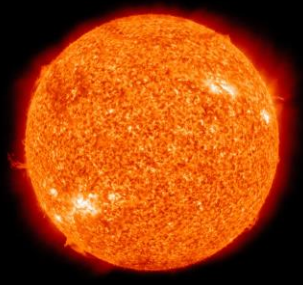
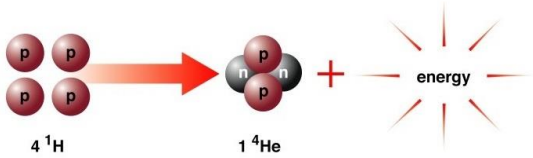
Basic Importance Of The Sun

- Powers circulation in the atmosphere and oceans
- Provides the energy for photosynthesis



Thermonuclear Fusion in The Sun



- Four hydrogen atoms fuse (combine) to form one helium, releasing energy in the process
- Requires extremely high temperatures (15 x 10^6 K) and pressures
- Gravitational forces in the Sun causes this to occur

Electromagnetic Spectrum

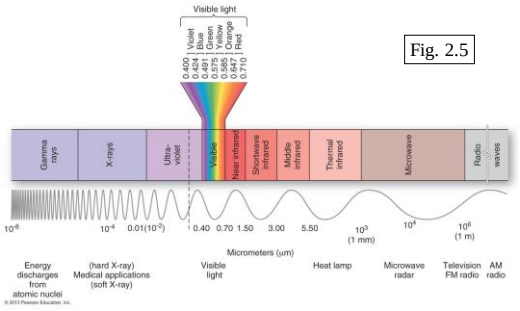


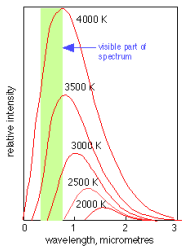
Fig. 2.5

The Sun's Radiation and the Electromagnetic Spectrum

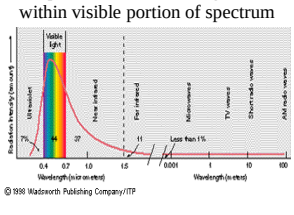
- A hot object emits radiation over a wide range of wavelengths
- The intensity of radiation, however, is not the same at all wavelengths:
  - The amount of emitted radiation is greater at some wavelengths than others
- The wavelength of greatest intensity is a function of the object's temperature and can be calculated using Wien's Law:

$$I_{max} = 3000000 / T \text{ (nm)}$$

- T = Temperature in Kelvin



Sun's intensity with a surface temperature of 6000 K is greatest within visible portion of spectrum



Maximum intensity of radiation shifts to shorter wavelengths as body becomes hotter

Is it just coincidence that we only see within the visible portion of the electromagnetic spectrum?

A hotter Sun at 6,000 K radiates shorter wavelengths with greatest intensities within the visible portion of the electromagnetic spectrum

Cooler Earth at 288 K emits longer wavelengths with greatest intensities within the infrared

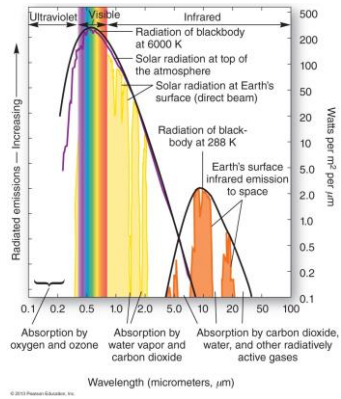
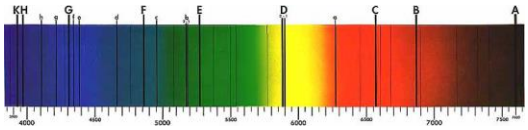


Fig. 2.6

Discovery of the Sun's Composition

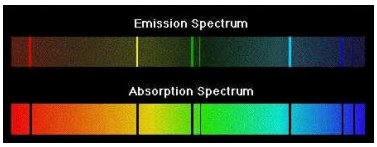


- Joseph Von Fraunhofer in 1814 used a prism to refract and disperse light from the Sun:
  - Found that the resulting spectrum contained dark lines
- Elements in the Sun absorb certain wavelengths of the emitted energy, preventing these wavelengths from reaching Earth:
  - These absorbed wavelengths appear as dark lines in the spectrum

Discovery of the Sun's Composition

Kirchoff Lines

Fraunhofer Lines

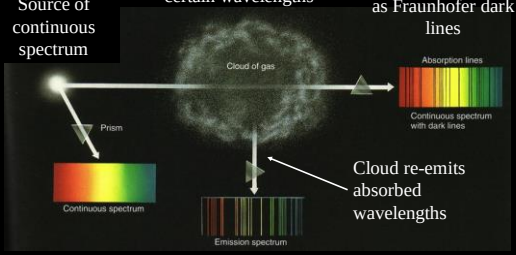


- Gustav Kirchoff similarly discovered that hot hydrogen gas emitted corresponding bright lines
- These bright lines occurred at the same wavelengths as the dark lines of Fraunhofer's spectrum:
  - The wavelengths absorbed by cooler hydrogen gas are thus emitted by hot hydrogen gas
- The Sun must consist mostly of hydrogen

Source of continuous spectrum

Hydrogen atoms in gas cloud absorb certain wavelengths

Absorbed wavelengths appear as Fraunhofer dark lines

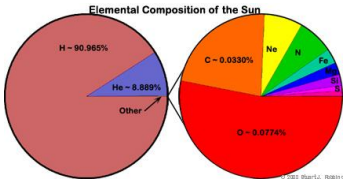


Cloud re-emits absorbed wavelengths

Emitted wavelengths appear as Kirchoff bright lines

Composition of the Sun

- Hydrogen H 91.0%
- Helium He 8.9%



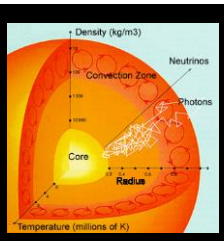
Sun Cross-Section

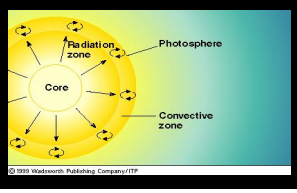
Photosphere: Visible part of Sun ~5700°C with granular appearance

Convective Zone: Gases cool at different rates, causing convection

Radiation Zone: Energy produced in core travels towards surface mostly by radiation

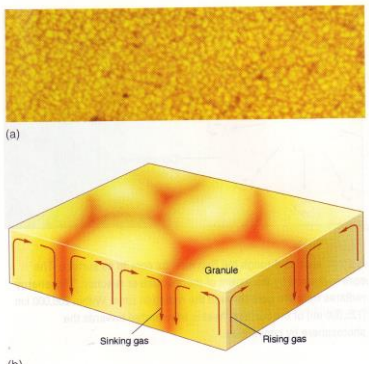
Core: Site of thermonuclear reactions





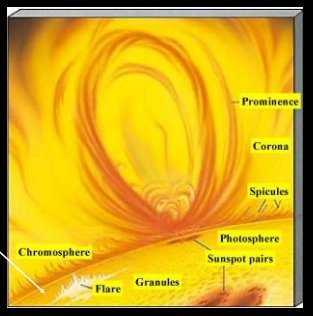
Photosphere appears as granules on the Sun's surface

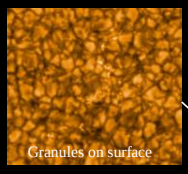
Granules due to temperatures differences resulting from underlying convection



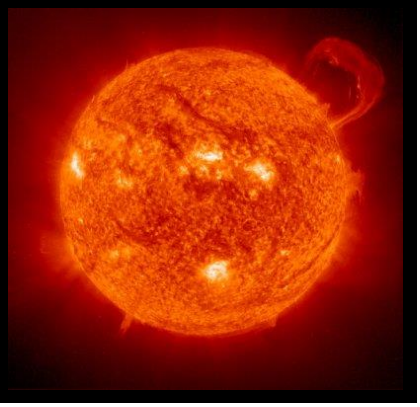
Chromosphere separates photosphere from overlying Corona

Prominences are arcs of hot gases trapped in magnetic field of sunspots

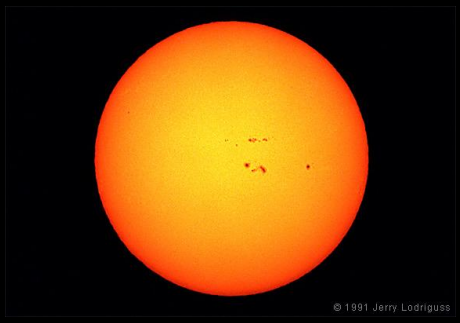




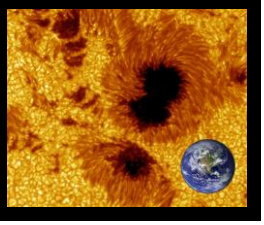
Solar flares are major magnetic storm systems on the Sun's surface that release bursts of highly charged particles

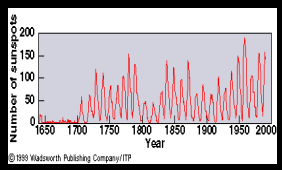


Sun Spots

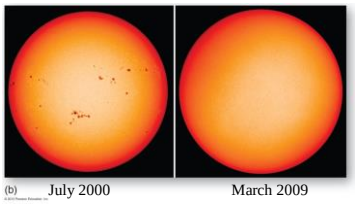


Sunspots are dark regions of cooler, depressed, and anomalously magnetic areas on the Sun's surface. Intense magnetic fields hurl charged particles into space.



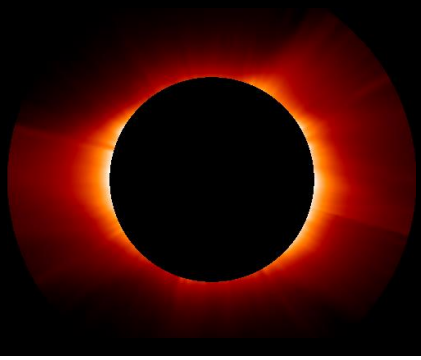


Sun Spot Cycle



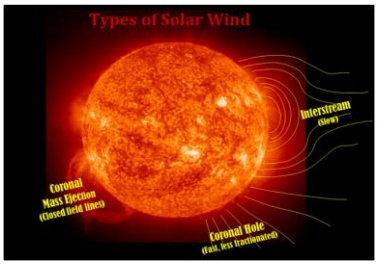
- Sun spot activity occurs in ~11 year cycles:
  - Over 11 year period, the number of sunspots declines and then increases to a peak
- Latest maxima were in 1991, 2002, and 2013

Sun's Corona Is the Outer Envelope That Appears As a Solar Crown During a Total Eclipse



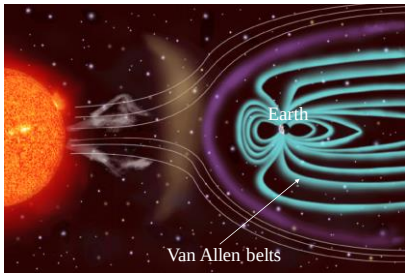
Surface of The Sun

The Solar Wind



- Motion of hot hydrogen ions in the Sun produces a magnetic field
- Differential rotation of the Sun distorts the magnetic field:
  - Sun rotates faster at equator than at poles
- Magnetic distortions cause ejection of ionized gases known as the solar wind that blow away from the sun at speeds of 300 to 800 km / sec

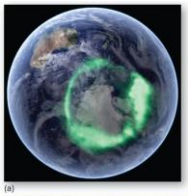
Solar Wind Interacts With Earth



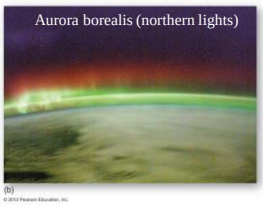
- Solar wind (high speed ions) that reaches Earth is affected by Earth's magnetic field
- Charged particles collect to form Van Allen Belts that align with Earth's magnetic field
- Electrical currents called aurora result

How Aurora Form

- Charge particles collect and align within Van Allen belts, producing electric currents
- Charged particles move down the Earth's magnetic lines of force at the north and south magnetic poles
- Particles interact with atmosphere to produce fingers of light called aurora
- Oxygen and nitrogen atoms in atmosphere have electrons excited and light is emitted:
  - Oxygen: green emission
  - Nitrogen: red/purple emission

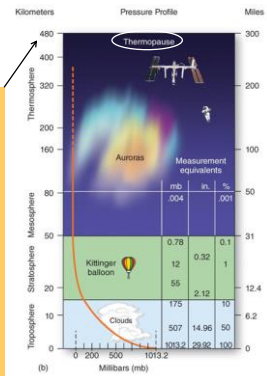


Aurora Australis (southern lights)



The Solar Wind

Incoming Radiation At The Top Of Earth's Atmosphere



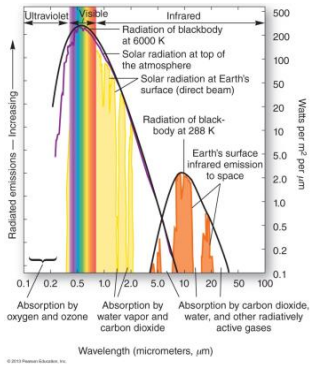
- The thermopause is the top of Earth's atmosphere ~480 km above the surface:
  - Outer boundary of Earth's energy system
  - Receives only one two-billionth of the Sun's total energy output
  - Nevertheless, this tiny fraction is still an enormous amount of energy flowing into Earth's systems

Radiation

Radiation intensity from the Sun, at 6000 K, is greatest within the visible portion of the electromagnetic spectrum

Radiation intensity from a cooler Earth, at 288 K, is greatest within the infrared portion of the spectrum

Fig. 2.6



Earth's Energy and Budget

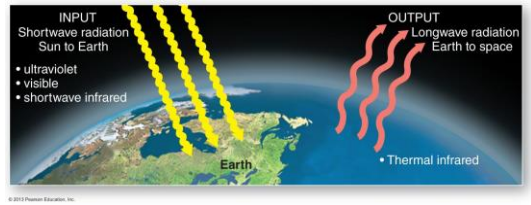
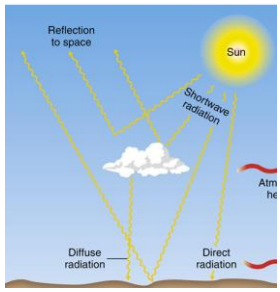


Fig. 2.7

Insolation

- Insolation is the radiation arriving at Earth's atmosphere and surface
- Solar constant (1372 W/m²) is the average insolation received at the thermopause at Earth's average distance from the Sun
- This insolation is reduced by half via reflection, scattering and absorption as it passes through the atmosphere:
  - Earth's surface only receives a small fraction of solar energy entering the upper atmosphere



Uneven Distribution of Insolation

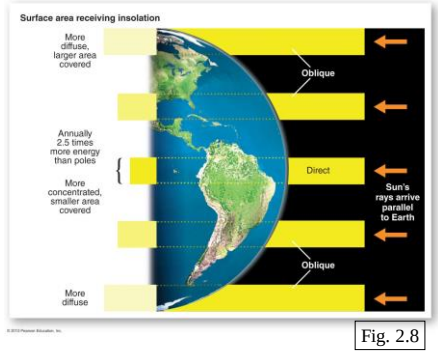
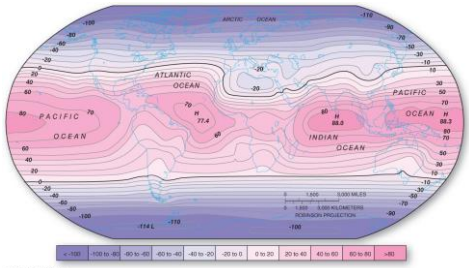


Fig. 2.8

Daily Net Radiation (W/m²) At The Top Of The Atmosphere



Global net radiation is the balance between incoming shortwave and outgoing longwave radiation:

- Energy inputs minus energy outputs

Earth's Revolution And Rotation

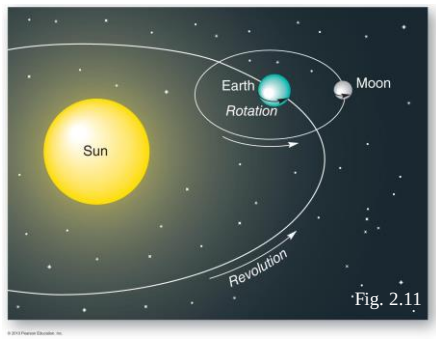
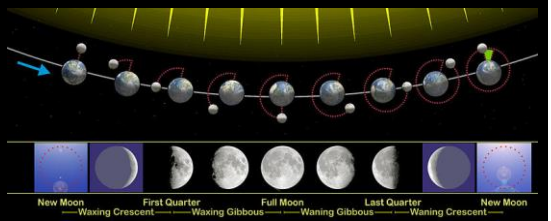


Fig. 2.11

The Moon's Rotation Is Synchronous With It's Orbit Around The Earth



The moon makes one complete rotation on its axis in about the same time that it takes to orbit the Earth (~27 days). As a result, the moon always keeps the same face turned towards Earth.

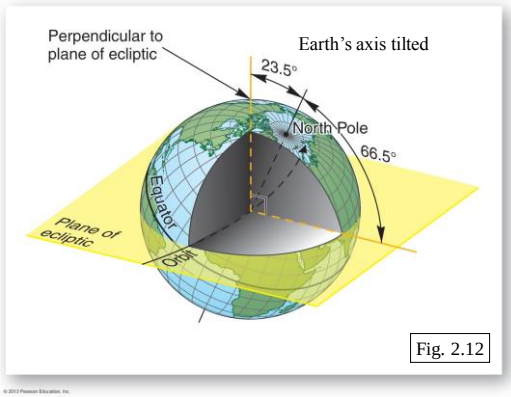
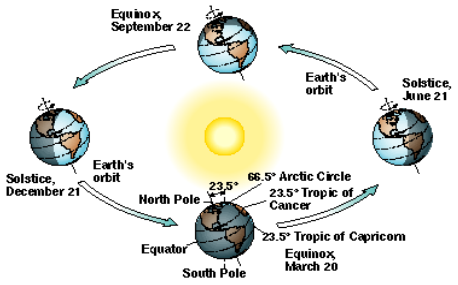


Fig. 2.12

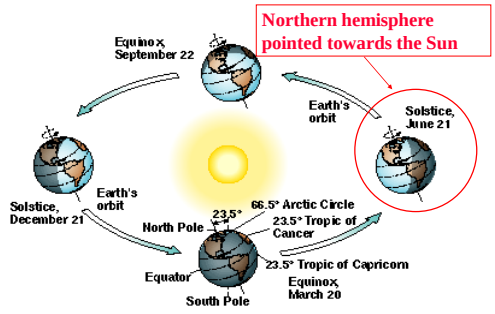
The Latitude At Which The Sun Shines Directly Overhead Changes Throughout The Year



Solstice

- **Tilt of the Earth relative to the Sun causes circle of illumination to exclude one of the polar regions**
- **Occurs twice a year:**
  - **Winter Solstice December 21-22: Circle of illumination excludes North Pole region**
  - **Summer Solstice June 20-21: Circle of illumination excludes South Pole region**

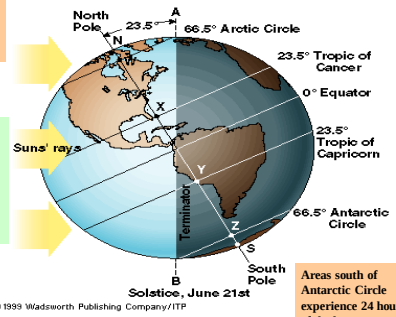
Summer Solstice



Summer Solstice

Areas north of Arctic Circle experience 24 hours of daylight

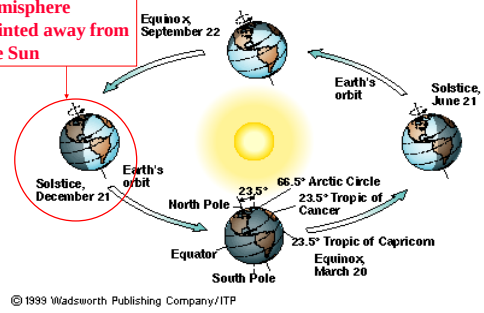
Tropic of Cancer is the most northerly latitude at which the Sun can appear directly overhead at noon. This event occurs at the June solstice.



Areas south of Antarctic Circle experience 24 hours of darkness

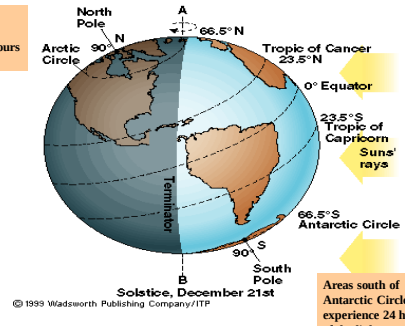
Winter Solstice

Northern hemisphere pointed away from the Sun



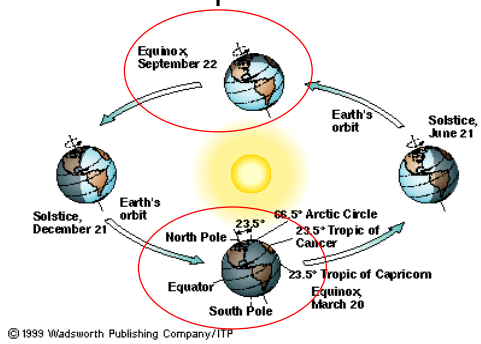
Winter Solstice

Areas north of Arctic Circle experience 24 hours of darkness



Areas south of Antarctic Circle experience 24 hours of daylight

Equinox



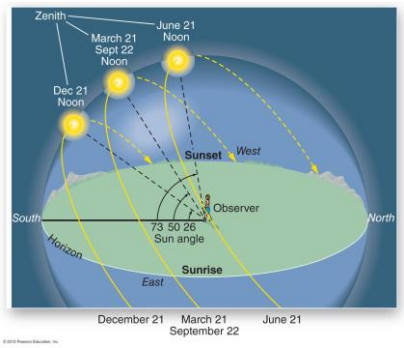
Equinox

- During the equinox, the circle of illumination passes through both poles:
  - All locations on Earth experience a 12-hour day and 12-hour night
- Equinox occurs twice a year:
  - Vernal Equinox March 20-21
  - Autumnal Equinox September 22-23

Seasonal Observations at 40º N Latitude

The Sun's altitude varies with the seasons

Fig. 2.15



Seasonal Changes From Orbit

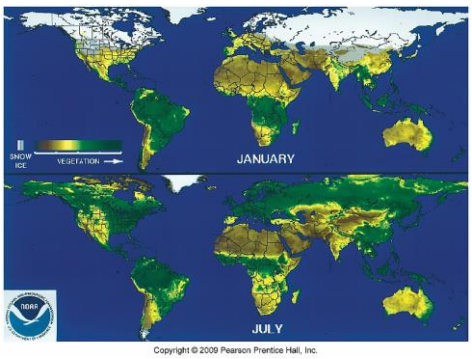


TABLE 2.1 Five Reasons for Seasons

Factor	Description
Revolution	Orbit around the Sun; requires 365.24 days to complete at 107,280 kmph (66,660 mph)
Rotation	Earth turning on its axis; takes approximately 24 hours to complete
Tilt	Axis is aligned at about 23.5° angle from a perpendicular to the plane of the ecliptic (the plane of Earth's orbit)
Axial parallelism	Remains in a fixed alignment, with Polaris directly overhead at the North Pole throughout the year
Sphericity	Appears as an oblate spheroid to the Sun's parallel rays; the geoid

Earth-Sun Relations