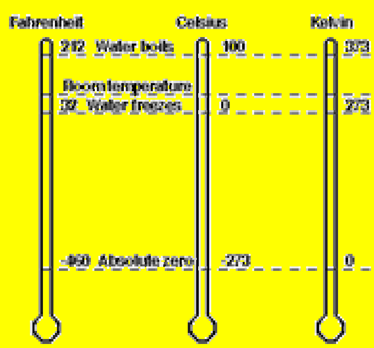
Lecture 2:

Scientific concepts critical to understanding climate

TEMPERATURE…

is a measure of the internal heat energy of a substance. The molecules that make up all matter are in constant motion. By "internal heat energy", we really mean this random molecular motion. Molecular motion is therefore the reason any substance has a temperature. The more the molecules that make up a substance move, the the higher its temperature.

Temperature Scales



HEAT TRANSFER…

can be accomplished through four means:

(1) <u>Conduction</u>: fast-moving molecules of substance 1 collide with neighboring molecules of substance 2, which are moving more slowly. This forces the molecules of substance 2 to speed up. Substance 2 becomes hotter as a result of its physical contact with substance 1. This form of heat transfer often occurs between the atmosphere and the earth's surface and is also known as sensible heat flux.

HEAT TRANSFER…

can be accomplished through four means:

(2) <u>Phase changes</u>: A liquid evaporates into an overlying gas, a process which requires energy and therefore removes heat from the liquid. This also occurs often between the atmosphere and earth's surface and is known as latent heat flux. The dryness of the desert surface means it can't cool through latent heat flux and therefore must cool almost exclusively through sensible heat flux. The inefficient ventilation of the desert surface is the reason the deserts are so hot.

HEAT TRANSFER…

can be accomplished through four means:

(3) <u>Convection</u>: Typically occurs when a liquid or gas is heated from below. The heated portion becomes lighter and rises, being replaced by heavier, and cooler liquid or gas. This redistribution of heat occurs in both the atmosphere and the ocean.

HEAT TRANSFER…

can be accomplished through four means:

(4) <u>Radiation</u>: The radiation emanating from substance 1 encounters substance 2, which absorbs the radiation. The absorbed radiation heats substance 2.

RADIATION…

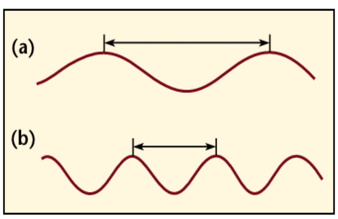
is an wave that moves through space at a constant speed: 300,000,000 m/s

This wave is analogous to the ripples on a pond that propagate when the pond's surface is disturbed by a rock. The difference is that instead of waves of water propagating through space, radiation involves waves of an electromagnetic field.

Radiation comes in many forms...

•radio waves •microwaves •heat from a fire •light

•Ultraviolet rays •X-rays •Gamma rays



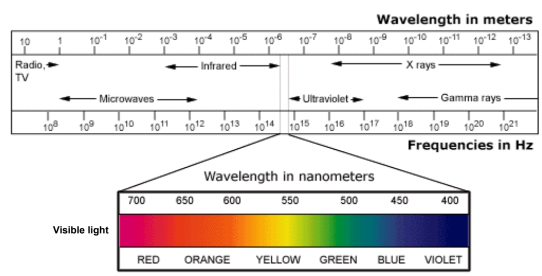
The various forms of radiation are distinguished by their **<u>wavelength</u>**, the distance between successive crests of the wave.

(a) has a long wavelength

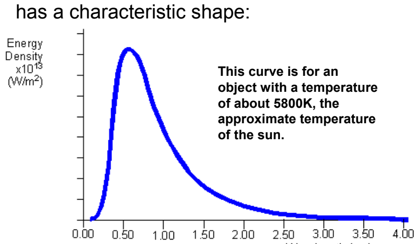
(b) has a short wavelength

The longer the wavelength, the less energetic, so that (a) is less energetic than (b).

The various forms of radiation are organized according to their wavelengths (and hence energy levels), creating the **electromagnetic spectrum**.

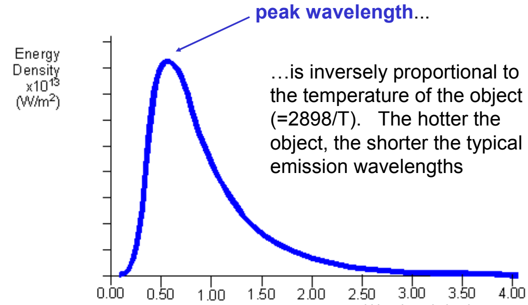


It turns out that all objects constantly emit radiation according to their temperature. Objects that emit with 100% efficiency are called **blackbodies**, and have a distribution of wavelengths of emitted radiation is given by the **Planck function**, which has a characteristic shape:



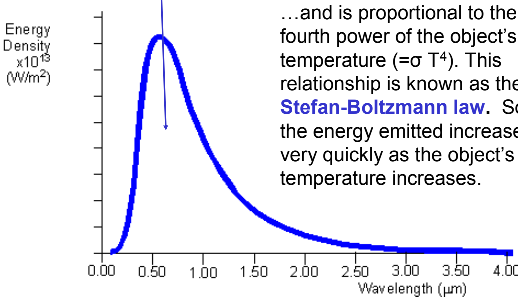
This curve is for an object with a temperature of about 5800K, the approximate temperature of the sun.

the distribution's
peak wavelength...



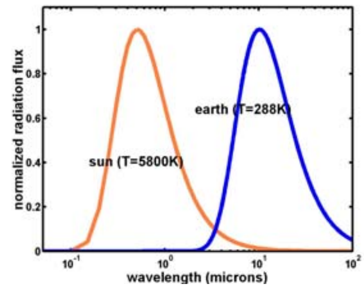
…is inversely proportional to the temperature of the object (=2898/T). The hotter the object, the shorter the typical emission wavelengths

The total energy emitted by the object is the **area** under the curve...



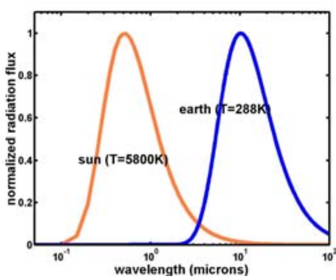
…and is proportional to the fourth power of the object's temperature (=σ T^4). This relationship is known as the **Stefan-Boltzmann law**. So the energy emitted increases very quickly as the object's temperature increases.

The wavelength distributions of the radiation emitted by the sun and the earth are very different, because the sun is so much hotter than the earth.



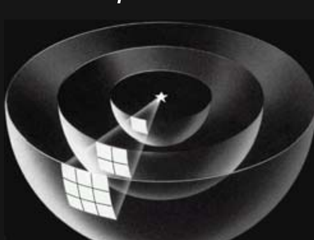
The Planck functions for temperatures characteristic of the sun and the earth. The peak wavelength of the sun's distribution is at about 0.5 microns (green light), while the peak wavelength for the earth's distribution is at about 10 microns (infrared radiation).

Because there is little overlap in wavelength between the radiation emitted by the earth and the radiation emitted by the sun, almost all light in the earth's atmosphere with a wavelength less than 3 microns is solar in origin, and is known as **solar radiation**. At the same time, almost all light in the earth's atmosphere with a wavelength greater than 3 microns comes from the earth or its atmosphere, and is called **terrestrial radiation.**



RADIATION FLUX

The total flux of energy transferred from one object to another varies according to the distance between the two objects. This relationship is known as the ***inverse-square law.***



Flux is proportional to $1/d^2$

We expect the sunshine a planet receives to decrease as the distance from the sun increases.

The radiation flux can also vary because of the angle between the surface intercepting the radiation and the direction of the radiation's propagation. The more oblique the angle, the less energy is absorbed. This is one reason the poles receive less energy than the equator.

The earth also reflects solar radiation. The reflectivity or **albedo** of the earth is about 0.3, meaning that about 30% of the incoming solar flux is reflected back to space. Certain regions are typically much more reflective than others.