Math Skills Laboratory

Lab 3 MS 3

MATH ACTIVITIES

Activity 1: ***Determining Period and Peak-to-peak Voltage from Oscilloscope Display***

Activity 2: ***Determining Frequency and Peak-to-peak Voltage from Oscilloscope Display***

Activity 3: ***Solving Electrical-rate Problems***

MATH SKILLS LAB OBJECTIVES

When you complete these activities, you should be able to do the following:

1. ***Determine period and peak-to-peak voltage of the signal when given a waveform display and control settings on an oscilloscope.***
2. ***Determine frequency and peak-to-peak voltage of the signal when given a waveform display and control settings on an oscilloscope.***
3. ***Substitute numerical values and units in electrical rate equations. Solve for unknowns.***

LEARNING PATH

1. ***Read the Math Skills Lab. Give particular attention to the Math Skills Lab Objectives.***
2. ***Study Examples A and B in Activities 1 and 2.***
3. ***Work the problems for Activities 1, 2 and 3.***

ACTIVITY 1:

Determining Period and Peak-to-peak Voltage from Oscilloscope Display

EQUIPMENT

If you have an oscilloscope and a waveform generator, you may wish to use the oscilloscope screen directly to show the drawings depicted in Examples A and B and the problems that follow.

When troubleshooting an electrical circuit, a technician must be able to "see" an electrical signal and analyze its properties. ***Oscilloscopes*** are designed to display electrical signals. The tube face (cathode-ray tube or CRT) of the oscilloscope is marked off in grid lines. The electrical signal on the face can be measured if you know the scope control settings.

Figure 1 shows the "volts-per-division (vertical)" and "time-per-division (horizontal)" controls of an oscilloscope. The figure also shows a triangle wave on the oscilloscope screen display.

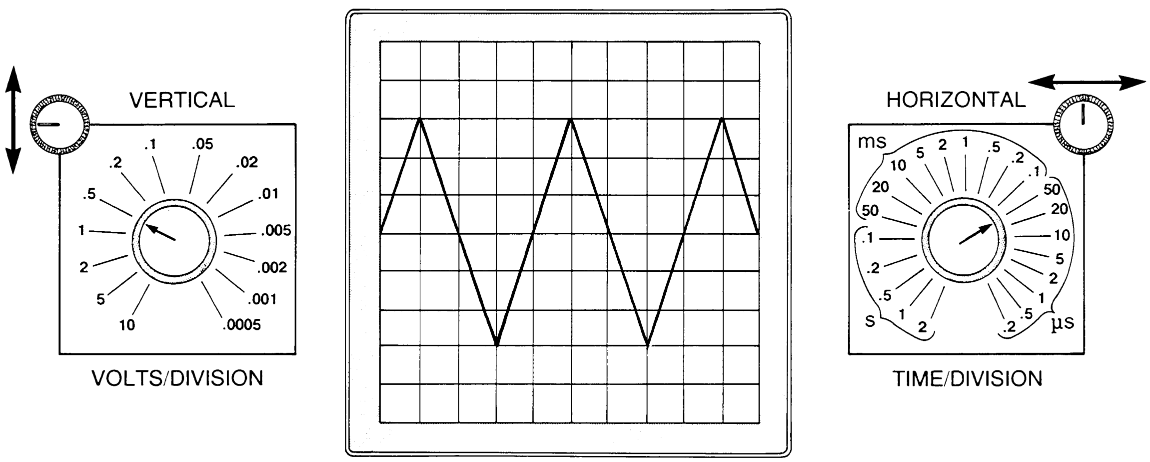
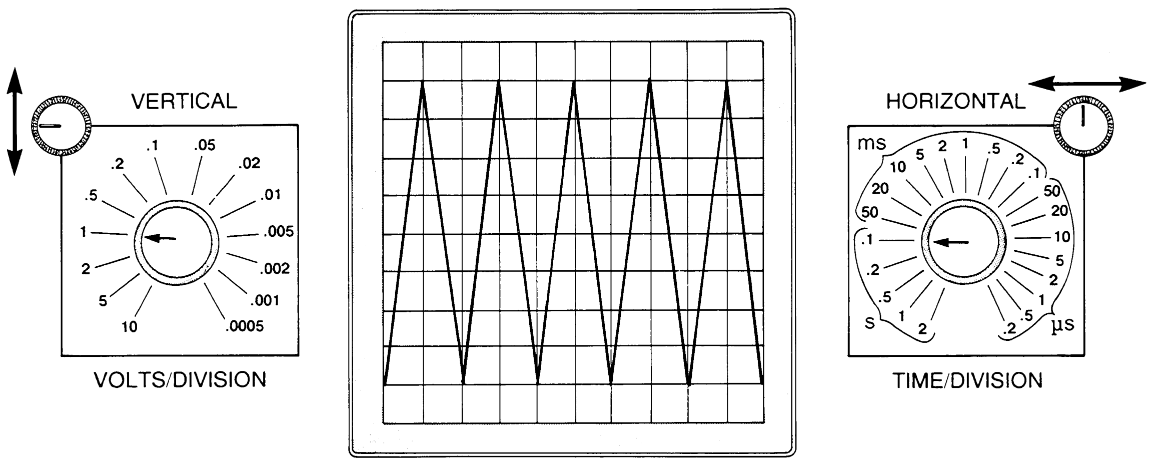


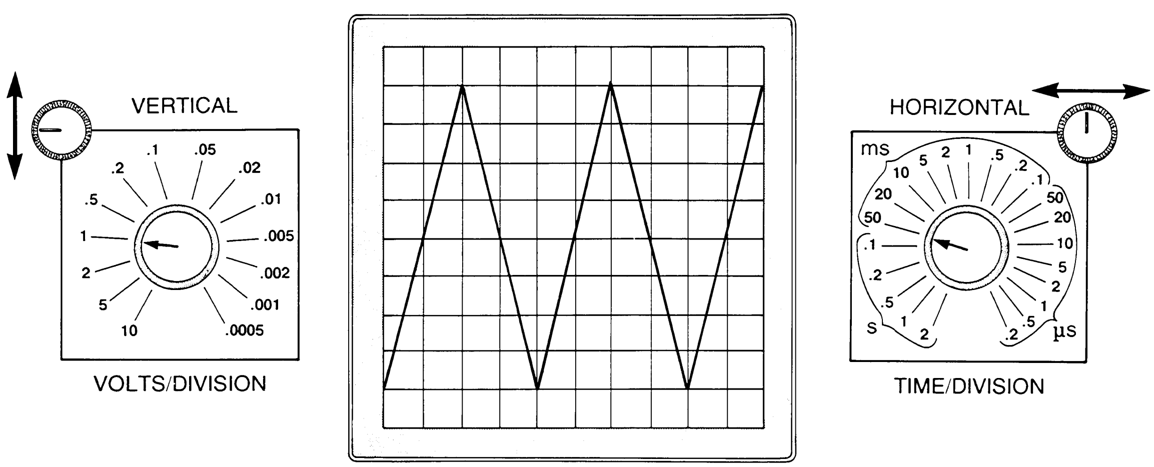
Fig. 1 Oscilloscope controls and display screen.

The ***vertical control*** changes only the height of the signal displayed. Turning the control to a ***higher number*** causes the height of the displayed signal to ***decrease.*** Turning the control to a ***lower number*** causes the height of the displayed signal to ***increase.***

The ***horizontal control*** is used to adjust the spacing between waveforms along the horizontal axis of the screen grid. Figure 2 shows how changing the "time/division" setting affects the display seen on the oscilloscope screen. The horizontal distance between the grid lines represents elapsed time. Numbered settings on the horizontal control indicate the value of the distance between grid lines. The horizontal control has three ranges of time—seconds (sec), milliseconds (msec), and microseconds (μsec). In Figure 2a, the horizontal control is set to 0.1 second per division (0.1 sec/div). There are five repetitions (cycles) of the triangle wave shown on the screen. Figure 2b shows what happens when we change the horizontal setting to 50 msec/div. Notice that now there are only 2 ½ repetitions of the triangle wave across the screen. Also notice that the height of the signal didn't change from Figure 2a to 2b. That's because we changed the horizontal control only. We left the vertical control set at 1 volt/div.



a. Display with 0.1 sec/div setting



b. Display with 50 msec/div

Fig. 2 Changing the horizontal control affects the displayed signal.

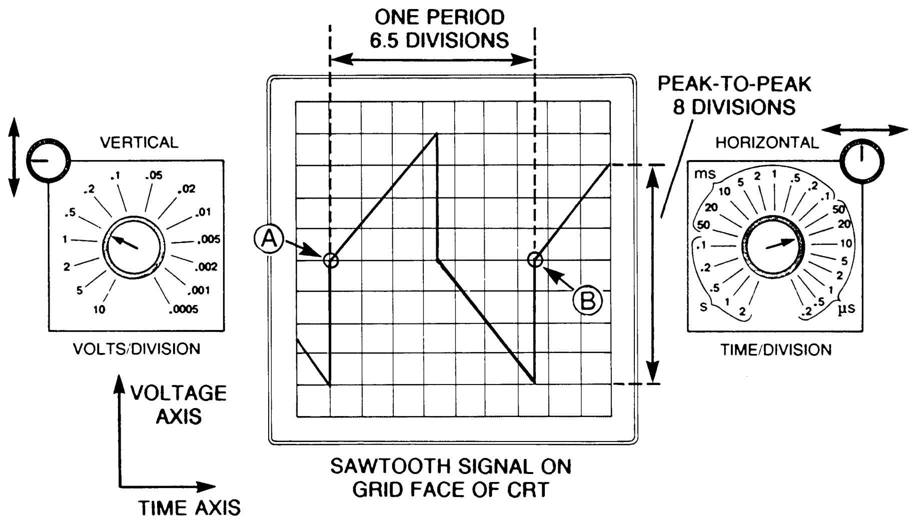
The waveform displayed by an oscilloscope can be used to find many characteristics of the input signal that's producing the waveform. One of these characteristics is the peak-to-peak height of the input signal. The peak-to-peak height is the vertical distance from the very bottom of the waveform to the very top.

Another characteristic that can be measured with the oscilloscope is the period (T) of the input signal. In this Math Skills Lab, you'll learn the various mathematical methods you need to convert the data you see on the oscilloscope control settings and screen into useful information.

The oscilloscope display in Example A shows a waveform that is sometimes called a ***sawtooth wave***. Work your way through the example, using the display and the control settings indicated. Note that the *time-per-division setting* controls time along the *horizontal* axis. The *volts-per-division setting* controls voltage along the *vertical* axis.

Example A: *Determining Voltage Level and Period*

Given: The oscilloscope has the settings shown below with a stable cathode-ray tube (CRT) display.



Find:
a. The period (T) of one cycle of the waveform.
b. The peak-to-peak voltage of this signal.
c. What type of waveform is this?

Solution:
a. The period of one cycle of the waveform. The "time/div" control is set at 20 μsec (microseconds) per division. (***Note:*** The Greek letter "μ"—pronounced "myoo"—stands for the prefix "micro.") If you count the number of divisions for one period from Point A to Point B on the grid face, you get approximately 6.5 divisions. Thus, the period (T) equals:

$$20 \frac{\mu\text{sec}}{\cancel{\text{div}}} \times 6.5\ \cancel{\text{div}} = 130\ \mu\text{sec}$$ (The "div" units cancel out.)

b. The peak-to-peak voltage of this signal. ***Note:*** Peak-to-peak is a measurement of the signal variation along the vertical (voltage) scale from the top-most point to the bottom-most point. The "volts/div" is set at 0.5 volts/div. Counting the number of divisions from the maximum positive trace point (top) to the maximum negative trace point (bottom) yields 8 divisions. Thus,

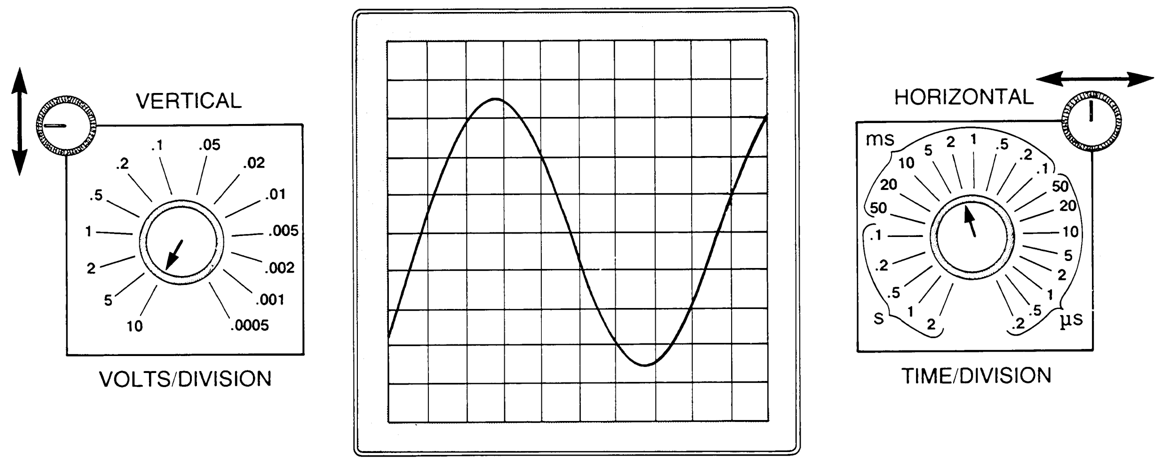
$$0.5 \frac{\text{volts}}{\cancel{\text{div}}} \times 8\ \cancel{\text{div}} = 4.0 \text{ volts peak-to-peak.}$$ (The "div" units cancel out.)

c. The waveform is of the sawtooth type.

PRACTICE EXERCISES FOR ACTIVITY 1

Problem 1: Given: The oscilloscope has the settings shown below with a stable CRT display.

Find:
1. Time/division and volts/division settings indicated.
2. The period of one cycle of this waveform, in seconds.
3. Voltage of signal, peak-to-peak.



Solution:

ACTIVITY 2:

Determining Frequency and Peak-to-peak Voltage from Oscilloscope Display

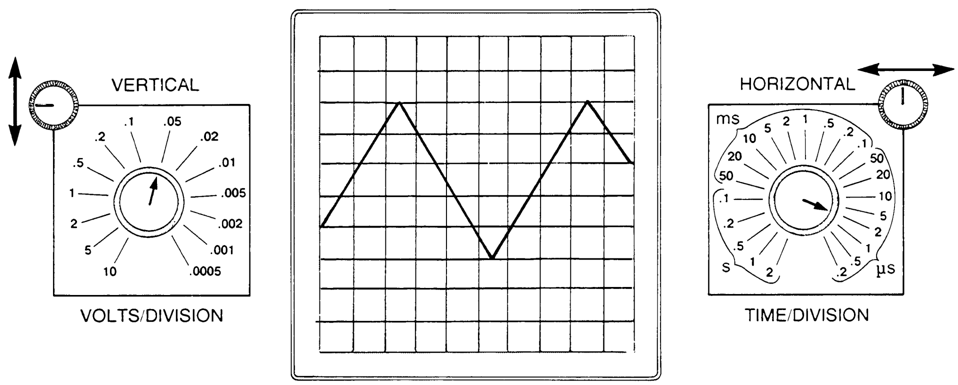
EQUIPMENT

See equipment for Activity 1.

This display is similar to the one shown in Activity 1. However, in this activity you will find the frequency and amplitude. Read through Example B carefully.

Example B: ***Calculating Frequency and Amplitude of a Signal***

Given: The oscilloscope has the settings shown below with a stable CRT display.



Find:
a. The frequency of the input signal.
b. The amplitude (peak-to-peak voltage) of the input signal.

Solution:
a. The “time/div” switch is set at 2 μsec/div. Counting the number of divisions for one period, we find about six divisions. Thus, the period (T) is:

$$T = 2\ \frac{\mu\text{sec}}{\cancel{\text{div}}} \times 6\ \cancel{\text{div}} = 12\ \mu\text{sec} \qquad \text{(Cancel “div” units.)}$$

Note: 12 μsec = 12 microseconds = 12×10^{-6} sec. Remember that the prefix “micro” always stands for 10^{-6}, or one-millionth.

Using the equation, $f = \frac{1}{T}$, we find that:

$$f = \frac{1}{T} = \frac{1}{12\ \mu\text{sec}} = \frac{1}{12 \times 10^{-6}\ \text{sec}} = \frac{1}{0.000012\ \text{sec}} = 83{,}333\ \frac{1}{\text{sec}}$$

Note: 12×10^{-6} seconds is equal to 0.000012 sec.

$$f = 83{,}333\ \text{Hz} \qquad \left(\text{Since } 1\ \text{Hz} = \frac{1}{\text{sec}}.\right)$$

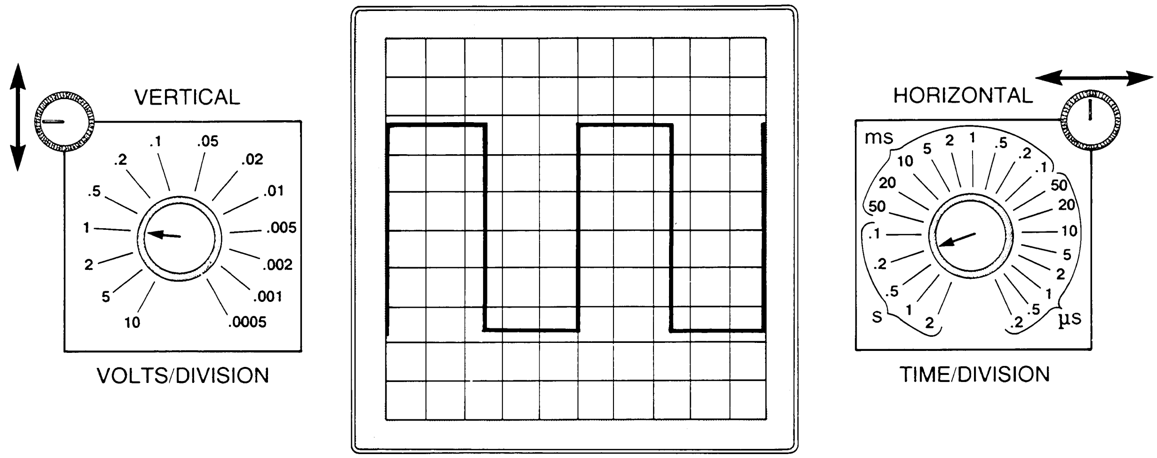
So, the frequency of the input signal, using scientific notation is 8.33×10^{4} Hz.

b. To find the amplitude of the voltage signal, peak-to-peak, notice that the “volts/div” switch is set to 0.05 volt per division. By counting the number of vertical divisions from peak-to-peak, we find five divisions. Therefore, the amplitude, or peak-to-peak voltage ($V_{p\text{-}p}$) is:

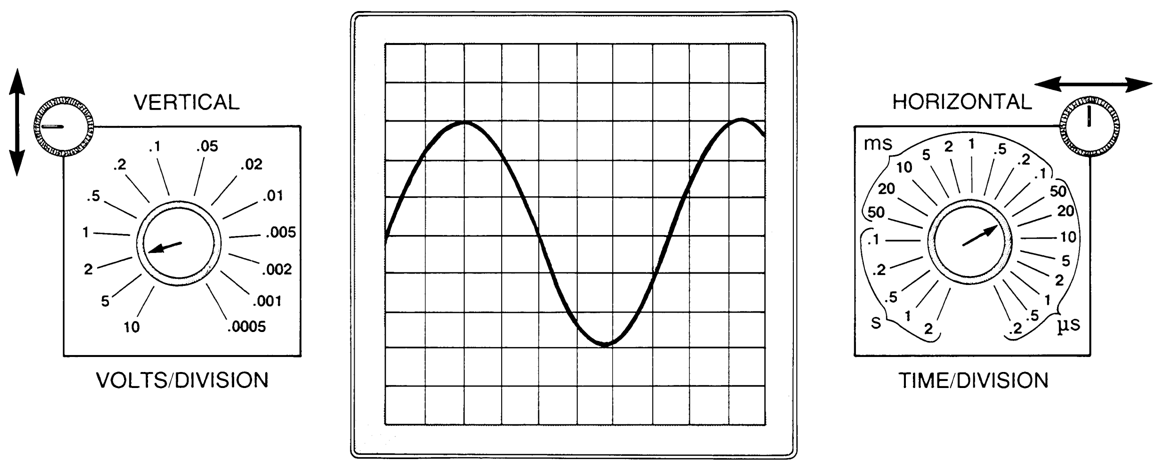
$$V_{p\text{-}p} = 0.05\ \frac{\text{volts}}{\cancel{\text{div}}} \times 5\ \cancel{\text{div}} = 0.25\ \text{V (peak-to-peak)}$$

PRACTICE EXERCISES FOR ACTIVITY 2

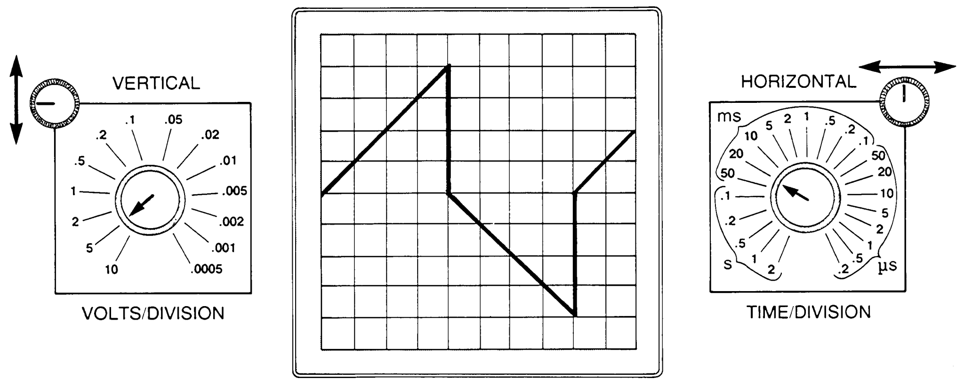
Problem 2: Name the type of waveform shown below. Find its period, frequency, and peak-to-peak voltage, given the control settings shown.



Problem 3: Find the peak-to-peak voltage, period and frequency of the ***sine waveform,*** given the control settings shown.

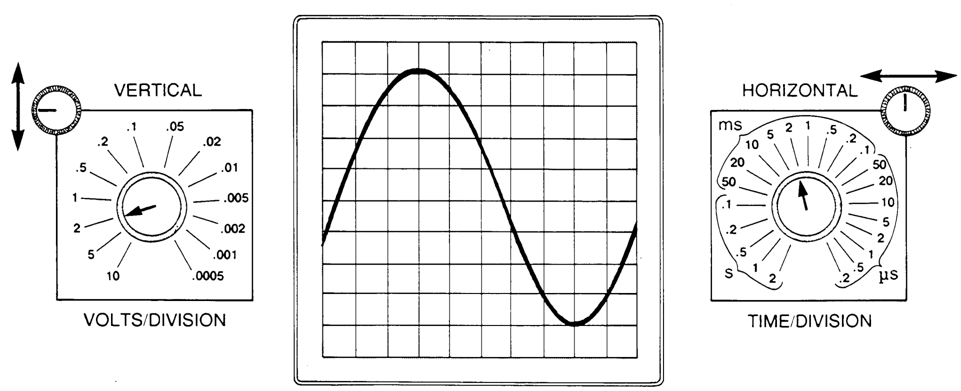


Problem 4: Find the amplitude (peak-to-peak voltage), period and frequency of the ***sawtooth waveform*** shown below, given the control settings shown. A "×10" oscilloscope probe was used to obtain the signal.



Note: A "×10" oscilloscope probe reduces the signal the oscilloscope receives by a factor of 10. Thus, if a 10-volt signal were applied to the probe, the scope would display only one volt. If a 100-volt signal were applied to the probe, the scope would read 10 volts. After making peak-to-peak voltage measurements on the "scope" face, the measurements should be *multiplied by 10* to get the true peak-to-peak voltage measured by the probe. The "×10" probe has no effect on the time/div control.

Problem 5: Find the peak-to-peak voltage and frequency of the sine wave shown below, given the control settings shown. Note that a "×10" oscilloscope probe was used to obtain the electrical signal.



ACTIVITY 3:

Solving Electrical-rate Problems

EQUIPMENT

For this activity, you'll need a hand calculator.

This activity will give you practice in rearranging equations to isolate an unknown. It also gives practice in solving for an unknown quantity by substituting numbers and units in electrical rate equations.

A. The equation for electrical charge-flow rate or current is:

$$\text{Electrical Current} = \frac{\text{Charge Transferred}}{\text{Elapsed Time}} \qquad \textbf{\textit{Equation 1}}$$

To simplify Equation 1, use the symbols:

$$I = \frac{q}{t} \qquad \textbf{\textit{Equation 2}}$$

where: I = electrical current (amperes)
q = charge transferred (coulombs)
t = elapsed time (hours, minutes, seconds)

B. The equation for electrical frequency is:

$$\text{Electrical Frequency} = \frac{\text{Number of Cycles}}{\text{Elapsed Time in Seconds}} \qquad \textbf{\textit{Equation 3}}$$

To simplify Equation 3, use the symbols:

$$f = \frac{n}{t} \qquad \textbf{\textit{Equation 4}}$$

where: f = frequency (cycles/sec)
n = number of cycles
t = elapsed time (seconds)

Note: Frequency is often expressed in the unit of ***hertz:*** 1 cycle/sec = 1 hertz.

C. Period and frequency of a repeating electrical signal are related by an inverse relationship. The equation for the period of an electrical wave with a known frequency is:

$$\text{Electrical Wave Period} = \frac{1}{\text{Electrical Wave Frequency}} \qquad \textbf{\textit{Equation 5}}$$

To simplify Equation 5, use the symbols:

$$T = \frac{1}{f} \qquad \textbf{\textit{Equation 6}}$$

where: T = period of electrical signal (usually in seconds)
f = frequency of electrical signal (cycles/sec or hertz)

PRACTICE EXERCISES FOR ACTIVITY 3

Before you work the following electrical rate problems, review the units used to describe electrical rates.

Electrical current is measured in ***amperes.***

Electrical charge is measured in ***coulombs.***

The frequency of an electrical signal is measured in ***cycles/sec or hertz.***

The period of an electrical signal is measured in ***seconds.***

Test your understanding by completing the following sentences:

a. The rate unit for electrical current is ______.

b. One coulomb per second is equal to ______.

c. Ten coulombs of charge flowing through a wire in two seconds is equal to ______ amperes of current.

d. An electrical frequency of 100 cycles per second is also equal to ______ hertz (Hz).

e. If an electrical signal has a frequency (f) of 10 Hz, it has a period of ______ seconds.

Use Equations 2, 4 and 6 to solve the following problems.

Problem 6: Given: A 110-V heating element in an electrical water heater is rated at 20 amperes.

Find: The charge that passes through the element in 10 seconds. (***Hint:*** Use the equation, $I = q/t$. Rearrange equation to isolate q. Then solve for q in coulombs. Remember that one ampere equals one coulomb per second.)

Solution:

Problem 7: Given: A solid-state device in a hand-calculator display has 3×10^{-2} coulombs of charge pass through it in 10 seconds.

Find: The current used by the calculator in milliamperes. (***Hint:*** Use the equation $I = q/t$. Note that 1 milliampere = $1/1000$ ampere = 10^{-3} ampere.)

Solution:

Problem 8: Given: In an electric motor, operating at a constant speed, 3×10^{4} coulombs of charge have moved through the motor. The motor is operated at a steady current of 50 amperes during the entire period of time.

Find: The length of time the motor operated at constant speed.

Solution: (***Hint:*** Use the equation, $I = q/t$. Rearrange the equation to isolate the time t. Then substitute values and solve for the time in seconds.)

Problem 9: Given: The electron gun in a TV picture tube scans the width of the screen. To form an image, it produces 15.75×10^{4} lines on the screen during a 5-minute period.

Find: The frequency (lines per second) of the electron gun.

Solution:

Problem 10: Given: The oscilloscope of an engine analyzer shows that the waveform for an electronic ignition device on a 6-cylinder engine has a frequency of 6000 pulses/minute at an engine speed of 2000 rpm.

Find:
a. The number of times the device pulses during a 5-minute test.
b. The period in seconds between successive pulses.

Solution: