CHAPTER 2. Solar Radiation and the Seasons

Review Questions:

1. Describe the different ways kinetic and potential energy may exist on Earth.

   Kinetic energy: light and other forms of radiation, heat, motion, and electrical power. Potential energy: reservoir behind hydroelectric dam, high pressure, five types of chemical potential energy (battery, gasoline, explosives, firewood, food).

2. Conduction and convection are alike in that both transfer heat within a substance. What is the critical difference between them?

   In conduction, heat transfers without molecular motion taking place. It is, therefore, restricted to solids. In fluids, heat energy transfers through molecular displacement, which is known as convection.

3. We have discussed sunlight, X-rays, etc., as electromagnetic radiation. Describe radiation as a wave phenomenon, and explain what is meant by “electromagnetic”.

   Energy propagates from an emitter in a pulsating wave form. These waves have both an electrical and a magnetic component.

4. Why is wavelength important in radiation transfer? That is, when discussing radiation, why isn’t it enough to specify the amount or rate of energy transfer?

   Wavelength differentiates the type of radiation emitted. Shorter wavelengths may penetrate objects (as the waves are smaller than the object’s molecules) whereas longer wavelengths may be absorbed into, or reflected from, objects.

5. Place the following wavelength bands in correct order of wavelength: visible, X-rays, ultraviolet, microwave, infrared.

   X-rays, ultraviolet, visible, infrared, microwave

6. Is there a temperature that has the same value on both the Fahrenheit and Celsius scales? If so, find that temperature. (Hint: Draw a graph of ^oC and ^oF.)

   - 40 ^{o} F and -40 ^{o} C are the same temperature.

7. Convert the following Fahrenheit temperatures to Celsius: -22 ^oF, 50 ^oF, 113 ^oF.

   -53 ^oC, 10 ^oC, 45 ^oC

8. Convert the following Celsius temperatures to Fahrenheit: -20 ^oC, 10 ^oC, 40 ^oC.

   13 ^oF, 38 ^oF, 54 ^oF

9. Why is the Kelvin scale superior to the Fahrenheit and Celsius scales in many scientific applications?

   Because there are no negative values.

10. Describe how the wavelengths and total energy emitted change as the temperature of an object increases.

    Emitted energy increases to the 4^{th} power of an object's absolute temperature.

11. The solar constant is about $1367W/m^2$. If the distance between Earth and Sun were to double, what would be the new value?

    $3.865 \times 10^{26}W / 4\ (3.14)\ (3 \times 10^{11})^{2\ =}\ 3.865^{27}/1.13094^{29} = 0.0342W/m^2$

12. What is the most important factor responsible for seasons on Earth?

    Earth's axial tilt and its subsequent relationship (orientation) to the Sun through Earth orbit.

13. Describe the annual march of solar declination.

    The solar declination migrates between the Tropic of Cancer (23.5^o N) and the Tropic of Capricorn (23.5^o S) through the year. On the summer solstice, the solar declination reaches its farthest poleward migration for that hemisphere. In the opposite hemisphere, that day marks the winter solstice.

14. What is the significance of the Arctic and Antarctic Circles?

    The Arctic and Antarctic Circles denote the farthest latitudinal migrations of the circle of illumination (the boundary between the lighted and darkened halves of the Earth).

15. If the solar declination were 10^o, where would the Arctic and Antarctic Circles be found? Would this cause a change in the dates of the solstices, equinoxes, and perihelion and aphelion?

    The solar declination is simply the latitudinal position of the subsolar point. As such, the Arctic and Antarctic Circles, the solstices, equinoxes, and perihelion and aphelion would remain exactly as they are. In fact, the solar declination is at 10^o both north and south latitude, four times per year.

16. Pick a day in the Northern Hemisphere winter. Describe the changes in daylength and solar position you would encounter if you were to travel from the North Pole to South Pole. Do the same for a day in the Northern Hemisphere summer.

Daylength and solar position will decrease with increasing latitude in Northern Hemisphere winter and increase with latitude in the Southern Hemisphere summer. Therefore, a trip from the North Pole to the South Pole will begin in the darkness of the central Arctic and end in the perpetual light of the South Pole. As one travels south from the North Pole, daylength and solar position will increase. Maximum solar position will be along a line of latitude in the tropics which receives the vertical solar ray. Maximum daylength will occur within the Antarctic Circle where the day is 24 hours long.

Exactly opposite conditions will occur during Northern Hemisphere summer (Southern Hemisphere winter).

17. Explain why the equator always has 12 hours of sunlight.

It is always equally divided between the lighted and darkened halves of the Earth.

18. Explain how changes in solar position influence the intensity of radiation on a horizontal surface.

Energy concentration is greatly affected by changes in solar position. Energy intensity is greater when solar position in high. This concentrates more energy per unit area. Lower solar angles decreases the intensity of energy per unit area as a greater surface area is illuminated.

19. If you were to travel from the equator to the North Pole, on what day would variations in solar radiation be smallest? Why? Explain how day length and solar angle change as you move poleward.

Actually, this question could be answered in two ways depending on the viewpoint:

1. The latitudinal radiation gradient would be least for a hemisphere on the summer solstice. This is due to the fact that the subsolar point is at its greatest poleward latitude. Therefore, day length increases poleward with latitude. Thus, the entire high latitude “circle” region receives 24 hours of light which partially offsets radiation attenuation factors such as beam spreading, low solar declinations, and atmospheric attenuation (beam depletion). These factors are reflected in the small latitudinal thermal gradients characteristic of summer.

So, on June 21, the summer solstice, the solar declination is at 23.5^{o} N, the Tropic of Cancer. At the pole, the sun would be at its highest point in the sky, 23.5^{o} above the horizon. Thus the difference in energy receipt would be minimized on this day. Traveling from the equator to the North Pole one would see increasing solar angles at noon from the equator to the Tropic of Cancer. At the equator one would experience a non solar angle of 66.5^{o} while at the Tropic of Cancer the noon solar angle would be 90^{o}. After this point, the noon solar angle would decrease to a minimum of 23.5^{o} above the horizon at the North Pole. Moving from the equator to pole would also bring about a change in day length. At the equator, one would experience a day length of 12 hrs. This will increase to a maximum of 24 hrs at the Arctic Circle, 66.5^o.

2. The difference in radiation received across the latitudes would be least on either the equinox. This is due to the fact that all latitudes receive exactly the same amount of radiation at the top of the atmosphere as every line of latitude is equally bisected by the circle of illumination. Because every line of latitude is equally bisected, every location on Earth experiences a 12 hour day and a 12 hour night. However, due to beam spreading, beam depletion, and low solar angles, polar regions will receive less radiation than low latitude locations.

20. Burlington, Vermont, is located at 44.5^o N. What is the angle of the noontime Sun on either of the equinoxes and on the solstices?

Equinoxes = 45^o; summer solstice =68.5^o; winter solstice = 21.5^o.