max

Note: **H** represents the distance between contacts; **Vc** represents the average velocity of the movable contact when the breaker is closing; **Vo** represents the average velocity of the movable contact when the

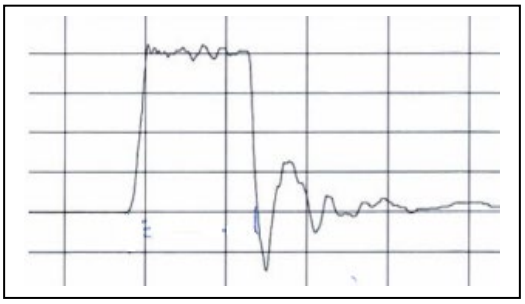
breaker is opening; **C** represents the time it takes for the breaker to close; **O** represents the time it takes for the breaker to open; **OC** represents the time it takes to first open the breaker and then re-close it; **CO** represents the time it takes to first close the breaker and then to re-open it.
In the medium voltage breakers, one of the two contacts moves back and forth to open and close the circuit and the other remains stationary. Opening (or tripping) the breaker means the two contacts were together (or touching) and the movable contact is pulled away from the stationary contact thus creating an opening between the contacts which stops the flow of current through them. Closing the breaker means the two contacts were apart and the movable contact is pushed against the stationary contact so that they are touching, therefor allowing current to flow from one to the other. During the testing of this type of breaker, the distance the face of the moving contact is from its resting position when the breaker is open is measured. Below are the graphs made by the breaker tester to record this distance as the breaker is put through various combinations of opening and closing. Each graph has time on the horizontal axis in ms with a scale (gridline increment) of 50 ms, and has distance traveled by the moveable contact on the vertical axis in mm with a scale of 2 mm.



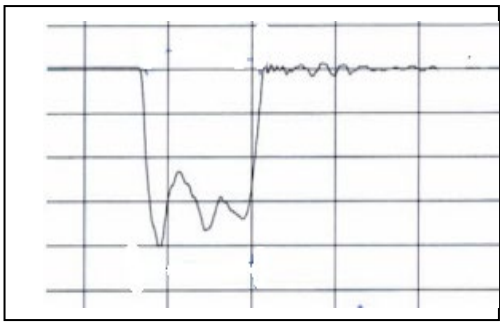
Closing the breaker



Opening/Tripping the breaker



Closing then Opening - CO



Opening then Closing - OC

WHERE DOES MATHEMATICS COME IN?
Unit conversations (metric prefixes) , reading/interpreting graphs , finding slope, critical thinking

Math Questions:

The videos linked below will assist you in understanding how a breaker works, both in the home and in a medium voltage circuit.

Watch the four-second video https://tinyurl.com/homebreakertripping showing a breaker that is opening or tripping. Then watch from 4:27 min to 4:40 min of the video https://www.youtube.com/watch?v=FXq3SzmjwQA that shows a medium voltage breaker that is opening.

The copper disks inside the breaker are called *contacts*. When opening or closing, only one contact moves and the other contact is stationary

Tasks 1-4 relate to Figures 5 and 6 below (Breakers A and B)

Task 1: Which breaker is closed? Which is open?

Task 2: If the lower contact on Breaker A moves a distance of 12 mm in 20 ms, find the contact's average speed.

Task 3: Convert 0.4 mm/ms into meters per second.

Task 4: If Breaker A changes to closed, which graphic below best shows the distance travelled by the movable contact? Explain your reasoning.

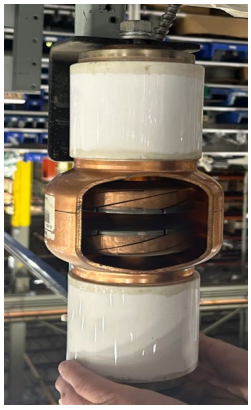


Fig. 5. Breaker A

Fig. 6. Breaker B

Based on the graph you selected in Task 4:

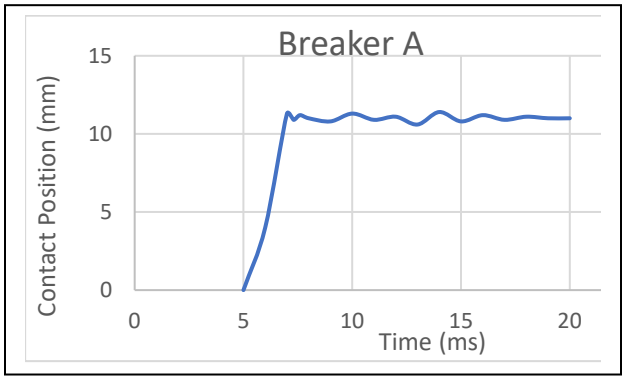
a) What is the average velocity of the movable contact 1 ms after it starts to close?

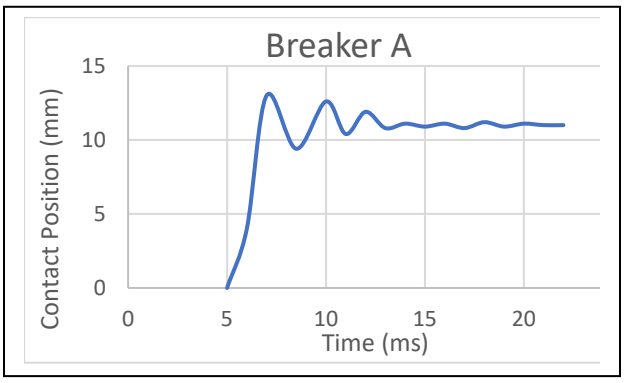
b) What is the average velocity of the movable contact 4 ms after it starts to close?

c) What is the average velocity of the movable contact 10 ms after it starts to close?

d) What is the average velocity of the movable contact 20 ms after it starts to close?

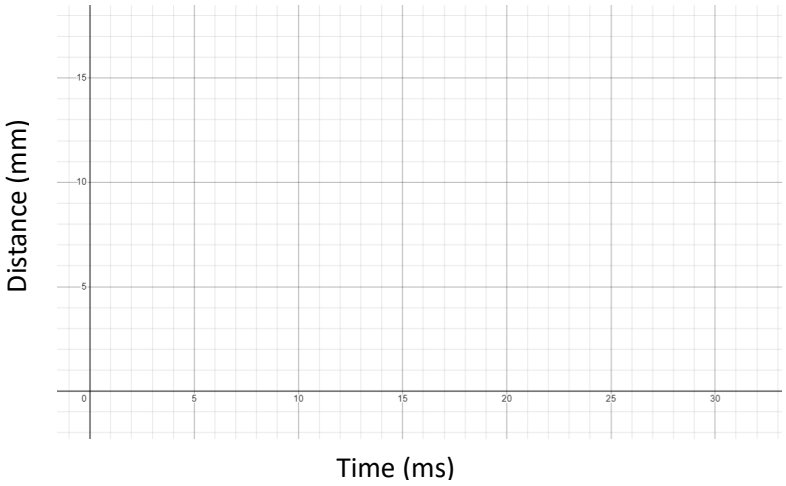
e) What would be the best measure of the average velocity of the movable contact from the moment the breaker is closed till it first makes contact with the stationary contact?





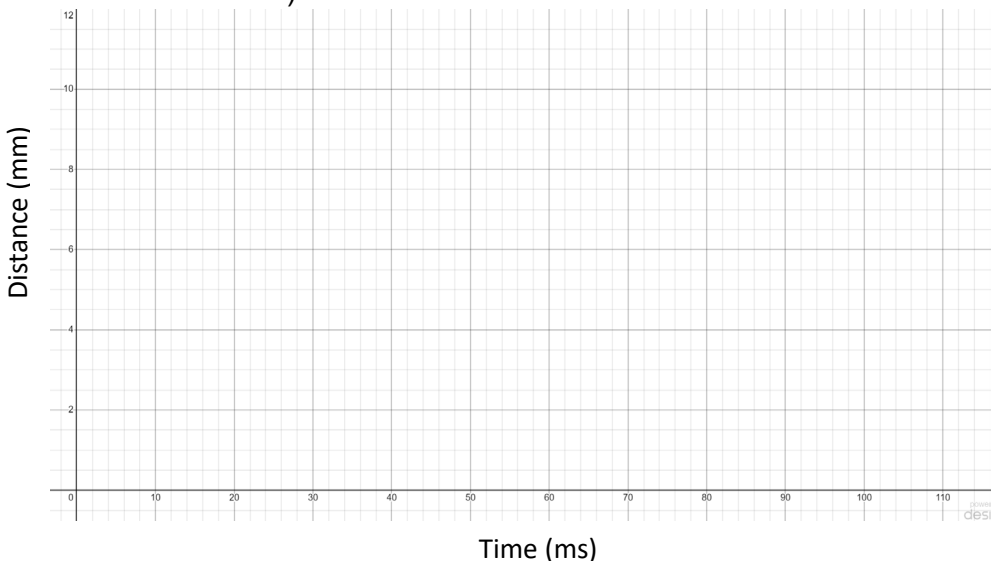
When this type of breaker is closed (contacts are touching and current is flowing), a motor is used to cock a heavy spring that when released will quickly pull the lower contact away from the upper contact thus "tripping or opening" the breaker (contacts will be apart and current will not be flowing). This is referred to as "tripping the breaker to the open position". The two videos linked below show the back view and front view of the breaker opening/tripping.
Back: https://drive.google.com/file/d/1sUj9udP06aLIWWu0RQFmj6OSVGe_MK1d/view?usp=drive_link
Front: https://drive.google.com/file/d/1EZz5ZiG4r9JsUKvGbqoQalBheNzZ1hfM/view?usp=drive_link
The one video whose link is below shows the back view of the breaking closing.
https://drive.google.com/file/d/1_WsnGEL5UNsp1_A0ABUvq3Ck1I5fmokP/view?usp=drive_link

Task 5: When a particular breaker is open, the distance between the contacts is a minimum of 12 mm apart. When the breaker is opening, the movable contact needs to travel at an average velocity of 0.5 m/s. Sketch a graph below that shows the distance traveled by the movable contact when the breaker is opening/tripping.

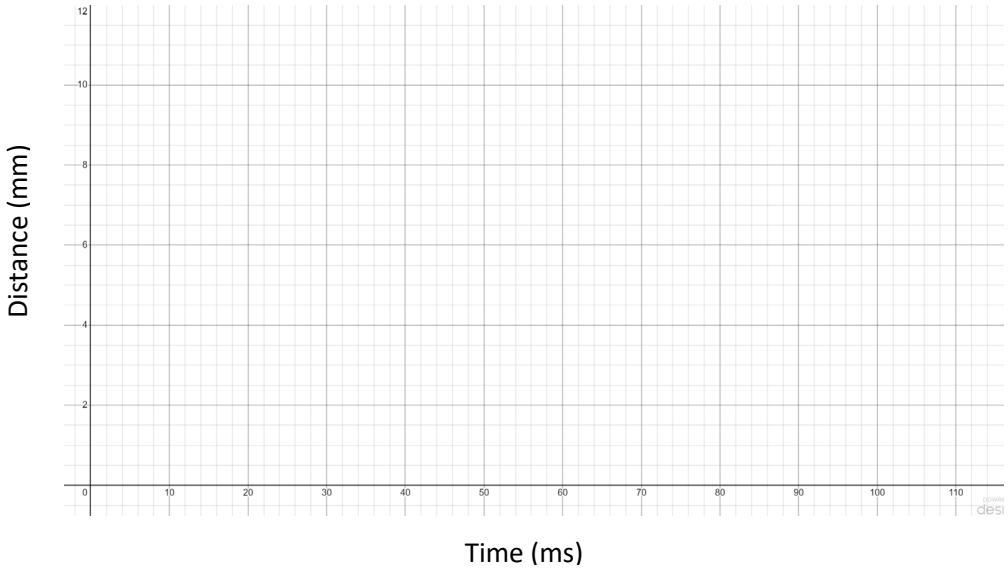


When testing breakers, a technician runs them through different sequences of closing and opening, which replicate how the breaker will be used on the job.

Task 6: One task is to determine how quickly the contacts can open from a closed position and then go back to a closed position. Suppose the lower contact moves 0.7 m/s to an open position and then moves 0.5 m/s to a closed position, the lower contact moves to a position of 7.5 mm apart, and also the total time from closing to open and back to closing takes 80 ms. Sketch a graph below that shows the distance traveled by the movable contact when the breaker is going through an open/close (OC) cycle. (????where is distance zero????)



Task 7: If this same breaker starts in the open position and is put through a close/open (CO) sequence, sketch the graph you predict the tester would record. Explain your reasoning. (Hint: you might want to refer to your graph in Task 6, above)



Each breaker has its own specifications for passing each criterion. The following table shows breaker types and a partial list of the criteria for passing. Use this table to answer Tasks 8 - 10 below.

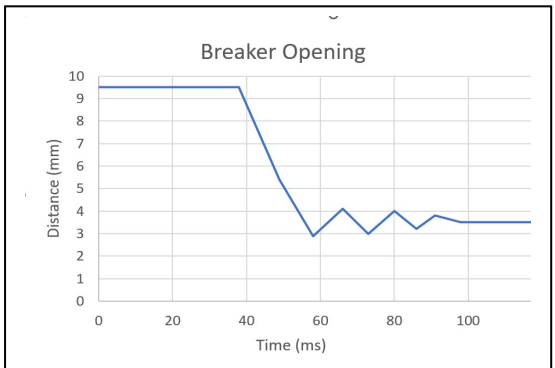
Type	H (mm)	Vc (m/s)	Vo (m/s)	C Time (ms)	O Time (ms)	O to C (ms)	C to O (ms)
B16-A-1200	5-7	0.4-0.8	0.6-1.2	62-85	24.8-41.6	130 max	140 max
C1-A-2000	10-12	0.8-1.3	1.0-1.8	51-77	24.8-41.6	130 max	140 max
E1-B-2000	7-9	0.4-1.1	0.7-1.4	51-77	24.8-41.6	130 max	140 max
D21-A-3000	18-22	1.1-1.7	1.3-1.8	63.8-83.8	24.8-41.6	130 max	140 max

Task 8: Breaker D21-A-3000 is being tested and the technician uses the graphs produced by the tester to determine the following measurements:

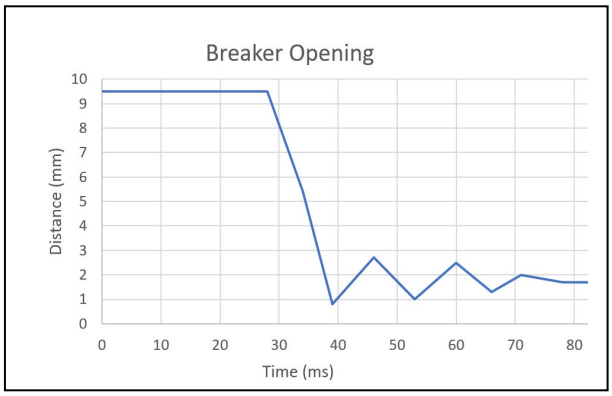
H= 18.9 mm; Vc = 1.41 mm/ms; Vo = 1.81 mm/ms; Time to close = 41 ms; Time to open = 25 ms; OC time = 120 ms; CO time = 135 ms.

Does this breaker pass inspection? Explain your reasoning. Be sure to reference all seven criteria.

Task 9: Breaker B16-A-1200 is being tested and the technician gets the graphical printouts below. Does this breaker pass inspection? If not, which criteria are not met and how do they need to be changed, by adjustments to the breaker assembly, in order for the breaker to pass?



Task 10: Breaker E1-B-2000 is being tested and the technician gets the graphical printouts below. Does this breaker pass inspection? If not, which criteria are not met and how do they need to be changed, by adjustments to the breaker assembly, in order for the breaker to pass?



Task 11: For a C1-A-2000 breaker, speculate on why each of the following "out of spec" values could be a problem with its operation or present potential safety issues. Explain your reasoning.

a) The breaker has an H value of 3 mm.

b) The breaker has an opening velocity of 2.8 m/s.

c) The breaker has a closing velocity of 3.5 mm/ms.

d) The breaker has a CO time of 250 ms.