

# Alternating and Direct Current Circuits

**Objectives:** To compare and contrast the behavior of common circuit elements in alternating current (AC) and direct current (DC) circuits; to study the characteristics of AC waveforms.

**Equipment:** Computer with Electronics Workbench®

**Discussion:** Some devices, such as resistors, act to modify the nature of current flow and voltage drop in much the same manner whether the circuit is DC or AC. Other electric devices act very differently in AC and in DC Circuits. In this exercise you will observe a variety of changes produced by various circuit devices in order to become familiar with the changes from device to device. We will use a computer in this exercise to model a number of different test circuits and instruments.

In the following exercises *it is extremely important that you not save any changes that you make in the circuits you load from your computer's hard disk.* If at any point during the simulation your circuit becomes scrambled, REVERT TO SAVED in the file menu will restore the circuit to its original form.

## Procedure: AC Waveforms

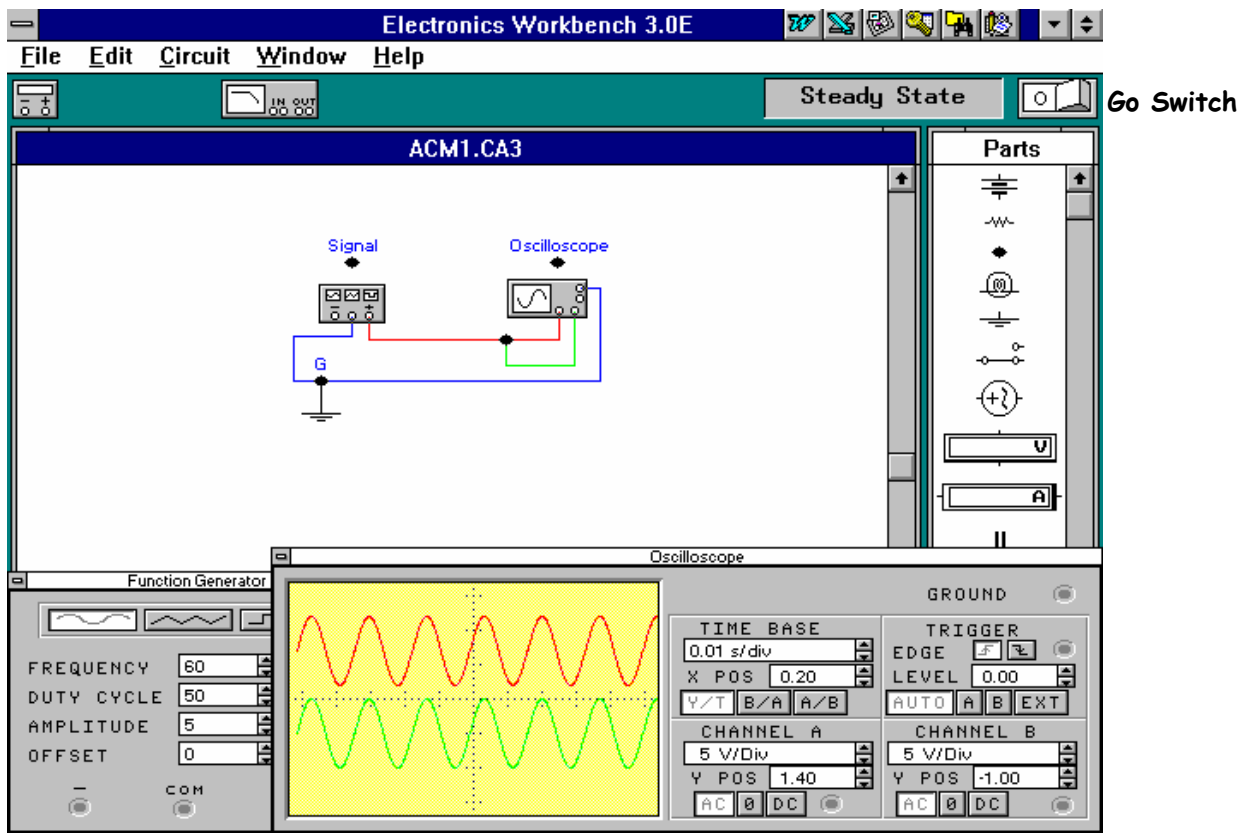


Figure 1.

Open circuit **acm1**. This circuit consists of an oscilloscope with two test probes measuring the AC output signal produced by a function generator. Move the cursor to the switch icon on the bar at the top right of the display. This switch is known as the *GO* switch and starts the simulation. You may activate the *GO* switch by clicking the mouse while the cursor is positioned over its right side. Turn on the *GO* switch now and see what happens (Figure 1).

Next change the frequency of the incoming signal to 15Hz (it should currently be set to 60Hz). This is accomplished by moving the cursor to the frequency control on the function generator, pressing and holding down the left mouse button, and moving the mouse up or down to change the setting. Release the left mouse button when the desired setting is achieved. Click the *GO* switch on the top button bar to start the simulation and observe the change of the waveform. Try settings 30Hz, 120Hz, and 240Hz. Observe the change in wavelength that corresponds with each change of frequency. Sketch these in your lab notebook. Recall that the velocity of a wave is given by:

$$v = \lambda f$$

What is the relationship between the frequency of the incoming signal and its wavelength (at a fixed value of  $v$ )? Does the oscilloscope trace support this conclusion?

Return the function generator to an output of 60Hz. Change the TIME BASE on the oscilloscope from 0.01s/DIV to 2.00ms/DIV. Click the *GO* switch on the top button bar to start the simulation and observe the change of the waveform. Change the Y pos on channel A of the oscilloscope to 0.00 and click the start switch. What happens? Change the Y position on channel A to 0.20. Set the channel B position to -0.20. Change the X pos to either 1.00 or -1.00 and click the *GO* switch. What happens?

### AC and DC Voltage Measurements

Open **acm2**. When the file manager asks if you want to save changes (in **acm1**) be sure to reply no. The 60 Hz signal being produced by the function generator is the same frequency as household AC current. The amplitude of the wave (its height) determines the voltage. Most electronic instruments (such as multimeters) are designed to measure RMS (root mean square) AC voltages. RMS voltages are average values that take into account the time varying amplitude of the AC waveform (Figure 3). The relationship between RMS and peak voltage (the maximum amplitude of the AC waveform) is:

$$V_{rms} = \frac{V_{peak}}{\sqrt{2}} \text{ or } V_{rms} = .707V_{peak}$$

Click the *GO* switch to start the simulation. The RMS voltage is displayed on the multimeter while the peak voltage may be read from the oscilloscope display. Use these values to verify the equation given above. If one measures the output from a wall socket with an AC voltmeter the reading obtained is

about 120VAC. This is an RMS value. What is the peak value of the voltage in common household current? Verify that the frequency is 60 Hz.

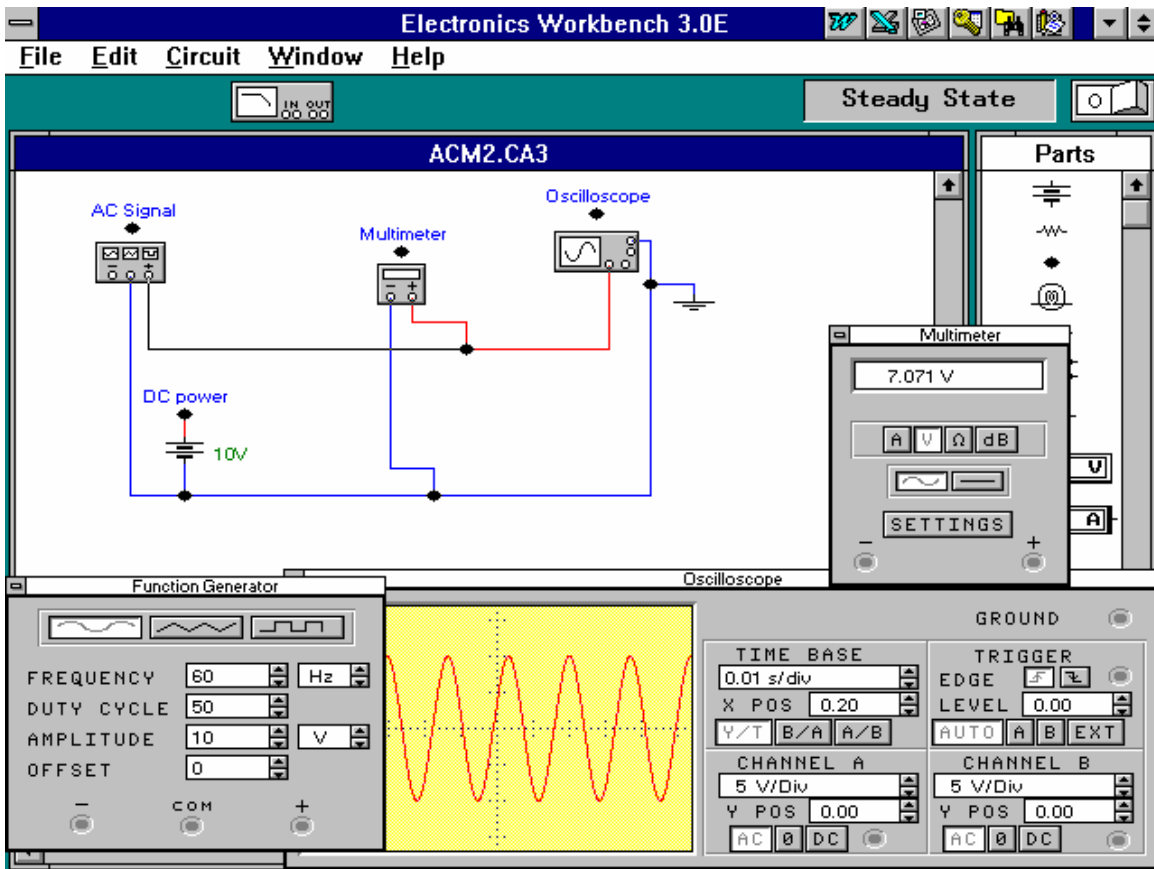


Figure 2.

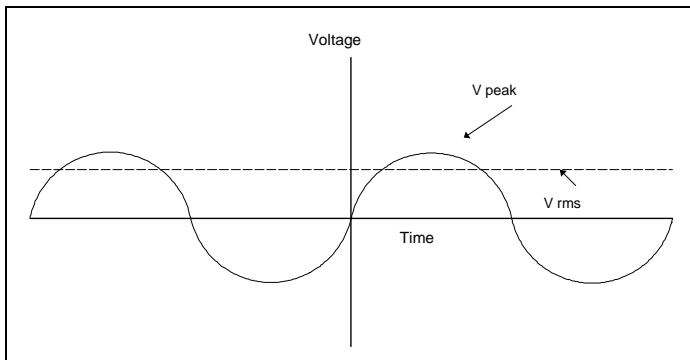


Figure 3. RMS voltage.

record the results. Notice that the concept of RMS voltage in DC circuits is meaningless because there is no transience in the signal (i.e., the signal does not vary in time). The signal from a DC source appears as a flat line on the oscilloscope; its offset from the signal base level representing the voltage of the signal.

Move the cursor to the wire on the right side of the AC Signal source and reconnect this wire to the DC power connector. Move the cursor to the DC controls on the face of the multimeter and the oscilloscope and click the left mouse to activate them. You can now measure the DC voltage with both the multimeter and the oscilloscope. What should the relationship between these two measurements be? Click the GO switch and

## AC and DC Behavior of Resistors

Open **acm4**. In this portion of the exercise you will measure the potential (voltage) drop across a combination of resistors in series. Click the **GO** switch and record the voltage displayed on the multimeter. How does this compare with the total voltage across the circuit (the voltage applied by the power supply)? Notice that you are measuring the potential drop across a single  $3\text{k}\Omega$  resistor. Move the green multimeter probe from TP1 to TP2 and record the voltage. Notice that you are now measuring the potential drop across both resistors. How does this compare with the total voltage across the circuit? Move the blue multimeter probe from TPO to TP1 and record the results. Notice that you are once again measuring the potential drop across a single  $3\text{k}\Omega$  resistor. What is the sum of the potential drops across each resistor? Can you formulate a relationship describing the voltage drops across resistors in series in a DC circuit based on your observations? Change the value of the resistor on the right to  $6\text{k}\Omega$  and repeat this procedure.

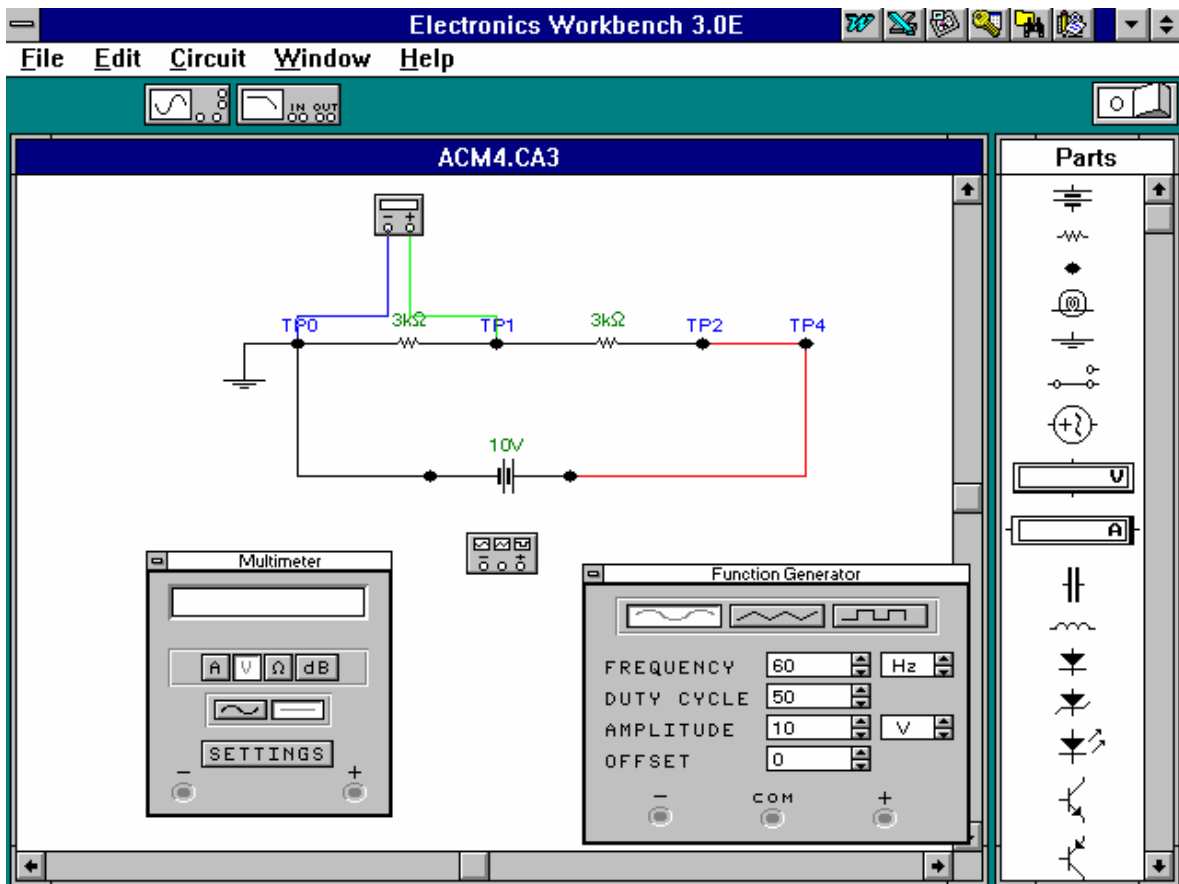


Figure 4.

Finally, move the blue and green probes to TP2 and TP4 respectively and measure the potential drop. How does this value fit into the relationship you derived based on the previous observations?

In a purely resistive circuit, such as this one that you are currently studying, do you think that a resistor behaves any differently if the voltage source is AC? In other words, does it matter which way current flows through an ordinary resistor (Hint: will a light bulb work with both DC and AC)? Connect the function generator in place of the battery (use the com and + connectors) and test the circuit. What conclusion can you make based on this?

### DC Behavior of Inductors and Capacitors

Capacitors and inductors exhibit different behaviors in alternating and direct current circuits. We will explore the behaviors of these components in AC circuits in detail later. Figure 5 is a schematic of a resistive-capacitive direct current circuit. The resistor in this circuit has the effect of slowing the charging cycle of the capacitor (by a fair amount) and has been included to make this process easier to observe.

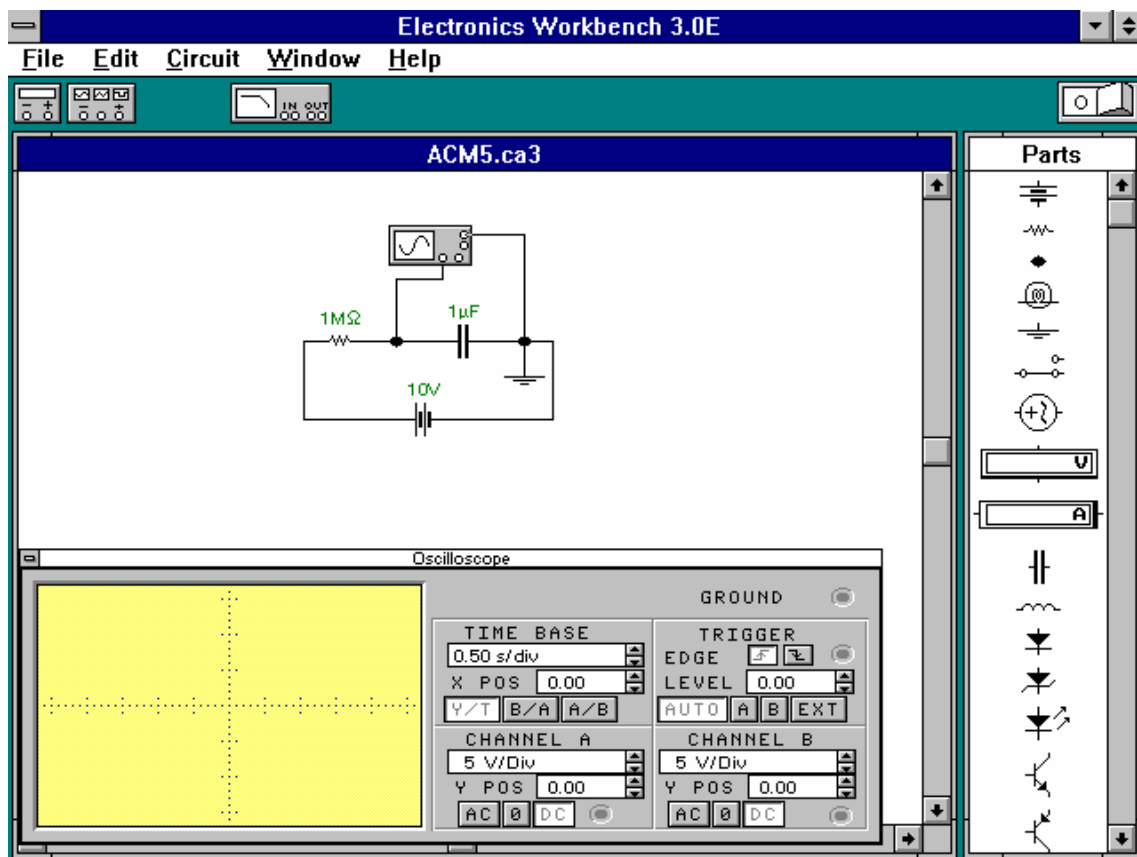


Figure 5. An R-C direct current circuit.

When this circuit is energized it will initially display what is known as *transient* behavior, i.e., changing behavior. As the capacitor charges current flow decreases (why is this so?), eventually reaching a *steady state* where the current flow is reduced to zero as the potential between the plates of the charged capacitor approaches the applied voltage. As the capacitor charges, the current decreases in a manner that may be expressed by:

$$I(t) = I_0 e^{-t/RC} = \frac{V_0}{R} e^{-t/RC}$$

while the potential *increases* to the value of the applied voltage,  $V_0$ :

$$V(t) = V_0 [1 - e^{-t/RC}]$$

where  $RC$  in each expression is commonly represented as  $\tau$ , known as the *time constant* of the circuit. The time constant is the time that it takes the current to decrease to  $(e^{-t/\tau}) = 37\%$  of its initial value,  $I_0$ , and voltage to increase to  $(1 - e^{-t/\tau}) = 63\%$  of its steady state value,  $V_0$ .

Open **acm5** and click the *GO* switch. The oscilloscope is set to pause after each screen with the first pause occurring at about 5 seconds. The time base is .5 sec/div. What is the potential across the capacitor at a time of 2.5 seconds? Are the mathematical relationships above verified by this finding?

Inductive direct current circuits display both transient and steady state behavior. Such a circuit is shown in Figure 6. Open **acm6**. The presence of the inductor in this circuit impedes the flow of current through the circuit to its steady state value by producing a "back EMF" that opposes the EMF produced by the battery while the current is changing - the larger the value of the inductor the slower the rise of the current. The current, as it approaches its steady state value, may be written:

$$I(t) = \frac{V_0}{R} [1 - e^{-t/\tau}]$$

Where the time constant,  $\tau$ , is equal to  $L/R$ .

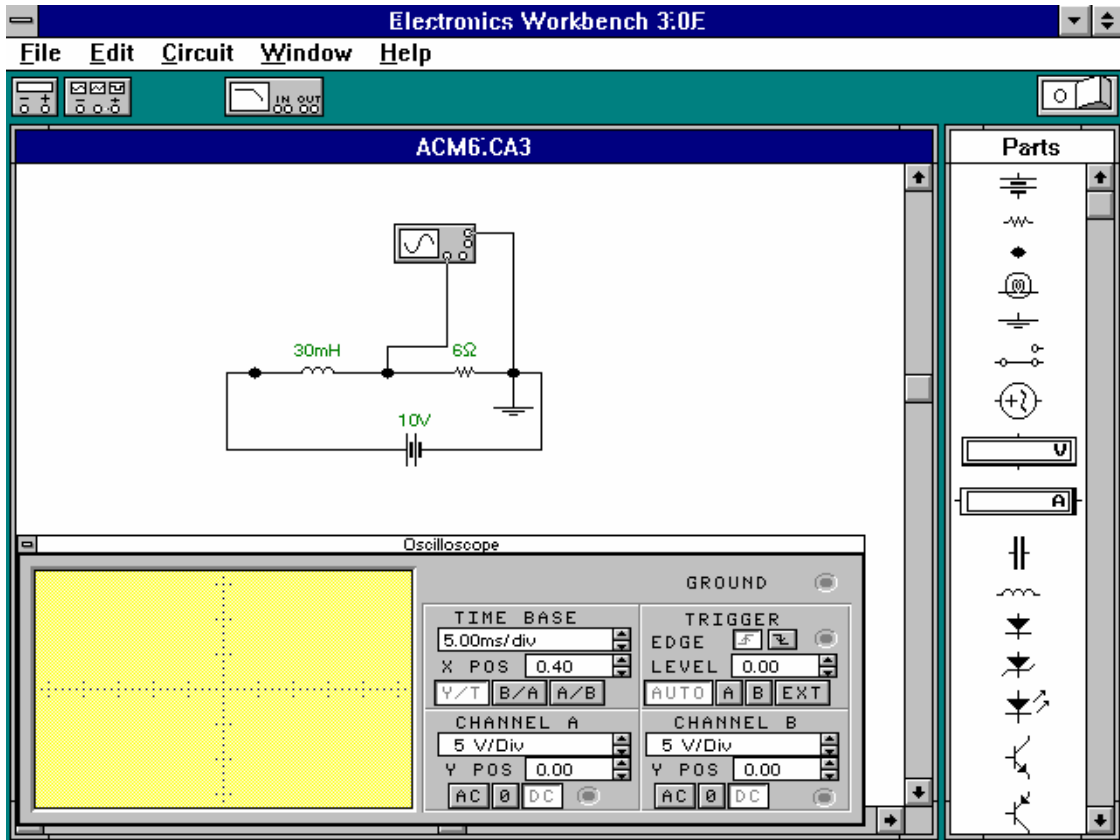
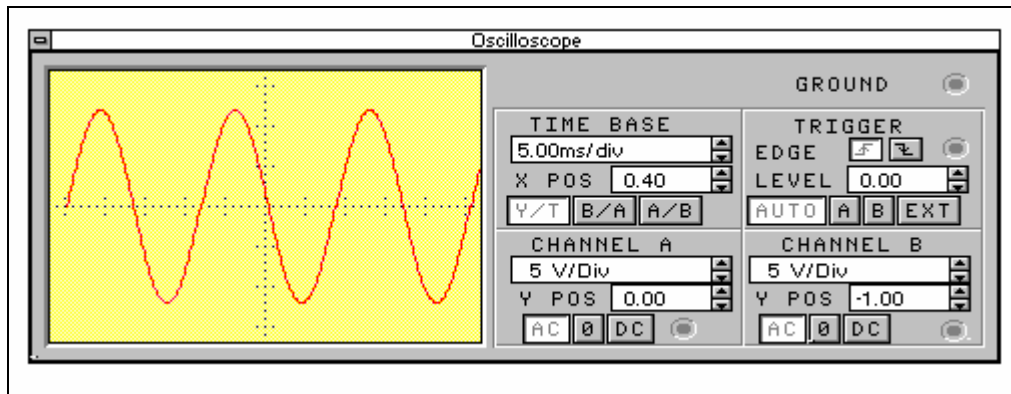


Figure 6. An R-L direct current circuit.

Click the GO switch to start the simulation. According to Ohm's Law the potential across the resistor increases at the same rate as the current. Does the trace on the oscilloscope verify this? Compute the time constant for this circuit. Calculate the current in the circuit and the potential across the resistor after one time constant has elapsed. Does the trace on the oscilloscope verify your calculations?

## Questions

1. What is the difference between a DC and an AC waveform?
2. Examine the oscilloscope trace below. Identify the type of signal, the peak voltage and the frequency.



3. An R-L circuit consists of a 30 mH coil, a 6  $\Omega$  resistor, and a 12 V battery. Find the time constant,  $\tau$ , for this circuit.
4. Calculate the current in the circuit given in the previous problem at  $t = 2$  ms.
5. Calculate the current in the circuit in the previous problem and the voltage across the resistor after one time constant has elapsed.
6. An R-C circuit consists of a 5  $\mu$ F capacitor, an  $8 \times 10^5 \Omega$  resistor and a 12 V power supply. Find the time constant for the circuit, the maximum voltage across the capacitor, the maximum current in the circuit, and the voltage and current as a function of time.
7. For the circuit in the previous problem, after how many time constants will the current through the circuit decrease to 1/4 of its initial value?
8. What does an oscilloscope measure?
9. Why does the current flow in a DC capacitive circuit slow as the capacitor charges?
10. Why does the inductor in a DC circuit only resist the rise of current while the current is changing?