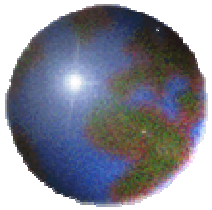
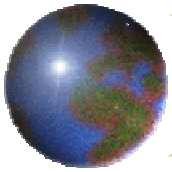


Part 1. Energy and Mass

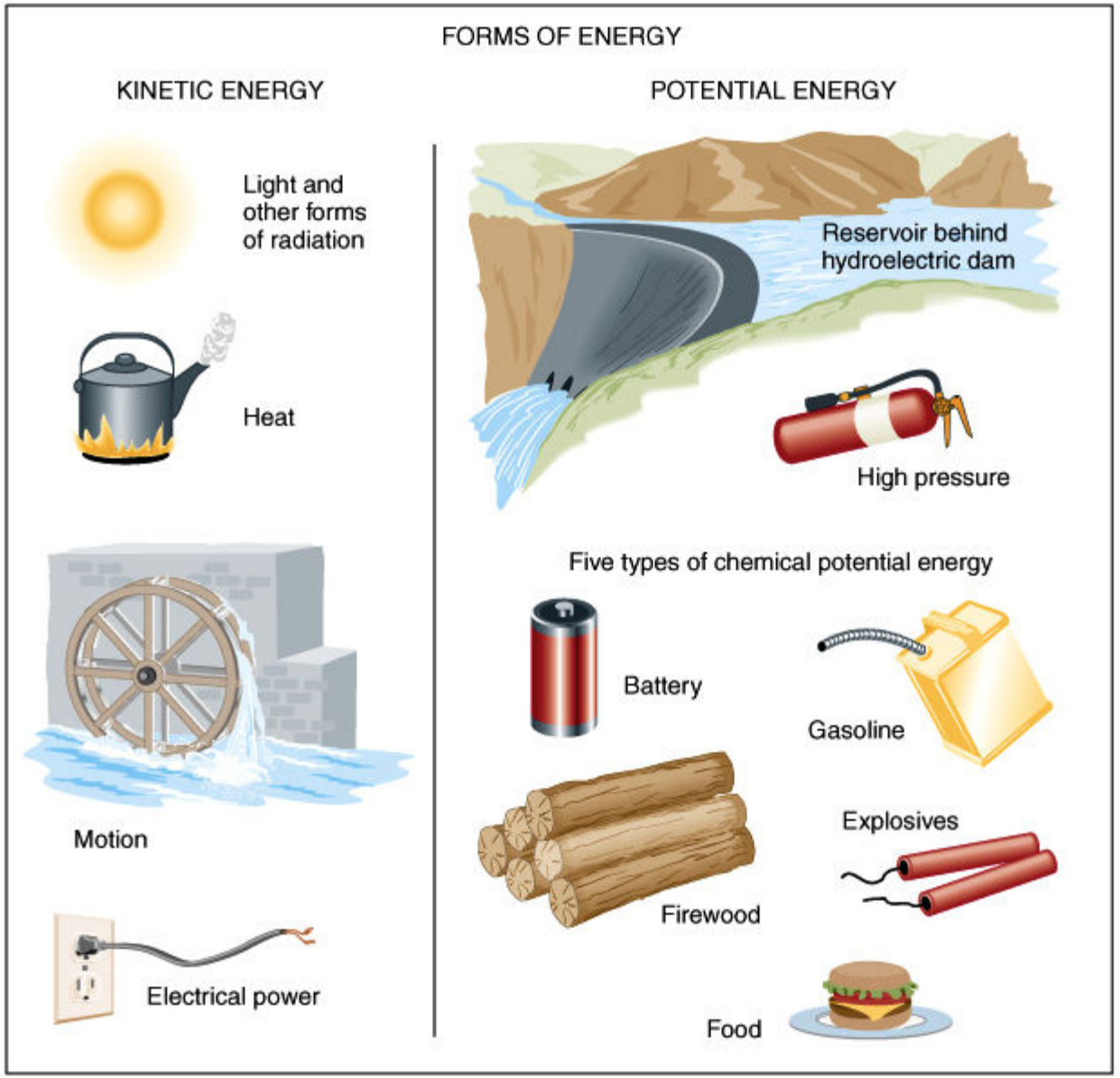
Chapter 2.

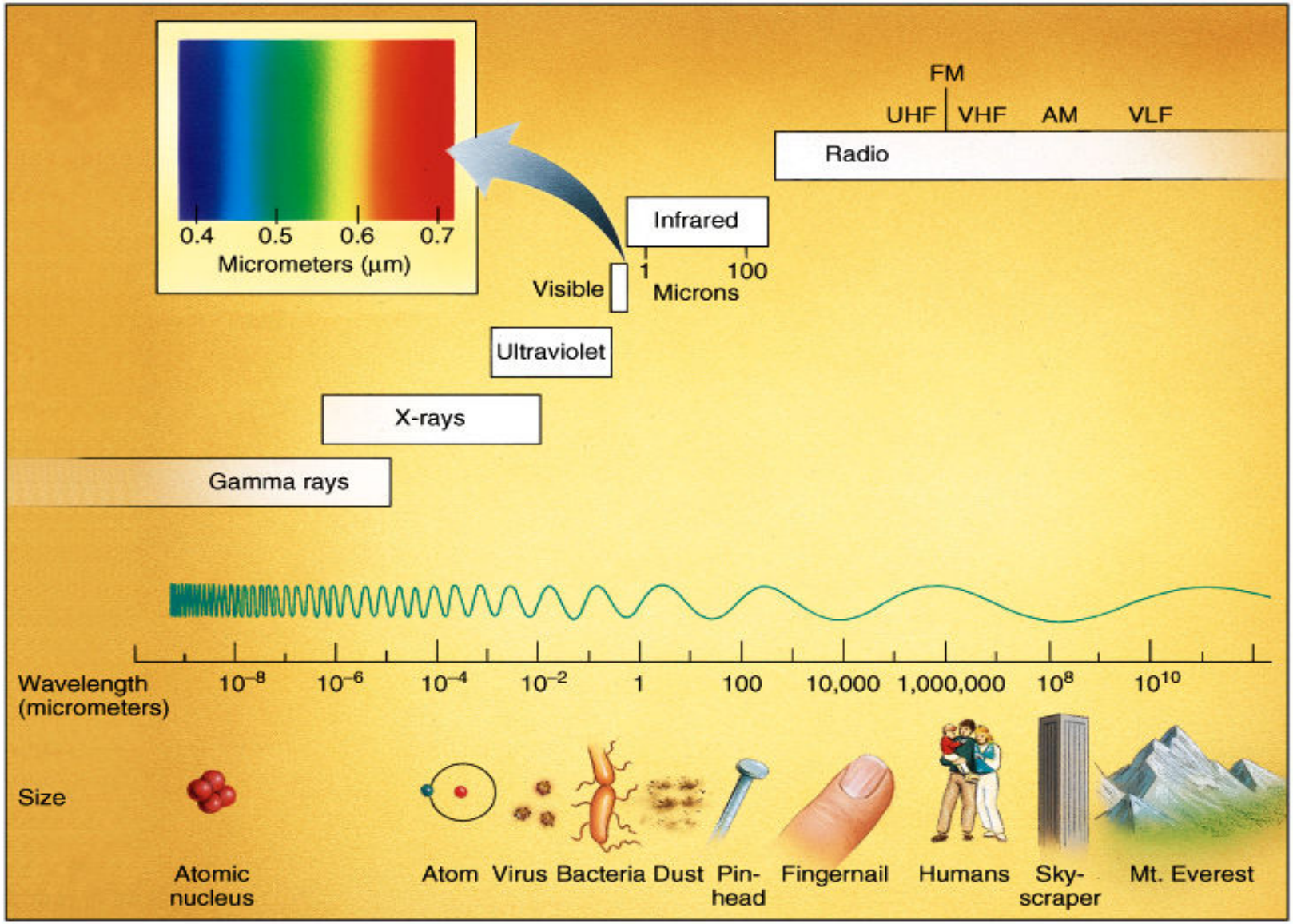
Solar Radiation and the Seasons



Introduction

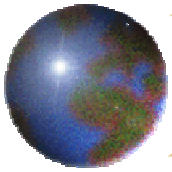
- Solar Radiation
  - Initiates atmospheric motions and weather processes
- Energy Classified as
  - *Kinetic* or *potential*


FORMS OF ENERGY
KINETIC ENERGY
POTENTIAL ENERGY
Light and other forms of radiation
Heat
Motion
Electrical power
Reservoir behind hydroelectric dam
High pressure
Five types of chemical potential energy
Battery
Gasoline
Explosives
Firewood
Food

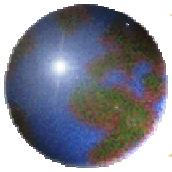

0.4
0.5
0.6
0.7
Micrometers (μm)
FM
UHF
VHF
AM
VLF
Radio
Infrared
1
100
Microns
Visible
Ultraviolet
X-rays
Gamma rays
Wavelength (micrometers)
10^{-8}
10^{-6}
10^{-4}
10^{-2}
1
100
10,000
1,000,000
10^{8}
10^{10}
Size
Atomic nucleus
Atom
Virus
Bacteria
Dust
Pin-head
Fingernail
Humans
Sky-scraper
Mt. Everest

- Intensity and Wavelengths of Emitted Radiation
  - Energy radiated over many wavelengths
  - Physical laws define the amount and wavelength of emitted energy

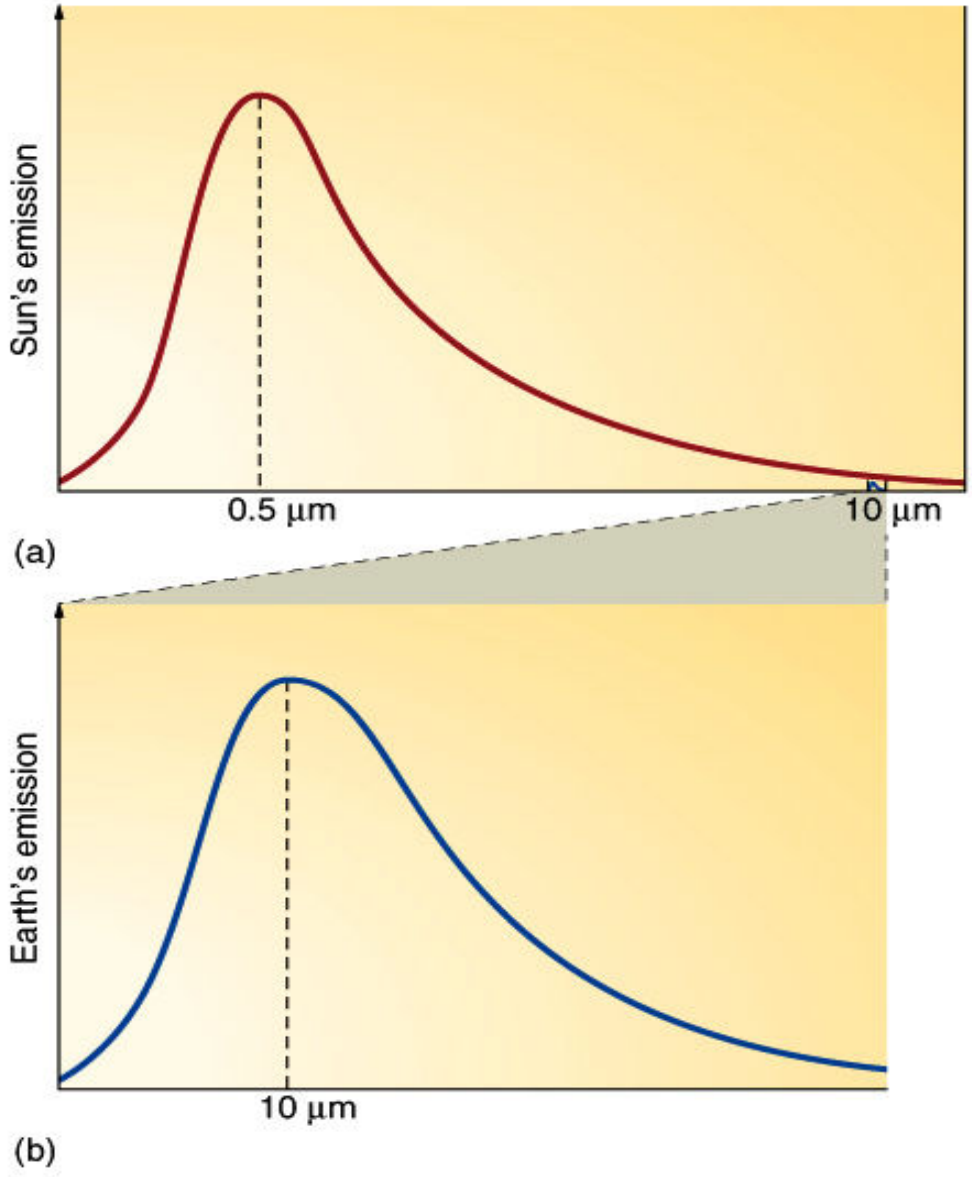
    • *Blackbodies* = hypothetical perfect emitters

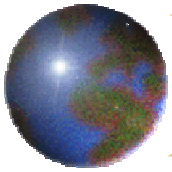


- *Stefan-Boltzmann Law*
  - Energy emitted is proportional to temperature
    - Hotter objects emit more energy
      - $I = \sigma T^4$
  - *Graybodies* emit a percentage of the maximum possible for a temperature
    - $I = \varepsilon \sigma T^4$



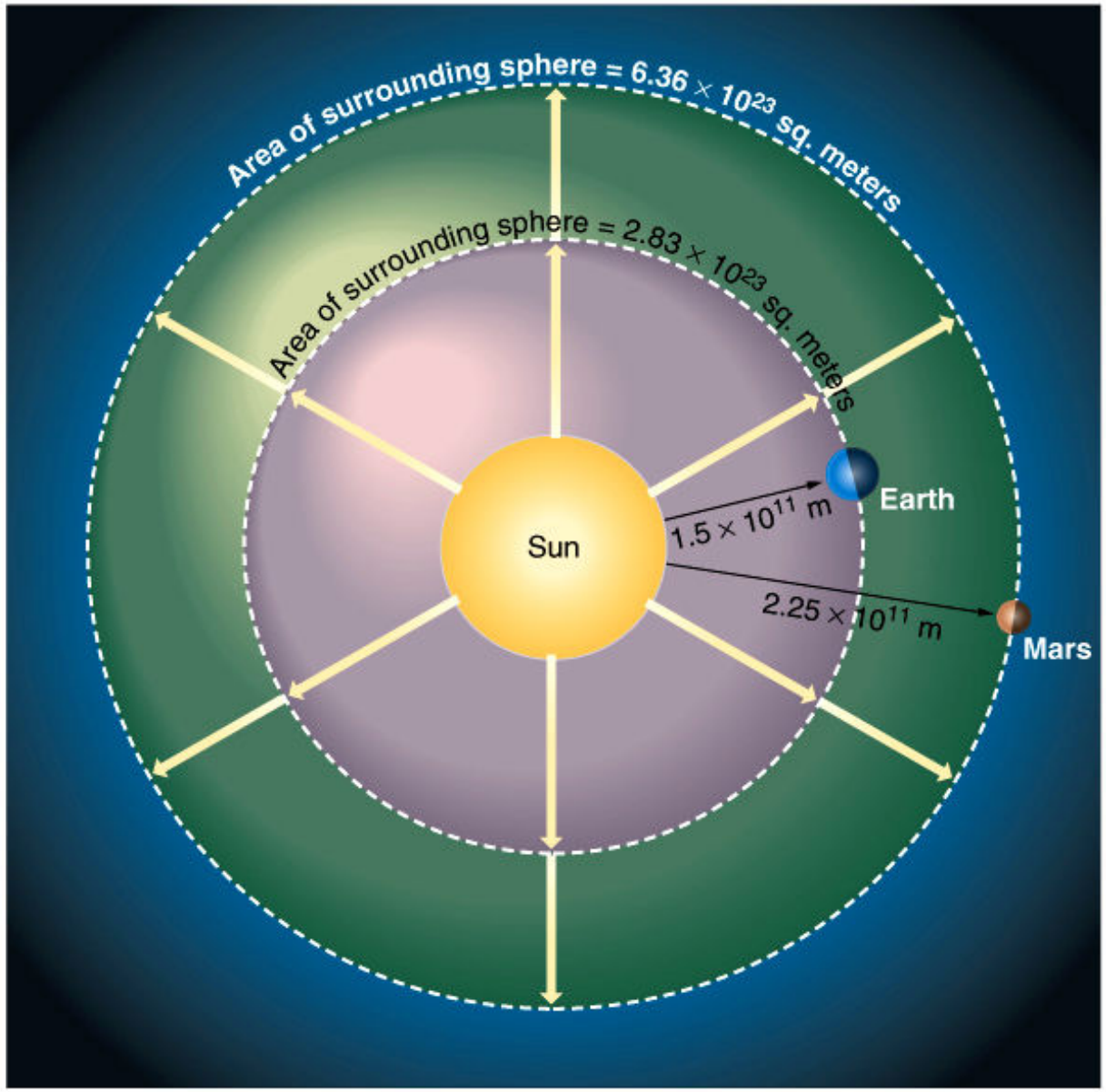
- *Wein's Law*
  - Determines peak wavelength
    - $\lambda_{max} = 2900/T$
  - Hotter objects = shorter wavelengths
    - Solar radiation = 0.5 μm peak
    - Terrestrial radiation = 10 μm peak

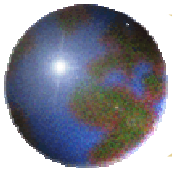

Sun's emission
0.5 μm
10 μm
(a)
Earth's emission
10 μm
(b)



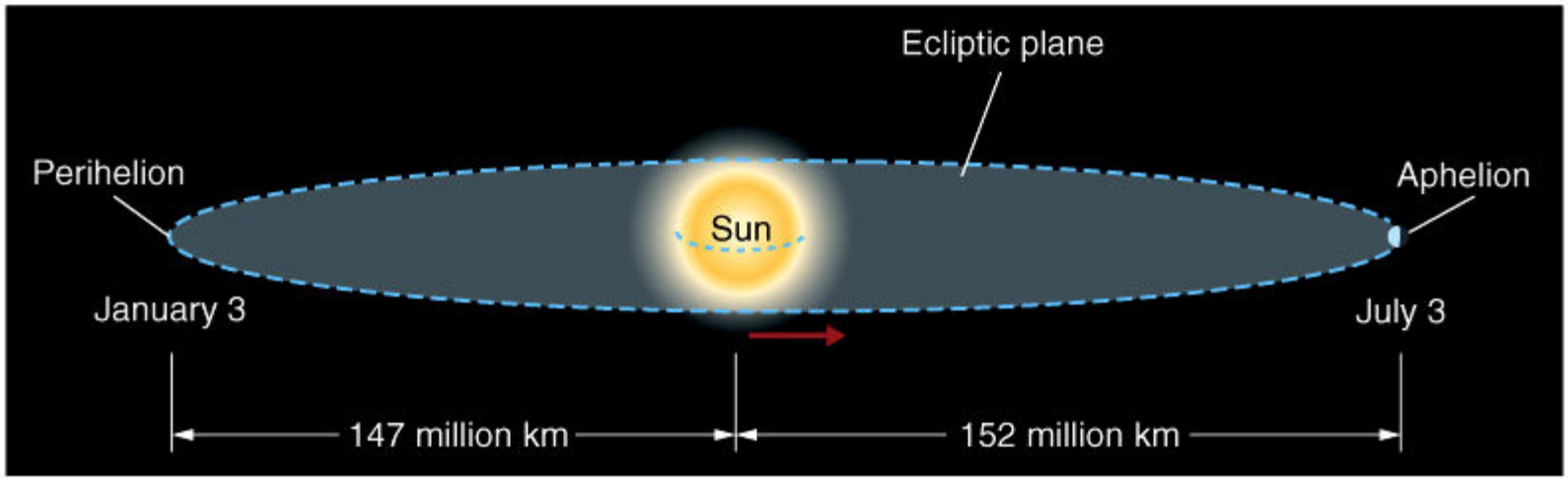
- The *Solar Constant*
  - Energy intensity decreases in proportion to the distance squared
  - *Inverse square law*
    - Solar emission =

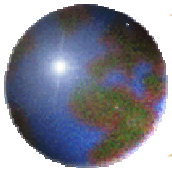
$3.865 \times 10^{26} W / 4\pi (1.5 \times 10^{11} m)^2 = 1367\ W/m^2$


Area of surrounding sphere = 6.36 × 10^23 sq. meters
Area of surrounding sphere = 2.83 × 10^23 sq. meters
Sun
Earth
1.5 × 10^11 m
2.25 × 10^11 m
Mars



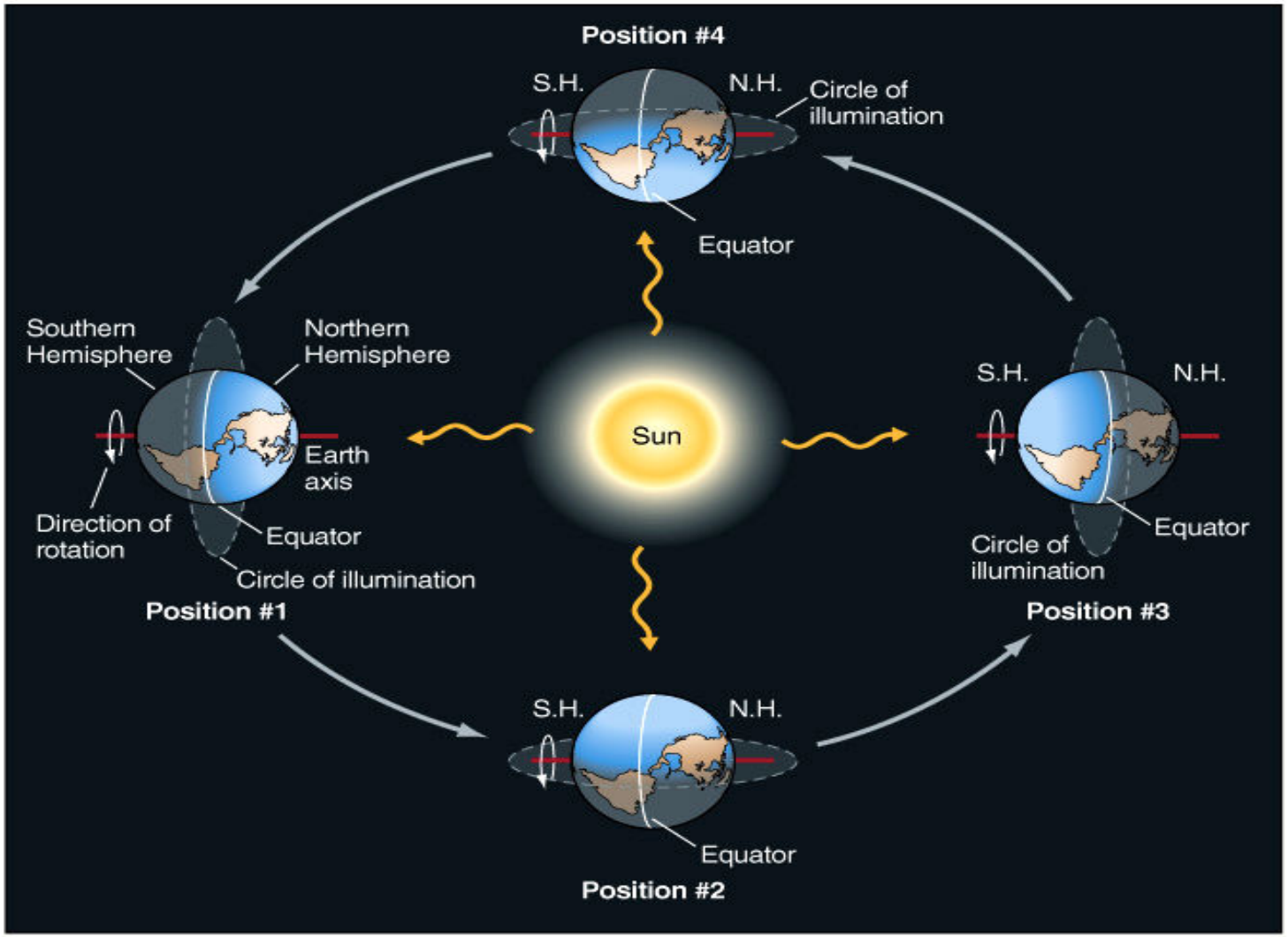
- Causes of the Earth's *Seasons*
  - Orbital alignment to the Sun = seasonal variations in solar energy
  - Revolution
    - The *ecliptic plane*
    - *Perihelion* (Jan 3; 147 mil km, 91 mil mi)
    - *Aphelion* (July 3; 152 mil km, 94 mil mi)
      - Seasonal radiation variation = ~7%

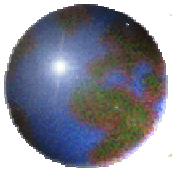

Ecliptic plane
Perihelion
Aphelion
Sun
January 3
July 3
147 million km
152 million km



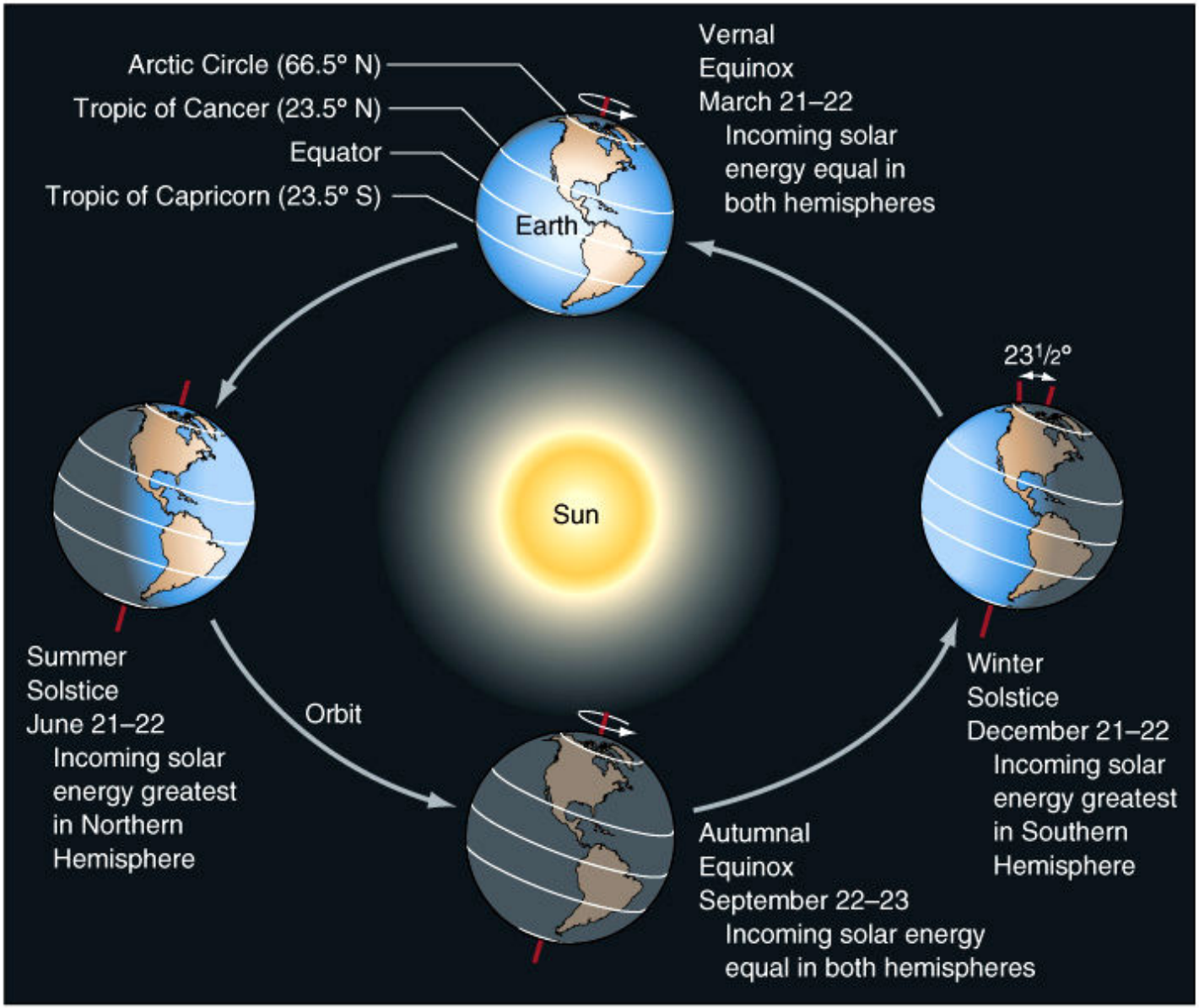
- Earth *Rotation*
  - Once every 24 hours
  - Rotational axis offset by 23.5^{o}
    - Axis is “fixed”
      - Changes hemispheric orientation through orbit
      - Causes seasons

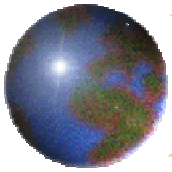
Extreme Hypothetical Axis Orientation



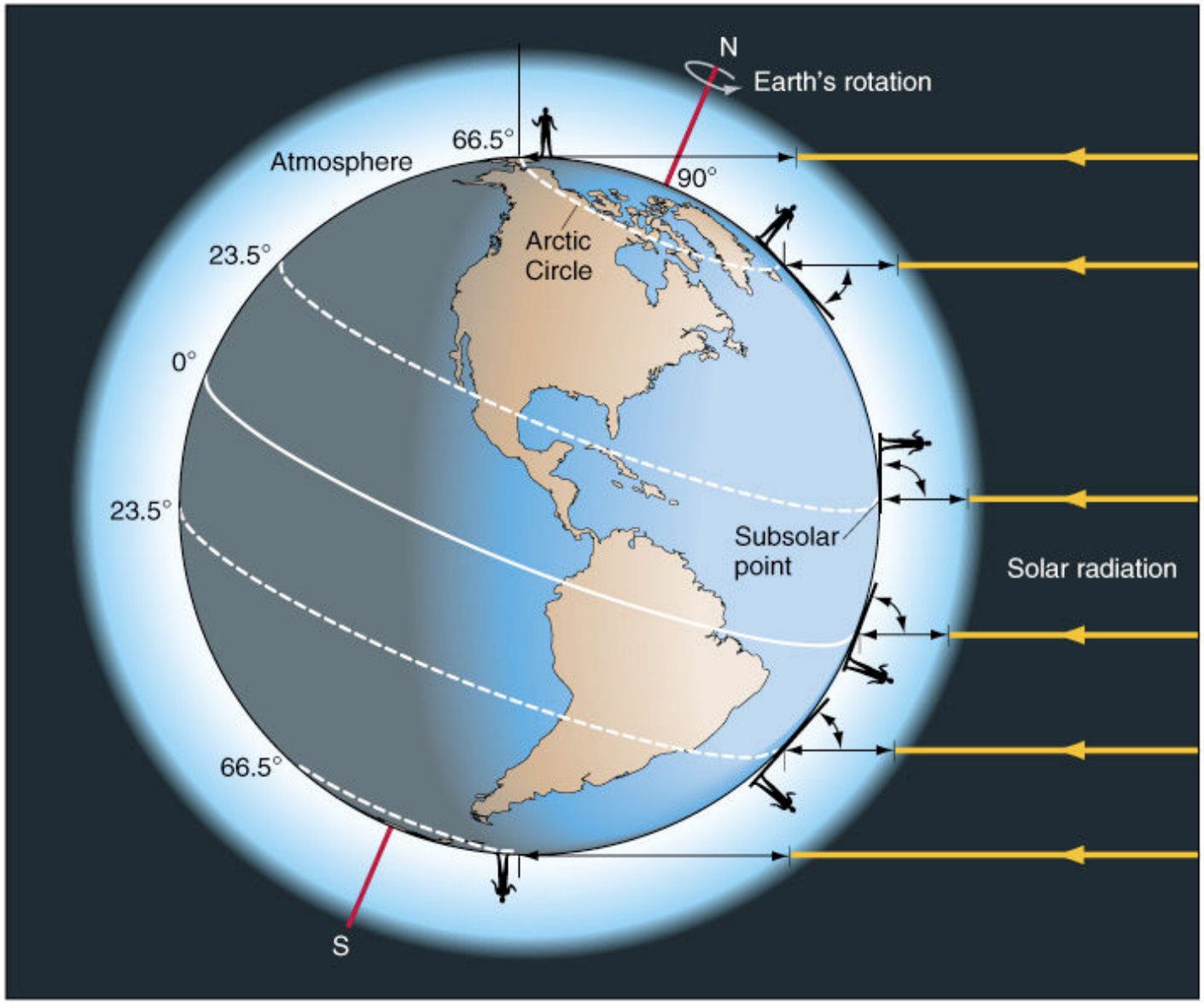


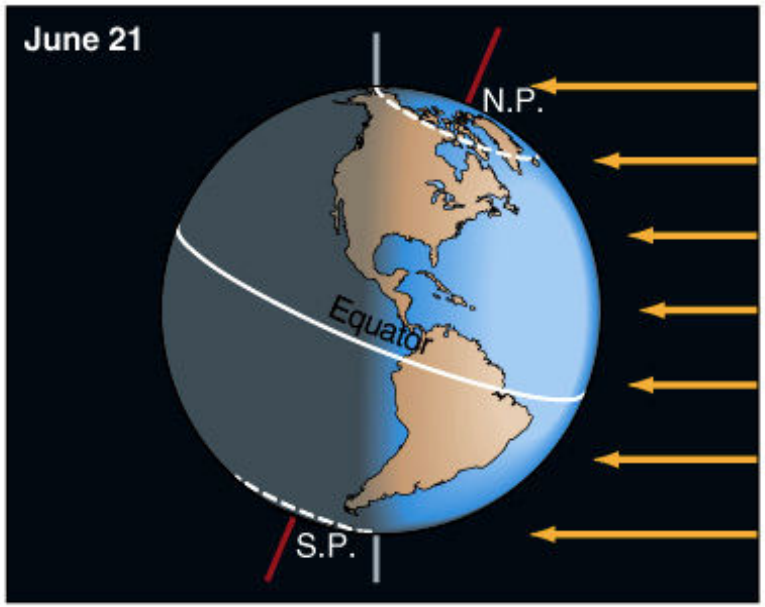
- *Solstices*
  - Maximum axial tilt in relation to the Sun
    - *June* and *December*
  - Hemispheric axes inclined toward or away from Sun
    - Causes maximum or minimum solar radiation receipt

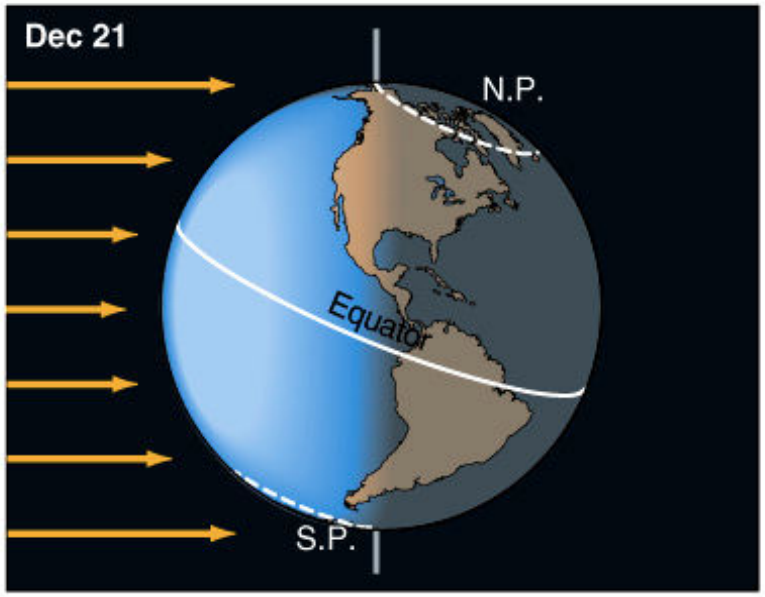

Arctic Circle (66.5° N)
Tropic of Cancer (23.5° N)
Equator
Tropic of Capricorn (23.5° S)
Earth
Vernal
Equinox
March 21–22
Incoming solar
energy equal in
both hemispheres
23½°
Sun
Summer
Solstice
June 21–22
Incoming solar
energy greatest
in Northern
Hemisphere
Orbit
Winter
Solstice
December 21–22
Incoming solar
energy greatest
in Southern
Hemisphere
Autumnal
Equinox
September 22–23
Incoming solar energy
equal in both hemispheres



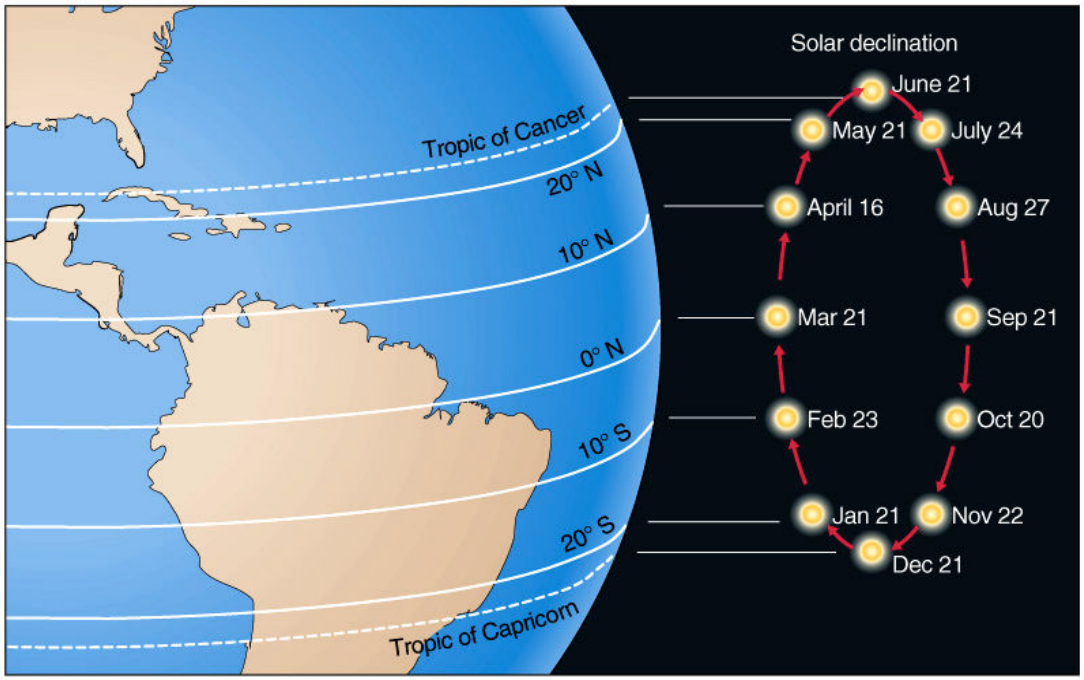
- June Solstice (~ June 21)
  - *Subsolar point* = Tropic of Cancer (23.5°N)
- December Solstice (~ Dec. 21)
  - *Subsolar point* = Tropic of Capricorn (23.5°S)
- Subsolar Point Migrates 47°
  - Between the Tropics

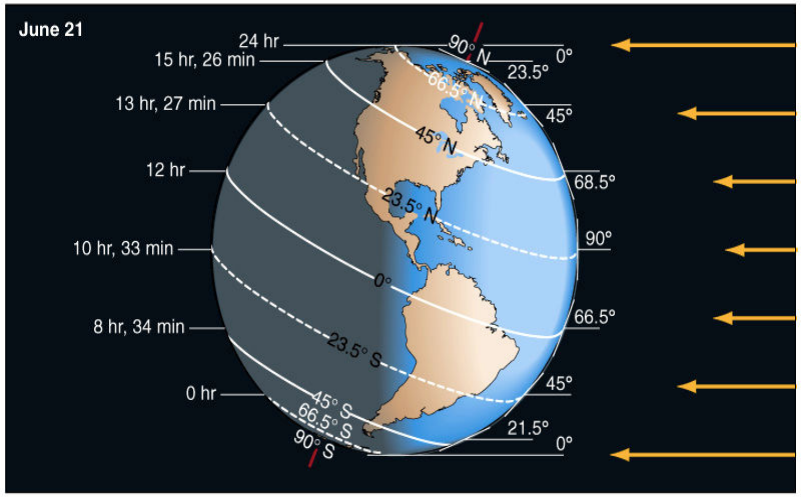

N
Earth's rotation
66.5°
Atmosphere
90°
Arctic
Circle
23.5°
0°
23.5°
Subsolar
point
Solar radiation
66.5°
S

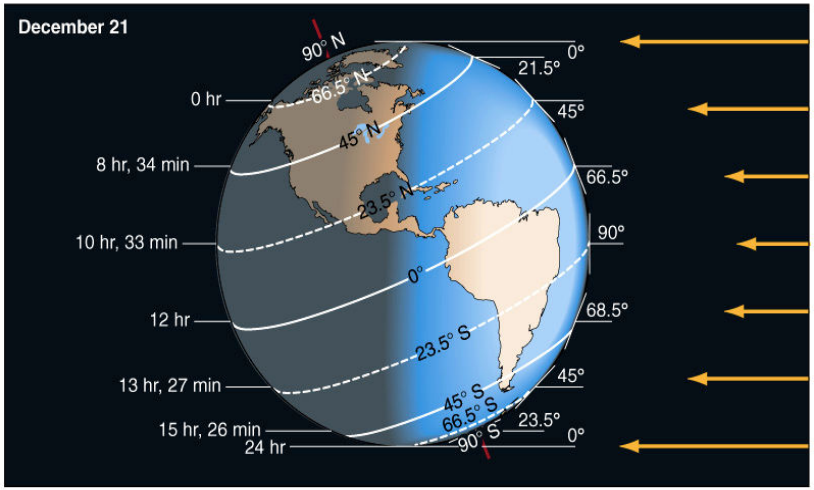

June 21
N.P.
Equator
S.P.

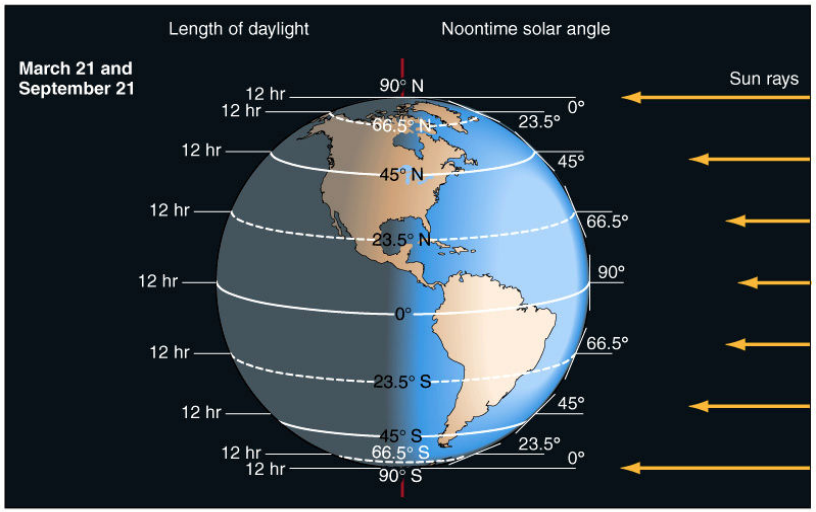

Dec 21
N.P.
Equator
S.P.

- *Equinoxes*
  - Temporally centered between solstices
    - ~ March 21 and ~ Sept 21
  - The subsolar point = 0^{o}



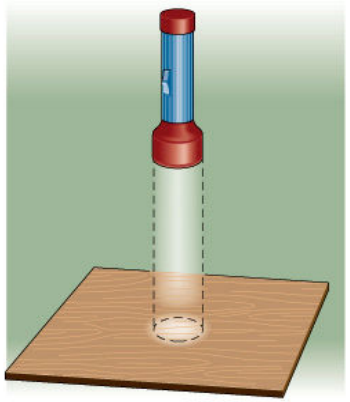

June 21
24 hr
15 hr, 26 min
13 hr, 27 min
12 hr
10 hr, 33 min
8 hr, 34 min
0 hr
90° N
66.5° N
45° N
23.5° N
0°
23.5° S
45° S
66.5° S
90° S
23.5°
45°
68.5°
90°
66.5°
45°
21.5°
0°


December 21
90° N
66.5° N
45° N
23.5° N
0°
23.5° S
45° S
66.5° S
90° S
0 hr
8 hr, 34 min
10 hr, 33 min
12 hr
13 hr, 27 min
15 hr, 26 min
24 hr
21.5°
0°
45°
66.5°
90°
68.5°
45°
23.5°
0°

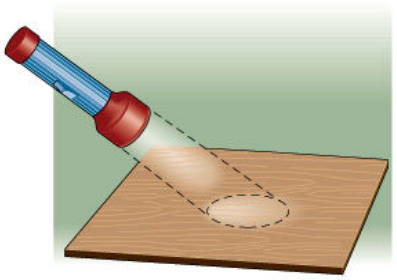

Length of daylight
Noontime solar angle
March 21 and
September 21
Sun rays
90° N
66.5° N
45° N
23.5° N
0°
23.5° S
45° S
66.5° S
90° S
12 hr
12 hr
12 hr
12 hr
12 hr
12 hr
12 hr
12 hr
12 hr
23.5°
45°
66.5°
90°
66.5°
45°
23.5°
0°

- *Solar Angle*
  - Radiation is proportional to solar angle
  - Higher angles equal reduced *beam spreading* = greater heating

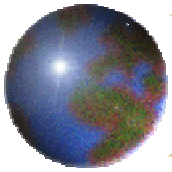
Angle of incidence



(a)



(b)



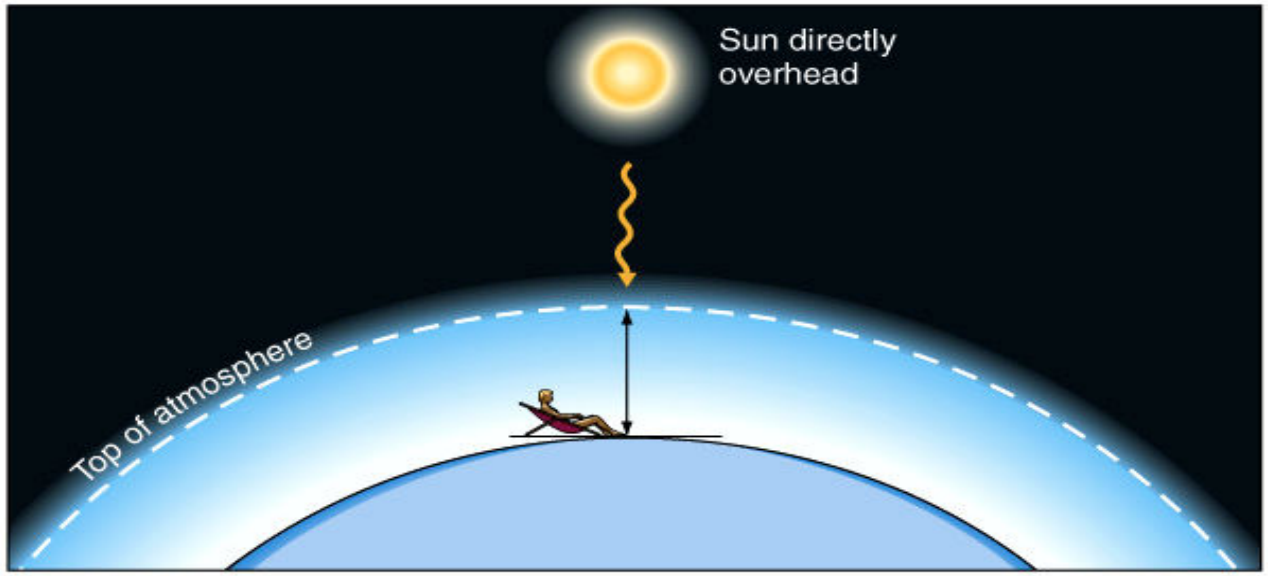
- Period of Daylight
  - *Circle of illumination* unequally bisects latitudes
  - *Day length* changes across latitudes
    - Latitudes are equally split everywhere on equinoxes

TABLE 2–2 Variations in Solar Angle and Daylength

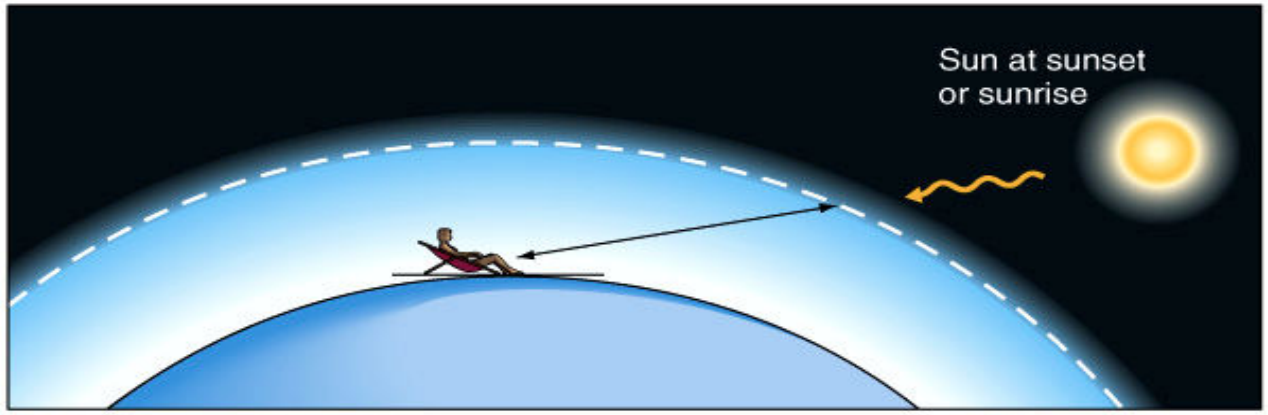
	SOLAR ANGLE AT NOON	LENGTH OF DAY	TOTAL RADIATION FOR DAY (Megajoules/m^2)
December 21			
Winnipeg	16.5°	7 hr, 50 min	7.44
Austin	36.5°	10 hr, 04 min	12.18
June 21			
Winnipeg	63.5°	16 hr, 10 min	37.15
Austin	83.5°	13 hr, 56 min	35.97

Copyright © 2007 Pearson Prentice Hall, Inc.

Lower Angles = Increased Path Length



(a)



(b)