Chapter 5, 6 and 7
Energy and Power
Lecture Notes

I. 5.1 The Nature of Energy
   a. **Energy** – the ability to do work or cause a change.
      i. work is the transfer of energy
      ii. SI unit for energy is the same as the SI unit for work – Joule
   b. Two main types of energy: **Kinetic and Potential**
      i. **Kinetic Energy**: the energy of motion
         1. The amount of kinetic energy depends on the objects **mass and velocity**
         2. Energy is transferred during work – the more work one does on an object, the more energy one imparts on the object.
         3. Calculating Kinetic Energy
            a. **Kinetic energy** = $\frac{\text{Mass} \times \text{Velocity}^2}{2}$ K.E = $\frac{10\text{ kg} \times (10\text{m/s})^2}{2}$

               K.E. = $\frac{10 \times 100}{2} = \frac{1000}{2} = 500$
            b. **When mass is doubled; Kinetic Energy is doubled** (from 500 to 1000)

               $\frac{\text{Mass} \times \text{Velocity}^2}{2}$ K.E = $\frac{20\text{ kg} \times (10\text{m/s})^2}{2}$

               K.E. = $\frac{20 \times 100}{2} = \frac{2000}{2} = 1000$
            c. **When velocity is doubled; Kinetic Energy is quadrupled!!** (from 500 to 2000)

               $\frac{\text{Mass} \times \text{Velocity}^2}{2}$ K.E = $\frac{10\text{ kg} \times (20\text{m/s})^2}{2}$

               K.E. = $\frac{10 \times 400}{2} = \frac{4000}{2} = 2000$
      ii. **Potential Energy:** Energy stored for use at a later time
         1. **Elastic Potential Energy:**
            a. Energy stored in springs, bow and arrow, stretched elastic or rubber bands.
            b. Associated w/ objects that can be stretched or compressed.
         2. **Gravitational Potential Energy**:
            a. **Height** and **weight** dependant
            b. GPE = work done to lift and object to a height
            c. Joules = Newtons x Meters
            d. **GPE = Weight x Height**
            e. Weight = Mass x Aceleration$_g$ = mass x 9.8 m/s^2
            f. Therefore….. **GPE = mass x 9.8 m/s2 x height**
      iii. Different Forms of Energy
         1. **Mechanical** – associated w/ the motion or position of an object

2. **Thermal Energy**– associated w/ the total energy of the particles (atoms and Molecules) in an object. As thermal energy increases, the particles increase in speed and the thermal energy (temperature) of the object increases.
3. **Chemical Energy** – the energy stored in chemical bonds. The potential energy stored in compounds.
4. **Electrical Energy** – moving electrical charges. Electricity!!
5. **Electromagnetic energy** – Travels in waves, associated w/ light, infrared, ultraviolet, microwaves, x-rays, etc.
6. **Nuclear Energy** – Associated w/ the fusion or fission of nuclear atoms.

iv. 5.2 Energy Conversion and Conservation

1. Most forms of **energy can be converted from one type to another**.
    a. Water falling onto a water turbine: mechanical energy converting into electrical energy
    b. A Toaster: Converts electrical energy into thermal energy to toast bread
    c. Striking a match: Converts mechanical energy (rubbing the match on a surface) into chemical energy (breaking chemical bonds to form fire) which is converted into thermal energy (heat from the fire) and Electromagnetic energy (see light coming from the fire on the match)
2. **Conservation of energy**
    a. **Law of the Conservation of Energy** states that energy cannot be created or destroyed. It simply changes from one form into another
    b. Part of Einstein's theory of Relativity tells us that a small amount of mass can be changed directly into a tremendous amount of energy
        i. **E = mc2**
            1. E = **the energy produced**
            2. m = **the mass being converted**
            3. c = **the speed of light (186,000 miles/second)**

v. 5.4 Power: the rate at which work is done

1. Power = work / time
2. Power = $\frac{\textbf{Force x Distance}}{\text{Time}}$
3. SI Unit for Power is the **Watt**
4. 1 **Watt = 1Joule / 1 Second**
5. 1 Watt is approx the power required to raise a glass of water to your mouth in 1 second.
6. **1000 watts = 1 kilowatt**
7. Power can also be described as the rate energy is transferred from one object to another or the rate energy is converted.
8. H**orsepower** : An American unit of power
    a. The amount of work a horse does when it lifts 33,000 ponds of coal to a height of 1 foot in 1 minute.
    b. 1 **horsepower = 746 watts**

II. Chapter 6 – Thermal energy and heat

a. Temperature – a measure of the AVERAGE kinetic energy of the individual particles of a substance.
b. Temperature scales:
    i. Fahrenheit, Celsius and Kelvin

ii. Absolute zero- that temperature where the individual particles contain no more energy. The particles (atoms and/or molecules) cease vibrating. No movement occurs. Absolute zero occurs at –460° F, -273° C and at 0° K

iii. "Need-to-Know" Table:

Scale	Abbreviation	Absolute Zero	Water Freezes	Water Boils
Fahrenheit	°F	-460	32	212
Celsius	oC	-273	0	100
Kelvin	oK	0	273	373

c. Thermal energy – TOTAL energy of all of the particles

d. Heat – thermal energy moving from a warmer object to a cooler object

e. Heat is transferred in one of three ways:

   i. Conduction, Convection and Radiation

      1. Conduction – heat is transferred from one particle to the next particle w/out the particles actually moving or changing place. Examples include: a metal spoon in hot water gets hot or a pot gets hot as it sits on an electric stove.
      2. Convection – movement that transfers heat by movement of currents within the particles. The particles actually are moving and thereby transferring the heat. Examples include: a pot of boiling water sets up convection currents to move the hot water at the bottom of the pot being heated to the cooler water at the top of the pot and the convection zone in the sun.
      3. Radiation Zone – transfer of energy by electromagnetic waves. Examples include: the Sun's energy traveling thru space and heating up the Earth w/out heating space itself, Heat lamps used at fast food restaurants, and the radiator of a car dissipating the heat of an engine.

f. Heat is transferred (moves) in only one direction: from a warmer object to a cooler object.

   i. Hot coffee cools to room temp because the heat of the coffee is transferred to the cooler temperature of the room.

   ii. A cold glass of Iced tea soon warms up to the surrounding room temperature because the warmer temperature of the room's surroundings is transferred to the colder glass of iced tea thereby warming it up.

g. Conductor – a material that transfers heat well: metal, tile, glass

h. Insulator – a material that does not transfer heat well: air, carpet, wood

   i. Tile floor and carpet are both the same temperature in the morning but when you step on them bare foot the tile feels cold because tile transfers the heat from your foot well. The carpet feels "not cold" because it doesn't transfer the heat well.

i. Specific Heat – the amount of energy required to raise the temperature of 1 kg of the object 1degree K. the unit is Joules/ Kg x °Kelvin

j. Change in energy = Mass x Specific Heat x change in Temp

   i. Shorthand way of writing:
      $\triangle E = MxSpx \triangle K$

   ii. How much heat is required to raise the temperature of 5Kg of water 10°K? Specific heat of water is 4,180 J/Kg°K

   iii. $\triangle E = 5Kg \times 4{,}180\ J/Kg^{o}K \times 10\ K$
      $E = 209{,}000\ J$

k. Thermal Energy and States of Matter

   i. Solid – atoms are in a fixed position, they only vibrate back and forth. Solids have both a definite shape and definite volume.

   ii. Liquid – atoms are free to slide over and upon each other. Liquids have a definite volume but not a definite shape.

iii. Gas – atoms are free to move independently of other atoms of the substance. Gases have neither a definite shape or volume.
iv. Matters change from one state to the next depending on if thermal energy is added or removed.
    1. terms: melting point, boiling point, freezing, melting, sublimation, condensation, Vaporization: evaporation and boiling
    2. Vaporization: two types
        a. Evaporation- surface vaporization only
        b. Boiling – vaporization at and below the surface of the liquid.

III. Chapter 7: Characteristics of waves
- a. What are waves?
    - i. Wave – a disturbance that transfers energy from place to place.
    - ii. Medium – the material thru which a wave passes
    - iii. Mechanical wave – a wave that requires a medium to travel through. Examples include sound waves and earthquake seismic waves
    - iv. Waves travel trough the medium without actually moving the medium with it. Basically the medium stays put while the wave moves some distance
- b. What causes waves?
    - i. A source of energy causes a medium to vibrate: a pebble dropped into a pond causes a circular wave to generate away from the point the pebble strikes the water.
- c. Types of waves: three main types that are classified according to how they move – transverse, longitudinal and surface waves
    - i. Transverse Waves: waves that move the medium at right angles to the direction in which the waves are traveling. Examples include a rope attached to a door and moved up and down, transverse waves have a crest and a trough
    - ii. Longitudinal Waves: move particles parallel to the direction the wave is moving, "push-pull" waves. These waves have compressions and rarefactions. Example: slinky
    - iii. Surface waves are combinations of both transverse and longitudinal waves.
- d. Properties of Waves – 4 basic properties: amplitude, wavelength, frequency and speed
    - i. Amplitude – in a transverse wave – the height away from the "rest" position. The amplitude in a longitudinal wave is the measure of how compressed or rarefied the medium becomes.
    - ii. Wavelength – the distance between two corresponding parts of a wave.
    - iii. Frequency – the number of complete waves that pass a given point in a cewrtain period of time. Frequency is measured in HERTZ, one Hz is a wave that occurs once every second.
    - iv. Speed – wavelength x frequency