

EARTH SYSTEMS

- Involves the dynamic interaction of three components:
 - Mass
 - Energy
 - Time

INTERACTION OVER TIME BETWEEN

- MASS
- ENERGY
- CHEMISTRY IS USED TO DETERMINE COMPOSITION AND PROPERTIES OF MASS
- PHYSICS IS USED TO TRACE THE TRANSFER PROCESS OF ENERGY

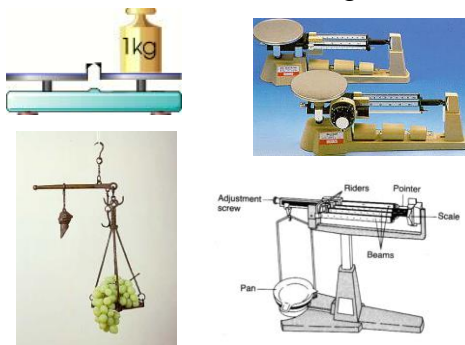
VARIABLES IN EARTH SYSTEMS

- PRESSURE P
- TEMPERATURE T
- VOLUME V
- COMPOSITION (MASS) M
- * DENSITY $\rho = M / V$
- HEAT Q
- * HEAT CAPACITY $C = Q / M / T$
- FORCE F

Mass

- A measure of the quantity of matter in a body, typically in units of grams, kilograms, etc.
- Mass of an object is measured relative to the known mass of a standard using a balance

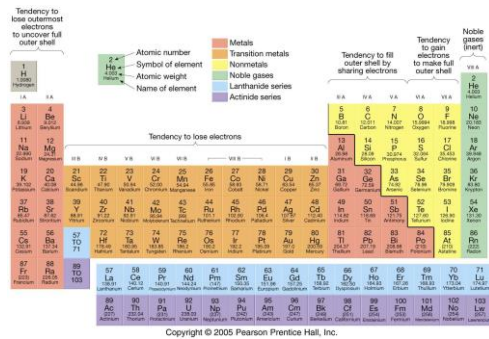
Balances For Measuring Mass



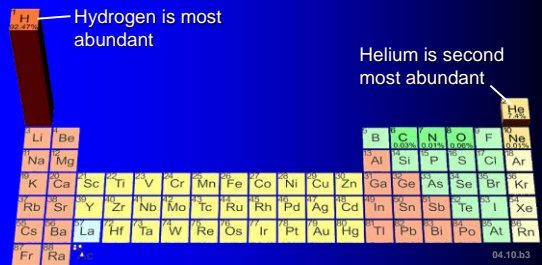
Mass Versus Weight

- Does an object have the same mass on Earth's surface as it does in the vacuum of space?
- What about weight?
 - Weight is a measurement (e.g. pounds, tons) of the gravitational force acting on an object

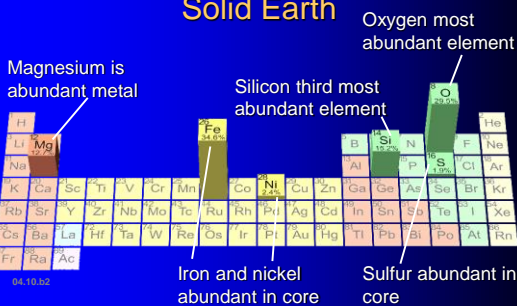
Elements of the Universe



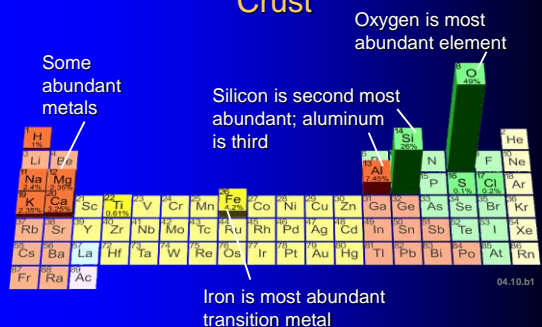
Average Abundances for the Universe



Average Abundances for the Entire Solid Earth



Average Abundances in Earth's Crust



Elements of Importance on Earth

Earth	Oceans	Atmosphere
Iron $^{56}\text{Fe}_{26}$	Hydrogen $^1\text{H}_1$	Nitrogen $^{14}\text{N}_7$
Oxygen $^{16}\text{O}_8$	Oxygen $^{16}\text{O}_8$	Oxygen $^{16}\text{O}_8$
Silicon $^{28}\text{Si}_{14}$	Sodium $^{23}\text{Na}_{11}$	Hydrogen $^1\text{H}_1$
Magnesium $^{24}\text{Mg}_{12}$	Chlorine $^{35}\text{Cl}_{17}$	
Aluminum $^{27}\text{Al}_{13}$		
	Mass Element	Protons

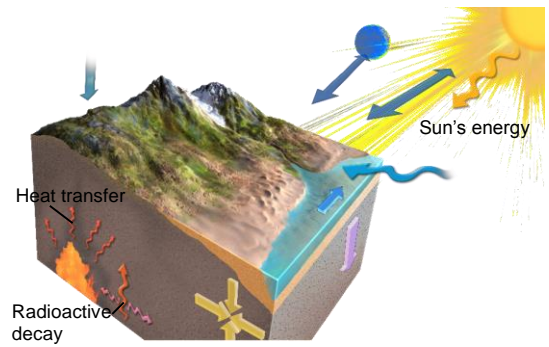
Substances of Importance

Solid Earth	Oceans	Atmosphere
Iron Fe	Water H_2O	Nitrogen N_2
Peridotite	Salt NaCl	Oxygen O_2
$\text{Mg}_u\text{Fe}_v\text{Si}_x\text{O}_z$		Water H_2O
Basalt		
$\text{Mg}_u\text{Fe}_v\text{Si}_x\text{O}_z$		
Granite		
$\text{Ca}_u\text{Na}_v\text{Al}_x\text{Si}_y\text{O}_z$		

Energy and Heat

- Energy is a measure of the capacity for doing work
- Heat is a form of energy

Earth's Energy Sources From The Inside And Outside



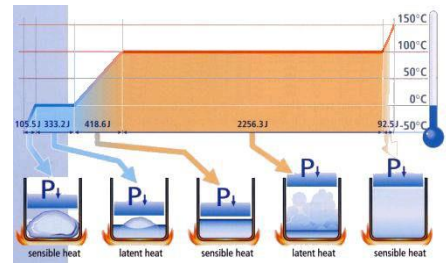
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Types of Heat

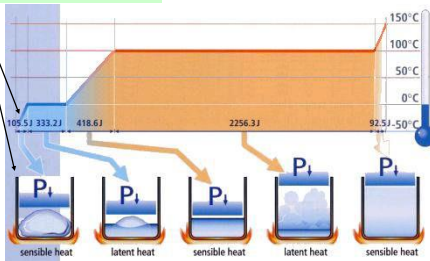
- **SENSIBLE HEAT:**
 - Heat that we feel
- **LATENT HEAT:**
 - Heat that is absorbed or released due to phase changes (e.g. liquid water freezes to ice)

Sensible heat is the heat we feel

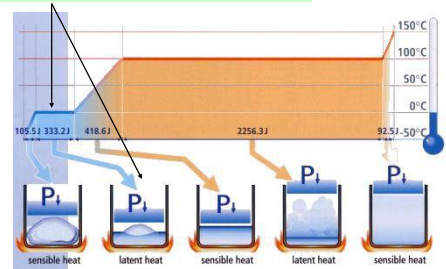
Latent heat is released or absorbed during phase changes



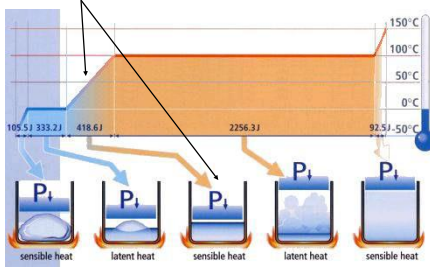
Sensible: As heat is added, the temperature of the ice rises



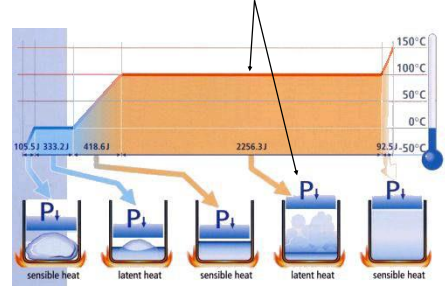
Latent: Phase change as ice melts to water. Temperature remains constant as heat is absorbed during phase change



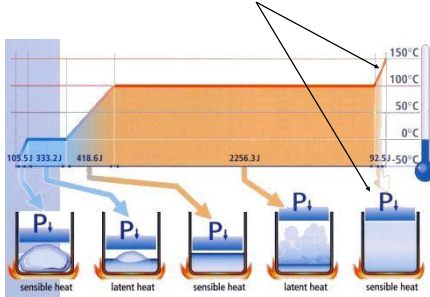
Sensible: After all the ice has melted, then adding additional heat will raise the temperature of the water



Latent: Another phase change as water converts to vapor. Temperature remains constant as heat is absorbed during phase change



Sensible: After all the water is converted to vapor, then any additional heat added will raise the temperature of the vapor



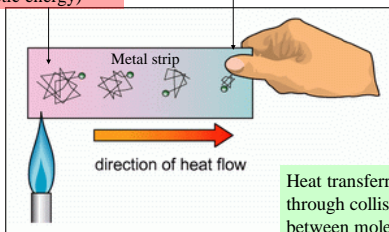
Transfer Of Heat

- Heat is transferred in three ways:
 - Conduction
 - Convection
 - Radiation

Conduction

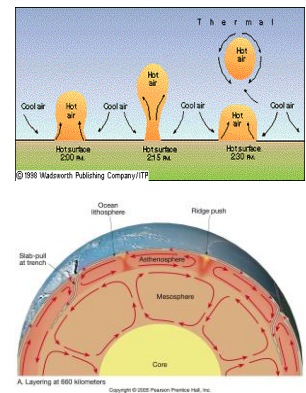
Molecules on hot end are rapidly vibrating (high kinetic energy)

Molecules on cooler end have lower kinetic energy



Convection

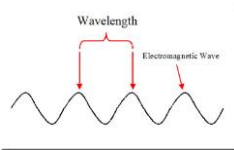
Heat transferred through movement of material due to temperature differences



Two Ways To Think Of Radiation

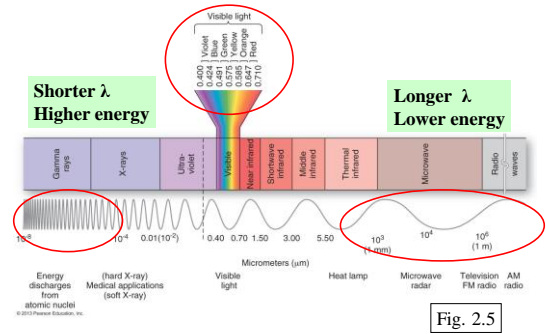


Photons: Discrete bundles (or *quanta*) of electromagnetic (or light) energy



Electromagnetic waves

Electromagnetic Radiation As Waves

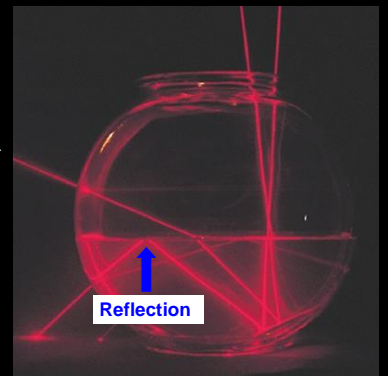


Properties of Waves

- Reflection
- Refraction
- Diffraction

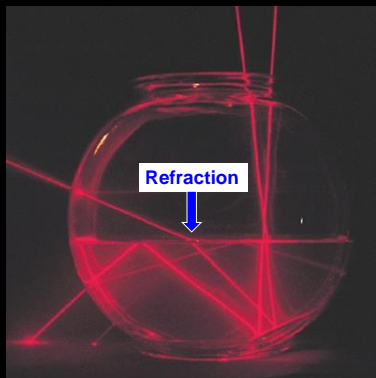
Reflection

Waves bounce off the interface between two different materials

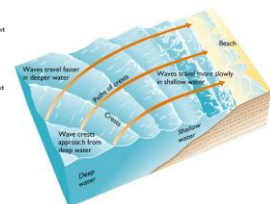
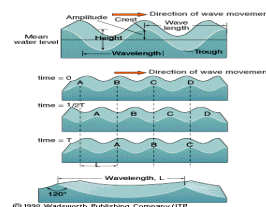


Refraction

The bending of waves while passing from one substance into another due to changes in the wave velocity



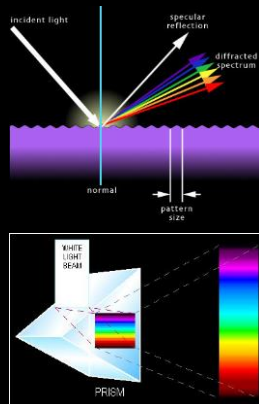
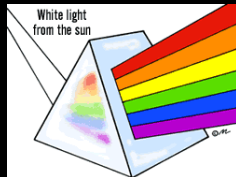
Ocean Waves



Refraction of Ocean Waves

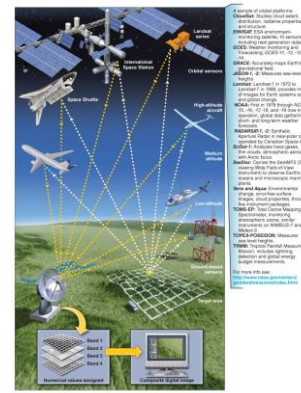
Diffraction

The breaking up of a ray of light into colors of the spectrum

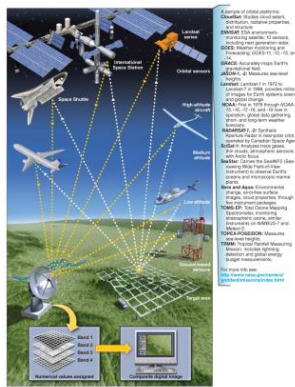


Remote Sensing

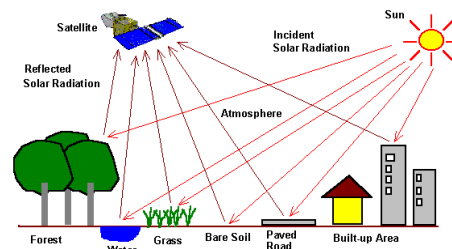
Remote-sensing technology measures and monitors Earth's systems at various wavelengths from orbiting spacecraft, aircraft in the atmosphere, and ground-based sensors.



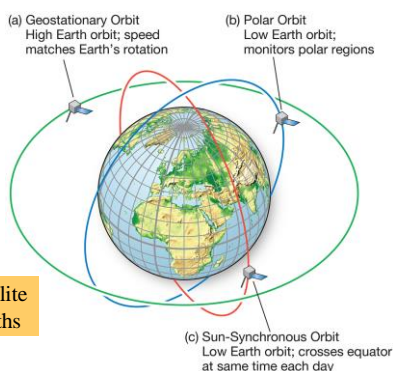
- Radiation absorbed and emitted by Earth materials can be measured by airborne instruments and satellites
- Instruments on board measure certain narrow bands of the electromagnetic spectrum:
 - Visible range (aerial photography)
 - Outside the visible range (e.g. ultraviolet, infrared, microwave)



Measuring Earth's Radiation Through Remote Sensing

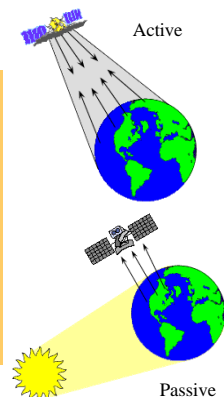


Three Satellite Orbital Paths

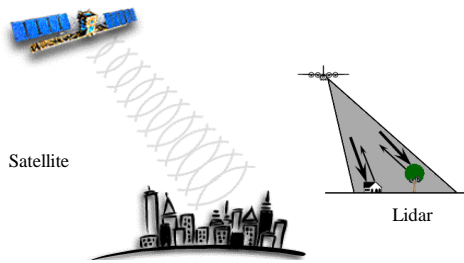


Remote Sensing

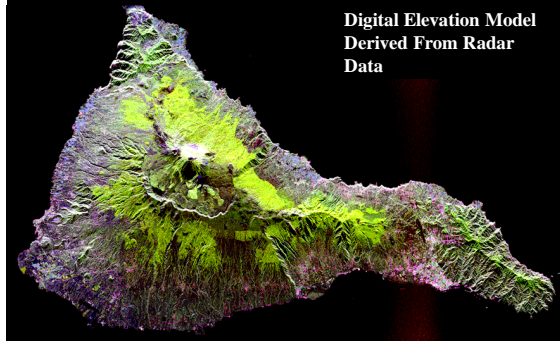
- Active Remote Sensing directs beam of energy (e.g. radar) at a surface and analyze energy reflected back
- Passive Remote Sensing records energy radiated from a surface:
 - Landsat satellites
 - NOAA weather satellites
 - NASA Earth Observing System (EOS)



Active Remote Sensing With Radar



Digital Elevation Model Derived From Radar Data

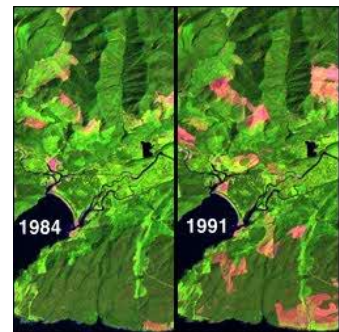


Aerial Photography

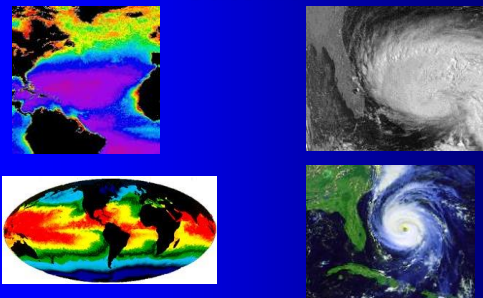


Landsat Satellites

Study changes in a landscape over many years due to urbanization, deforestation, drought, etc.

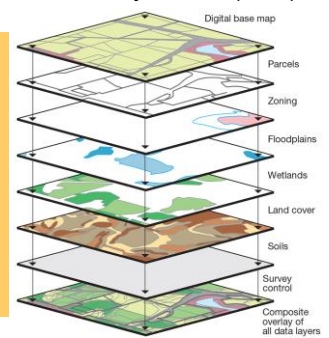


Weather/Marine Studies Satellites



Geographic Information Systems (GIS)

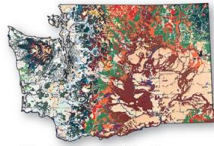
- Computer-based, data-processing tool for gathering, manipulating, and analyzing geographic information
- Individual maps displaying different features for the same geographic area can be constructed as layers
- Layers can then be overlain to form a composite map



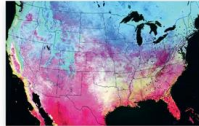
(a) Layered spatial data in a GIS format

Geographic Information Systems (GIS)

- Earth and human phenomena can be analyzed spatially and over time:
 - Mapping the spread of diseases
 - Population changes over time
 - Land use
 - Geology and Earth resources



(b) Land-cover map, Washington state



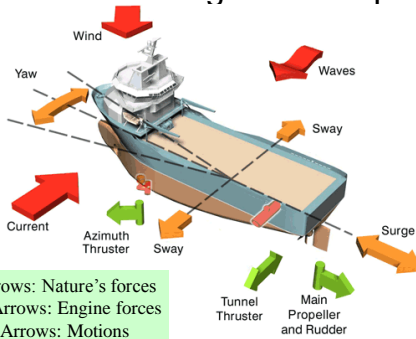
(c) Probability map for spread of West Nile virus (Red areas represent greatest probability for spread of virus.)

Force

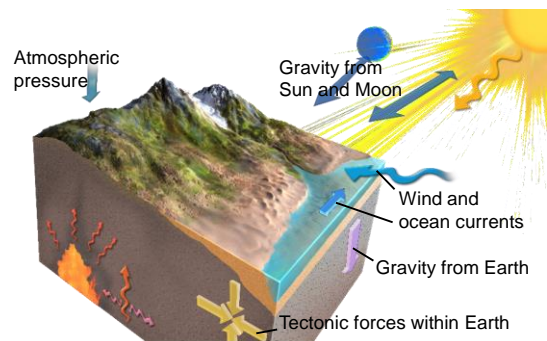
- That which tends to put stationary objects in motion or changes the motions of moving objects
- Force has both magnitude and direction

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$

Forces Acting On A Ship

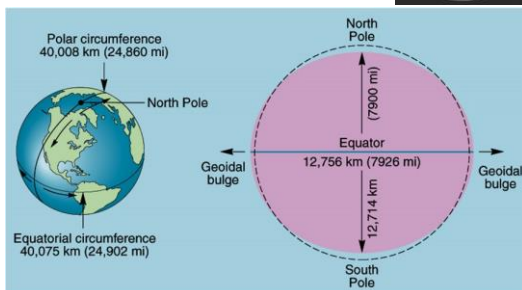
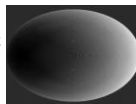


Forces that affect Earth's materials from the inside and outside



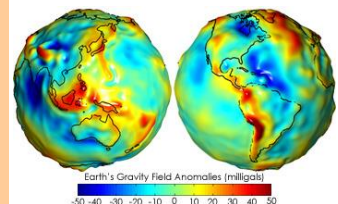
Earth's rotation causes it to flatten at the poles and bulge at the equator

Perfect spheroid



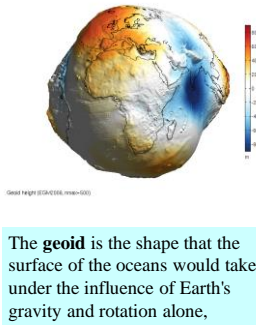
Variations In Earth's Gravity

- Sea level is not uniform everywhere, but varies in height due to differences in Earth's gravitational attraction at different locations
- Variations in gravity are due to density differences of materials below Earth's surface

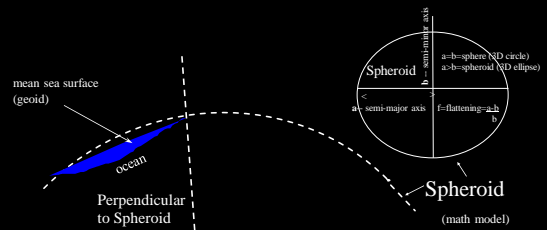


The Geoid

- The geoid is a representation of sea level and is distorted relative to a perfect spheroid formed solely by Earth's rotation
- Differences in the height of the geoid, relative to the perfect spheroid, are caused by density differences (gravitational attraction) below Earth's surface



Relationship of Land Surface to Geoid and Spheroid



Relationship of Land Surface to Geoid and Spheroid

*GPS (global positioning system) measures elevation relative to **spheroid**.*

*Traditional surveying via leveling measures elevation relative to **geoid**.*

