Warming the Earth and the Atmosphere

Chapter Two begins by examining the concepts of temperature and heat. It then considers how heat energy is transferred in our atmosphere. Next, it covers the topics of absorption and emission of energy in terms of heating and cooling the earth. At this point we examine the atmospheric greenhouse effect and the various gases that produce it. Here we learn that without a greenhouse effect, the average surface temperature of our planet would be considerably colder than it is now. We also see that it is the enhancement of the greenhouse effect by the increasing concentrations of greenhouse gases that is of concern to most scientists. The section that follows describes how the earth and its atmosphere are warmed. Included here is a section on the energy balance of the earth and its atmosphere. Toward the end of the chapter is a discussion on seasonal temperature variations in the Northern and Southern Hemispheres. Here we learn that our seasons are caused by the earth being tilted on its axis as it revolves around the sun. The chapter concludes with a section that describes how seasonal variations in solar energy can influence temperatures on a much smaller scale, such as on the north and south side of a hill.

Some important concepts of this chapter:

1. The temperature of a substance is a measure of the average speed of its molecules.

2. The transfer of heat within our atmosphere can take place by conduction, convection and radiation.

3. Evaporation is a cooling process and condensation is a warming process.

4. Latent heat is an important source of atmospheric energy.

5. Rising air expands and cools, while sinking air is compressed and warms.

6. All objects with a temperature above absolute zero emit radiation.

7. The higher an object's temperature, the more total radiation emitted each second by the object and the shorter are the wavelengths of emitted radiation.

8. The earth's surface absorbs solar radiation only during the daylight hours; however, it constantly emits infrared radiation, both during the day and at night.

9. Water vapor and carbon dioxide are important atmospheric greenhouse gases that selectively absorb and emit infrared radiation, thereby keeping the earth's average surface temperature warmer than it would be otherwise.

10. Enhancement of the atmospheric greenhouse effect may be taking place because of the increasing concentrations of greenhouse gases.

11. The lower part of our atmosphere is mainly heated from below.

12. The annual average temperature of the earth and the atmosphere remains fairly constant from one year to the next because the amount of energy they absorb each year is equal to the amount of

energy they lose.

13. The seasons are caused by the earth being tilted on its axis as it revolves around the sun. This causes seasonal variations in both the length of daylight and the intensity of sunlight that reaches the surface.

14. When the Northern Hemisphere experiences winter (Dec., Jan., Feb.), the Southern Hemisphere experiences summer (and vice versa).

15. South-facing sides of hills tend to be warmer and drier than their north-facing counterparts.

Match the Following

_____ 1. Heat transfer process that depends upon the movement of air
_____ 2. Objects that selectively absorb and emit radiation
_____ 3. Rising bubbles of air
_____ 4. The heat we can feel and measure with a thermometer
_____ 5. The horizontal transfer of any atmospheric property by the wind
_____ 6. Energy transferred by electromagnetic waves
_____ 7. One millionth of a meter
_____ 8. A measure of the average speed of air molecules
_____ 9. The horizontal distance between two wave crests
_____ 10. This is released as sensible heat during the formation of clouds
_____ 11. The transfer of heat by molecule-to-molecule contact
_____ 12. The sun emits radiation with greatest intensity in this region of the spectrum
_____ 13. A temperature scale where 0^0 represents freezing and 100^0 boiling
_____ 14. Wavelengths longer than those of red light
_____ 15. Visible light given off by excited atoms and molecules in the upper atmosphere
_____ 16. Electromagnetic waves whose wavelengths are shorter than those of visible light
_____ 17. Temperature scale that begins at absolute zero

a. conduction
b. sensible heat
c. infrared
d. selective absorber
e. temperature
f. Kelvin
g. convection
h. aurora
i. radiation
j. wavelength
k. visible
1. thermals
m. latent heat
n. micrometer
o. ultraviolet
p. advection
q. Celsius

Additional Matching (The Seasons)

_____ 1. The astronomical beginning of fall
_____ 2. The day with the fewest hours of daylight in the Northern Hemisphere
_____ 3. The latitude at which days and nights are always of equal length
_____ 4. The day when, at noon, the sun is at its highest position in the Northern Hemisphere
_____ 5. The astronomical beginning of spring
_____ 6. An unseasonably warm spell with clear weather usually near the middle of autumn

a. winter solstice
b. vernal equinox
c. autumnal equinox
d. Indian summer
e. summer solstice
f. equator

Fill in the Blank

1. Energy of motion is also known as _____

2. Sunlight that bounces off a surface is said to be _____

3. A perfect absorber and a perfect emitter of radiation is called a _____

4. How much radiation would an object be emitting if its temperature were at absolute zero? _____

5. The _____ represents the reflectivity of a surface.

6. The two most significant atmospheric greenhouse gases in the earth's atmosphere are _____ and _____

7. At night objects on the ground cool by the process of emitting _____

8. The combined albedo of the earth and its atmosphere averages about _____ percent.

9. During January, it is winter in the Northern Hemisphere, and _____ in the Southern Hemisphere.

10. The sun emits maximum radiation in the _____ portion of the spectrum, while the earth emits maximum radiation at _____wavelenghs.

11. If the present concentration of $C0_2$ doubles in 100 years, climatic models predict that for the earth's average temperature to rise 5^0C, the gas _____ must also increase in concentration.

12. The sun will be directly above Honolulu, Hawaii (latitude 21^0N) _____ time(s) each year.

13. At the North Pole, the sun rises above the horizon on the vernal equinox and stays above the horizon until the _____

14. The wavelength range where neither water vapor nor carbon dioxide absorbs much of the earth's infrared radiation is known as the atmospheric _____.

15. Air that sinks, warms by _____

Multiple Choice

1. As the average speed of air molecules decreases, the temperature of the air:

    a. increases
    b. decreases
    c. does not change

2. The proper order of waves from longest to shortest is:

    a. visible, infrared, ultraviolet
    b. infrared, visible, ultraviolet
    c. ultraviolet, visible, infrared
    d. visible, ultraviolet, infrared
    e. ultraviolet, infrared, visible

3. Heat is energy in the process of being transferred from:

    a. low pressure to high pressure
    b. cold objects to hot objects
    c. high pressure to low pressure
    d. hot objects to cold objects
    e. regions of low density toward regions of high density

4. The rate at which radiant energy is emitted by a body:

    a. increases with decreasing temperature
    b. increases with increasing temperature
    c. does not depend on the body's temperature

5. If the earth had no atmospheric greenhouse effect, the average surface temperature would be:

    a. lower than at present
    b. higher than at present
    c. the same as it is now

6. Which below is *not* a primary reason for the seasons in the middle latitudes of the Northern Hemisphere?

    a. the closeness of the earth to the sun
    b. the angle at which sunlight reaches the earth
    c. the length of daylight hours

7. The moon's surface can only cool by (hint: the moon has no atmosphere):

    a. convection b. conduction
    c. radiation

8. The earth's atmospheric greenhouse effect is produced mainly by water vapor and carbon dioxide absorbing and re-emitting:

   a. visible radiation
   b. infrared radiation
   c. ultraviolet radiation

9. Annually, polar regions lose more heat energy than they receive, yet they are prevented from becoming progressively colder each year mainly by the:

   a. absorption of heat by snow and ice surfaces
   b. conduction of heat through the interior of the earth
   c. storage of heat in the soil beneath the snow cover
   d. circulation of heat by the atmosphere and oceans
   e. release of sensible heat to the atmosphere when the polar ice melts

10. The most important reason why summers in the Southern Hemisphere are not warmer than summers in the Northern Hemisphere is that:

   a. a greater percentage of the Southern Hemisphere is covered with water
   b. the earth is farther from the sun during the Southern Hemisphere summer

True-False

_____ 1. A degree Fahrenheit is larger than a degree Celsius.

_____ 2. Sinking air always warms and rising air always cools.

_____ 3. The earth comes closer to the sun in January than it does in July.

_____ 4. Incoming sunlight in middle latitudes is less in winter than in summer partly because the sun’s rays slant more and spread their energy over a larger area.

_____ 5. An air temperature of 0^0K would be the same as an air temperature of 0^0C.

_____ 6. In the middle latitudes of the Northern Hemisphere, between Christmas and New Year's, the length of daylight increases each day.

_____ 7. The sun's radiation is also referred to as shortwave radiation.

_____ 8. Clouds are poor absorbers and emitters of infrared radiation.

_____ 9. Only selective absorbers in the atmosphere emit radiation.

_____ 10. The term "latent" means hidden.

_____ 11. On the average, about 50 percent of the solar radiation that strikes the outer atmosphere eventually reaches the earth's surface.

_____ 12. An ultraviolet photon carries more energy than an infrared photon.

_____ 13. Air is a poor conductor of heat.

_____ 14. The earth's atmosphere behaves as a black body.

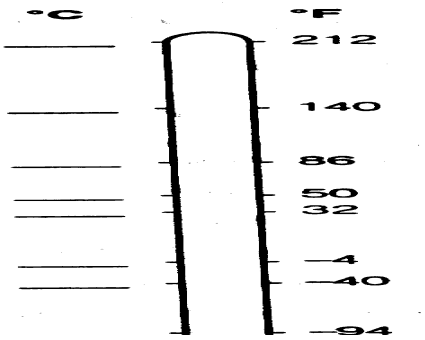
_____ 15. On the average, each year the earth-atmosphere system sends off into space just as much energy as it receives.

_____ 16. The earth emits most of its radiation in the ultraviolet portion of the spectrum.

_____ 17. An object with a high albedo appears brighter than an object with a low albedo.

_____ 18. The process of condensation releases sensible heat into the environment.

Additional Questions



1.In the spaces provided in Figure 1, convert the temperature from degrees Fahrenheit into degrees Celsius. (Hint: conversion factors are found in appendix A of your textbook.)

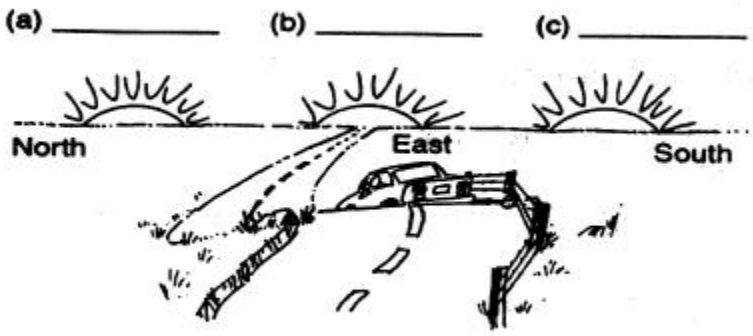


Figure 2

2. The above diagram (Fig. 2) represents sunrise on three different days. One day is the autumnal equinox (Sept.23), one is the Summer solstice (June 22), and the third is the winter solstice (Dec.22).

   a. In the space above each sun, place the proper date.

   b. Look back through old newspapers (and court records if available) to see if there is a propensity for accidents (both auto and pedestrian) near sunrise around the autumnal equinox in your area. If there is, explain why with the aid of figure 2.

Additional Readings

"Astronomical vs. Meteorological Winter" by Thomas Schiatter, *Weatherwise,* Vol.38, No.1 (February 1985), p.42.

"All That's Best of Dark and Bright" by Craig F. Bohren, *Weatherwise*, Vol.43, No.3 (June 1990), p.160.

"Solar Energy-How Much Do We Receive?" by Uri Gamiel and Oved Kedem, *P4ysics Teacher,* Vol 21, No.9 (December 1983), p.573.

“The Awesome Aurora" by Roy S. Hall, *Weatherwise,* Vol.40, No.2 (April 1987), p.76.

“The Greenhouse Effect Revisited" by Craig F. Bohren, *Weatherwise*, Vol. 42 No.1 (February 1989), p.50.

"Trace Gases, $C0_2$, Climate and the Greenhouse Effect" by Gordon J. Aubrecht**,** II, *Physics Teacher***,** Vol.26, No.3 (March 1988), p.145.

"Solar Radiation and the Earth's Atmosphere" by William Kuhn and Susan Postawko, *Physics Teacher,* Vol.26, No.5 (May 1980), p.266.