Introduction to Earth Systems Science

I. INTRODUCTION

A. **Initial Comment**: The earth is our home and habitat, without its abundant resources (air, water, heat) we would not be in existence today.

1. The Earth is approximately 4.6 billion years old,

2. Basic Earth-Resource Visualization

a. Solar Energy + Plants + Earth Soil (weathered rock) = FOOD!
b. clothing: synthetics/oil, natural/soil
c. building materials: plastics/oil, gypsum, cement, metals
d. energy: gas, electric/coal, fuel oil = fossil fuels from solar energy
e. transportation: gasoline, cars

B. **Earth System Science Defined**: Interdisciplinary study of the earth's naturally occurring phenomena, its processes and evolution.

1. Earth Science by necessity involves the marriage of a number of specialty sciences

a. **Astronomy**- Study of the origin, evolution and composition of the universe, solar system and planetary bodies.

(1) Cosmology: origin of the universe
(2) Astrogeology: comparison of extra-terrestrial planetary bodies with the earth
(3) Astrophysics: quantitative study of the physical nature of the universe

b. **Geology**- study of the earth, its composition, origin, evolution and processes.

(1) Mineralogy/Petrology: study of rocks and minerals
(2) Geophysics: study of earth physics and processes
(3) Volcanology: study of volcanoes
(4) Seismology: study of earthquakes and seismic waves
(5) Geomorphology: study of surface processes and landforms
(6) Paleontology/Historical Geology: study of past life and historical evolution of the earth through time
(7) Plate Tectonics

c. **Meteorology**: Study of atmospheric phenomena

(1) Climatology: study of geographic climate patterns: processes and causes

(a) Future Climate Prediction: Green House
(b) Paleoclimatology

(2) Weather studies and weather prediction
(a) Storm Prediction and Emergency Management

(3) Atmospheric Science: study of physics and chemistry of earth's atmosphere

(a) Environmental/Air Pollution Control

d. **Oceanography**: study of earth's ocean systems

(1) Earth's surface covered by 70% ocean water... hence the reference to the "Blue Planet".
(2) Study of ocean chemistry and circulation patterns
(3) Physical study of seafloor

C. Environmental Spheres of the Earth

1. the earth can be subdivided into spheres" of composition represented by the complex interface of four principal components of the environment: the lithosphere, atmosphere, hydrosphere, and biosphere.

a. The **Geosphere**: comprised of the solid, inorganic portion of the earth's framework including elements to form atoms to form minerals to form rocks (the very foundation of the planet)

(1) Lithosphere and Interior of the Solid Earth - The earth is comprised of a series of compositionally distinct shells of rock.

(a) inner core, a solid iron-rich zone with a radius of 1216 km
(b) outer core, a molten metallic layer 2270 km thick
(c) mantle, a solid rocky layer 2885 km thick
i) includes the upper portion of the mantle referred to as the aesthenosphere - a plastic, viscous zone that is capable of flowing

(d) Lithosphere/crust, the outer rocky skin of the earth, 4 - 40 km thick, designated to include the upper portion of the aesthenosphere and near surface crustal rocks, thicker over continents and thinner over oceans (continental crust vs. oceanic crust).

The earth is a dynamic organism, even though it is made of solid "rock" it is capable of global movements on the lithosphere

b. The **Atmosphere**: the gaseous envelope of air that surrounds the earth

(1) a thick envelope of air (100's of miles thick) that surrounds the earth's surface. Provides the air we breath, together coupled with the sun's energy, drives our climatic and weather systems.

(2) Troposphere-Stratosphere-Mesosphere-Thermosphere-Magnetosphere\

(3) Average composition of elemental gases in dry air
(a) Nitrogen (N_2)= 78%
(b) Oxygen (O_2)= 21%
(c) Argon (inert) = 0.93%
(d) Carbon Dioxide (CO_2) = 0.035%

i) Ability to absorb heat in atmosphere from energy radiated from earth's surface, helps keep the atmosphere warm

(e) All Others = trace (includes Water Vapor)

c. The **Hydrosphere**: the waters of the earth including ground water (beneath the surface), surface water (rivers, streams, lakes, oceans), and water locked up as ice in the form of glaciers.

(1) the water and liquid that is present on the earth's surface, in its atmosphere, and beneath its surface.

(2) Oceans cover 71% of the earth's surface and contain 97% of the earth's water.

(3) Water cycles from the ocean's to the air via evaporation, moves to land, precipitates as rain/snow, partially infiltrates the earth's surface, and eventually flows back to oceans via rivers.

Water and air uniquely combine on the earth's surface and make it habitable for life forms.

d. **Biosphere**: all living matter and cellular tissue on the earth, in the form of plant and animal, both microscopic and macroscopic.

(1) All life on the planet is contained within its uppermost layer of the earth, including its atmosphere.

(2) the vast majority of all earthly life inhabits a zone less than 3 miles thick, and the total vertical extent of the life zone is less than 20 miles.

These 4 environmental spheres are not discrete and separated but are interdependent and interwoven with one another.

E.g. soil- composed of mineral matter (lithosphere), contains life forms (biosphere), soil moisture (hydrosphere), and soil gas (atmosphere) in pore spaces.

D. Basic Earth Perspective

1. The Earth is our home

a. Seemingly infinite in its size and abundance relative to our personal lives, our Earth however is merely an infinitesimal speck floating in the vastness of space, the buffer of life between us as individuals and the hostile vacuum of space.

2. Earth Facts:
Radius = 4000 miles
Diameter = 8000 miles
Circumference = 24,900 miles
Distance to Moon = 230,000 miles
Distance to Sun = 93,000,000 miles
Distance to Next Nearest Star=2.5 x 10^{13} mi.
Highest Elevation = 30,000 ft AMSL
Lowest Elevation = 36,000 ft BMSL

a. Shape of Earth: almost a perfect sphere, but not quite, actually best termed an "oblate spheroid", i.e. the diameter of the earth at the poles is slightly less than the diameter at the equator
(1) Polar diameter = 7900 miles
Equatorial diameter = 7927 miles

Plus topographic irregularities and the concentration of the earth's continents in the northern hemisphere make it slightly less than a perfect blue ball.

E. The Scientific Method

Modern science believes that fundamental, organized laws exist in nature and that through detailed study these laws can be transcribed into human symbolism. Steps in scientific investigations:

1. Collection of scientific facts through careful observation.

a. Use of Earth "Sensing" Instruments for measurements of:
(1) Magnetism
(2) Seismic Waves
(3) Satellite Imagery
(4) Physical Atmospheric Properties
b. Quantification of Data
c. Pattern Recognition, Relationship Definition

2. The development of a working hypothesis to explain the existence of these relationships
a. Quantitative Model Development: Explanation

3. Construction of experiments to validate or reject the hypostheses
    a. Hypothesis Testing
    b. Repeatable results

4. The acceptance, modification, or rejection ofthe hypothesis basedon extensive testing
    a. Development of Scientific Theory/Paradigm: accepted as truth

II. Matter and Energy

A. Matter - all the material of the universe that has mass and exists
    1. Mass - measured typically in grams and kilograms
    2. Matter is comprised of: atoms of elements

B. Energy - ability to do work

    1. work in physics = force and motion
    2. Examples of Energy
        a. Kinetic Energy - energy of motion
            (1) e.g. falling rock
        b. Potential Energy - energy of position, related to gravitational force
            (1) e.g. rock perched on a cliff
        c. Thermal or Heat Energy
            (1) kinetic energy of atoms in a system
            (2) e.g. air temperature = how fast air atoms are moving and vibrating
        d. Electrical Energy
            (1) free flow of electrons
        e. Sound Energy
        f. Mechanical Energy

C. Law of Conservation of Energy - the total energy of the universe is finite, it is neither created nor destroyed, but may be transformed from one type to another
    1. e.g. transfer from potential energy (perched rock on cliff) to kinetic energy (falling rock)

D. Einstein said: Mass (material) and Energy are Interchangeable

    1. $E = mC^2$ - Energy may be converted to mass, and mass to energy

        e.g. solar energy + tree = wood (energy to mass)
            heat + oxygen + wood = fire (mass to energy)

III. Systems and Models
A. System - isolated portion of Universe selected for purposes of observation and measurement

    1. Hierarchy: Universe --- System ---- System Components

2. Scale Examples
    a. Solar System (Sun + Planets)
    b. Earth System (Geosphere + Atmosphere + Hydrosphere + Biosphere)
    c. Classroom-Scale System:

        Question - What are the essential components of our classroom system??

    d. Bench-Top System
        (1) e.g. a beaker half-filled with air and water

B. Boundary Conditions of System
1. Boundary -limits interaction between system components
    a. Open Boundaries vs. Closed Boundaries

2. Open System - boundary conditions are such that matter and energy can enter or exit the system freely

    a. Example - this classroom!

3. Isolated System - boundary conditions are such that matter and energy are contained, neither may enter or leave the system.

    a. Does this exist - can you think of an example?

4. Closed System - boundary conditions are such that matter can not exit or enter the system, but energy can exchange freely.

    a. Earth = approximates a closed system
        (1) Neglects meteorite impacts to Earth surface or influx of cosmic atomic material (matter addition)
        (2) Energy freely transferable into and out of the system
            (a) Atmospheric heat loss to space
            (b) Solar Energy influx
        (3) Material Resources of Earth are Finite
        (4) Components of the System Interact with One Another
            (a) e.g. Global Warming model
                i) Biosphere + Hydrosphere + Geosphere regulate carbon dioxide content of atmosphere
                ii) Carbon dioxide content contributes to regulation of atmospheric temperatures

C. Systems Interactions
1. Transfer of Energy ("Energy Flux")
    a. e.g. Atmospheric Processes
2. Transfer of Mass / Matter ("Mass Flux")
    a. e.g. Tectonic Processes

3. Cycling of Mass and Energy
    a. Repetitive flow / transfer of matter/energy between system components
        (1) e.g. oceanic evaporation / atmospheric precipitation
    b. Rates of Change= amount of transfer / change per unit time
        (1) e.g. discharge in a river = gallons / minute

4. System Response Functions

    a. system feedback - response of the system to changes in system components
    b. Negative Feedback - the system response is in the opposite direction of output from a specific function

        (1) Book Example - thermostat control on home heating system

            thermostat - metal electrical connection: heating expands the metal, cooling contracts the metal

            cooling room air = thermostat contraction = electrical connection = furnace on = heating of room

            the net result of room heating is opposite of the initial system condition of room cooling - this is a negative feedback

        (2) Earth Example of Negative Feedback
            Consider Landslides on Steep Mountain Slopes:
                - steep mountain slopes are subject to gravity-driven landslides

                -landslides result in erosion of mountain slopes

                -erosion of mountain slopes reduces the slope angle

                -reduced slope angles do NOT promote gravity-driven landslides

    c. Positive Feedback - the system response is in the same direction as output from a specific function

        (1) Book Example - fire and wet wood

            wet wood does not burn easily

            once fire is started, the heat dries out the wood, and promotes further burning

            ** the net result of wet wood burning is in the same direction asa the initial condition of fire burning ** - this is a positive feedback

(2) Earth System Example of Positive Feedback
Assume Global Warming is Happening...

-Carbon Dioxide Buildup in the Atmosphere Results in Global Warming

-Global Warming results in higher air temperatures

-Higher air temperatures result in drying of forests

-Dry Forests are subject to forest fire

- Forest fire releases more carbon dioxide into atomosphere

-Increased atmospheric carbon dioxide leads to more global warming

IV. Examples of Primary Cycling Functions in the Earth System

A. Energy Cycle

1. Basic Rules of Energy (laws of thermodynamics)
   a. Energy is neither created nor destroyed, but it may be changed from one form to another ("Law of Conservation of Energy")

   b. Energy will naturally transfer from a more organized state to a more disorganized state
      (1) Entropy - measure of disorganization in a system

         (a) example- a clean room easily transforms into a messy room, but a messy room does NOT easily transform into a clean room

2. Earth's Energy Budget

   a. Solar Energy (electromagnetic radiation)

      (1) Source of Solar Energy - hydrogen fusion / hydrogen fuel

      (2) Electromagnetic Radiation Products from Sun
         (a) visible light (colors of rainbow - ROYGBV)
         (b) infrared radiation ("heat")
         (c) ultraviolet radiation (sun burn material)

      (3) Earth System Response to Solar Energy

         (a) Plant Photosynthesis - the basis of Earth life
         (b) Atmospheric Processes
            i) wind, evaporation / condensation, storms

(c) Oceanic Processes
i) wind/waves, ocean currents

b. Geothermal Energy (internal heat of Earth)

(1) Evidence that the Earth is hot on the inside:
(a) hotsprings, geysers
(b) volcanic eruptions
(c) deep mine shafts / wells

(2) Source of Geothermal Energy
(a) Decay of radioactive elements with heat as a by-product
i) e.g. Uranium

(3) Earth System Response to Geothermal Energy
(a) volcanic eruptions
(b) plate tectonic motion
(c) mountain building
(d) earthquakes

c. Tidal Energy in Oceans

(1) Tides - driven by force of gravity
(a) gravitational pull of ocean water by moon and sun

3. Energy Transformation by Earth System

a. Atmospheric reflection of incoming solar radiation

(1) ~40% of incoming solar radiation is reflected by into space

(2) albedo - measure of the degree of reflectiveness of the Earth's surface

b. Absorption of incoming solar radiation at Earth's surface

(1) heat transfer to atmosphere, plants, oceans

c. Geothermal energy transfer
(1) internal heat loss via
(a) volcanic eruptions
(b) transfer to mechanical energy
i) earthquakes
ii) plate tectonic motion

B. Hydrologic Cycle (include basic chemical composition of sea water)

1. Significance of Water

a. Essential for animal and plant life to exist, forms the medium in which biochemistry can take place.
b. Water solutions transport nutrients and elements to organic tissues, nourishing them. Carries waste products out of tissues.
(1) Mass of living organisms comprised of water ranges from 65-95%
c. Surface water covers more than 70% of the earth's surface

2. Hydrologic Cycle

a. Closed System

(1) Water is neither created nor destroyed, the hydrosphere is essentially a closed system,
(2) BUT water may be transformed from one form to another, and moved from one place to another.

(3) The Hydrologic Cycle: a circuit of water movement, with storage areas interconnected by various transfer processes... water moves not only geographically, but through physical states as well.

b. Basic Model: Ocean Water----sun's energy---- evaporation -----atmospheric moisture----- condensation/precipitation------land/continental waters-----downgradient flow due to gravity------ back to ocean------and cycling through.

c. Surface to Air: Evaporation prime mechanism for transfer to atmospheric moisture.

(1) Ocean Evaporation- heat and wind operate on oceans and result in evaporation of water from liquid to vapor form (especially effective in lower latitudes, areas with most direct heating from sun's rays)

(2) Land Evapotranspiration- water is not only release to the atmosphere on land through evaporation, but also through transpiration of water vapor from plants/trees to the atmosphere.

(3) Water Vapor Movement:

(a) Convection- vertical movement of moisturelaiden air masses through heat transferprocess
(b) Advection - horizontal transport of airmasses by wind

d. Air to Surface: atmospheric water vapor is eventually condensed into liquid or sublimated into ice to form cloud particles = precipitation

e. Surface and Ground Waters: precipitation on land can run several possible courses:

(1) accumulation/ponding on the continental surfaces (will subsequently be subject to high rates of evaporation).
(2) surface runoff: in form of streams and rivers, eventually being subject to partial evaporation and final emptying back to sea.
(3) Infiltration into the ground and uppermost strata comprising the lithosphere; forming "ground water"

(4) Vegetative interception: the interception of precipitation by the vegetative canopy of the biosphere, may be subject to evaporation or eventually fall to ground.

f. Duration of Cycle: water may become temporarily stored and removed from the cycle from hours to days, to years to 100's of thousands of years...depending on the geohydrologic circumstance.

3. Moisture Inventory:

a. Oceans: contain 97% of earth's water
b. Glaciers: 2% of all moisture, comprising 75% of worlds fresh water
c. Ground water: 0.5% of total
d. Surface Water: 0.2%
e. Soil Moisture: 0.1%
f. Atmospheric Moisture: 0.0001%
g. Biological Water: negligible

C. Ultimate Controlling Mechanisms of Earth System Processes
1. Solar Energy (hydrogen fusion)
2. Geothermal Energy (internal radioactive decay)
3. Gravity (driving force of pull)

V. Deep Geologic Time and the Age of the Earth

A. Age of the Earth

1. Archbishop Ussher in 1658 provided first attempt at dating the Earth based on the Bible and Genesis

a. Result: Earth created on October 23, 4004 BC
b. Age of Earth according to biblical reconstruction ~ 6000 years old

2. Modern Chronology Based on Astronomy, Physics, Geochemistry, Paleontology, and Archeology

a. 15-20 billion years ago - Big Bang: beginning of present Universe
b. 5-10 billion years ago - Earth solar system begins developing
c. 4.6 billion years ago - Planet Earth assembled with basic geologic structure
d. 4.0 billion years - first simple cells of life formed
e. 3.5 billion years - oldest known fossils (soft, single cell)
f. ~3.0 billion years - primitive photosynthetic plant cells
g. 600 million years - first multicellular organisms
h. 600-400 million years - invertebrate ocean critters
i. 400 million years - vertebrate / fishes evolve
j. 300- 400 million years ago - plants evolve, amphibians
k. 200 million years - primitive mammals, reptiles / dinosaurs dominate
l. 65 million years - land mammals dominate, extinction of dinosaurs
m. 2 million years - human-like critters evolve
n. 18,000-20,000 years ago - Last major glacial cover on North America (Seattle was under a 1000 ft of ice!)
o. 15,000 years ago - earliest archeological evidence for modern man in North America
p. 500 years ago - Spanish explorers to "New World"
q. 15-20 years ago - MTV evolves
r. 5 years ago - the internet takes off
s. today - You and I are here thinking about it....

B. Geologic Rock Record:

1. Rocks - record of Earth history

a. Analogous to a tape recording in which some historical events are preserved and recorded, others have been erased, and still others were not taped at all

2. Types of Records Preserved in Rocks
a. Past Life (fossils)
b. Past Climate Conditions
(1) e.g. "Glacial Ages"
c. Past Geographic Organization
d. Past Oceanic Conditions
e. Past Magnetic Field Conditions

C. Basic Principles
1. Principle of Uniformitarianism
a. "The present is the key to the past".

b. Natural laws that are presently observable, have been operating throughout Earth history

c. Very slow, incremental geologic processes have occurred over immense amounts of time, to result in large scale changes of the earth.

2. Principle of Catastrophism

a. Catastrophist View: large-scale catastrophic processes are responsible for most of the changes and evolution of the earth (floods, earthquakes, volcanic eruptions, storms)

(1) Short bursts of violent (high energy) processes, followed by slow process cycles

b. Original Premise - Church / biblical view of Earth history
(1) Phase 1 - all time since creation before Noah's Flood
(2) Phase 2 - all time since Noah's Flood to the present
(3) Noah's Flood
(a) used to explain most geologic phenomena originally

D. Methods of Determing Ages of Rock Materials

1. Relative Dating
a. Earth history placed in the context of relative sequences of geologic events.
b. Example - Law of superposition- in an undisturbed sequence of sedimentary rocks, the lowermost rock layers are the oldest, and the uppermost rock layers the youngest.

2. Absolute / Numeric Geochemical Dating

a. Chemical Technique - uses radioactive elements contained within minerals and rocks chemically and quantitatively determine the absolute age of that rock within the framework of statistical and/or experimental error.
b. Precise dating of geologic events from the rock record
c. Example: Uranium decays into lead at a known, constant rate
(1) measure the amount of lead and uranium in a mineral, can determine it's age since formation

GS104 Basics Review of General Science

I. Scientific Method
   A. Process
      1. Basic Observation (Data Collection = "Sensing the Environment")

      2. Hypothesis / Working Model = a preliminary attempt at understanding a system
         a. Processes - Interactions - Mechanisms

      3. Hypothesis / Model Testing
         a. Methodical Data Collection

      4. Adjusting the Hypothesis / Reformulating the Model
         a. Data Supports or Rejects the Hypothesis
         b. Data does NOT Prove a Hypothesis

      5. More Data Collection... goal = consistent results

      6. Hypotheses lead to Theories; Theories lead to Scientific Facts or Beliefs

      7. Review of Science Terms

         a. fact - agreed-upon observations, subject to change and modification with additional data collection.

         b. hypothesis - educated guess or prediction, subject to testing.
            (1) e.g. "students will enjoy this class by the end of the semester"

         c. law or principle - a hypothesis is elevated to a law once it has been repeatably tested and supported, with no contradictions.
            (1) e.g. Newton's law of gravity

         d. Theory - a comprehensive concept representing a synthesis of a large body of knowledge that encompasses verified hypotheses.
            (1) e.g. theory of atom, theory of plate tectonics

   B. Observational vs. Experimental Science

      1. Observation - passive data collection
      2. Experimental - active data collection
         a. Experimental Design... with a purpose

C. Good Scientific Techniques

1. Unbiased Observation
   a. Organized / Thorough Note Taking

2. Understanding the Purpose of the Investigation

3. Hypothesis Formulation / Prediction

4. Hypothesis Testing through Experimental / Observational Design
   a. Controls = "known quantities of comparison"

5. Reporting Results
   a. Introduction
   b. Purpose
   c. Methods
   d. Data / Results
   e. Interpretation / Conclusion
   f. Recommendation for Further Research

II. Chemistry Basics

A. Definitions

0. Matter- any material that occupies space and has mass.

1. Elements - all matter are made of elements, over 100 elements are known. Elements include O, Au, Ag, N, H, C and have a unique, and identifiable atomic structure.

   a. Refer to periodic table/handout
      (1) 92 naturally occurring elements
      (2) 11 man-made elements (103 total)

2. Compounds - combination of two or more elements joined together at the atomic level.

3. Atom - the smallest recognized particle of matter that retains the properties of a given element. Atoms of elements are combined together to form compounds.

B. Atomic Structure - Theory of atoms and atomic structure are based on experimental evidence and mathematical models. Atoms are generally too small to observe directly even with the most powerful microscope, but they can be observed indirectly by modeling.

1. Nucleus - central portion of an atom which contains even smaller sub-atomic particles called protons and neutrons.

   a. Protons - very dense, positively charged subatomic particles in the nucleus of an atom.

b. Neutrons - dense, neutrally charged subatomic particles in the nucleus of an atom.

2. Electrons - negatively charged particles that orbit very rapidly about the nucleus of an atom. Generally considered that electrons are moving so fast, that it is difficult to locate their position at any given moment....view electrons as a cloud of charged particles hovering about the nucleus.

a. Electron clouds are organized at certain distances from the nucleus in regions called energy level shells. Each energy level shell at a given distance from the nucleus can only hold a certain number of electrons at any given time.

3. Atomic number - is the number of protons located in the nucleus, each element has its own unique atomic number making it distinct from other elements (e.g. C a.n. = 6, O a.n. = 8)

b. Isotope: same number of protons, variable no. of neutrons
(1) e.g. O^{18}/O^{16}: 8 protons but 10 and 8 neutrons respectively

4. Atomic charge balance - all atoms contain the same number of negative electrons as positive protons, thus as neutrons have no charge, then net positive charges = net negative charges (protons = electrons)

Elements can be considered to be large collection of electrically neutral atoms, having the same atomic number or no. of protons.

III. Physics
A. Physics - Study of the Physical Universe
1. Basic nature of things
a. matter / atoms, motion, forces, energy, heat, sound, light, electricity

2. Physics forms basis of other sciences
a. chemistry, geology, meteorology, astronomy

B. Linear Motion

1. Motion = displacement or change in position in space
a. Linear Motion = straight line or curvilinear displacement

2. Terms
a. Displacement = change in position = "distance" between two points = "HOW FAR"
b. Time = the amount of time to move from pt. A to pt. B
c. Speed = rate of displacement per unit time = "HOW FAST"

(1) speed = distance/time
(a) Instantaneous Speed vs. Average Speed

(2) speed = magnitude only = "scalar" quantity
(a) "magnitude" = amount or how much

d. Velocity = magnitude + direction = "vector" quantity = "HOW FAST and WHAT DIRECTION"
(1) V=d/t

e. Acceleration = rate of change in velocity per unit time = "ARE WE SPEEDING UP OR SLOWING DOWN?" - "HOW QUICKLY ARE WE SPEEDING UP OR SLOWING DOWN" - better yet ... "HOW LONG DOES IT TAKE TO SPEED UP OR SLOW DOWN"

(1) Acceleration = change in Velocity/time
(2) e.g. Acceleration = 2 m/sec/sec = 2 m /sec^2

C. Force

1. Inertia - resistance to motion
2. Mass - how much matter is contained in an object
   a. > matter, > inertia
   b. mass is a measure of the degree of inertia
   c. does not change with respect to force of gravity
3. Weight - force exerted upon an object due to gravity
   a. changes with respect to force of gravity
4. Force - "push or pull" on an object, anything that can cause an object to accelerate or move
   a. the greater the force, the greater the potential for acceleration

** It is possible to be "weightless" in space, but not "massless" ... the relative inertia of an object is constant regardless of gravitational force of attraction. **

5. Units of Measure
   a. Weight in U.S. = pounds = a force
   b. Mass = grams / kilograms
      (1) 1 kg = 2.2 lb
   c. Weight force in metric = Newtons
      (1) 1 kg mass = 9.8 Nt
   d. volume - 3-D size of object = length x width x height
   e. Density = mass / volume

6. Friction as a Force

   a. Friction = force that occurs when two objects slide over or in contact with one another
      (1) Frictional force = applied in direction opposite to motion

   Applied Force < Friction Force ==== No Acceleration / No Motion

Applied Force > Friction Force ==== Acceleration / Motion

(2) Static Friction = friction of bodies at Rest
(3) Sliding Friction = friction of bodies in motion
(a) static friction > sliding friction
(b) once in motion, sliding friction < initial friction

b. Gravity - a force that permeates the universe, the pulling action between any two bodies in space

"bodies" in space = atoms, molecules, people, planets, solar systems, galaxies, etc.

Newton's Law of Attraction:

$$F = G\,[(m_1 m_2)/r^2]$$

where F = force of gravity, G = gravitational constant, m = mass of 2 objects in space, r = distance separating the two objects in space. Given all other variables constant, F > with < r, and F < with >r. Each body exerts an equal force of attraction.

(1) Earth Gravitation Force

$$F = mg = \text{"weight"}$$

F = force of Earth gravity (i.e. "weight"), m = mass (kg), and g = acceleration of a falling object (e.g. sediment) due to gravitational force F, assumed to be constant at 980 cm/sec^2 (9.8 m/sec^2)

D. Energy

1. Energy = that which enables work to be done

a. Work = force applied to matter with motion resulting

2. Mechanical Energy = energy due to position or motion of objects in the system

a. Potential Energy = energy of position = "stored energy"
(1) position of 1 object relative to another

b. Kinetic Energy = energy of motion = "released energy"

3. Other forms of kinetic and potential energy
a. heat (thermal) energy
(1) Temperature = measure of kinetic molecular energy in a system

b. sound energy
(1) defined by kinetic and potential energy of vibrating air molecules

c. light energy

(1) emitted via kinetic energy of electrons within atoms

d. electrical energy
(1) controlled by kinetic energy associated with electrons in motion

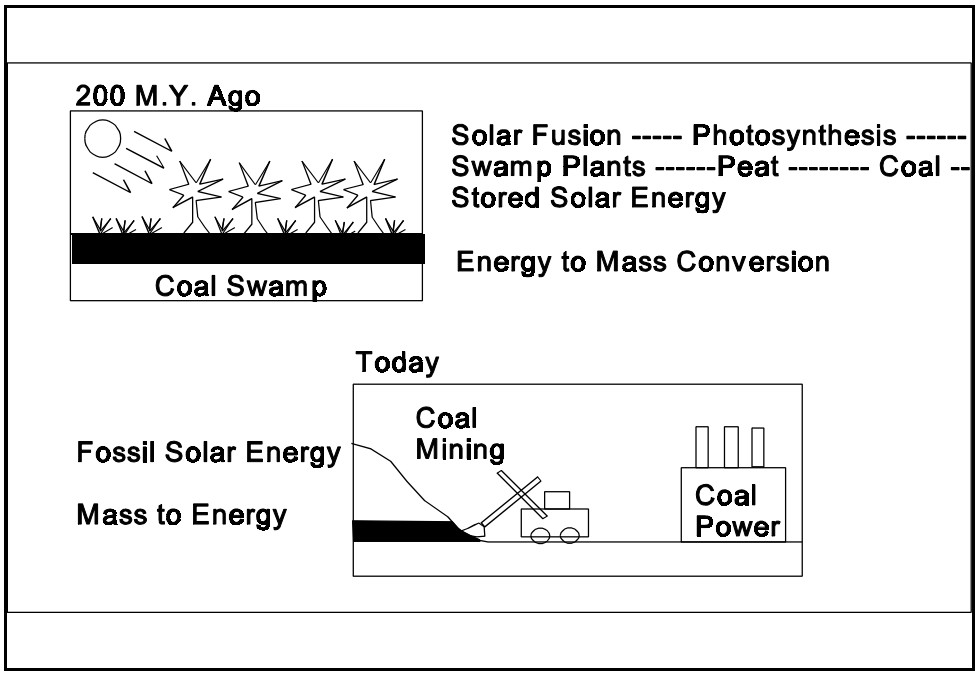
4. Conservation of Energy

a. Law of Conservation of Energy
(1) Energy cannot be created or destroyed, but may be transformed from one form to another

b. The total energy in a system is constant (i.e. closed systems)
(1) Energy In = Energy Out

c. Stored Energy vs. Transformation of Energy
(1) Energy may be stored in a system and transformed
(2) Energy may be converted from mass, and mass converted to energy

(a) matter in it's pure form is energy
(b) $E = mc^2$ Einstein's Equation relating mass to energy
i) E = total energy, m = mass, c = speed of light



E. Thermal Energy, Heat, and States of Matter
1. States or Phases of Matter

a. The state of matter is determined by the amount of vibrational energy at the atomic and molecular level

(1) atoms / molecules possess kinetic energy
(a) electron orbits
(b) bond vibration

2. Three States of Matter
   a. Solid
      (1) Fixed "hard" shape to matter
      (2) atoms / molecules are in fixed positions
      (3) kinetic or vibrational energy is relatively low
   b. Liquid
      (1) "fluid" material / changes shape easily; conforms to shape of container
      (2) atoms / molecules are mobile (not fixed / rigid)
      (3) higher kinetic / vibrational energy compared to solid
   c. Gas
      (1) Even higher state of kinetic / vibrational energy
      (2) atoms / molecule separated
      (3) "fluid" material / "invisible" matter

3. Heat Flow

   a. "Thermodynamics" = study of heat, heat flow and behavior of heat

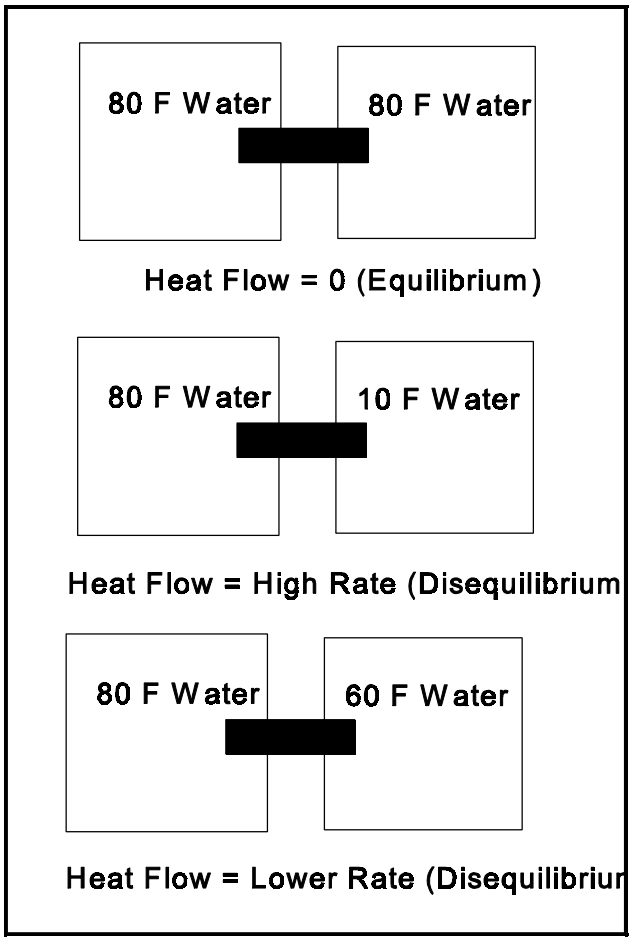
   b. Heat Flow : An Equilibrium Process

      (1) Temperature Imbalance Causes Heat to Flow or Transfer
      (2) Substances at Same Temperature = Temperature Equilibrium

   c. Heat Flows from High Temperature Regions to Low Temperature Regions

      (1) At temperature equilibrium: net heat flow = 0
      (2) The higher the temperature differential, the faster the heat flow
      (3) The lower the temperature differential, the slower the heat flow

Consider an experiment with two vessels of water, with variable heat-content. They are connected by a tube that allows heat to exchange between the two vessels.



4. Mechanisms of Heat Transfer

a. Conduction: heat and vibrational kinetic energy is passed from molecule to molecule, without actual transfer of mass
   (1) heat transfer without mass transfer
   (2) e.g. heating an iron rod, the heat is transferred from one end to the other without transfer of mass

   (3) Examples
      (a) Good conductors of heat = iron / metal (rapidly transmit heat)
      (b) Poor conductors of heat = adobe / brick, fiber glass insulation
         i) Poor conductor = "good insulator"

b. Convection - heat transferred via transfer of mass

   (1) e.g. "fluid currents" transfer heat

   (2) Convection cells common in ocean, atmosphere, and earth's interior
      (a) e.g. Warm air rises, cools, sinks
      (b) e.g. Warm ocean water rises, cools, sinks

c. Radiation - heat transfer via electromagnetic radiation

   (1) infrared radiation = "thermal radiation"
      (a) remember: infrared = wavelengths longer than visible spectrum

   (2) Emitters of radiant energy
      (a) Sun (hydrogen fusion)
      (b) Earth (radioactive decay of elements)

   (3) Absorbers and Emitters of Radiation
      (a) Good Absorbers are Good Emitters
         i) e.g. black paper experiment in lab
            a) black objects cool and warm faster
            b) black is a poor reflector of energy
      (b) Poor Absorbers are Poor Emitters
         i) e.g. white paper experiments in lab
            a) white objects cool and warm slower
            b) white reflects radiant energy
      (c) All materials absorb and emit radiation at the same time

F. List of Basic Equations

Velocity = Distance / Time V = d/t m/sec
Volume = length x length x length Vol = L^3 m^3
Density = mass / volume D = m/Vol gm/cm^3 kg/m^3

Temperature Conversions

From C to F: $F = 9/5C + 32^o$
From F to C: $C = 5/9(F - 32^o)$

E.g. convert 40 C to F ... $F = 9/5(40) + 32 = 104^o$ F

Degrees K = Degrees C + 273
0 C = +273 K

IV. Biology - study of life

A. Characteristics of Living Matter
1. metabolism - biochemical reactions / energy transfer
2. growth - making larger molecules out of smaller ones
3. reproduction - making copies
4. evolutionary history - selective success of some living organisms, some more than others

B. Hierarchy of Life
1. atoms / molecules
2. cells - complex group of chemical compounds, bounded by membrane
3. tissues - arrangment of cells
4. organs - complex tissue arrangement
5. organisms - complex arrangement of organs
6. population of organisms
   a. species - interbreeding possible
      (1) genus - sharing of genetic characteristics
7. Ecological Communities - interactive associations of species
   a. biomes - classes of ecosystems

C. Autotrophic Organisms - the basis of life and food chain on Earth
1. Autotrophs - self feeding organisms, create own food from energy

   a. Photosynthetic Plants

   b. Photosynthesis: sunlight + carbon dioxid + water = carbohydrates (sugars and starches) = food

$CO_2 + H_2O$ + sunlight (energy) => $CH_2O + H_2O$