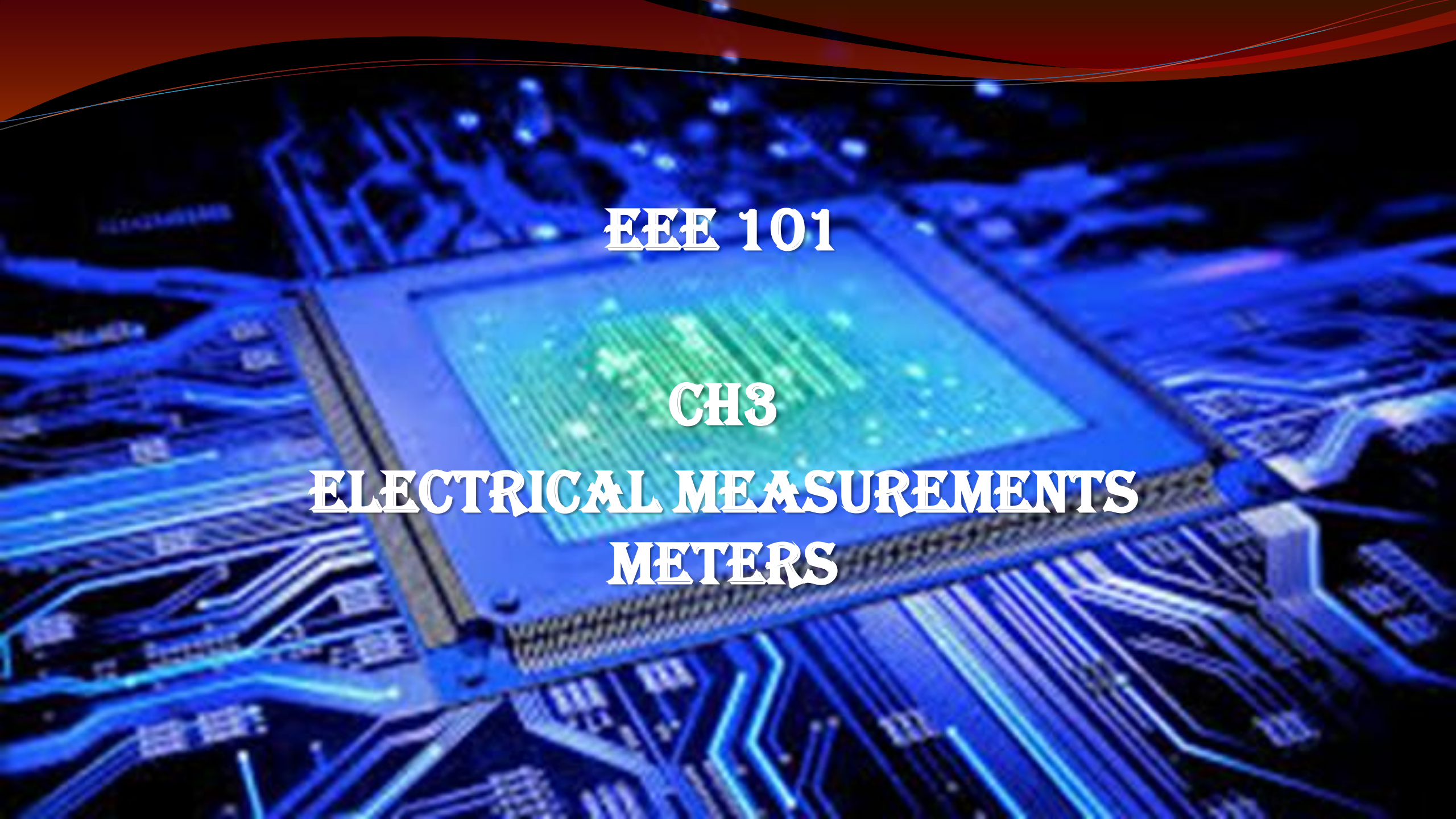

EEE 101
CH3
ELECTRICAL MEASUREMENTS
METERS

CH3 – Electrical Measurements - Meters

OBJECTIVES

After completing this chapter, the student will be able to:

- Identify the two types of meter movements available.
- Describe how a voltmeter is used in a circuit.
- Describe how an ammeter is used in a circuit.
- Identify the functions of a multimeter.
- Identify the advantages and disadvantages of DMMs(Digital multimeter) and VOMs(volt-ohmmilliammeter).
- Describe how to use a multimeter to measure voltage, current, and resistance.
- Describe how to measure current using an ammeter.
- Describe how to connect an ammeter into a circuit.
- List safety precautions for using an ammeter.
- Describe how to connect a voltmeter to an electrical circuit.
- List safety precautions for connecting a voltmeter to a circuit.
- Describe how resistance values are measured using an ohmmeter.
- Define continuity check.
- Describe how an ohmmeter is used to check open, short, or closed circuits.

Electrical Measurements - Meters

- In the field of electricity, accurate quantitative measurements are essential. A technician commonly works with current, voltage, and resistance.
- Ammeters, voltmeters, and ohmmeters are used to provide the essential measurements.
- A good understanding of the design and operation of electrical measuring meters is important.
- This chapter describes the more commonly used analog meters, including the multimeter, or multifunction meter.

Introductlon to Meters

- Meters are the means by which the invisible action of electrons can be detected and measured. Meters are indispensable in examining the operation of a circuit.
- Two types of meters are available. One type is the analog meter, which uses a graduated scale with a pointer (Figure 1). The other type is the Digital meter, which provides a reading in numbers (Figure 2). Most meters are housed in a protective case.
- Digital meters are easier to read and provide a more accurate reading than analog meters. However, analog meters provide a better graphic display of rapid changes in current or voltage.
- Terminals are provided for connecting the meter to the circuit. The polarity of the terminals must be observed for proper connection. A red terminal is positive and a black terminal is negative.
- Before using an analog meter, the pointer should be adjusted to 0. A small screw is located on the front of the meter to permit this adjustment (Figure 3). To zero the meter, place the meter in the position where it is to be used. If the needle does not point to 0, use a screwdriver to turn the screw until it does. The meter should not be connected to a circuit while this adjustment is being made.

Analog meters.



A digital meter.



Location of the zero adjustment screw on an analog meter.



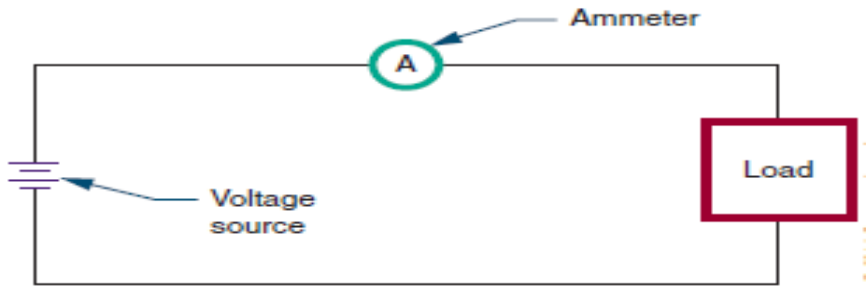
Types of Meters

- An **ammeter** is used to measure current in a circuit. An ammeter (schematic symbol shown in Figure 1) can be considered a flow meter. It measures the number of electrons flowing past a given point in a circuit. The electrons must flow through the ammeter to obtain a reading as shown in Figure 2, and this is accomplished by opening the circuit and inserting the ammeter.
- A **voltmeter** is used to measure the voltage (difference of potential) between two points in a circuit. A voltmeter can be considered a pressure gauge, used to measure the electrical pressure in a circuit (Figure 3).
- Resistance is measured with an **ohmmeter**. To measure resistance, a voltage is placed across the device to be measured, inducing a current flow through the device (Figure 4). When there is little resistance, a large current flows and the ohmmeter registers a low resistance. When there is great resistance, a small current flows and the ohmmeter registers a high resistance.

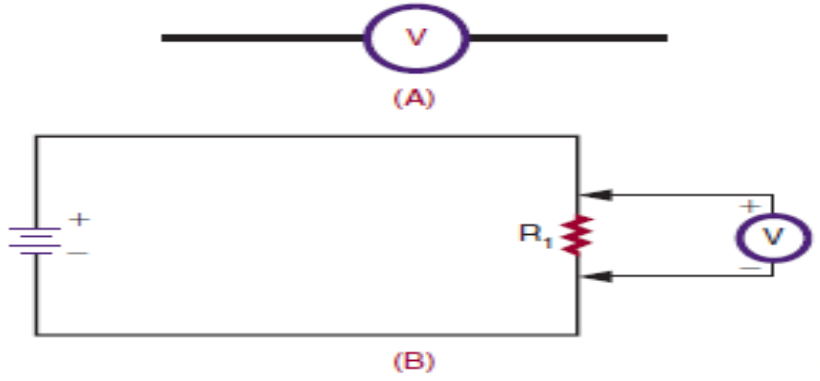
Schematic symbol for an ammeter.



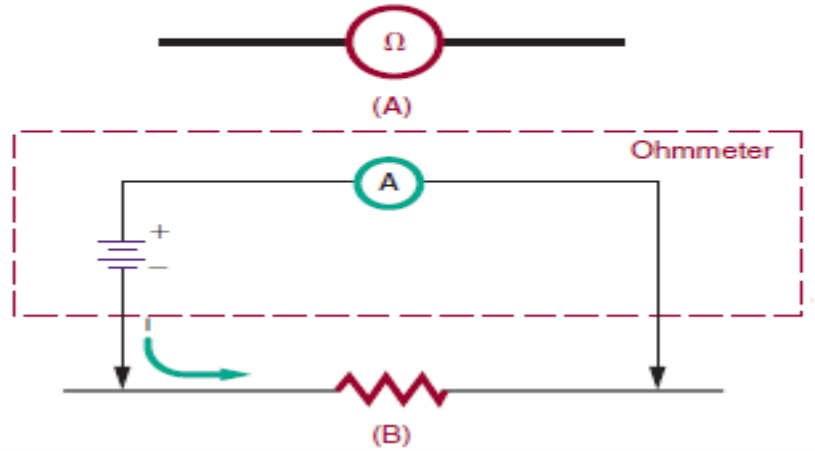
The placement of an ammeter in a circuit.



(A) Schematic symbol for a voltmeter. (B) A voltmeter is connected in parallel in a circuit.



(A) Schematic symbol for an ohmmeter. (B) An ohmmeter applies a voltage across the component being measured and monitors the current flowing through it.



MultiMeters

- When working on a piece of equipment, many different measurements must be taken. To eliminate the need for several meters, the voltmeter, ammeter, and ohmmeter can be combined into a single instrument called a **multimeter**.
- An analog multimeter is referred to as a **volt-ohm-milliammeter (VoM)**, Figure. A **digital multimeter** is also referred to as a **dMM**.
- The meter in Figure has five voltage positions, four current positions, and three resistance positions.
  - There are five scales on the meter to accommodate the various ranges and functions.
  - The technician selects the switch on the multimeter for the desired voltage, current, or resistance range.
  - The zero-ohm control adjusts the ohmmeter circuit to compensate for variations in the voltage of the internal batteries.
  - The function switch has three positions: -DC, +DC, and AC. To measure current, DC voltage, and resistance, the function switch is placed at -DC or +DC, according to the polarity of the applied current or voltage.
  - The function switch permits reversal of the test lead connections without removing the leads from the circuit being tested.



MultiMeters

- To measure DC voltage, set the function switch to +DC. With the function switch set at +DC, the common jack is negative and the plus jack is positive. The voltmeter is connected in parallel with the circuit.
  - When measuring an unknown voltage, always set the meter to the highest range (500 volts).
  - If the measured voltage is lower, a lower position can be selected. This procedure protects the meter from damage. Read the voltage on the scale marked DC.
  - For the 2.5-volt range, use the 0–250 scale and divide by 100.
  - For the 10-volt, 50-volt, and 250-volt ranges, use the scales directly.
  - For the 500-volt range, use the 0–50 scale and multiply by 10.
- To measure current, the selector switch is set for the desired current position and the meter is connected in series with the circuit. The DC scale on the meter is used.
  - For the 1 mA range, use the 0–10 scale and divide by 10.
  - For the 10 mA range, use the 0–10 scale directly. For the 100 mA range, use the 0–10 scale and multiply by 10.
  - For the 500 mA range, use the 0–50 scale and multiply by 10.



MultiMeters

- To measure resistance, set the selector switch to the desired resistance range. Short the test leads together. Rotate the zero-ohm control until the pointer indicates zero ohms. Separate the test leads and connect them across the component being measured.
- For measuring resistance between 0 and 200 ohms, use the R x 1 range. To measure resistance between 200 and 20,000 ohms, use the R x 100 range. For resistance above 20,000 ohms, use the R x 10,000.
- When measuring resistance in digital and semiconductor circuits, do not use the R x 1 scale. This scale is energized by a 9 V battery and could damage the circuitry.
- Observe the reading on the ohm scale at the top of the meter scales. Note that the ohm scale reads from right to left.
- To determine the actual resistance value, multiply the reading by the factor at the switch position. The letter K equals 1000.
- To use the other voltage and current jacks located on the multimeter, refer to the operator's manual.



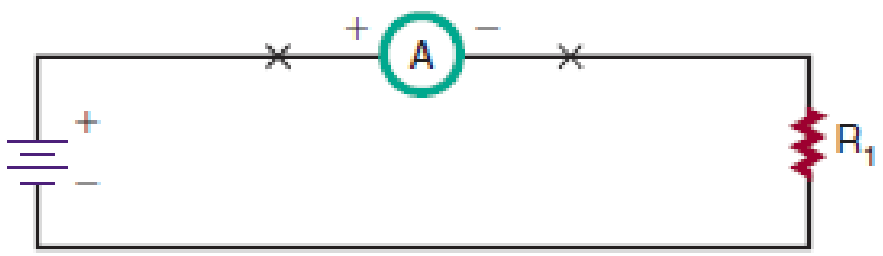
MultiMeters

- With a DMM, the meter movement is replaced by a digital readout, which is similar to the readout used in an electronic calculator. The difference is that the display is typically four digits.
- The controls of a DMM are similar to those found on an analog meter. The exception is with a digital meter that has an autoranging feature. It does not need to identify the range of the signal being tested.
- The readout of the DMM automatically places the decimal point with the appropriate unit prefix. DC measurements are displayed with a + or - sign. This avoids the necessity of reversing the test leads.
- The advantages of DMMs over VOMs include these:
  - Easier readability, resulting in a higher Accuracy with smaller voltage, and results that are repeatable with different readers
  - Autoranging capabilities
  - Autozeroing for resistance reading
  - Autolock of a displayed value
- The disadvantages of a DMM include these:
  - Requirement for batteries or other source of electricity
  - Voltage limitation that if exceeded could seriously damage the meter
  - Inability to measure an instantaneous change in a signal that is faster than the sampling time

Measuring Current

- To use an ammeter to measure current, the circuit must be opened and the meter inserted into the circuit in series (Figure 1).
- When placing the ammeter in the circuit, polarity must be observed. The two terminals on an ammeter are marked: red for positive and black for negative (or common) (Figure 2).

An ammeter is connected in series in a circuit.

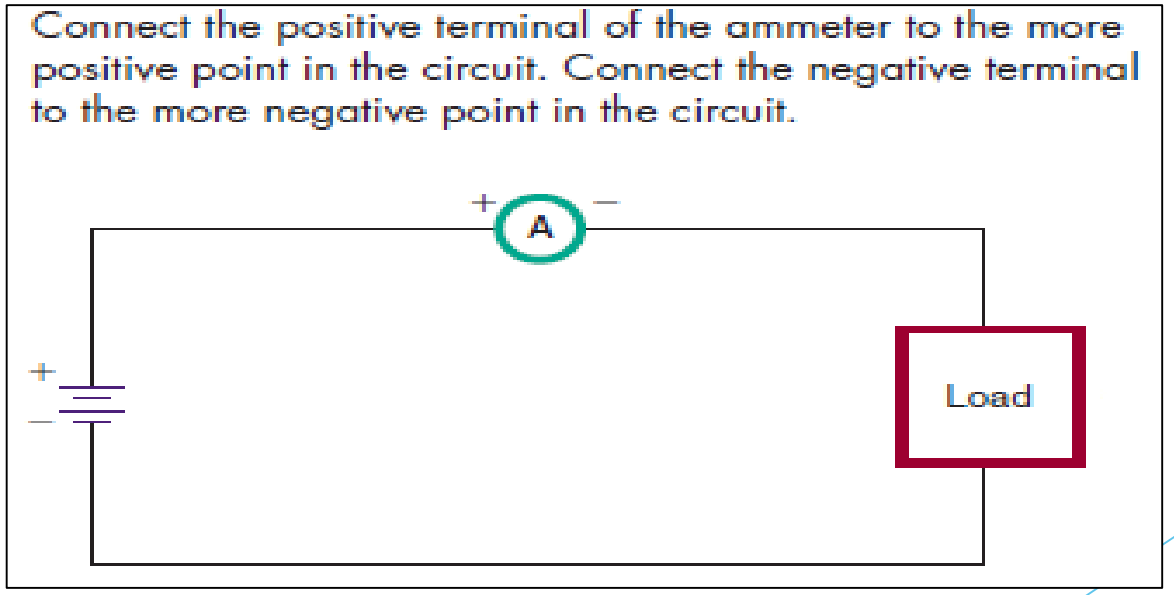


An ammeter is one part of this VOM. A black negative lead plugs into the common or negative jack. A red positive lead plugs into the jack with the plus symbol.



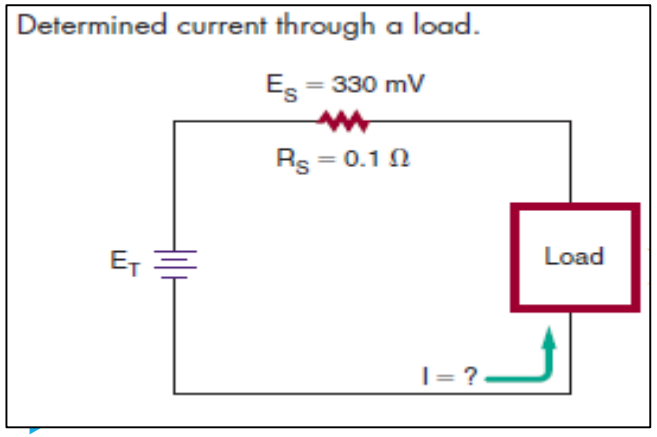
Measuring Current

- The negative terminal must be connected to the more negative point in the circuit, and the positive terminal to the more positive point in the circuit (Figure).
- When the ammeter is connected, the needle (pointer) of the meter moves from left to right. If the needle moves in the opposite direction, reverse the leads.
- The best meter to use is a DMM because it is able to accurately measure small voltages.



Measuring Current

- Another way to measure current that does not require opening the circuit and placing an ammeter in series is to use a resistor of a known value in the circuit. The resistor is referred to as an **ammeter shunt** and may be installed by the manufacturer or inserted for temporary use. The resistor may be left in for future testing of the circuit and must be of a small enough value to not interfere with the normal operation of the circuit. The resistor's purpose is to provide a small output voltage for measuring.
- Ohm's law (I = E/R) is used to calculate the amount of current measured by the shunt. Dividing the voltage read by the resistance value yields the current flowing in the circuit.
- Figure shows a 0.1 Ω resistor used as a shunt. If the DMM reads 330 mV, then the circuit has 3.3 A flowing through it.



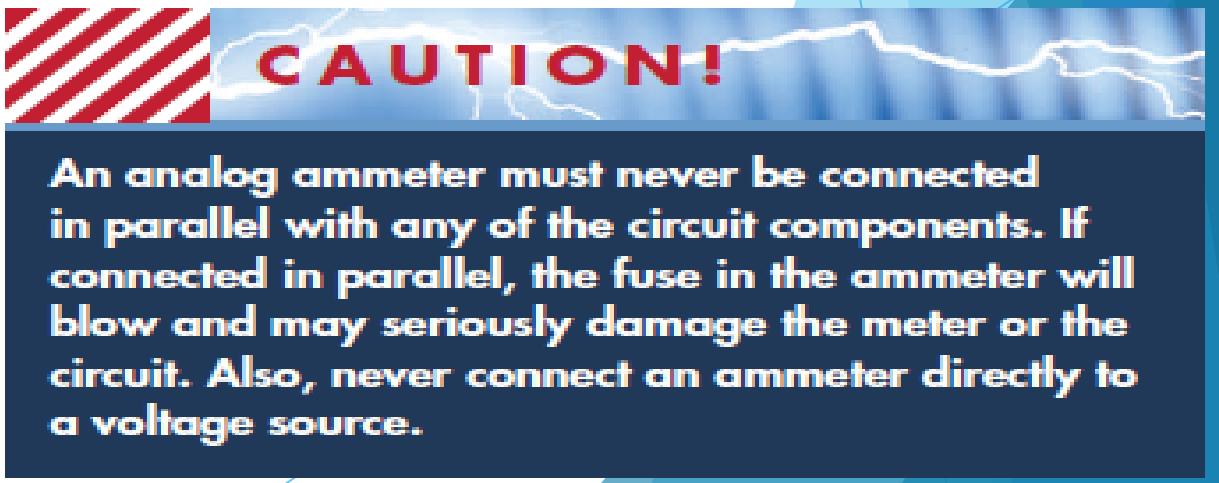
$$I = \frac{E}{R} \qquad I = \frac{0.330}{0.1} \qquad I = 3.3\ A$$

The advantage of using this technique is that the circuit does not have to be opened and an ammeter inserted. Also note that voltage—rather than current—was read.

Measuring Current

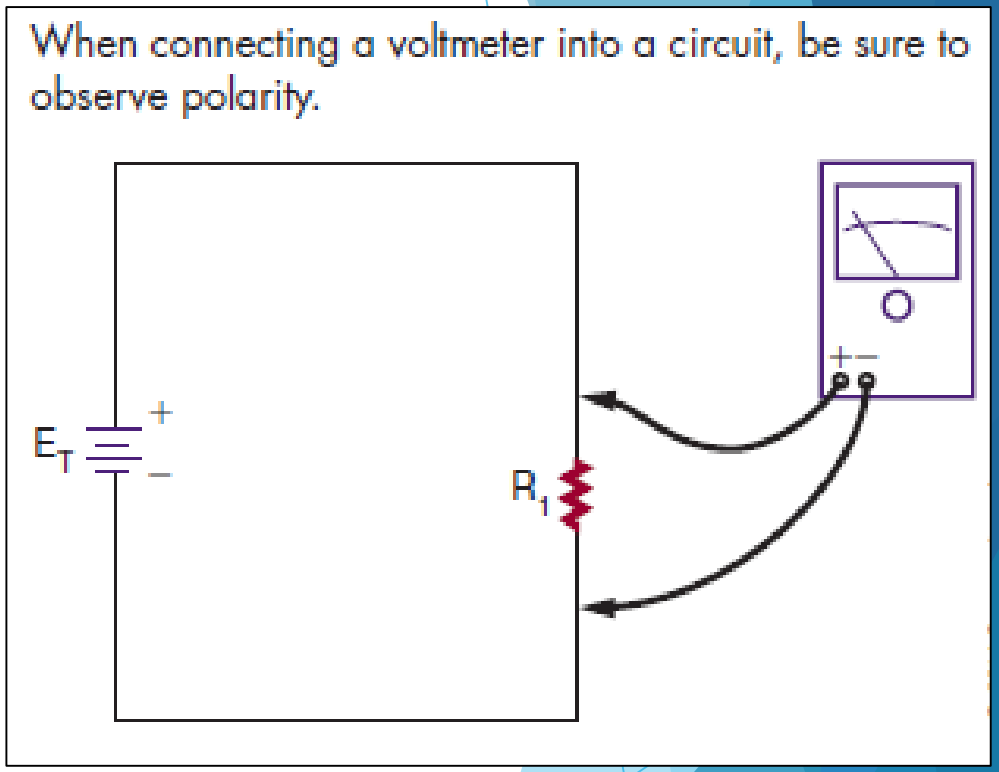
- Before turning on power to the circuit after the ammeter is installed, set the meter to its highest scale (its highest ammeter range before applying power).
- After the power is applied, the ammeter can be set to the appropriate scale. This prevents the needle of the meter from being driven into its stop.
- The internal resistance of the ammeter adds to the circuit and increases the total resistance of the circuit. Therefore, the measured circuit current can be slightly lower than the actual circuit current. However, because the resistance of an ammeter is usually minute compared to the circuit resistance, the error is ignored.
- A clip-on ammeter requires no connection to the circuit being measured and uses the electromagnetic field created by the current flow to measure the amount of current in the circuit.

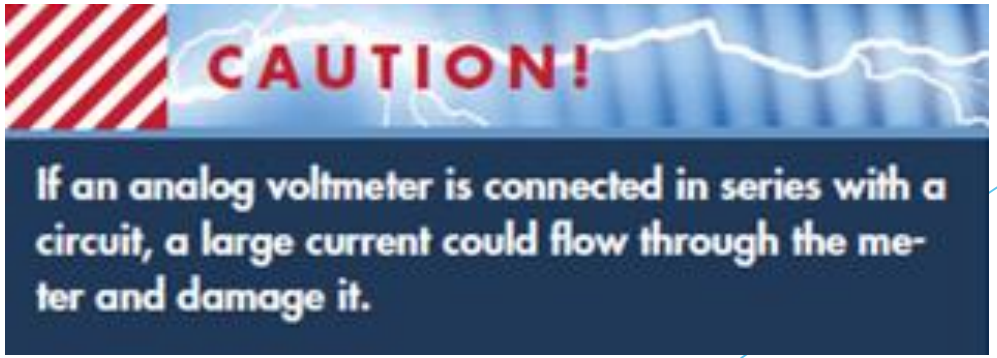




Measuring Voltage

- Voltage exists between two points; it does not flow through a circuit as current does. Therefore, a voltmeter, used to measure voltage, is connected in parallel with the circuit.
- **Polarity** is important with analog meters. The negative terminal of the voltmeter must be connected to the more negative point in the circuit, and the positive terminal to the more positive point in the circuit (Figure).
- If the connections are reversed, the pointer deflects toward the left side of the meter, registering no measurement. If this occurs, reverse the meter leads.





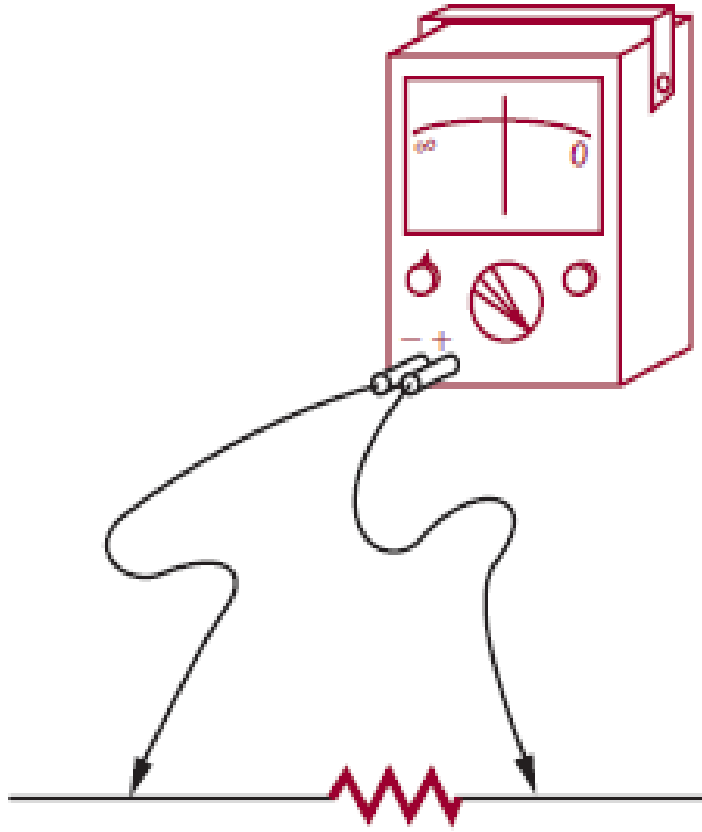
Measuring Voltage

- A good practice is to remove power from the circuit, connect the voltmeter, and then reapply power.
- Initially, set the voltmeter for its highest scale. After the voltage is applied to the circuit, set the meter down to the proper scale.
- The voltmeter's internal resistance is connected in parallel with the component being measured.
- The total resistance of resistors in parallel is always less than that of the smallest resistor. As a result, the voltage read by the voltmeter is smaller than the actual voltage across the component. In most cases, the internal resistance of a voltmeter is high, so the error is small and can be ignored. However, if voltage is being measured in a high-resistance circuit, meter resistance may have a noticeable effect. Some voltmeters are designed with extra-high internal resistance for such purposes.
- Currently, the DMM is the best all-around meter available. The voltage ranges have very little loading effect on the circuits being measured. The meter's internal resistance is typically up to 10 MΩ on its voltage range, compared to a quality analog meter with an internal resistance of 20,000 Ω /V, which would yield 20,000 Ω on its 1 V range.

Measuring Resistance

- An ohmmeter measures the resistance of a circuit or component by applying a known voltage. Batteries supply the voltage.
- When a constant voltage is applied to the meter circuit through the component under test, the pointer is deflected based on the current flow. The meter deflection varies with the resistance being measured. To measure the resistance of a circuit or component, the ohmmeter is connected in parallel with the circuit or component.
- When measuring a component in a circuit, disconnect one end of the component from the circuit. This eliminates parallel paths, which result in an incorrect resistance reading. The device must be removed from the circuit to obtain an accurate reading. Then, the ohmmeter leads are connected across the device (Figure). Because the primary purpose of an ohmmeter is to measure resistance, it can be used to determine whether a circuit is open, shorted, or closed.

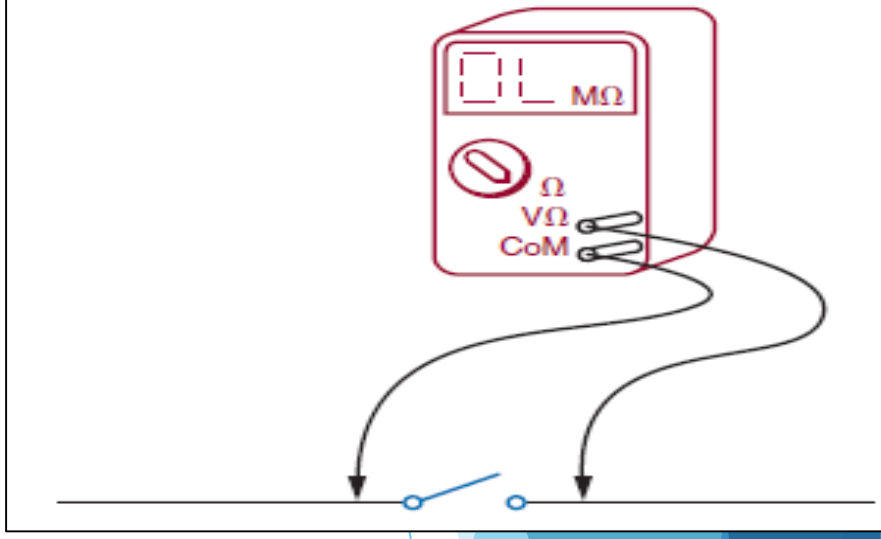
When you are using an ohmmeter to measure resistance, the component being measured must be removed from the circuit.



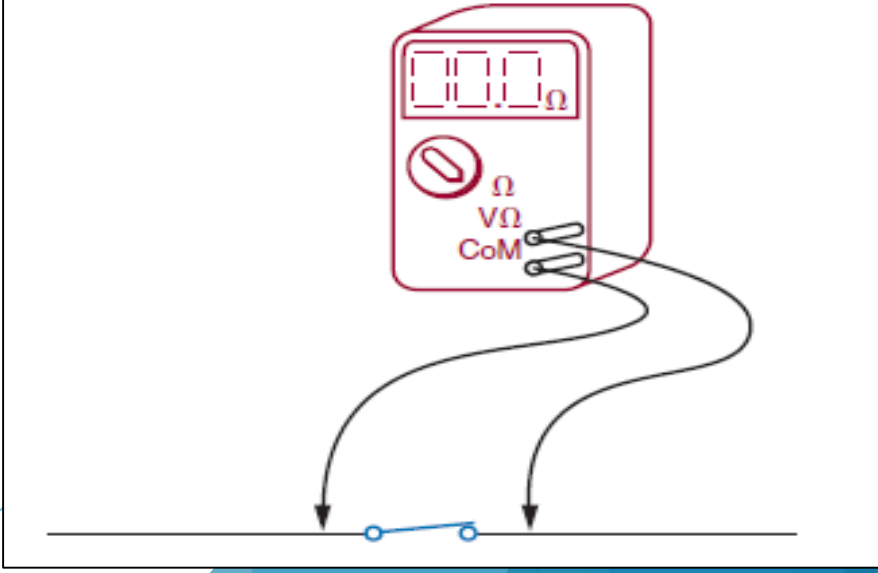
Measuring Resistance

- An **open circuit** has infinite resistance because no current flows through it (Figure 1). A **short circuit** has 0 ohms of resistance because current flows through it without developing a voltage drop. A **closed circuit** is a complete path for current flow. Its resistance varies depending on the components in the circuit (Figure 2).
- The testing for an open, short, or closed circuit is called a **continuity test**, or check. It is a check to determine whether a current path is continuous.
- To determine whether a circuit is open or closed, the lowest scale on the ohmmeter should be used. First ensure that there are no components in the circuit that may be damaged by the current flow from the ohmmeter. Then place the leads of the ohmmeter across the points in the circuit to be measured. If a reading occurs, the path is closed or shorted. If no reading occurs, the path is open. This test is useful to determine why a circuit does not work.

An ohmmeter can be used to determine whether a circuit is open. An open circuit indicates a high resistance.



An ohmmeter can be also be used to determine whether a circuit offers a complete path for current flow. A closed circuit indicates a low resistance.



Measuring Resistance

- The DMM has several advantages over the analog multimeter, including higher accuracy, digital readout, and repeatability of the reading.
- Unlike the VOM, the DMM uses very little current to test resistances. This allows the testing of semiconductor junctions.
- In fact, many DMMs have a special range for testing semiconductor junctions. These meters use approximately 1 mA of current through the junction under test.
- Another feature of a DMM is an audio signal, or “beeper,” for continuity testing. This allows the operatör to focus on the circuit rather than on the meter for continuity testing. The use of the beeper function is not to check for resistance, but rather for continuity.



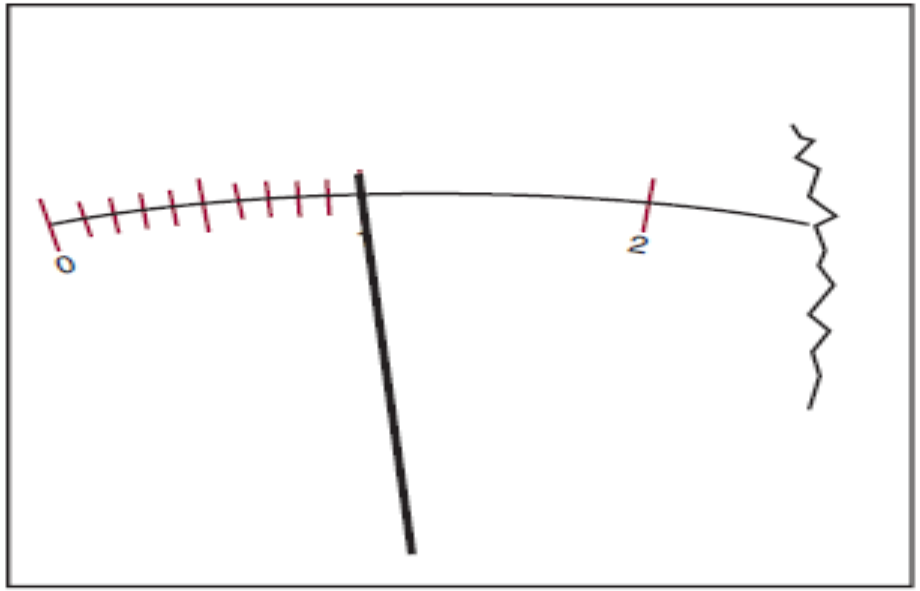
NOTE

When using any meter, it is important to keep fingers from touching the probes to avoid putting body resistance in parallel with the component under test, thereby introducing errors.

Reading Meter Scales

- Voltmeter and ammeter scales are read in the same manner. However, voltmeters measure volts, and ammeters measure amperes.
- The maximum value indicated by a meter is called the **full-scale value**. In other words, the maximum voltage or current that a meter can read is its full-scale value.
- The measured value of voltage or current is read on the scale under the pointer. For example, the pointer in Figure is shown deflected one major division, indicating a voltage of 1 volt or a current of 1 ampere.

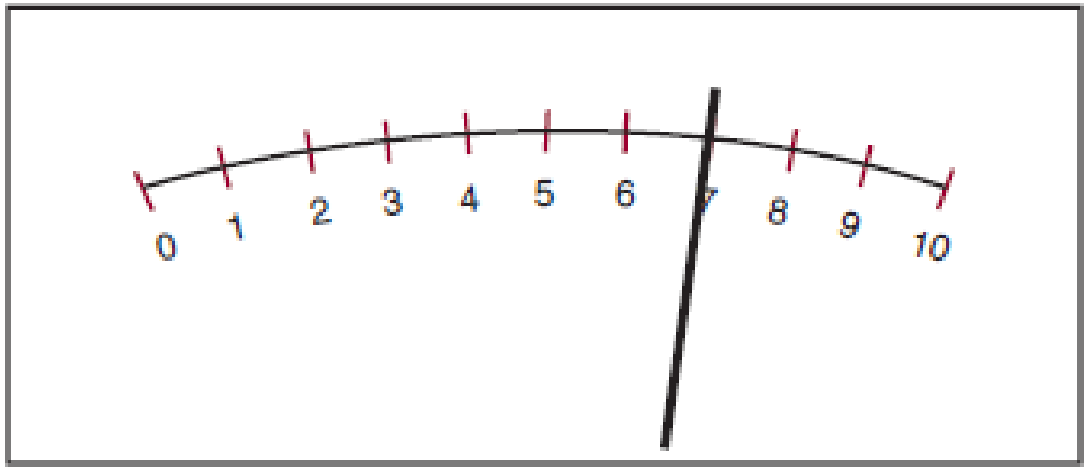
The reading indicates 1 volt or ampere.



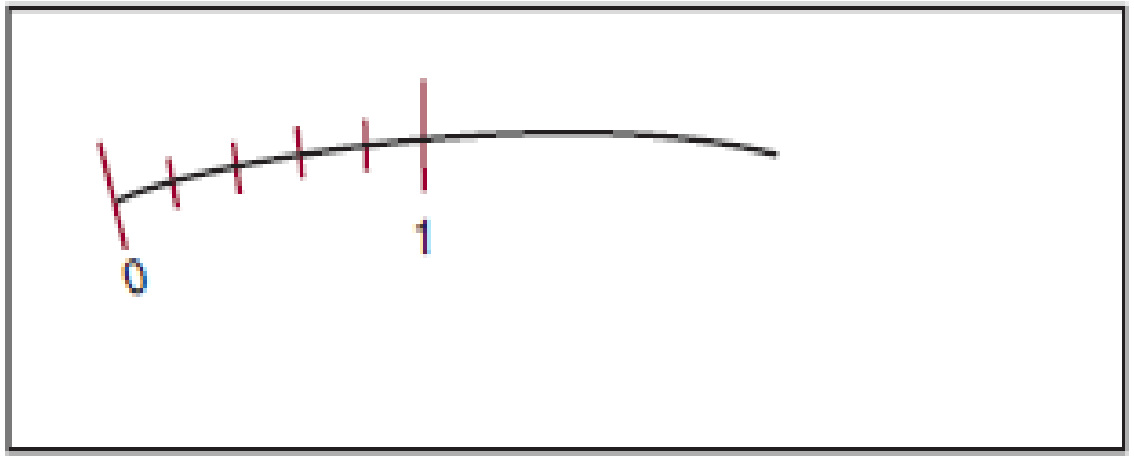
Reading Meter Scales

- In Figure 1, the meter is shown deflected seven major divisions, indicating a current of 7 amperes or a voltage of 7 volts.
- If the pointer of the meter rests between the major divisions of the scale, the smaller divisions are read.
- Figure 2 shows four small lines between each major division of the scale, creating five equally spaced intervals. Each of these small intervals represents one fifth of the major interval, or 0.2 units.

The reading indicates 7 volts or amperes.



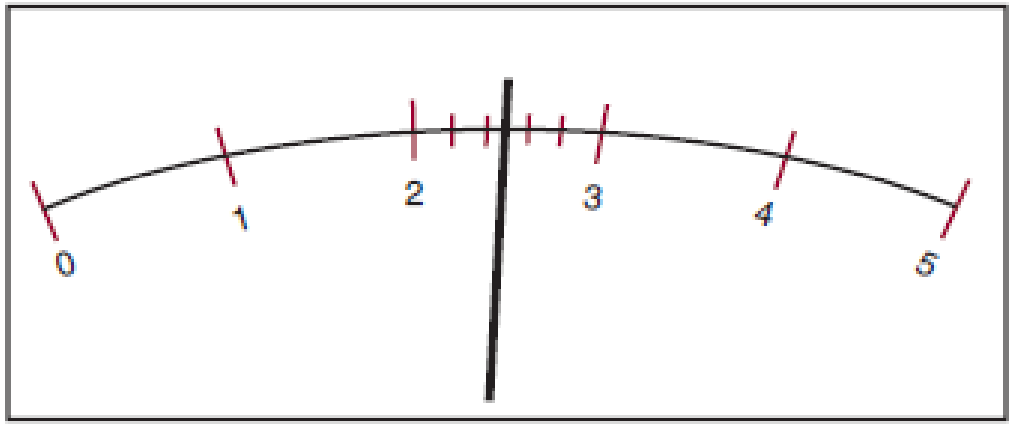
Each small division represents 0.2 volt or ampere.



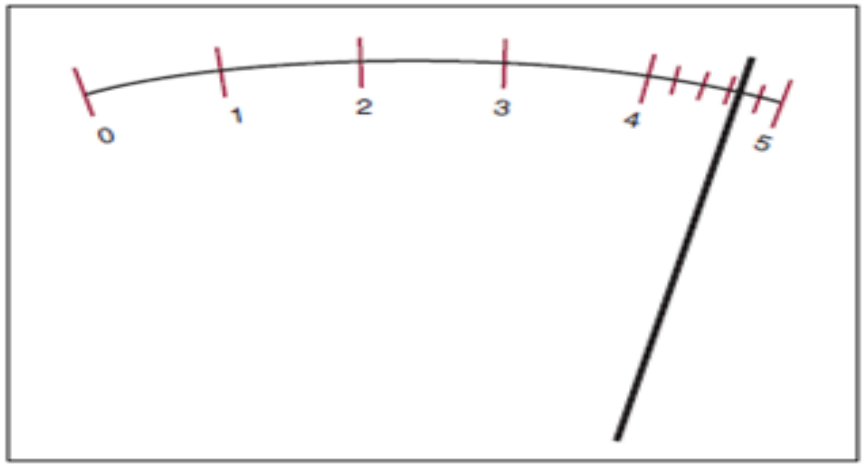
Reading Meter Scales

- If the pointer falls between the small lines on a meter scale, the value must be estimated. In Figure 1, the pointer falls between the 2/5 (0.4) and 3/5 (0.6) marks. This indicates a value of approximately 2.5 volts or amperes. In Figure 2, the pointer is one-fourth of the distance between the 3/5 (0.6) and 4/5 (0.8) marks.
- Each small interval represents 0.2. One-fourth of 0.2 is 0.05. Therefore, the pointer indicates a value of about 4.65 volts or amperes.
- The number of major and minor divisions on a meter scale depends on the range of the voltage or current that the meter is designed to measure. In all cases, the value of the small intervals can be found by dividing the value of the major interval by the number of spaces it contains.

The reading indicates 2.5 volts or amperes.



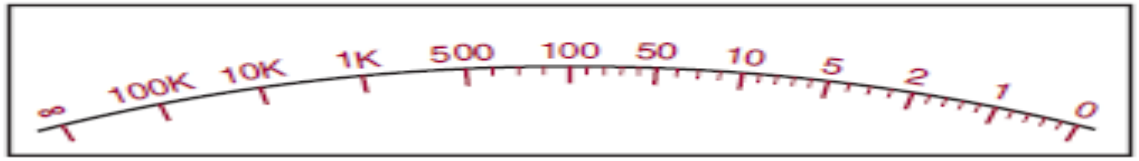
The reading indicates 4.65 volts or amperes.



Reading Meter Scales

- The ohm scale on a meter is different from most voltage and current scales (Figure 1). It is read from right to left instead of from left to right. Also, it is a nonlinear scale, so the number of small spaces between the major intervals is not the same throughout the scale.
- Between 0 and 1 there are five small spaces, which equal 0.2 unit each.
- There are four intervals between 5 and 10, representing 1 unit each, and between each of these there is a minor division that represents 0.5 unit.
- Between the 50 and 100 marks are five small intervals, which each represent 10 units. Between 100 and 500, there are four small intervals, each representing 100 units.
- The last mark on the left is labeled infinity (∞). If the pointer deflects to this mark, the resistance is beyond the range of the meter. The pointer normally rests on the infinity mark when no resistance is being measured.

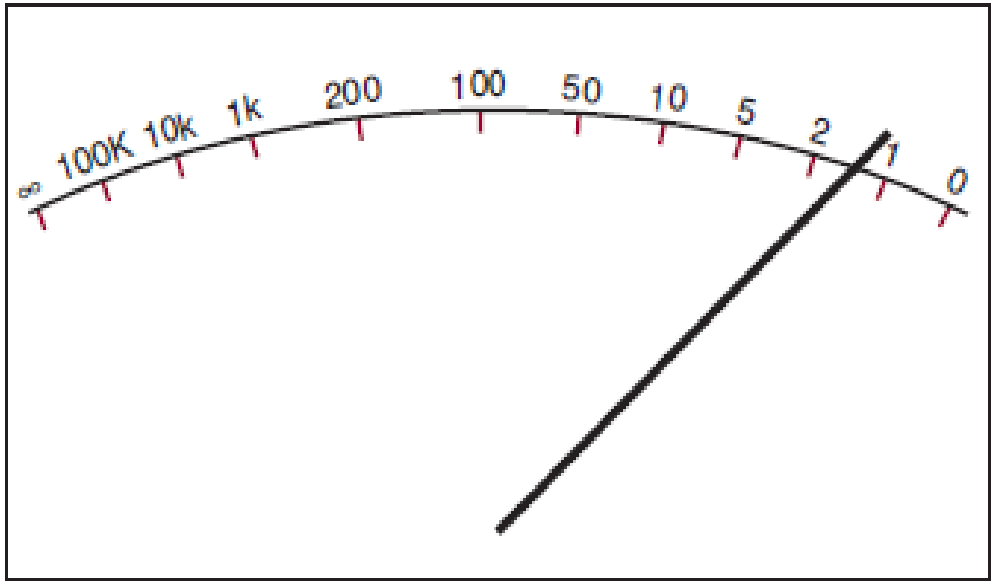
The ohmmeter scale is read from right to left.



Reading Meter Scales

- Figure 1 shows the pointer deflected to 1.5 ohms.
- Figure 2 shows the pointer indicating 200 ohms.
- Before an ohmmeter is used, the test leads are shorted together and the zero control is adjusted so the pointer rests on the zero mark. This calibrates the meter and compensates for battery deterioration.

The reading indicates 1.5 ohms.



The reading indicates 200 ohms.

