The Sun and Solar Radiation:

The Sun provides the energy to power the Earth. There are many different types of energy – e.g. kinetic energy, potential energy, thermal energy, chemical energy, electrical energy, and radiative energy. Energy can neither be destroyed nor created, but can be converted from one form to another (1st law of thermodynamics). The sun generates radiative energy through nuclear fusion reactions: H + H $\rightarrow$ He + energy. The Sun’s energy is transported to Earth through space via radiation (light). Radiation is the only mechanism capable of transferring energy through a vacuum.

Radiation can be thought of as waves moving through space at the speed of light (300,000 km/sec). Radiation can also be described as small particles called photons that move at the speed of light. Photons are the smallest unit of radiation. Packets of photons make up a wave, and groups of waves compromise a beam. The main difference between different types of waves is their wavelength ($\lambda$). A wavelength is measured in units of micrometers (or microns for short). One meter equals 1,000,000 ($10^6$) microns ($\mu$m). The wavelength of radiation is inversely proportional to the frequency of radiation. The proportionality constant is the speed of light.

$$\lambda = c/f$$

Energy of a single unit of radiation (photon) depends on the wavelength (or frequency):

$$E = hf = hc/\lambda.$$

where $h = $ Planck’s constant = 6.63 x $10^{-34}$ J sec

The units of energy transfer are energy per unit time per unit area. Energy per unit time is also called ‘power’ and has the unit watts (abbreviated by W). Hence the rate of energy transfer (e.g., by radiation) is expressed in watts per square meter. We call this the ‘flux’ of radiation. The flux of solar radiation incident on a flat horizontal surface when the sun is directly overhead and the sunlight is undepleted by the atmosphere is 1370 watts per square meter. 1370 watts is roughly equivalent to the electrical power consumed by a hair dryer.

Spectrum of Radiation:

Radiation comes in a spectrum of wavelengths (continuous), all traveling at the speed of light. Wavelengths vary over many orders of magnitude (an order of magnitude is a factor of 10). Beams of radiation are composed of waves of different wavelengths. Higher frequency (shorter $\lambda$) means higher energy.

Names for ranges of the electromagnetic spectrum (in order of increasing wavelength):
X-RAY- (< 0.01 microns) passes through living tissue, lethal in high doses
ULTRAVIOLET (UV)- capable of causing sunburn and skin cancer
VISIBLE- (0.3-0.7 microns) the narrow range that human eyes are sensitive to
INFRARED (IR) (0.7-100 microns) important for energy emitted by planets
MICROWAVE- (beyond 100 microns) carry radio and television signals

X-rays have the highest frequencies, radio waves the lowest.

**Blackbody Radiation:**

While the Sun is the energy source, the surface of the Earth, as well as the atoms and molecules in the Earth’s atmosphere, are receivers of this energy. The Earth and its atmosphere absorb some of the sun’s radiation, and emit it back to space at longer (infrared) wavelengths. All bodies in the universe emit radiation. A blackbody is a body that absorbs all radiation incident upon it, and that emits radiation with perfect efficiency. No body is a perfect blackbody.

Two important properties of blackbody radiation are 1) the total power radiated by the object per unit area and 2) the wavelength of most intense emission.

1) **Stephan-Boltzmann Law**

The maximum amount of radiation that a body can emit, summed over all wavelengths, is proportional to its temperature (degrees Kelvin) raised to the fourth power. This relationship is the Stefan-Boltzmann law, and is expressed as:

\[
\text{Emitted radiation} = \text{constant} \times T^4
\]

where \( \text{constant} = 5.67 \times 10^{-8} \text{ W/m}^2/\text{K}^4 \)

2) **Wien’s Displacement Law**

Wien’s displacement law states that the wavelength at which the blackbody emission spectrum is most intense varies inversely with the blackbody’s temperature.

\[
\lambda = \frac{2900}{T} [\mu m]
\]

Bodies the temperature of planets (i.e., hundreds of degrees K) emit virtually all their radiation in the infrared range (around 10 microns).

**The Earth from Space:**

The Earth and its atmosphere absorb much of the incident solar radiation. This absorbed energy is re-emitted as heat (infrared radiation). Some gases in the atmosphere can also absorb infrared radiation emitted by the Earth. This further warms the Earth and
is called the Greenhouse effect. Some (~30%) solar radiation is also reflected back to space at approximately the same wavelength as the original solar radiation (i.e. no heating occurs). The amount of sunlight reflected back to space is referred to as the Earth’s “albedo”. The amount of absorption versus reflection of solar radiation depends on the property of the material (solid or gas), e.g. how the material interacts with the sunlight. What will absorb more solar radiation: a cloud or the surface of the ocean? The concepts of the greenhouse effect and albedo will be covered in more detail in week 10.