MODULE 02

FOR A CERTIFICATION

PHYSICS

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WELCOME

The publishers of this Aviation Maintenance Technician Certification Series welcome you to the world of aviation maintenance. As you move towards EASA certification, you are required to gain suitable knowledge and experience in your chosen area. Qualification on basic subjects for each aircraft maintenance license category or subcategory is accomplished in accordance with the following matrix. Where applicable, subjects are indicated by an "X" in the column below the license heading.

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We wish you good luck and success in your studies and in your aviation career!

REVISION LOG

VERSION	EFFECTIVE DATE	DESCRIPTION OF CHANGE
001	2013 12	Module Creation and Release
002	2020 02	Minor Appearance Updates
002.1	2020 05	Clarified formulas for Buoyant Force (page 2.7) and Vibration (page 2.11)
002.2	2021 05	Corrected formulas for Pendular Movement and Vibration. Sub-Module 02, page 2.11

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2.1 - MATTER

Matter is the foundation for any discussion of physics. Matter is what all things are made of; whatever occupies space, has mass, and is perceptible to the senses in some way. According to the Law of Conservation, matter cannot be created or destroyed, but it is possible to change its physical state. When liquid gasoline vaporizes and mixes with air, and then burns, it might seem that this piece of matter has disappeared and no longer exists. Although it no longer exists in the state of liquid gasoline, the matter still exists in the form of the gases given off by the burning fuel.

NATURE OF MATTER

All matter is made up of atoms. An atom is the smallest unit of matter that establishes the unique characteristics of a substance. There are over 100 different kinds of matter each made up of atoms with different physical attributes. These varied and unique kinds of matter are called elements. They cannot be further broken down into simpler substances without losing their unique identity.

Atoms of different elements are similar to each other in that they contain the same basic parts. An atom has a nucleus within the nucleus are subatomic particles. One or more protons are found at the nucleus of all atoms. The proton has a positive electrical charge. One or more neutrons are also found at the nucleus of all atoms. A neutron has no electrical charge. Orbiting around the nucleus is a third kind of subatomic particle called an electron. An electron has a negative electrical charge. Electrons are configured around the nucleus in orderly, concentric rings known as shells. ***Figure 1-1*** illustrates the basic structure and components of atoms.

Generally, each atom contains the same number of electrons and neutrons as the atom has protons. However, the number of these particles that each atom contains is what causes the elements to be different. For example, an atom of hydrogen, has one proton, one neutron and one electron. It is the simplest element. An atom of Oxygen, has eight protons, eight neutrons and eight electrons. Copper has 29 of each of these subatomic particles and so forth. The number of subatomic particles that each atom contains defines the type of element it is and its inherent properties. The mass of an atom is related to how many characteristic subatomic particles make up the atom of each element.

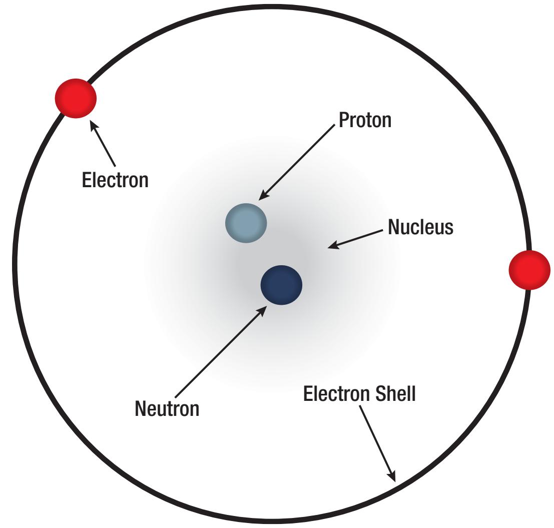

Figure 1-1. An atom and its sub-atomic particles.

Elements are assigned an atomic number according to how many protons are found at the nucleus of their atoms. Each element also has a distinctive 1, 2, or 3 letter abbreviation. The elements are arrange in a table known as the periodic table of elements. The table groups the elements by periods horizontally and by groups vertically to show similar characteristics of the elements. (***Figure 1-2***)

Atoms of the same or different elements may chemically bond to form a molecule. When two or more atoms of the same element bond to form a molecule, it will have the inherent properties of that element. When atoms of different elements bond to form a molecule, the molecule has properties and characteristics completely different than those of each individual elements that comprise it. A water molecule, for example, is made up of two hydrogen atoms and one oxygen atom. Water has its own unique properties that are completely different than those of hydrogen or oxygen alone.

When atoms bond to form molecules, they share electrons. The closest shell to the nucleus can only contain two orbiting electrons. If the atom has more than two electrons, they are found in the next orbital shell farther away from the nucleus. This second shell can only hold eight electrons. If the atom has more than ten electrons (2 first shell + 8 second shell), they orbit in a third shell farther out from the nucleus. This third shell is filled with up to eight electrons and then

Figure 1-2. The periodic table of elements.

a fourth shell starts to fill if the element still has more electrons. However, when the fourth shell contains eight electrons, the number of electrons in the third shell begins to increase again until a maximum of 18 is reached. (***Figure 1-3***)

The outer most orbital shell of any atom's electrons is called the valence shell. The number of electrons in the valence shell determines the chemical bonding properties of the material as well as other characteristics such as conductivity. When the valence shell has the maximum number of electrons, it is complete and the electrons tend to be bound strongly to the nucleus. Materials with this characteristic are chemically stable. It takes a large amount of force to move the electrons in this situation from one atom valence shell to that of another. Since the movement of electrons is called electric current, substances with complete valence shells are known as good insulators because they resist the flow of electrons (electricity). (***Figure 1-4***)

In atoms with an incomplete valence shell, that is, those without the maximum number of electrons in their valence shell, the electrons are bound less strongly to the nucleus. The material is chemically disposed to combine with other materials or other identical atoms to fill in the unstable valence configuration and bring the number of electrons in the valence shell to maximum. Two or more substances may share the electrons in their valence shells and form a covalent bond. A covalent bond is the method by which atoms complete their valence shells by sharing valence electrons with other atoms. Molecules are formed this way.

Electrons in incomplete valence shells may also move freely from valence shell to valence shell of different atoms or compounds. In this case, these are known as free electrons. As stated, the movement of electrons is known as electric current or current flow. When electrons move freely from atom to atom or compound to compound, the substance is known as a conductor. (***Figure 1-5***)

ISOTOPES

When atoms of the same element have different numbers of neutrons, they are called isotopes. Because of the differing numbers of neutrons, various isotopes of the same element have different masses. Mass is the word for how much matter something has and therefore how much it weighs. Because different isotopes have different numbers of neutrons, they do not all weigh the same. Different isotopes of the same element have the same atomic number because they have the same number of protons. The atomic number is decided by the number of protons. (***Figure 1-6***)

Shell or Orbit Number	1	2	3	4	5
Maximum Number Of Electrons	2	8	18	32	50

Figure 1-3. Maximum number of electrons in each orbital shell of an atom.

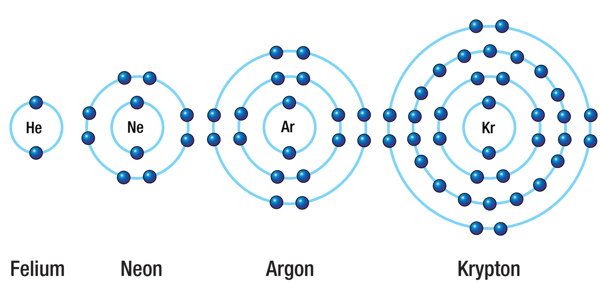

Figure 1-4. Elements with full valence shells are good insulators. Most insulators used in aviation are compounds of two or more elements that share electrons to fill their valence shells.

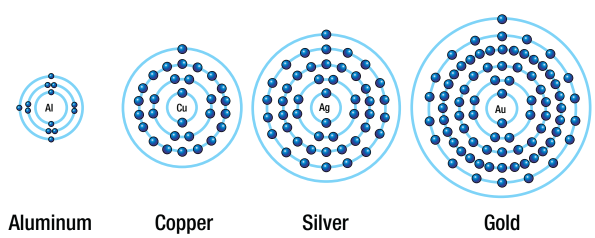

Figure 1-5. The valence shells of elements that are common conductors have one (or three) electrons.

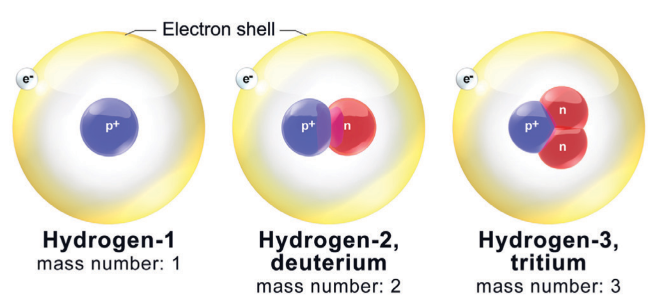

Figure 1-6. Isotopes of hydrogen.

Isotopes of the same element also have the same number of electrons and the same electronic structure. Because how an atom acts is decided by its electronic structure, isotopes are almost the same chemically, but they are different physically because of their different masses.

Hydrogen, the most common element, has three common isotopes. Its most common isotope with only one proton and no neutrons is called protium (1H). A hydrogen atom with one proton and one neutron (atomic mass of 2) is called deuterium(2H). A hydrogen atom with one proton and two neutrons (atomic mass of 3) is called tritium(3H). Protium and deuterium are stable isotopes, while tritium is a radioactive isotope.

CHEMICAL COMPOUNDS

Materials made up of two or more elements that have chemically bonded are known as compounds. Compounds have properties different than the elements from which they are made. They can only be separated through chemical reaction. They have a unique chemical structure with a fixed ratio of atoms of different elements that are bonded together chemically. Compounds should not be confused with mixtures. Mixtures are atoms and molecules that are physically mixed together but are not chemically bonded. The properties and characteristics of a mixture are closely related or dependent on the properties of the individual constituents. Mixtures can usually be separated by filtering, evaporation or some other mechanical means.

STATES OF MATTER

Matter exists in four common states; solids, liquids, gases and plasma. A state of matter is the physical condition of a substance. Solids, liquids and gases are the primary states of matter of concern for the aviation maintenance professional. The compound(s) from which a substance is made do not change, regardless of the state of matter. Atoms and molecules that make up a substance are always in a state of motion due to heat energy in the material. The physical state of matter is related to the degree of motion between these particles with solids having the least motion and gases and plasma having the most.

PLASMA

Plasma is a unique state of matter comprised of ionized gas consisting of positive ions and free electrons in proportions resulting in a relatively neutral electric charge. Its particles are close enough together that they act collectively when exposed to a magnetic field. Plasma is also electrically conductive. It is sustained easily at the extremely high temperatures present in stars and as such is the most common form of matter in the universe.

SOLID

Matter is said to be solid when it has a definite volume and shape. The molecules of a solid are tightly bound to each other. They resist changing shape or volume. Solids may be geometrically or irregularly structured. They are incompressible and do not contain enough movement of the molecules to permit a physical change of shape.

LIQUID

Liquid matter is characterized by molecules that have more energy and increased movement. This causes the molecules to be able flow and not take a rigid shape such as a solid. Liquids take the shape of their container even though the volume of a liquid does not change significantly. Liquids are said to be incompressible. While liquid molecules are able to slide past each other, they are still closely packed enough that the application of pressure does little to change the volume. The molecules are also closely bound enough to each other that surface tension is created. Surface tension keeps liquids from complete freedom of expansion. It can be observed when a container is filled with a liquid to slightly over the brim yet the liquid does not spill over.

GAS

Matter also exists as a gas. This type of matter contains even more heat energy and movement in its molecules. The bonding that causes surface tension in a liquid does not exist in a gas. A greater space between molecules exists. Gases take the shape of their container but unlike liquids, gases are compressible. When pressure is applied, the molecules can be made to exist closer to each other. It is possible to put a gas under so much pressure that it changes to a liquid state.

CHANGES BETWEEN STATES

Matter can change between the states by adding or removing energy. The chemical composition of the material remains the same during all states of matter but the energy level causes it to be a solid, liquid, or gas. For example, water is always H_2O, millions of pairs of hydrogen atoms covalently bonded to a single oxygen atom loosely held next to each other in a liquid state.

When energy is removed and water becomes ice, it is still H_2O. However, the motion of the molecules is greatly reduced and they no longer have the energy to slide past one another as a liquid. The same is true when heat energy is added to water. Water vapor is formed as the motion of the molecules causes more freedom of movement between molecules. But the water existing as a gas (vapor) is still formed from millions of H_2O molecules.

The heat energy added or subtracted to a substance is typically measured by temperature. The higher the temperature of a substance, the more energy it contains. Heat always flows from hot to cold. These terms (hot and cold) express the relative amount of energy present in the substance. They do not measure the absolute amount of heat present. Without a difference in energy levels, there is no transfer of energy (heat).

Adding heat to a substance does not always raise its temperature. When a substance changes state, such as when a liquid changes into a vapor, heat energy is absorbed. This is called latent heat. When a vapor condenses into a liquid, this heat energy is given off. The temperature of a substance remains constant during its change of state. All energy absorbed or given off, the latent heat, is used for the change process. Once the change of state is complete, heat added to a substance raises the temperature of the substance. After a substance changes state into a vapor, the rise in temperature of the vapor caused by the addition of still more heat is called superheat.

The temperature at which a substance changes from a liquid into a vapor when heat is added is known as its boiling point. This is the same temperature at which a vapor condenses into a liquid when heat is removed. The boiling point of any substance varies directly with pressure. When pressure on a liquid is increased, its boiling point increases, and when pressure on a liquid is decreased, its boiling point also decreases. For example, water boils at 100°C (212°F) at normal atmospheric pressure (14.7 psi). When pressure on liquid water is increased to 20 psi, it does not boil at 100°C. More energy is required to overcome the increase in pressure. It boils at approximately 108°C (226.4°F). The converse is also true. Water can also boil at a much lower temperature simply by reducing the pressure upon it. With only 10 psi of pressure upon liquid water, it boils at 90°C (194°F). (***Figure 1-7***)

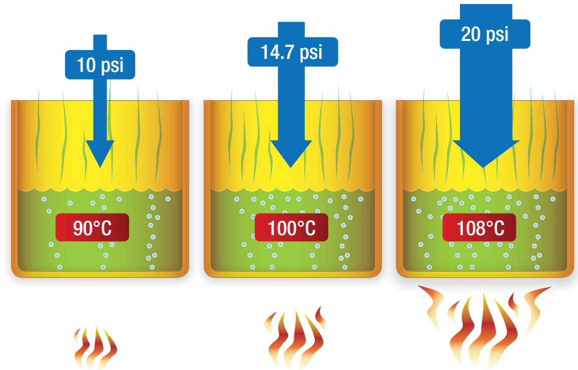

Figure 1-7. Boiling point of water changes as pressure changes.

Vapor pressure is the pressure of the vapor that exists above a liquid that is in an enclosed container at any given temperature. The vapor pressure developed by various substances is unique to each substance. A substance that is said to be volatile, develops high vapor pressure at standard day temperature 15°C (59°F). This is because the boiling point of the substance is much lower. The vapor pressure of any substance varies directly with temperature.

CATALYST

A catalyst is a substance that causes or accelerates a chemical reaction without itself being affected. A two part epoxy mix is a good example of a catalyst. The main ingredient is the epoxy resin itself. The second ingredient, when mixed with the resin, causes the resin to harden faster and then remains as part of the epoxy resin mix. The opposite of a catalyst is an inhibitor. Inhibitors slow down reactions.