SUMMARY

In this chapter, we have seen how the concepts of heat and temperature differ and how heat is transferred in our environment. We learned that latent heat is an important source of atmospheric heat energy. We also learned that conduction, the transfer of heat by molecular collisions, is most effective in solids. Because air is a poor heat conductor, conduction in the atmosphere is only important in the shallow layer of air in contact with the earth’s surface. A more important process of atmospheric heat transfer is convection, which involves the mass movement of air (or any fluid) with its energy from one region to another. Another significant heat transfer process is radiation—the transfer of energy by means of electromagnetic waves.

The hot sun emits most of its radiation as shortwave radiation. A portion of this energy heats the earth, and the earth, in turn, warms the air above. The cool earth emits most of its radiation as longwave infrared radiation. Selective absorbers in the atmosphere, such as water vapor and carbon dioxide, absorb some of the earth’s infrared radiation and radiate a portion of it back to the surface, where it warms the surface, producing the atmospheric greenhouse effect. Because clouds are both good absorbers and good emitters of infrared radiation, they keep calm, cloudy nights warmer than calm, clear nights. The average equilibrium 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.

Finally, we examined how the sun’s energy in the form of solar wind particles interacts with our atmosphere to produce auroral displays.

KEY TERMS

The following terms are listed (with page numbers) in the order they appear in the text. Define each. Doing so will aid you in reviewing the material covered in this chapter.

energy, 30
potential energy, 30
kinetic energy, 30
temperature, 30
heat, 31
absolute zero, 31
Kelvin scale, 31
Fahrenheit scale, 31
Celsius scale, 31
heat capacity, 32
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sensible heat, 33
conduction, 34
convection, 34
thermals, 35
advection, 36
radiant energy (radiation), 37
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radiant energy (radiation), 37
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wavelength, 37
micrometer, 37
photon, 37
Stefan-Boltzmann law, 38
Wien’s law, 38
longwave radiation, 39
shortwave radiation, 39
visible region, 39
ultraviolet (UV) radiation, 39
infrared (IR) radiation, 39
blackbody, 41
radiative equilibrium temperature, 42
selective absorbers, 42
Kirchhoff’s law, 42
greenhouse effect, 42
atmospheric window, 43
solar constant, 45
scattering, 46
reflected (light), 46
albedo, 46
solar wind, 50
aurora borealis, 51
aurora australis, 51
airglow, 52

QUESTIONS FOR REVIEW

1. How does the average speed of air molecules relate to the air temperature?
2. Distinguish between temperature and heat.
3. (a) How does the Kelvin temperature scale differ from the Celsius scale?
   (b) Why is the Kelvin scale often used in scientific calculations?
   (c) Based on your experience, would a temperature of 250 K be considered warm or cold? Explain.
4. Explain how in winter heat is transferred by:
   (a) conduction;
   (b) convection;
   (c) radiation.
5. How is latent heat an important source of atmospheric energy?
6. In the atmosphere, how does advection differ from convection?
7. How does the temperature of an object influence the radiation that it emits?
8. How does the amount of radiation emitted by the earth differ from that emitted by the sun?
9. How do the wavelengths of most of the radiation emitted by the sun differ from those emitted by the surface of the earth?
10. Which photon carries the most energy—infrared, visible, or ultraviolet?
11. When a body reaches a radiative equilibrium temperature, what is taking place?
12. If the earth’s surface continually radiates energy, why doesn’t it become colder and colder?
13. Why are carbon dioxide and water vapor called selective absorbers?
14. Explain how the earth’s atmospheric greenhouse effect works.
15. What gases appear to be responsible for the enhancement of the earth’s greenhouse effect?
16. Why do most climate models predict that the earth's average surface temperature will increase by an additional 3.0°C (5.4°F) by the end of this century?
17. What processes contribute to the earth's albedo being 30 percent?
18. Explain how the atmosphere near the earth's surface is warmed from below.
19. If a blackbody is a theoretical object, why can both the sun and earth be treated as blackbodies?
20. What is the solar wind?
21. Explain how the aurora is produced.

QUESTIONS FOR THOUGHT
1. Explain why the bridge in the diagram is the first to become icy.

2. Explain why the first snowfall of the winter usually "sticks" better to tree branches than to bare ground.
3. At night, why do materials that are poor heat conductors cool to temperatures less than the surrounding air?
4. Explain how, in winter, ice can form on puddles (in shaded areas) when the temperature above and below the puddle is slightly above freezing.
5. In northern latitudes, the oceans are warmer in summer than they are in winter. In which season do the oceans lose heat most rapidly to the atmosphere by conduction? Explain.
6. How is heat transferred away from the surface of the moon? (Hint: The moon has no atmosphere.)
7. Why is ultraviolet radiation more successful in dislodging electrons from air atoms and molecules than is visible radiation?
8. Why must you stand closer to a small fire to experience the same warmth you get when standing farther away from a large fire?
9. If water vapor were no longer present in the atmosphere, how would the earth's energy budget be affected?
10. Which will show the greatest increase in temperature when illuminated with direct sunlight: a plowed field or a blanket of snow? Explain.
11. Why does the surface temperature often increase on a clear, calm night as a low cloud moves overhead?
12. Which would have the greatest effect on the earth's greenhouse effect: removing all of the CO₂ from the atmosphere or removing all of the water vapor? Explain why you chose your answer.
13. Explain why an increase in cloud cover surrounding the earth would increase the earth's albedo, yet not necessarily lead to a lower earth surface temperature.
14. Could a liquid thermometer register a temperature of −273°C when the air temperature is actually 1000°C? Where would this happen in the atmosphere, and why?
15. Why is it that auroral displays above Colorado can be forecast several days in advance?
16. Why does the aurora usually occur more frequently above Maine than above Washington State?

PROBLEMS AND EXERCISES
1. Suppose that 500 g of water vapor condense to make a cloud about the size of an average room. If we assume that the latent heat of condensation is 600 cal/g, how much heat would be released to the air? If the total mass of air before condensation is 100 kg, how much warmer would the air be after condensation? Assume that the air is not undergoing any pressure changes. (Hint: Use the specific heat of air in Table 2.1, p. 32.)
2. Suppose planet A is exactly twice the size (in surface area) of planet B. If both planets have the same exact surface temperature (1500 K), which planet would be emitting the most radiation? Determine the wavelength of maximum energy emission of both planets, using Wien's law.
3. Suppose, in question 2, the temperature of planet B doubles.
   (a) What would be its wavelength of maximum energy emission?
(b) In what region of the electromagnetic spectrum would this wavelength be found?

(c) If the temperature of planet A remained the same, determine which planet (A or B) would now be emitting the most radiation (use the Stefan-Boltzmann relationship). Explain your answer.

4. Suppose your surface body temperature averages 90°F. How much radiant energy in W/m² would be emitted from your body?