UNIT

1 Matter

INTRODUCTION

Where does electricity come from? To know that, you must first understand something about the physics of matter. Studying the nature of matter lays the foundation for understanding electrical theory. Knowing the theory will give you confidence in the practical aspects of electrical work.

When people have a hard time understanding and applying the *National Electrical Code (NEC),* the root cause is often a lack of knowledge of the basic physics behind electricity. When you know the physics, then you can understand the rules, codes, and laws that arise from it.

1.1 Matter

Everything on earth that has weight and occupies space is called matter, which is made up of atoms of elements. When the atoms of elements combine, they produce compounds. The smallest particle of a compound is called a "molecule." Figure 1–1

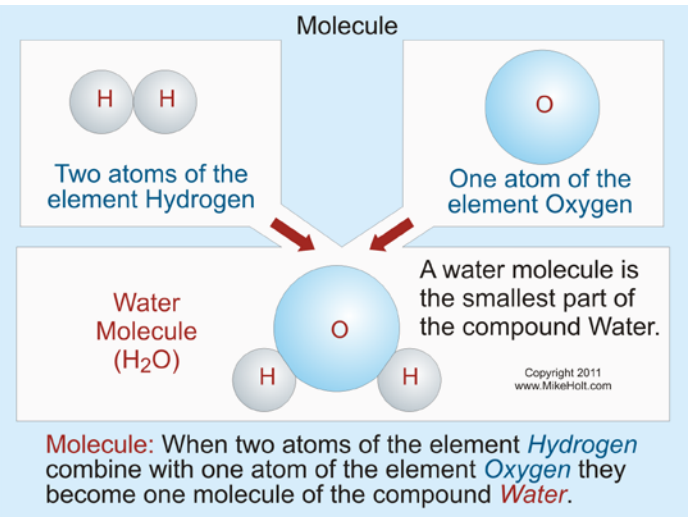


Figure 1–1

1.2 Atomic Theory

An atom contains three types of subatomic particles: electrons, protons, and neutrons. The central part of the atom is called the nucleus and it contains protons (positive charge) and neutrons (no charge). Electrons (negative charge) orbit around the nucleus. Figure 1–2

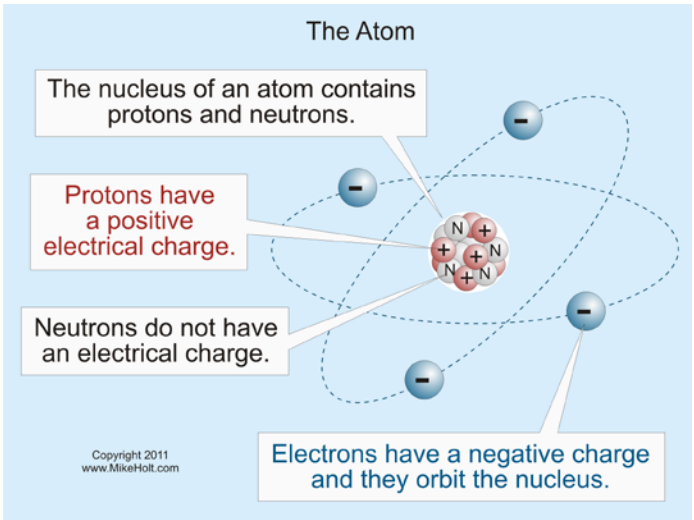


Figure 1–2

Electrons. Electrons are much smaller than protons and they are 1,840 times lighter. Because of their light weight and mobility (ease of separation from the atom), electrons actively participate in the transfer, or flow, of electrical energy.

Electrons have a negative electrical charge that is visualized as lines of force coming straight into the electron from all sides. Figure 1–3

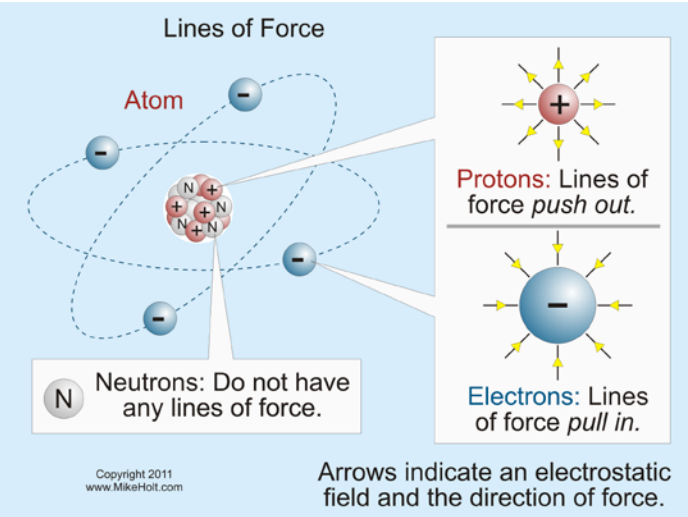


Figure 1–3

Protons. Protons are the same size as neutrons and have nearly the same mass (1,840 times as heavy as an electron), therefore they don't actively participate in the flow of electrical energy. Protons have a positive electrical charge with lines of force going straight out in all directions. See Figure 1–3.

Neutrons. Neutrons have no electrical charge, no lines of force, and do not take an active role in the flow or transfer of electrical energy. See Figure 1–3.

1.3 Law of Electrical Charges

Subatomic particles that attract or repel other subatomic particles follow the Law of Electrical Charges which states that, "Particles with like charges repel each other and particles with unlike charges attract each other." Therefore, electrons repel electrons and protons repel protons, but electrons and protons are attracted to each other. Figure 1–4

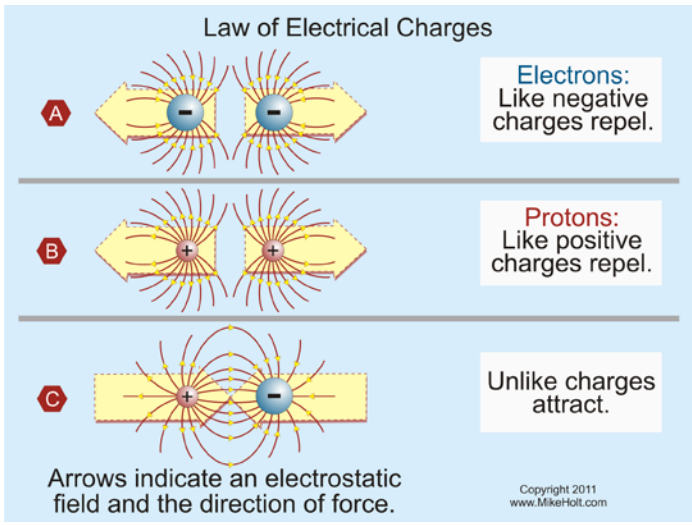


Figure 1–4

Author's Comment: This attracting and repelling force on subatomic particles (charged materials) is sometimes called the "electrostatic field."

1.4 Law of Atomic Charges

Most of the time, the electrical charge of an atom is balanced or neutral; there are an equal number of positive and negative charges within the atom (the number of electrons equal the number of protons). Under this condition, the atom has no electrical charge. Figure 1–5A

Negative Atomic Charge

However, if an atom contains more electrons than protons, then it has a negative charge. This occurs if an atom picks up an additional electron or two and stores them in its electron cloud. Figure 1–5B

Positive Atomic Charge

If an atom contains more protons than electrons, then it has a positive charge. This is the case when an atom loses an electron or two from its electron cloud. Charged atoms are called "ions" and they are either positively or negatively charged. Figure 1–5C

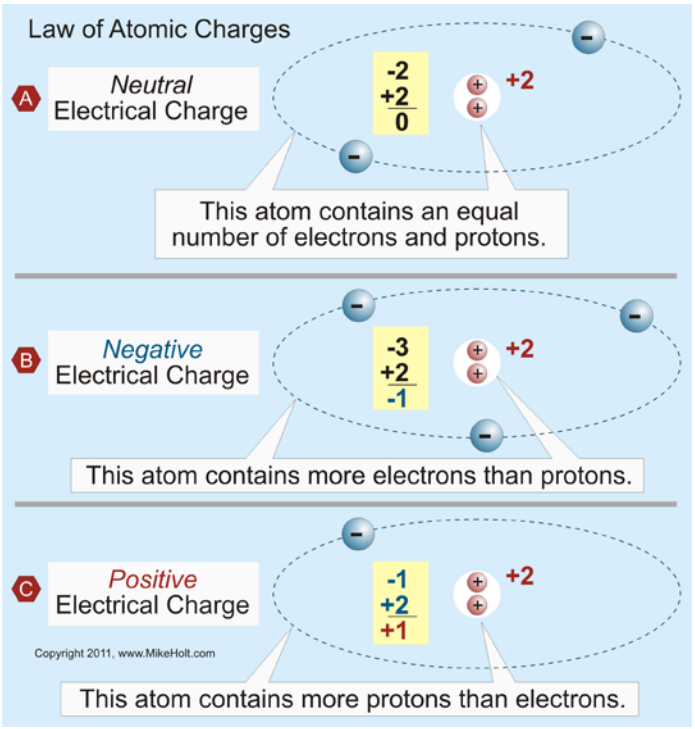


Figure 1–5

1.5 Charged Material (Static Charge)

If two conductive materials in contact with each other are separated, most of the electrons will return to the original surfaces before the separation is complete.

When unlike insulated material are in intimate contact, electrons from one material move across the interface to the surface of the other, but the protons remain on the first surface. When the bodies are quickly separated, both display a charge because one material has an excess of electrons (negative charge) while the other has fewer electrons (positive charge). Static charge is due to an excess of, or a deficiency of, electrons between objects that have been separated. Figure 1–6

The human body in a low-humidity area may accumulate a dangerous static charge of several thousand volts by contact of shoes with floor coverings, or by working close to machinery that generates static electricity.

Author's Comment: An object can become positively or negatively charged depending on whether it loses or gains electrons.

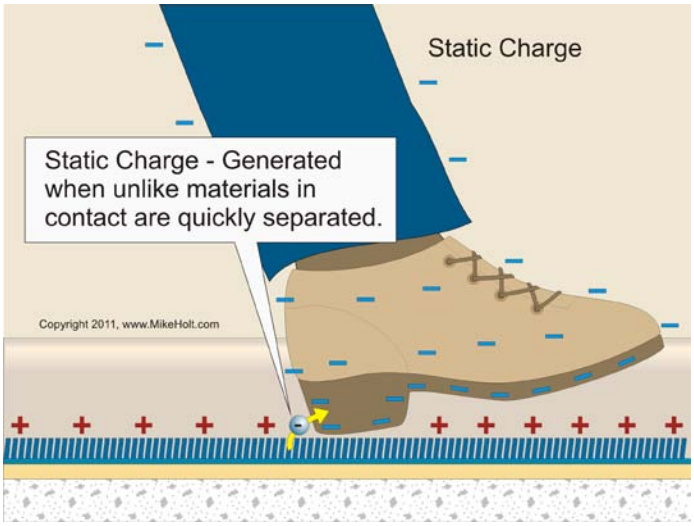


Figure 1–6

Static Voltage

The voltage developed is related to the amount of charge deposited on a body and to the capacitance of this body with respect to its surroundings. This voltage can continue to grow on an insulating body under the influence of continuous charge generation. If leakage of charge from the surface of the insulating body is not rapid enough, a sparking voltage can be reached and a high-voltage static discharge can occur.

DANGER: *High-voltage static discharge introduces:*

- *Ignition risk in areas where flammable or explosive liquids, gases, dusts, or fibers are present.* Figure 1–7
- *Risk that a person subjected to a static shock may fall or accidentally come into contact with a piece of moving equipment.*
- *Problems for people with heart rhythmic sensitivity who may suffer dysfunctional heart rhythm thus causing great discomfort or even injury.*
- *Damage to sensitive electronic equipment.*
- *Loss of electronically stored data.*

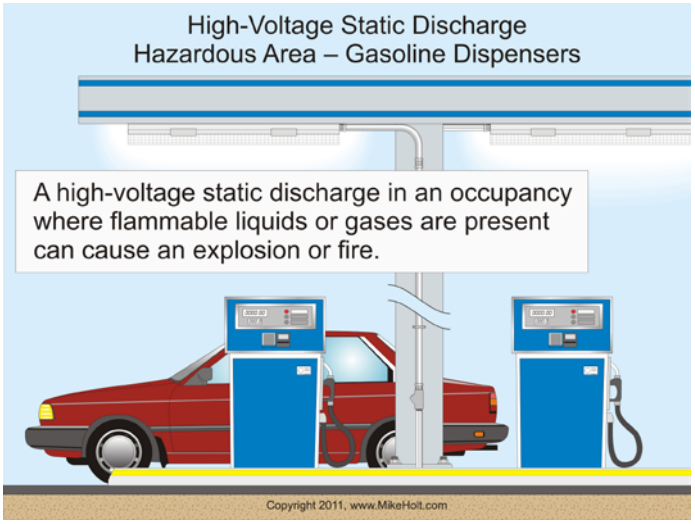


Figure 1–7

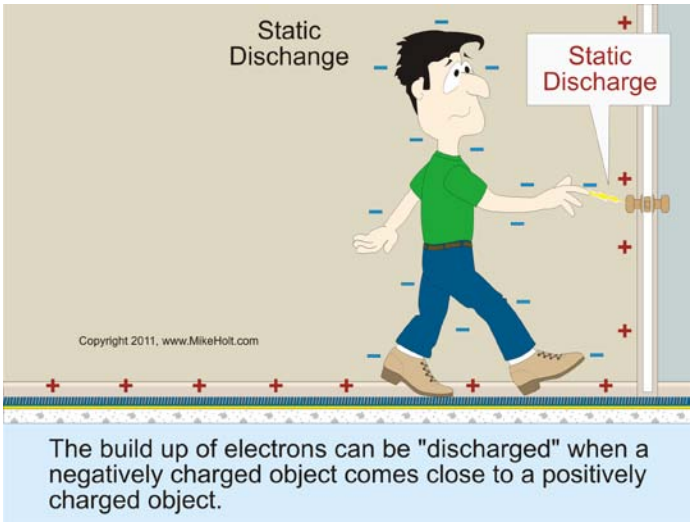


Figure 1–8

Reducing Static Charge

Providing a path to the earth can often reduce the electrostatic charge between objects. In addition, cotton clothing, ion generators, and humidifiers, as well as antistatic furniture, walls, and flooring are used to reduce this charge. For more information on solving problems associated with static electricity, see *IEEE 142—Recommended Practice for Grounding of Industrial and Commercial Power Systems (Green Book), NFPA 77—Recommended Practice on Static Electricity,* and *API RP 2003-1998—Protection Against Ignitions Arising Out of Static Lightning and Stray Currents.*

1.6 Neutralizing a Charge

Because of the Law of Electrical Charges [1.3], the build up of electrons on a negatively charged object can discharge when it comes close enough to a positively charged or uncharged object. The discharge is sometimes seen as an arc, and the distance that the spark can jump is determined in part by the voltage and dielectric between the bodies. The temperature of the arc is dependent on the amperage.

Figure 1–8 shows how electrons picked up by a person walking across a carpet in a low humidity environment can arc to the positively charged surface of the metal doorknob.

1.7 Lightning

Lightning is the discharging of high-voltage cells (usually negatively charged) within clouds to each other, to the earth, and sometimes to space. These charged cells in clouds normally attract charges of opposite polarity on high objects located on the earth. When the cell charge reaches a critical level (when the insulation between cloud and earth breaks down), it develops a "stepped leader" ionized path resulting in a high-current discharge (stroke), which temporarily neutralizes the positive and negative charges between the objects. Figure 1–9

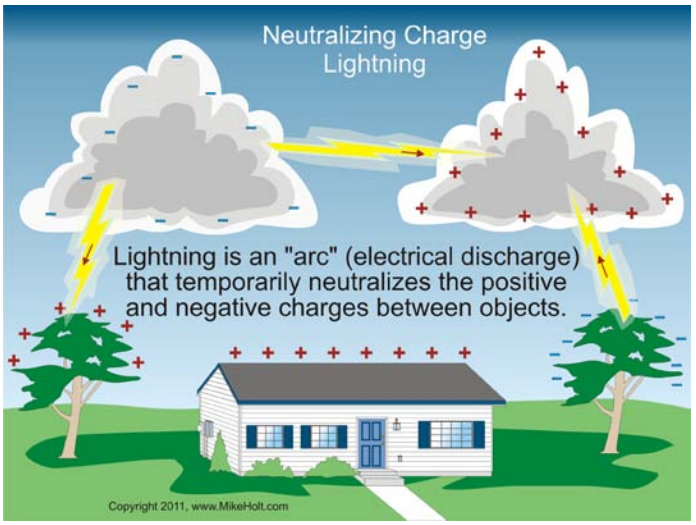


Figure 1–9

Author's Comment: "High-voltage cells" are areas within clouds that have built-up charges through friction associated with air movement. "Stepped leaders" are just ionized paths that zigzag toward the earth.

CAUTION: *Lightning strokes frequently terminate to an elevated point, such as a tree, a building, a transmission line, or similar raised structures, like a human body. Contrary to popular belief, lightning strikes both metallic and nonmetallic objects with the same frequency.*

The temperature at the terminal of the stroke, or at any high-resistance point in the path over which the current flows en route to ground, is likely to ignite combustible materials. Figure 1–10

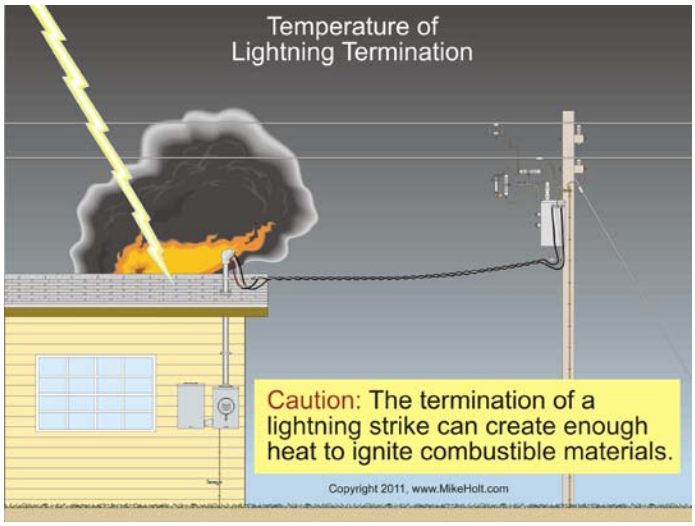


Figure 1–10

DANGER: *Over 100 deaths, 250 injuries, and billions of dollars in property damage are caused each year in the United States because of lightning. Lightning bolts can have a voltage as high as thirty million volts (30,000,000V) and current over twenty thousand amperes (20,000A).*

1.8 Lightning Protection

To protect property such as building structures from a lightning discharge, air terminals (often called "lightning rods") are placed on top of the structure. They are connected together and to the earth by large conductors so that lightning can be harmlessly directed from the structure into the earth. Figure 1–11

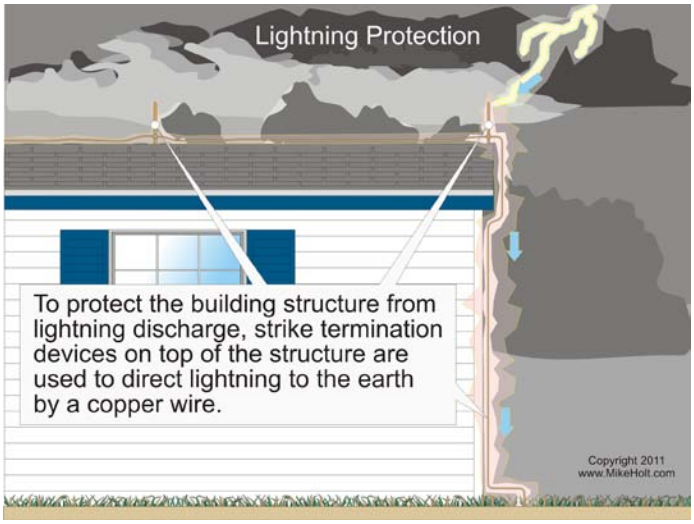
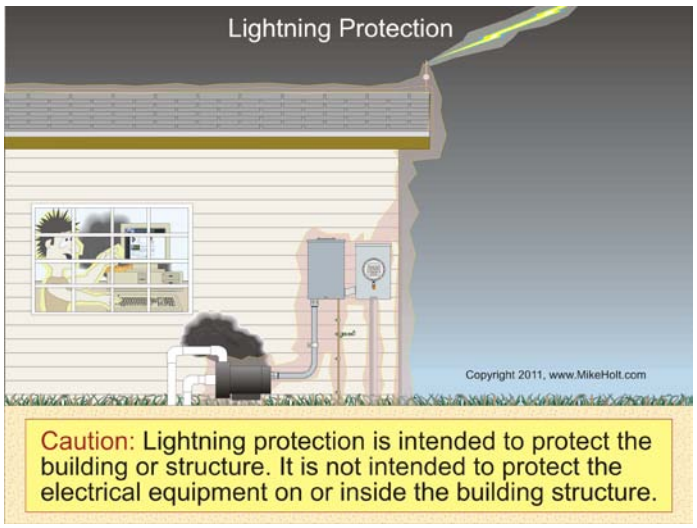


Figure 1–11

CAUTION: *Lightning protection is intended to protect the building itself; it is not intended to protect electrical equipment on or inside the structure. If protection of electrical equipment from lightning is important, then surge-protection devices must be installed on the electrical system in accordance with the* National Electrical Code. *See Article 280 for Surge Arrester requirements and Article 285 for rules on Transient Voltage Surge Suppressors (TVSSs).* Figure 1–12


Lightning Protection
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Caution: Lightning protection is intended to protect the building or structure. It is not intended to protect the electrical equipment on or inside the building structure.

Figure 1–12

UNIT 1

Summary

SUMMARY

1.1 Matter

When the atoms of elements combine, they produce compounds. The smallest particle of a compound is called a "molecule."

1.2 Atomic Theory

An atom contains three types of subatomic particles: electrons, protons, and neutrons. Electrons have a negative charge, are much smaller than protons, and actively participate in the transfer, or flow, of electrical energy. Protons have a positive charge. Neutrals have no electrical charge.

1.3 Law of Electrical Charges

The Law of Electrical Charges states that, "Particles with like charges repel each other and particles with unlike charges attract each other." Therefore, electrons repel electrons and electrons and protons are attracted to each other.

1.4 Law of Atomic Charges

Most of the time, the electrical charge of an atom is balanced or neutral. Under this condition, the atom has no electrical charge. If an atom contains more electrons than protons, it has a negative charge. If an atom contains more protons than electrons, it has a positive charge.

1.5 Charged Material (Static Charge)

Static charge is due to an excess of, or a deficiency of, electrons between objects that have been separated. An object can become positively or negatively charged depending on whether it loses or gains electrons.

Static Voltage

The voltage developed is related to the amount of charge deposited on a body and to the capacitance of this body with respect to its surroundings. If leakage of charge from the surface of the insulating body is not rapid enough, a sparking voltage can be reached, and a high-voltage static discharge can occur.

Reducing Static Charge

Providing a path to the earth can often reduce the electrostatic charge between objects. In addition, cotton clothing, ion generators, and humidifiers, as well as antistatic furniture, walls, and flooring are used to reduce this charge.

1.6 Neutralizing a Charge

Because of the Law of Electrical Charges [1.3], the build up of electrons on a negatively charged object can discharge when it comes close enough to a positively charged or uncharged object.

1.7 Lightning

Lightning is the discharging of high-voltage cells within clouds to each other, to the earth, and sometimes to space. When the cell charge reaches a critical level, it develops a "stepped leader" ionized path resulting in a high-current discharge, which temporarily neutralizes the positive and negative charges between the objects.

CAUTION: *Contrary to popular belief, lightning strikes both metallic and nonmetallic objects with the same frequency.*

DANGER: *Over 100 deaths, 250 injuries, and billions of dollars in property damage are caused each year in the United States because of lightning.*

1.8 Lightning Protection

To protect property, air terminals connected together and to the earth by large conductors are placed on top of structures so that lightning can be harmlessly directed from the structure into the earth.

CAUTION: *Lightning protection is intended to protect the building itself. If protection of electrical equipment from lightning is important, then surge-protection devices must be installed on the electrical system in accordance with the* National Electrical Code.

CONCLUSION

A basic understanding of the physics of matter is essential to understanding electrical theory. The movement of electrons in atoms that make up the matter of our universe is what produces electricity.

A solid foundation in the understanding of the physics of matter helps develop your knowledge of electricity. Test your foundation by completing this unit's practice questions:

UNIT 1

Practice Questions

PRACTICE QUESTIONS

1.1 Matter

1. Everything on earth that has weight and occupies space is called _____, which is/are made up of atoms of elements.

   (a) matter
   (b) elements
   (c) energy
   (d) compounds

2. When the atoms of elements combine, they produce _____. The smallest particle of a (n) _____ is called a "molecule."

   (a) matter
   (b) element(s)
   (c) energy
   (d) compound(s)

1.2 Atomic Theory

3. Atoms contain three types of subatomic particles: electrons, protons, and neutrons. The _____ orbit around the nucleus.

   (a) electrons
   (b) protons
   (c) neutrons
   (d) nuclei

4. Because of their light weight, _____ actively participate in the transfer of energy.

   (a) electrons
   (b) protons
   (c) neutrons
   (d) nuclei

5. _____ do not participate in the flow of energy and they have a positive electrical charge with lines of force going straight out in all directions.

   (a) Electrons
   (b) Protons
   (c) Neutrons
   (d) Nuclei

1.3 Law of Electrical Charges

6. The Law of Electrical Charges states that, "Particles with like charges repel each other."

   (a) True
   (b) False

7. The Law of Electrical Charges states that, "Particles with unlike charges repel each other."

   (a) True
   (b) False

1.4 Law of Atomic Charges

8. If an atom contains more electrons than protons, the atom has a negative atomic charge.

   (a) True
   (b) False

1.5 Charged Material (Static Charge)

9. If two conductive materials in contact with each other are separated, most of the electrons will return to the original surface before the separation is complete.

   (a) True
   (b) False

10. When insulated materials are in contact with each other, electrons move to the surface of each other, but the protons remain on the original surface.

    (a) True
    (b) False

11. When insulated bodies are quickly separated, both display an electrostatic charge because one surface has an excess of electrons while the other surface has fewer electrons.

    (a) True
    (b) False

12. Electrostatic charge is due to an excess of, or a deficiency of, electrons between objects that have been separated.

    (a) True
    (b) False

13. The human body in a low-humidity area may accumulate a dangerous electrostatic charge of several thousand volts.

    (a) True
    (b) False

14. Providing a path to the earth often helps reduce electrostatic charge.

    (a) True
    (b) False

1.6 Neutralizing a Charge

15. The discharge of electrons from a negatively charged object is sometimes seen as an arc, and the arc distance is a function of the _____ between the bodies.

    (a) static voltage
    (b) dielectric
    (c) a and b
    (d) a or b

1.7 Lightning

16. Lightning is the discharging of high-voltage cells within clouds to each other, to the earth, and sometimes to space.

    (a) True
    (b) False

17. The high-current discharge from the negatively charged cloud to a positively charged object permanently neutralizes the cloud.

    (a) True
    (b) False

18. Lightning frequently terminates to an elevated point and it strikes nonmetallic as well as metallic objects with the same frequency.

    (a) True
    (b) False

19. The termination of the lightning stroke is unlikely to ignite combustible materials.

    (a) True
    (b) False

20. Over 100 deaths, 250 injuries, and billions of dollars in property damage are caused each year in the U.S. because of lightning.

    (a) True
    (b) False

1.8 Lightning Protection

21. Lightning protection is intended to protect the building itself, as well as the electrical equipment on or inside the structure.

    (a) True
    (b) False

22. If protection of electrical equipment from lightning is desired, then a listed surge-protection device must be installed on the electrical system in accordance with the *NEC*.

    (a) True
    (b) False