Boxed Content Answers
p. 40
2–1–1 Electrons orbit the nucleus of atoms in prescribed zones called shells.
2–1–2 Photons at shorter wavelengths have more energy than photons at longer wavelengths.

p. 43
2–2–1 Core, photosphere, and chromosphere.
2–2–2 Granules are the ever-present tops of convection cells that transport energy from the base of the photosphere to its surface. Sunspots (each lasting a few weeks or months) are dark regions on the photosphere with diameters of about 10,000 km (6000 mi) and temperatures about 1500 °C cooler than the surrounding surface. Flares are intensely hot flashes (perhaps 100 million °C) across the photo- sphere surface due to magnetic instabilities.

Checkpoint Answers
p. 35
1. Potential energy is energy that is stored and is not yet in use.
2. A raindrop will contain potential energy as long as it is suspended in a cloud. As the raindrop begins to fall, gravity is responsible for turning the potential energy into kinetic energy.

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3. Energy is transferred by conduction when there is molecule-to-molecule contact without appreciable movement. When a gas or liquid is heated (or cooled) and mixed, energy is transferred by convection (remember that the atmosphere is a gas, and acts like a very thin liquid). Transfer of energy by radiation requires no medium in between. Neither liquid nor solid is required.
4. As the fire burns, the potential energy stored in the wood is changed into heat energy that radiates upward to the cooking pot (radiation). The heat energy is absorbed by the cooking pot and transferred to both the soup and the cook's hand (conduction). The soup is then mixed by the heat from the bottom of the iron pot, and rises to the top. The cooler soup from the top then circulates downward (convection) and becomes warmed.

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5. Electromagnetic radiation is a type of energy which contains both electric and magnetic fields, oscillating in waves.
6. Depending on the frequency (the distance between waves), electromagnetic radiation will appear and behave differently. These differing "wavelengths" are categorized into bands ranging from short-wave to long-wave.

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7. An increase in temperature will bring a much larger increase in radiation. The Stefan-Boltzmann Law indicates that radiation will increase to a factor of four times more than the temperature increase.
8. An increase in temperature would result in four times more radiation from the Earth.

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9. The higher an object's temperature, the shorter the wavelength of its radiation.
10. In the infrared, cooler clouds will radiate at longer wavelengths than warmer clouds. By imaging these differences (by assigning different wavelengths to different shades of white and gray), we can tell where the clouds are both day and night. The cooler the cloud, the brighter it is in the image, and the higher it is in the atmosphere. Identifying the cloud's temperature and comparing it to an upper-air observation can then tell us the height of the cloud. Thicker, lower clouds will radiate at longer wavelengths, and appear as a darker grey. Colors can be applied to the image for more precise analysis.

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11. As electromagnetic energy moves through space it is not depleted as it moves toward Earth. Radiation traveling through space carries the same amount of energy and has the same wavelength as when it left the solar surface. However, at greater distances from the Sun, it is distributed over a greater area, which reduces its intensity.
12. The solar constant is the amount of solar energy received by a surface perpendicular to the incoming rays at the mean Earth–Sun distance. Consider a sphere completely surrounding the Sun whose radius is equal to the mean distance between Earth and the Sun. As the distance from the Sun increases, the intensity of the radiation diminishes in proportion to the distance squared. This relationship is known as the inverse square law.

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13. On the winter solstice the Earth has the minimum tilt towards the sun, on the summer solstice maximum tilt, and intermediate tilt on the equinoxes in the Northern Hemisphere..
14. As the sun appears to be higher or lower in the sky during the year, the point with the most intense midday heating will move as well. The latitude of this point varies during the year from the Tropic of Cancer (23 1/2° north latitude) on the June solstice to the Equator (0° latitude) on the September equinox, to the Tropic of Capricorn (23 1/2° south latitude) on the December solstice, and back to the Equator on the March equinox.

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15. A lower solar angle and day length equates to less heating and high solar angle and day length equate to high heating.
16. There is greater variability in solar angle and day length at higher latitudes as compared to lower latitudes creating a greater seasonality.

Review Question Answers

1. Potential Energy (stored for use) Water behind a dam, energy in a battery, pressure in a can or bottle or fire extinguisher, energy stored in firewood, food energy, fuels, and a can on a high shelf (potential energy from gravity), a race car or locomotive at rest, leaves on

a tree, a raindrop or snowflake in a cloud. Kinetic Energy (in use) Visible light, heat (radiation energy), a race car or locomotive in motion, electricity, falling leaves, falling rain or snow

2. Conduction is transfer of energy from molecule to molecule by touching. Convection is transfer of energy through the mixing of a liquid or gas.

3. “Electromagnetic” refers to the properties of a wave. One part is an electrical field, one part is a magnetic field. Differing lengths of waves (wavelengths) result in different characteristics of their radiation. The hotter an object’s temperature is, the shorter the wavelength and the more energetic the radiation.

4. Some objects and gases have “selective absorption.” This means that the same amount of radiation will produce different results. Most notably, atmospheric gases respond differently to short-wave (solar) and long-wave (Earth) radiation.

5. X-ray, Ultraviolet (UV), Visible, Infrared (IR), microwave

6. The Kelvin scale measures very low temperatures including absolute zero.

7 As the temperature of an object increases, its radiation increases by a power of 4 (Stefan-Boltzmann’s Law). Its emissivity depends on its temperature as well, but “selective emissivity” means that some gases behave differently than others.

8. 341.75 w/m2

9. The angle of the sun.

10. The latitude of the solar declination (the point where the sun is directly overhead at noon, or sub-solar point) reaches its northern maximum on the June solstice at 23 1/2° north latitude (the Tropic of Cancer), and moves to the Equator (0° latitude) on the September equinox, the south to 23 1/2° south latitude on the December solstice (Tropic of Capricorn) and then back to the Equator on the March equinox.

11. The Arctic and Antarctic Circles denote the lines poleward of which there is either no light or 24 hours of light at the solstices. For example, the area north of the Arctic Circle receives 24 hours of sun on the June solstice, when the area south of the Antarctic Circle is in complete darkness.

12. The Arctic and Antarctic Circles are computed by subtracting the tilt of the Earth from 90°. For today, they are at 66 1/2° north and south latitude (90-23 1/2°). If the Earth were tilted at 10°, the Arctic and Antarctic Circles would be at 80° north and south latitude (90-10°). The dates of solstices, equinoxes, perihelion, and aphelion would not change.

13. Example: December solstice (beginning of northern hemisphere winter) North Pole: Sun is below the horizon, darkness is 24 hours Tropic of Cancer: shortest daylight of the year Equator: 12 hours of sunlight Tropic of Capricorn: Longest daylight of the year South Pole: Sun is above horizon for 24 hours. Example: June solstice (beginning of northern hemisphere summer) North Pole: Sun is above horizon for 24 hours Tropic of Cancer: Longest daylight of the year Equator: 12 hours of sunlight Tropic of Capricorn: Shortest daylight of the year South Pole: Sun is below horizon for 24 hours

14. Although the sun appears to travel north and south of the Equator during the year, it is always visible above the Equator. This is the point on the curved surface of the Earth that receives 12 hours of light every day. Daylight increases and decreases north and south of the Equator depending on the season, except on the equinoxes, when the entire Earth receives 12 hours of light and dark.

15. As the angle of the sun decreases (the sun appears lower in the sky) the same amount of solar radiation becomes spread over a larger area (beam spreading). This results in a reduction of total incoming solar radiation.
16. In the northern hemisphere, the day with the least variation in solar radiation would be the June solstice. Because beam spreading would be at a minimum (compared to the southern hemisphere), the radiation received would vary the least. The length of day would vary from 12 hours at the Equator to 24 hours at the pole
17. Angle of noontime sun= (90-latitude) = declination June solstice = (90°-44.5°)+23.5° (Sun over Tropic of Cancer)=45.5°+23.5°=67.5° September and March equinox = (90°-44.5°)+0°(sun over Equator)=45.5° December solstice = (90°-44.5°)-23.5° (negative because sun is over Tropic of Capricorn in southern hemisphere below the Equator)=44.5°-23.5°=22.0°

Critical Thinking Questions
1. Air is a poor conductor. Cold from the outside and warmth from the inside do not "conduct" through the air pockets.
2. Technically, no. The heat from the hot water is transferred through the pipes, and then through the tiles, by conduction. It then rises into the room by convection.
3. The sun's radiation is received at more wavelengths than visible light (ultraviolet, infrared, etc.)
4. The earth would receive the same total radiation as a whole. However, how much energy is reflected, stored and reradiated could change. For example, slower rotation would mean longer exposure of land areas to solar radiation. They would heat up and cool off more rapidly)
5. Yes. Latitude does not change.
6. There is less variation in solar insolation in the tropics than at higher latitudes.
7. Clouds and atmospheric gases absorb and reradiate solar radiation. Albedo from the ocean and ice reduce incoming radiation as well. On the moon, with a very, very thin atmosphere and no clouds, the solar angle and small differences in the albedo would be the only factors affecting how much radiation reaches the surface.
8. Temperatures would rise and fall earlier in the day on east- facing slopes. The opposite is true for west-facing slopes.
9. The angle of incidence would be 0°. The length of the slope from top to bottom would increase the atmospheric path length. The sunlight beam would be spread over the entire distance.
10. The sun would appear to circle the sky just above the horizon.
11. There would still be 12 hours of daylight, but the sun would rise and set further north of east on the June solstice, and rise and set further south of east on the December solstice.

Chapter 2 Exercises and Problems

1. Stefan-Boltzman law, $I = \sigma T^4$. The ocean temperature would be $T^4 = \sigma/I$
2. The reduction in emissivity.
3. 1361 W/m^2 / 9.5 = 143 W/m^2 solar constant for Saturn. The distribution of wavelengths should be the same.
4. Calculate solar constant using inverse square law with perihelion and aphelion distances in place of average 5×10^{11} m.

5. The noon solar angle for 10°N is approximately 77° on the summer solstice and 57° on the winter solstice. The noon solar angle for 30°N is approximately 83° on the summer solstice and 37° on the winter solstice. Such difference indicate greater seasonality at 30°N
6. Higher latitudes will always have greater variability in solar angle and as a result have greater seasonality.

Chapter 2 Visual Analysis

1. Infrared radiation.
2. The flames color would change to shorter wavelength colors if hotter and turn green or blue.
3. Wien's Law.