UNITED STATES MARINE CORPS

LESSON PLAN

HEAT AND ENERGY

INTRODUCTION:

1. Gain Attention. How many of us have touched a hot stove burner or gotten a little too close to a fire? Why is it that the burner (or fire) made us hotter, vice us making the burner or fire cooler? Did you ever wonder why waterbeds have heaters? Have you ever wondered how a refrigerator or an engine works? How can birds stand in icy water without losing a lot of body heat? Why are sidewalks made in sections? Why do large bridges have expansion joints? How do heat pumps work?

2. Overview. This period of instruction provides the student(s) with a fundamental understanding of energy, as well as, its relationship to heat.

3. Introduce Learning Objectives.

a. Terminal Learning Objectives. Without the aid of, but in accordance with the reference, provide a fundamental understanding of the different types of heat and energy, heat transfer mechanisms, and the phase changes that water goes through.

b. Enabling Learning Objectives. Without the aid of references, complete the following:

(1) Describe the differences between sensible, specific and latent heat types.

(2) Provide examples of kinetic and potential energy.

(3) Explain the 1st Law of Thermodynamics and it relationship to heat.

(4) State which phase changes absorb or release heat and describe their respective energy states.

(5) Define and discuss the methods in which heat may be transferred.

4. Method/Media. This period of instruction will be taught using the lecture method with aid of QMMCBT-001 "Introduction to the Dynamics of the Atmosphere".

5. Evaluation. The student shall be evaluated by verbally demonstrating a fundamental understanding heat and energy.

BODY:

1. Overview of energy and heat. The Universe is made up of matter and energy. Matter is made up of atoms and molecules (groupings of atoms) and energy that cause the atoms and molecules to always be in motion - either bumping into each other or vibrating back and forth. The motion of atoms and molecules creates a form of energy called *heat* or *thermal energy* that is present in all matter. Even in the coldest voids of space, matter still has a very small but still measurable amount of heat energy. Energy can take on many forms and can change from one form to another. Many different types of energy can be converted into heat energy. Light, electrical, mechanical, chemical, nuclear, sound and thermal energy itself can each cause a substance to heat up by increasing the speed of its molecules. So, put energy into a system and it heats up, take energy away and it cools.

TRANSITION. One should be familiar with energy; as for we see it everyday. Some common forms of energy are heat, chemical, nuclear, radiant (light - refer to QMMPH1-008), and gravitational energy. However, energy classifications fall into two (2) major categories, *kinetic* and *potential* energy.

2. The different types of energy. Energy is defined as the property of a system that generally enables it to do work, where work is force times distance (W = fd).

a. Kinetic energy is the energy of motion. An object which has motion - whether it is vertical or horizontal motion - has kinetic energy. There are many forms of kinetic energy - vibrational (the energy due to vibrational motion), rotational (the energy due to rotational motion), and translational (the energy due to motion from one location to another).

(1) The amount of kinetic energy which an object has depends upon two variables: the mass (m) of the object and the speed (v) of the object. The kinetic energy (KE) of an object can be represented mathematically as, $KE = 1/2mv^2$, where "m" is the mass of the object, and "v" is its velocity. Standard measurement for KE is in Joules (J).

(2) This equation reveals that the kinetic energy of an object is directly proportional to the square of its speed. That means that for a twofold increase in speed, the kinetic energy will increase by a factor of four; for a threefold increase in speed, the kinetic energy will increase by a factor of nine; and for a fourfold increase in speed, the kinetic energy will increase by a factor of sixteen. The kinetic energy is dependent upon the square of the speed.

(3) Kinetic energy is a scalar quantity; it does not have a direction. Unlike velocity, acceleration, force, and momentum, the kinetic energy of an object is completely described by magnitude alone.

(4) An example of KE would be the motion of a hammer when driving a nail. Because of its motion, the hammer is physically able to move another object (or do work). The faster the hammer is swung, the greater kinetic energy (energy

of motion) it possesses. Similarly, a larger, more massive, hammer will possess more kinetic energy than a smaller hammer – provided that they are swung at the same velocity.

(5) Another example would be the winds of a hurricane possessing more kinetic energy than a localized sea breeze. Hurricane force winds are larger in scale, or more massive, and travel at higher velocities.

(6) Kinetic energy can also be significant at an atomic level. All matter is composed of atoms and molecules that are constantly vibrating. By the constant vibrations, the atoms or molecules have kinetic energy. When a pan of water is placed on a stove, the stove heats the water and causes the molecules to vibrate faster. It can be concluded than when a solid, liquid, or a gas is heated, the atoms or molecules will move faster and thus possess more kinetic energy.

Figure 1 - While the car is sitting on top of the hill, it has potential energy. It has the potential to roll down the hill.

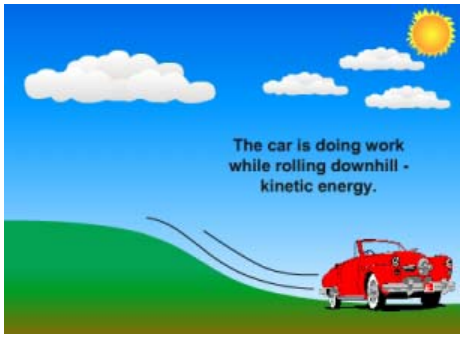

Figure 2 – While the car is rolling down the hill, it has energy, kinetic energy.

b. Potential energy (PE) is defined as energy that the body possesses by virtue of its position with respect to their bodies in the field of gravity, or an object can store energy as the result of its position.

(1) An example of potential energy is a heavy ram of a pile driver is storing energy when it is held at an elevated position. This stored energy of position is referred to as potential energy.

(2) Similarly, a drawn bow is able to store energy as the result of its position. When assuming its *usual position* (i.e., when not drawn), there is no energy stored in the bow. Yet when its position is altered from its usual equilibrium position, the bow is able to store energy by virtue of its position. This is another example of potential energy.

(3) Potential energy can be stated mathematically as PE = mgh, where "m" is the mass of the object, "g" is acceleration due to gravity (a constant at 9.8 m/s^2), and "h" is the height of the object.

TRANSITION. Energy may exist in a variety of forms and may be transformed from one type of energy to another. However, these energy transformations are constrained by a fundamental principle, the Conservation of Energy.

3. First Law of Thermodynamics. The 1st Law of Thermodynamics states that energy can be neither created nor destroyed (conservation of energy). Thus power generation processes and energy sources actually involve conversion of energy from one form to another, rather than creation of energy from nothing. In other words, energy that is lost in a process must equal the energy gained in another process.

TRANSITION. Students have difficulty understanding that molecules are constantly moving in all states of matter. Many students accept the fact that molecules are moving in liquid water because they can see water flow. However, these students have difficulty believing that the molecules in ice are also moving. Nevertheless, molecules are always moving, even in substances such as ice where no motion of the substance is visible. The next subject discusses different types of heat and how heat affects energy.

4. Different types of heat. Heat is defined as a form of energy transferred between systems by virtue of their temperature differences. When you touch a hot stove, heat enters your hand because the stove is hotter than your hand. Or, when you hold an ice cube, heat is transferred from your hand to the ice cube because your hand is warmer than the ice cube. Heat flows from warmer to cooler objects, and stops flowing when the temperatures are equal. There are several types of "heat":

a. Sensible Heat. Sensible heat is the sensation of temperature that the human body feels in contrast to the actual temperature of the environment as measured with a thermometer.

b. Specific Heat. Specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius. Objects are made of different materials, and therefore will have different specific heat values. For example, land heats three times

as fast as water, blacktop heats faster than cement.

Table 1 - Various Specific Heat Values.

Substance	Specific Heat Value (cal/g°C)	Substance	Specific Heat Value (cal/g°C)
Land	.33	Air	.25
Water Vapor	.44	Glass	.20
Ice	.56	Wood	.42
Fresh Water	1.0	Ocean Water	.93

c. Latent Heat. "Latent" means hidden, therefore latent heat can be classified as a "hidden" heat. Each time water changes state, energy is absorbed or released. This energy is latent heat. Latent heat is the energy absorbed or released when a substance changes its physical state.

(1) Latent heat of condensation (Lc): Refers to the heat gained by the air when water vapor changes into a liquid. Lc=2500 Joules per gram (J/g) of water or 600 calories per gram (cal/g) of water.

(2) Latent heat of fusion (Lf): Refers to the heat lost or gained by the air when liquid water changes to ice or vice versa. Lf=333 Joules per gram (J/g) of water or 80 calories per gram (cal/g) of water.

(3) Latent heat of sublimation (Ls): Refers to the heat lost or gained by the air when ice changes to vapor or vice versa. Ls=2833 Joules per gram (J/g) of water or 680 calories per gram (cal/g) of water.

(4) Latent heat of vaporization (Lv): Refers to the heat lost by the air when liquid water changes into vapor. This is also commonly known as the latent heat of evaporation. Lv= -2500 Joules per gram (J/g) of water or -600 calories per gram (cal/g) of water.

TRANSITION. We have already learned that energy is conserved, that is it is nor created, not destroyed, but what happen when an ice cube melts into water? Water is a substance that exists as a liquid, solid, and gas; therefore, for the purpose of this period of instruction, water will be the substance of focus.

5. H2O Phase Changes. A "phase change" is when a substance changes from one state to another, i.e. liquid to solid, liquid to gas, gas to solid, etc… Water has a much high capacity for storing energy than other common substances such as soil or water due to its specific heat capability. Water can store large amounts of energy with little energy change.

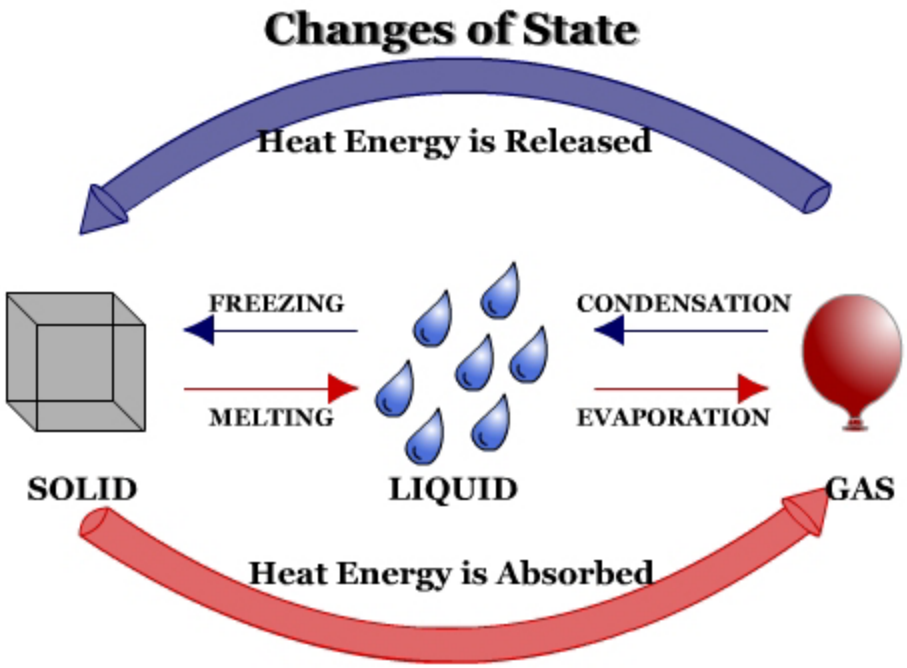

Figure 3 – Phase changes for an appropriate molecule.

a. Types of phase changes. There are two (2) classifications for phase changes, changes which absorb heat go from a low to high-energy state and changes releasing heat go from a high to low energy state.

(1) Phase changes absorbing heat. During this type of phase change, water molecules absorb energy from the surrounding environment and use all the energy to complete the phase change. The molecules have gone from a low energy state to a higher one. None of this heat is used to change the sensible temperature of water. For example, when ice changes into liquid, the liquid will maintain the same temperature of the ice until all of the ice has melted.

(a) Melting – the conversion from solid to liquid.
(b) Evaporation – the conversion from liquid to vapor.
(c) Sublimation – the conversion from solid to vapor.

(2) Phase changes releasing heat. During this type of phase change, water molecules release energy and then the released energy can be used to heat the surrounding air. During the phases, all the energy that was previous absorbed is now released during the phase change. The molecules will return to a low energy state. The release of latent heat will change the sensible temperature of an object.

(a) Freezing – the conversion from liquid to solid.
(b) Condensation – the conversion from vapor to liquid.
(c) Deposition – the conversion from vapor to solid.

TRANSITION. We have had an in depth discussion on heat and energy and how it is changed. But, how is heat transported?

6. Heat Transfer Mechanisms.

a. Conduction is defined as the transfer of heat by molecular activity from one substance to another, or through a substance. Transfers always from warmer to colder regions.

b. Convection is defined as motions in a fluid that result in the transport and mixing of fluid's properties. In meteorology, convection usually refers to atmospheric motions that are predominantly vertical, such as rising air currents due to surface heating. The rising of heated surface air and the sinking of cooler air aloft are often called free convection.

c. Advection is defined as horizontal transfer of any atmospheric property by the wind.

d. Radiation is the process in which energy, and therefore heat, is emitted from a body.

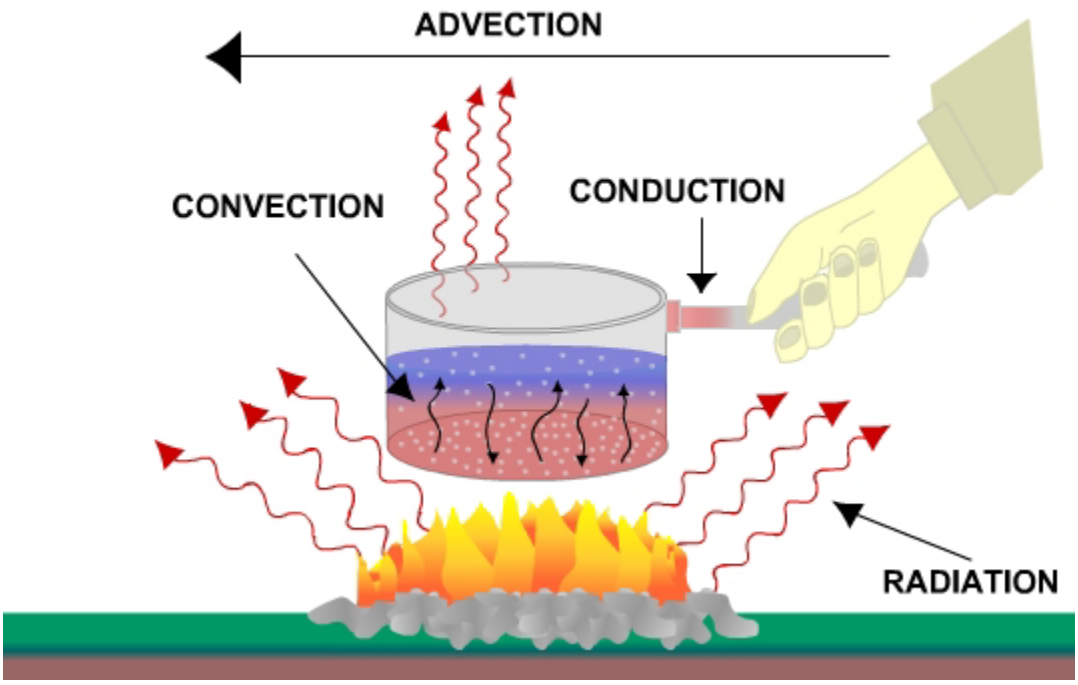

Figure 4 – Four different methods of transferring heat.

OPPORTUNITY FOR QUESTIONS:

1. Questions from the Class. At this time are there any questions pertaining to the material that has just been presented to you?

2. Questions to the Class.

a. QUESTION. What is the difference between kinetic and potential energy?

b. ANSWER. Kinetic energy is within a body that is a result of its motion and Potential energy (PE) is defined as energy that the body possesses by virtue of its position with respect to their bodies in the field of gravity, or an object can store energy as the result of its position.

c. QUESTION. The reason why land heats and cools faster than water is because of its _____ content.

d. ANSWER. Specific heat.

e. QUESTION. The three phases that end up at a lower energy state and increase the sensible heat of the environment are.

f. ANSWER. Freezing, Condensation, and deposition.

SUMMARY: During this period of instruction, the fundamental concepts of energy and heat were introduced. Specifically, the differences between kinetic and potential energy, the types of heat, the conservation of energy, substance phase changes, and the various ways that heat is transported.

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