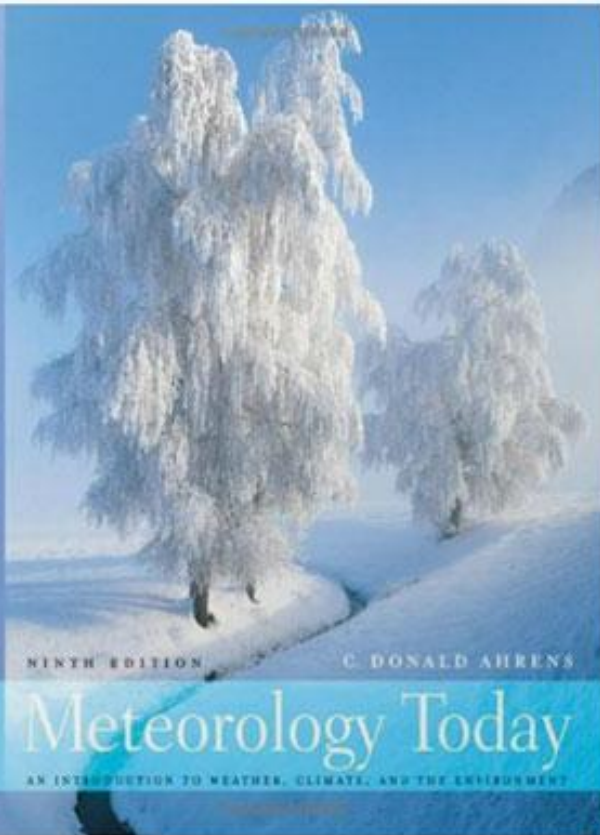# TEST BANK

NINTH EDITION

C. DONALD AHRENS

Meteorology Today

AN INTRODUCTION TO WEATHER, CLIMATE, AND THE ENVIRONMENT

Chapter 2
Energy: Warming the Earth and the Atmosphere

Chapter Summary

This chapter begins with a definition of temperature and a comparison of the absolute (Kelvin), Celsius, and Fahrenheit temperature scales. Heat, the flow of energy between objects having different temperatures, occurs in the atmosphere by the processes of conduction, convection, and radiation. Air is a relatively poor conductor of heat but can transport heat efficiently over large distances by the process of convection. The latent heat energy associated with changes of phase of water is shown to be a very important energy transport mechanism in the atmosphere also. A physical explanation of why rising air cools and sinking air warms is given.

The nature of and rules which govern the emission of electromagnetic radiation are reviewed next. Students should find the discussion of sun burning and UVB radiation in this section interesting and relevant. The atmospheric greenhouse effect and the exchange of energy between the earth's surface, the atmosphere, and space are examined in detail. As the role of greenhouse gases in climate change is undergoing vigorous investigation, the latest research results are presented. Students will see that, because the amounts of energy absorbed and emitted by the earth are in balance, the earth's average radiative equilibrium temperature varies little from year to year. Students should understand that the energy the earth absorbs from the sun consists primarily of short-wave radiation. Energy emitted by the earth is almost entirely in the form of infrared radiation. Selective absorbers in the atmosphere, such as water vapor and carbon dioxide, absorb some of the earth's infrared radiation and re-radiate a portion of it back to the surface. Because of this effect, the earth's average surface temperature is much higher than would otherwise be the case. A useful focus section describes this effect in the context of radiative equilibrium. Results from recent research relating to the effect of increasing concentrations of carbon dioxide and other greenhouse gases and the effects of clouds on the earth's energy balance are reviewed.

The final portion of the chapter describes the physical characteristics of the sun and the causes of the aurora.

The chapter includes focus sections on "The Fate of a Sunbeam," "Rising Air Cools and Sinking Air Warms," Wave Energy, Sun Burning, and UV Rays," "Blue Skies, Red Suns, and White Clouds," and "Characteristics of the Sun."

Teaching Suggestions

1.   Heat a thin iron bar in a flame (from a Bunsen burner or a propane torch). Begin by holding the bar fairly close to the end of the bar. Students will see that heat is quickly conducted through the metal when the instructor is forced to move his or her grip down the bar. Repeat the demonstration with a piece of glass tubing or glass rod. Glass is a poor conductor, and the instructor will be able to comfortably hold the glass just 2 or 3 inches from the tip. Ask the students if they believe energy is being transported away from the hot glass and if so, how? Without heat loss by conduction, the glass will get hotter than the iron bar and the tip should begin to glow red—a good demonstration of energy transport by radiation. Faint convection currents in the air can be made visible if the hot piece of glass is held between an overhead projector and the projection screen. Ask the students what they would do to quickly cool a hot object. Many will suggest blowing on it, an example of forced convection. Someone might suggest plunging the hot object into water. This makes for a satisfying end to the demonstration. Evaporating water can be seen and heard when the hot iron rod is put into the water (the glass will shatter if placed in the water). The speed with which the rod is cooled is proof of the large amount of latent heat energy associated with changes of phase.

2.   Ask the students whether they believe water could be brought to a boil most rapidly in a covered or an uncovered pot. The question can be answered experimentally by filling two beakers with equal amounts of water and placing them on a single hot plate (to insure that energy is supplied to both at equal rates). It is a good idea to place boiling stones in the beakers to insure gentle boiling. Cover one of the beakers with a piece of foil. The covered pot will boil first. Explanation: a portion of the energy added to uncovered pot is used to evaporate water, not to increase the water's temperature.

3.   The concept of equilibria is sometimes difficult for students to grasp. Place a glass of water on a table top and ask the students whether they think the temperature of the water in the glass is warmer, cooler, or the same as the surroundings. Many will say it is the same. Ask the students whether they think there is any energy flowing into or out of the glass. With some encouragement, they will recognize that the water is slowly evaporating and that this represents energy flow out of the glass. Energy flowing out of the glass will cause the water's temperature to decrease. Will the water just continue to get colder and colder until it freezes? No, as soon as the water's temperature drops below the temperature of the surroundings, heat will begin to flow into the water. The rate at which heat flows into the glass will depend on the temperature difference between the glass and the surroundings. The water temperature will decrease until energy flowing into the glass balances the loss due to evaporation.

4.   Use a lamp with a 150 Watt reflector bulb to help explain the concept of radiation intensity. Blind-fold a student and hold the lamp at various distances from the student's back. Ask the student to judge the distance of the bulb. Use the same lamp to illustrate the concepts of reflection, albedo, and absorption by measuring the amount of reflected light from various colored surfaces with a sensitive light meter. The reflectivity of natural surfaces outdoors could be measured or form the basis for a student or group project.

5.   A 200 Watt clear light bulb connected to a dimmer switch can be used to illustrate how the temperature of an object affects the amount and type of radiation that the object will emit. Explain that passage of electricity through the resistive filament heats the filament. The filament's temperature will increase until it is able to emit energy at the same rate as it gains energy from the electric current. With the dimmer switch set low, the bulb can be made to glow a dull red. At low temperatures, the bulb emits low-intensity, longwave radiation. As the setting on the dimmer switch is increased, the color of the filament will turn orange, yellow, and then white as increasing amounts of shortwave radiation are emitted. The intensity of the radiation will increase dramatically.

6.   Many students don't understand that a colored object appears that way because it reflects or scatters light of that color. The object isn't emitting visible light (ask the student whether they would see the object if all the lights in the room were turned off). Some students have the misconception that a green object reflects all colors but green. Similarly it is important that students understand that a red or green filter transmits red or green light. Put a red and a green (or blue) filter on an overhead projector and draw a hypothetical filter transmission curve. Put the two filters together and show that no light is transmitted. Ask students what happens to the light that is not transmitted by the filter.

7.   Thought experiment to illustrate the magnitude of latent heat of evaporation/condensation: Ask students to think about taking a hot shower. Their body temperature is ~ 100°F; the water temperature is > 100°F; the air temperature in the room is ~75°F. Why, then, do you feel cold when you step, dripping wet, out of the shower?

8.   Use the Energy Budget for Earth/Atmosphere section of the Meteorology Resource Center to step through the earth-atmosphere energy balance at various times of day, to demonstrate the magnitudes of the different energy budget components.

Student Projects

1.   Solar irradiance (energy per unit time per unit area) at the ground can be measured relatively easily. Begin with a rectangular piece of aluminum a few inches on a side and 3/8 or 1/2 inch thick. Drill a hole in one side so that a thermometer can be inserted into the middle of the block. Paint one of the two surfaces with flat black paint. Position the block in a piece of Styrofoam insulation so that the painted surface faces outward and is flush with the Styrofoam surface. Insert the thermometer into the side of the block. Orient the block so that the black surface is perpendicular to incident radiation from the sun. Note the time and measure the block temperature every 30 seconds for 10 to 15 minutes. When plotted on a graph, students should find that temperature, T, increases linearly with time, t. The slope of this portion of the graph can be used to infer the solar irradiance, S, using the following equation:

$$S = \frac{mass \times specific\ heat}{area} \times \frac{\Delta T}{\Delta t}$$

2.	Use the Energy Budget for Earth/Atmosphere section of the Meteorology Resource Center to compare the solar energy balance for Goodwin Creek, MS and Fort Peck, MT. What are the noontime albedos for each location? Why are they different? Which component of the albedo (earth's surface, clouds, or atmosphere) dominates in each case? Explain why.

3.	Using the Energy Budget for Earth/Atmosphere section of the Meteorology Resource Center, compare the values of the wintertime earth-atmosphere energy balance components for Penn State, PA and Desert Rock, NV. Explain any differences you find.

Answers to Questions for Review

1.	Temperature is a measure of the average speed of atoms and molecules.

2.	Heat is energy in the process of being transferred from one object to another because of the temperature difference between them.

3.	a. Each degree on the Kelvin scale is exactly the same size as a degree Celsius, and a temperature of 0 K is equal to –273°C.
b. Because there are no negative values
c. Cold, because 250K = -23°C = -9°F

4.	Conduction: The transfer of heat from molecule to molecule within a substance. Convection: The transfer of heat by the mass movement in liquids and gases. Radiation: Heat transfer from one object to another without the space between them necessarily being heated.

5.	When water vapor condenses into clouds, latent heat is released into the atmosphere. This provides a tremendous amount of heat in storms, such as thunderstorms and hurricanes.

6.	Advection is horizontal; convection is vertical.

7.	A small increase in temperature results in a large increase in the amount of radiation emitted, because doubling the absolute temperature of an object increases the maximum energy output by a factor of 16, which is 24.

8.	Because the earth is cooler than the sun, it emits a lot less radiation than the sun.

9.	Because the earth is cooler, its radiation is at longer wavelengths than that of the sun.

10.	Ultraviolet

11.	The amount of radiation entering the surface of the body equals the amount exiting the surface of the body.

12.	Because it is also continually receiving energy from the sun and the atmosphere.

13.	Because they absorb radiation at certain wavelengths and not others.

14. The atmosphere allows visible radiation to pass through, but inhibits, to some degree, the passage of infrared radiation leaving the earth's surface.

15. CO_2, methane (CH_4), nitrous oxide (N_2O), and chlorofluorocarbons (CFCs)

16. By enhancing the earth's greenhouse effect

17. Reflection and scattering of solar radiation by the atmosphere, clouds, and the earth's surface.

18. Longwave radiation from the earth, conduction and convection

19. Because they absorb and radiate with nearly 100 percent efficiency for their respective temperatures.

20. Charged particles (ions and electrons), or plasma, travelling through space.

21. The aurora is produced by the solar wind disturbing the magnetosphere. The disturbance involves high-energy particles within the magnetosphere being ejected into the earth's upper atmosphere, where they excite atoms and molecules. The excited atmospheric gases emit visible radiation, which causes the sky to glow like a neon light.

Answers to Questions for Thought

1. The bridge will become icy first because it is able to lose heat energy over its entire surface; it cools on top, on the sides, and on the underside. The road, on the other hand, loses heat energy quickly, but only at its upper surface. Also, when the road begins to cool, heat may flow up from warmer ground below.

2. The branches cool rapidly by emitting infrared energy. The bare ground cools also, but it gains heat from the warmer soil below. Thus, the temperature of the bare ground may not drop below freezing and the freshly fallen snow will melt.

3. These objects must be good emitters of radiation. Good emitters of radiation will cool to temperatures less than that of the surrounding air. Energy lost by radiation is not quickly replaced by conduction. Air is a selective emitter of radiation and does not cool as rapidly as the ground.

4. The ice can form when the air is <u>dry</u> and a <u>strong wind</u> blows over the water, causing rapid evaporation and cooling to the freezing point.

5. Winter. Even though the oceans are cooler in winter than in summer, there is a greater temperature contrast between the oceans and the atmosphere in winter.

6. In the form of electromagnetic radiation only

7.	Ultraviolet radiation carries more energy per photon than visible radiation does.

8.	At a given distance from the large fire, the energy received per unit area and per unit time is greater than the energy received at the same distance from the small fire.

9.	Without water vapor to absorb the earth's emitted infrared radiation, the earth will lose more heat.

10.	A plowed field. A plowed field is dark and has a low albedo; it is a poor reflector and a good absorber of sunlight. The snow surface has a high albedo and is a good reflector and poor absorber of sunlight.

11.	The low cloud absorbs energy emitted by the earth's surface and re-radiates infrared radiation back to the surface. A portion of the energy lost by the earth is returned.

12.	Removing the water vapor, because water vapor is a strong absorber of infrared radiation and atmospheric concentrations of H_2O are much higher than concentrations of CO_2.

13.	An increase in cloud cover would increase the earth-atmosphere albedo and, thus, less sunlight would reach the earth's surface. Depending on the height and thickness of the cloud cover, the clouds might absorb more infrared earth radiation and, thus, tend to strengthen the atmospheric greenhouse effect.

14.	This could happen in the upper atmosphere where the air is quite thin. Here the molecules move at average speeds proportional to a temperature of 1000 ºC. However, few molecules would strike the thermometer and transfer heat to it. Consequently, the thermometer would lose energy much faster than it would gain energy. The thermometer would cool until it eventually registered a temperature near -273 ºC.

15.	The energized particles from a large solar flare, that may produce auroral displays at lower latitudes, usually take a day or so to reach the earth's outer atmosphere.

16.	In Fig. 2.22, note that the aurora belt extends closer to Maine than to Washington state. The aurora belt circles the magnetic north pole, not the geographic North Pole.

Answers to Problems and Exercises

1.	500 g x 600 cal/g = 300,000 calories
	300,000 cal/(100,000 g x 0.24 cal/gm ºC) = 12.5 ºC warmer

2.	Planet A, with the largest surface area, would be emitting the most radiation. The wavelength of maximum emission for both planets would be $\square$ = 3000/1500 = 2 $\square$m.

3.   (a) the wavelength of maximum emission for Planet B would be 1 μm.
        (b) Near-infrared.
        (c) Once its temperature is doubled, Planet B emits 8 times more energy per unit time than
         Planet A. Once its temperature doubles, Planet B would emit 16 times more energy per unit
         area of surface than Planet A (Stefan-Boltzmann law). Planet B has only half the total surface
         area that Planet A does however.

4.   Radiant energy $E = \sigma T^4$. Converting T from Fahrenheit to Kelvin gives T = [5/9 x (90-32) +
        273] = 305.2 K. Using T = 305.2 K and σ=5.67 x 10^{-8} $W/m^2/K^4$, we find E = 492 W/m^2.

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Multiple Choice Questions

1.   Which of the following provides a measure of the average speed of air molecules?
       a. pressure
       b. temperature
       c. density
       d. heat

ANSWER: b

2.   A change of one degree on the Celsius scale is _____ a change of one degree on the Fahrenheit scale.
       a. equal to
       b. larger than
       c. smaller than
       d. is in the opposite direction of

ANSWER: b

3.   Which of the following is <u>NOT</u> considered a temperature scale?
       a. Fahrenheit
       b. Kelvin
       c. Calorie
       d. Celsius

ANSWER: c

4.   The temperature scale where $0°$ represents freezing and $100°$ boiling is called:
       a. Fahrenheit.
       b. Celsius.
       c. Kelvin.
       d. absolute.

ANSWER: b

5.   The temperature scale that sets freezing of pure water at $32°$ F is called:
       a. Kelvin.
       b. Fahrenheit.
       c. Celsius.
       d. British.

ANSWER: b

6.	If the temperature of the air is said to be at absolute zero, one might conclude that:
	a. the motion of the molecules is at a maximum.
	b. the molecules are occupying a large volume.
	c. the molecules contain a minimum amount of energy.
	d. the temperature is 0° F.
	e. the air temperature is 0° C.

ANSWER: c

7.	In the Celsius temperature scale, what is the significance of the temperature increment of 1°C?
	a. It is the freezing point of water.
	b. It is the boiling point of salt water.
	c. It is one-tenth of the interval between the freezing point and the boiling point of water.
	d. It is one-tenth of the interval between the freezing point and the boiling point of salt water.
	e. It is 1/100 of the interval between the freezing point and the boiling point of water.

ANSWER: e

8.	Energy of motion is also known as:
	a. dynamic energy.
	b. kinetic energy.
	c. sensible heat energy.
	d. static energy.
	e. latent heat energy.

ANSWER: b

9.	Heat is energy in the process of being transferred from:
	a. hot objects to cold objects.
	b. low pressure to high pressure.
	c. cold objects to hot objects.
	d. high pressure to low pressure.
	e. regions of low density toward regions of high density.

ANSWER: a

10.	The heat energy released when water vapor changes to a liquid is called:
	a. latent heat of evaporation.
	b. latent heat of fusion.
	c. latent heat of fission.
	d. latent heat of condensation.

ANSWER: d

11.	The change of state of ice into water vapor is known as:
	a. deposition.
	b. sublimation.
	c. melting.
	d. condensation.
	e. crystallization.

ANSWER: b

12.	When water changes from a liquid to a vapor, we call this process:
	a. freezing.
	b. condensation.
	c. sublimation.
	d. deposition.
	e. evaporation.

ANSWER: e

13.	What is released as sensible heat during the formation of clouds?
	a. potential energy
	b. longwave radiation
	c. latent heat
	d. shortwave radiation
	e. kinetic energy

ANSWER: c

14.	The cold feeling that you experience after leaving a swimming pool on a hot, dry, summer day represents heat transport by:
	a. conduction.
	b. convection.
	c. radiation.
	d. latent heat.

ANSWER: d

15.	The term "latent" means:
	a. late.
	b. hot.
	c. light.
	d. hidden.
	e. dense.

ANSWER: d

16.   The processes of condensation and freezing:
        a. both release sensible heat into the environment.
        b. both absorb sensible heat from the environment.
        c. do not affect the temperature of their surroundings.
        d. do not involve energy transport.

ANSWER: a

17.   The transfer of heat by molecule-to-molecule contact is:
        a. conduction.
        b. convection.
        c. radiation.
        d. ultrasonic.

ANSWER: a

18.   Which of the following is the poorest conductor of heat?
        a. still air
        b. water
        c. ice
        d. snow
        e. soil

ANSWER: a

19.   The horizontal transport of any atmospheric property by the wind is called:
        a. advection.
        b. radiation.
        c. conduction.
        d. latent heat.
        e. reflection.

ANSWER: a

20.   A heat transfer process in the atmosphere that depends upon the movement of air is:
        a. conduction.
        b. absorption.
        c. reflection.
        d. convection.
        e. radiation.

ANSWER: d

21.   The amount of heat energy required to bring about a small change in temperature is called the:
        a. radiative equilibrium.
        b. dead heat.
        c. specific heat.
        d. latent heat.

ANSWER: c

22.   Snow will usually melt on the roof of a home that is a:
        a. good radiator of heat.
        b. good conductor of heat.
        c. poor radiator of heat.
        d. poor conductor of heat.

ANSWER: b

23.   Rising air cools by the process of _____.
        a. expansion
        b. evaporation
        c. compression
        d. condensation

ANSWER: a [p.

24.   The temperature of a rising air parcel:
        a. always cools due to expansion.
        b. always warms due to expansion.
        c. always cools due to compression.
        d. always warms due to compression.
        e. remains constant

ANSWER: a

25.   The proper order from shortest to longest wavelength is:
        a. visible, infrared, ultraviolet.
        b. infrared, visible, ultraviolet.
        c. ultraviolet, visible, infrared.
        d. visible, ultraviolet, infrared.
        e. ultraviolet, infrared, visible.

ANSWER: c

26.   Sinking air warms by the process of:
        a. compression.
        b. expansion.
        c. condensation.
        d. friction.

ANSWER: a

27.   Heat transferred outward from the surface of the moon can take place by:
        a. convection.
        b. conduction.
        c. latent heat.
        d. radiation.

ANSWER: d

28.   How do red and blue light differ?
        a. Blue light has a higher speed of propagation.
        b. The wavelength of red light is longer.
        c. Red light has a higher intensity.
        d. Red and blue light have different directions of polarization.

ANSWER: b

29.   If the average temperature of the sun increased, the wavelength of peak solar emission would:
        a. shift to a shorter wavelength.
        b. shift to a longer wavelength.
        c. remain the same.
        d. be impossible to tell from given information.

ANSWER: a

30.   Solar radiation reaches the earth's surface as:
        a. visible radiation only.
        b. ultraviolet radiation only.
        c. infrared radiation only.
        d. visible and infrared radiation only.
        e. ultraviolet, visible, and infrared radiation.

ANSWER: e

31.   Electromagnetic radiation with wavelengths between 0.4 and 0.7 micrometers is called:
        a. ultraviolet light.
        b. visible light.
        c. infrared light.
        d. microwaves.

ANSWER: b

32.   The sun emits a maximum amount of radiation at wavelengths near _____, while the earth emits maximum radiation near wavelengths of _____.
    a. 0.5 micrometers, 30 micrometers
    b. 0.5 micrometers, 10 micrometers
    c. 10 micrometers, 30 micrometers
    d. 1 micrometer, 10 micrometers

ANSWER: b

33.   The blueness of the sky is mainly due to:
    a. the scattering of sunlight by air molecules.
    b. the presence of water vapor.
    c. absorption of blue light by the air.
    d. emission of blue light by the atmosphere.

ANSWER: a

34.   Which of the following determine the kind (wavelength) and amount of radiation that an object emits?
    a. temperature
    b. thermal conductivity
    c. density
    d. latent heat

ANSWER: a

35.   Often before sunrise on a clear, calm, cold morning, ice (frost) can be seen on the tops of parked cars, even when the air temperature is above freezing. This condition happens because the tops of the cars are cooling by _____.
    a. conduction
    b. convection
    c. latent heat
    d. radiation

ANSWER: d

36.   One micrometer is a unit of length equal to:
    a. one million meters
    b. one millionth of a meter
    c. one tenth of a millimeter
    d. one thousandth of a meter

ANSWER: b

37. Evaporation is a _____ process.
    a. cooling
    b. heating
    c. can't tell - it depends on the temperature
    d. cooling and heating

ANSWER: a

38. If you want to keep an object cool while exposed to direct sunlight,
    a. put it inside a brown paper bag.
    b. wrap it in black paper.
    c. wrap it in aluminum foil with the shiny side facing inward.
    d. wrap it in aluminum foil with the shiny side facing outward.

ANSWER: d

39. Which of the following has a wavelength shorter than that of violet light?
    a. green light
    b. blue light
    c. infrared radiation
    d. red light
    e. ultraviolet radiation

ANSWER: e

40. If the absolute temperature of an object doubles, the maximum energy emitted goes up by a factor of _____.
    a. 2
    b. 4
    c. 8
    d. 16
    e. 32

ANSWER: d

41. At which temperature would the earth be radiating energy at the greatest rate or intensity?
    a. -5°F
    b. -40°F
    c. 60°F
    d. 32°F
    e. 105°F

ANSWER: e

42.   How much radiant energy will an object emit if its temperature is at absolute zero?
       a. the maximum theoretical amount
       b. none
       c. the same as it would at any other temperature
       d. depends on the chemical composition of the object

ANSWER: b

43.   Most of the radiation emitted by a human body is in the form of:
       a. ultraviolet radiation and is invisible.
       b. visible radiation but is too weak to be visible.
       c. infrared radiation and is invisible.
       d. humans do not emit electromagnetic radiation.

ANSWER: c

44.   Clouds never form by:
       a. sublimation.
       b. condensation.
       c. evaporation.
       d. deposition.
       e. both sublimation and evaporation.

ANSWER: e

45.   The sun emits its greatest intensity of radiation in:
       a. the visible portion of the spectrum.
       b. the infrared portion of the spectrum.
       c. the ultraviolet portion of the spectrum.
       d. the x-ray portion of the spectrum.

ANSWER: a

46.   Air that rises always:
       a. contracts and warms.
       b. contracts and cools.
       c. expands and cools.
       d. expands and warms.

ANSWER: c

47. The earth's radiation is often referred to as _____ radiation, while the sun's radiation is often referred to as _____ radiation.
a. shortwave; longwave
b. shortwave; shortwave
c. longwave; shortwave
d. longwave; longwave

ANSWER: c

48. If the earth's average surface temperature were to increase, the amount of radiation emitted from the earth's surface would _____, and the wavelength of peak emission would shift toward _____ wavelengths.
a. increase; shorter
b. increase; longer
c. decrease; shorter
d. decrease; longer

ANSWER: a

49. A football field is about _____ micrometers long.
a. 10^{-8}
b. 10^{-6}
c. 10^{6}
d. 10^{8}

ANSWER: d

50. The earth emits radiation with greatest intensity at:
a. infrared wavelengths.
b. radio wavelengths.
c. visible wavelengths.
d. ultraviolet wavelengths.

ANSWER: a

51. "A good absorber of a given wavelength of radiation is also a good emitter of that wavelength." This is a statement of:
a. Stefan-Boltzmann's law.
b. Wien's Law.
c. Kirchhoff's Law.
d. the First Law of Thermodynamics.
e. the Law of Relativity.

ANSWER: c

52.   Which principle best describes why holes develop in snow around tree trunks?
        a. Snow is a good absorber of infrared energy.
        b. Snow is a good emitter of infrared energy.
        c. Snow is a poor reflector of visible light.
        d. Snow is a poor absorber of visible light.
        e. Snow is a poor absorber of ultraviolet light.

ANSWER: a

53.   Which of the following statements is not correct?
        a. Calm, cloudy nights are usually warmer than calm, clear nights.
        b. Each year the earth's surface radiates away more energy than it receives from the sun.
        c. The horizontal transport of heat by the wind is called advection.
        d. Good absorbers of radiation are usually poor emitters of radiation.

ANSWER: d

54.   Without the atmospheric greenhouse effect, the average surface temperature would be:
        a. higher than at present.
        b. lower than at present.
        c. the same as it is now.
        d. much more variable than it is now.

ANSWER: b

55.   The earth's atmospheric window is in the:
        a. ultraviolet region.
        b. visible region.
        c. infrared region.
        d. polar regions.

ANSWER: c

56.   The atmospheric greenhouse effect is produced mainly by the:
        a. absorption and re-emission of visible light by the atmosphere.
        b. absorption and re-emission of ultraviolet radiation by the atmosphere.
        c. absorption and re-emission of infrared radiation by the atmosphere.
        d. absorption and re-emission of visible light by clouds.
        e. absorption and re-emission of visible light by the ground.

ANSWER: c

57.   Suppose last night was clear and calm. Tonight low clouds will be present. From this you
        would conclude that tonight's minimum temperature will be:
        a. higher than last night's minimum temperature.
        b. lower than last night's minimum temperature.
        c. the same as last night's minimum temperature.
        d. above freezing.

ANSWER: a

58.   Which of the following is known primarily as a selective absorber of ultraviolet radiation?
        a. carbon dioxide
        b. ozone
        c. water vapor
        d. clouds

ANSWER: b

59.   Low clouds retard surface cooling at night better than clear skies because:
        a. the clouds absorb and radiate infrared energy back to earth.
        b. the water droplets in the clouds reflect infrared energy back to earth.
        c. the clouds start convection currents between them.
        d. the clouds are better conductors of heat than is the clear night air.
        e. the formation of the clouds releases latent heat energy.

ANSWER: a

60.   At night, low clouds:
        a. enhance the atmospheric greenhouse effect.
        b. weaken the atmospheric greenhouse effect.
        c. are often caused by the atmospheric greenhouse effect.
        d. have no effect on the atmospheric greenhouse effect.

ANSWER: a

61.   Which of the following gases are mainly responsible for the atmospheric greenhouse effect in
         the earth's atmosphere?
        a. oxygen and nitrogen
        b. nitrogen and carbon dioxide
        c. ozone and oxygen
        d. water vapor and carbon dioxide

ANSWER: d

62. Of the gases listed below, which is <u>NOT</u> believed to be responsible for enhancing the earth's greenhouse effect?
a. chlorofluorocarbons (CFCs)
b. molecular oxygen (O_2)
c. nitrous oxide (N_2O)
d. carbon dioxide (CO_2)
e. methane (CH_4)

ANSWER: b

63. The combined albedo of the earth and the atmosphere is approximately _____ percent.
a. 4
b. 10
c. 30
d. 50
e. 90

ANSWER: c

64. According to the Stefan-Boltzmann law, the radiative energy emitted by one square meter of an object is equal to a constant multiplied by its temperature raised to the _____ power.
a. negative third
b. zeroeth
c. fourth
d. tenth

ANSWER: c

65. The albedo of the moon is 7 percent. This means that:
a. 7 percent of the sunlight striking the moon is reflected.
b. 7 percent of the sunlight striking the moon is absorbed.
c. the moon emits only 7 percent as much energy as it absorbs from the sun.
d. 93 percent of the sunlight striking the moon is reflected.

ANSWER: a

66. If the present concentration of CO_2 doubles in 100 years, and climate models predict that for the earth's average temperature to rise 5° C, what gas must also increase in concentration?
a. nitrogen
b. oxygen
c. methane
d. water vapor

ANSWER: d

67.	The albedo of the earth's surface is only about 4 percent, yet the combined albedo of the earth and the atmosphere is about 30 percent. Which set of conditions below <u>BEST</u> explains why?
a. high albedo of clouds, low albedo of water
b. high albedo of clouds, high albedo of water
c. low albedo of clouds, low albedo of water
d. low albedo of clouds, high albedo of water

ANSWER: a

68.	According to Wein's displacement law, the wavelength at which maximum radiation occurs:
a. is inversely proportional to the temperature.
b. is proportional to the temperature.
c. is inversely proportional to the pressure.
d. is proportional to the pressure.

ANSWER: a

69.	Clouds _____ infrared radiation and _____ visible radiation.
a. absorb; absorb
b. absorb; reflect
c. reflect; reflect
d. reflect; absorb

ANSWER: b

70.	An increase in albedo would be accompanied by _____ in radiative equilibrium temperature.
a. an increase
b. a decrease
c. no change
d. unstable oscillations

ANSWER: b

71.	On the average, about what percentage of the solar energy that strikes the outer atmosphere eventually reaches the earth's surface?
a. 5 percent
b. 15 percent
c. 30 percent
d. 50 percent
e. 70 percent

ANSWER: d

72.   If the amount of energy lost by the earth to space each year were not approximately equal to that received,
a. the atmosphere's average temperature would change.
b. the length of the year would change.
c. the sun's output would change.
d. the mass of the atmosphere would change.

ANSWER: a

73.   If the sun suddenly began emitting more energy, the earth's radiative equilibrium temperature would:
a. increase.
b. decrease.
c. remain the same.
d. begin to oscillate.

ANSWER: a

74.   Sunlight that bounces off a surface is said to be _____ from the surface.
a. radiated
b. absorbed
c. emitted
d. reflected

ANSWER: d

75.   The major process that warms the lower atmosphere is:
a. the release of latent heat during condensation.
b. conduction of heat upward from the surface.
c. absorption of infrared radiation.
d. direct absorption of sunlight by the atmosphere.

ANSWER: c

76.   Atmospheric concentrations of N_2O and CH_4 contribute _____ to the earth-atmosphere albedo.
a. significantly
b. little

ANSWER: b

77.   The atmosphere near the earth's surface is "heated from below." Which of the following is <u>NOT</u> responsible for the heating?
a. conduction of heat upward from a hot surface
b. convection from a hot surface
c. absorption of infrared energy that has been radiated from the surface
d. heat energy from the earth's interior

ANSWER: d

78. The earth's radiative equilibrium temperature is:
    a. the temperature at which the earth is absorbing solar radiation and emitting infrared radiation at equal rates.
    b. the temperature at which the earth is radiating energy at maximum intensity.
    c. the average temperature the earth must maintain to prevent the oceans from freezing solid.
    d. the temperature at which rates of evaporation and condensation on the earth are in balance.

ANSWER: a

79. Perspiration cools the body by:
    a. advective heat transfer.
    b. radiative heat transfer.
    c. conductive heat transfer.
    d. latent heat transfer.

ANSWER: d

80. Charged particles from the sun that travel through space at high speeds are called:
    a. radiation.
    b. the aurora.
    c. solar wind.
    d. solar flares.

ANSWER: c

81. In the earth's upper atmosphere, visible light given off by excited atoms and molecules produces:
    a. flares.
    b. the solar wind.
    c. the aurora.
    d. prominences.

ANSWER: c

82. The aurora is produced by:
    a. reflections of sunlight by polar ice fields.
    b. fast-moving charged particles colliding with air molecules.
    c. burning oxygen caused by the intense sunlight at high altitude.
    d. the combination of molecular and atomic oxygen to form ozone.
    e. scattering of sunlight in the upper atmosphere.

ANSWER: b

83.   On a clear night, the best place to see the aurora would be:
        a. at the magnetic north pole.
        b. northern Maine.
        c. northern Washington.
        d. Colorado.
        e. Alaska.

ANSWER: e

84.   The luminous surface of the sun is known as the:
        a. chromosphere.
        b. thermosphere.
        c. corona.
        d. photosphere.
        e. exosphere.

ANSWER: d

85.   Sunspots:
        a. appear darker than the rest of the sun's surface.
        b. are cooler regions on the sun's surface.
        c. are located in regions of strong magnetic fields.
        d. reach a maximum on the sun approximately every 11 years.
   e. all of the above

ANSWER: e

86.   The aurora are seen:
        a. in the Northern Hemisphere only.
        b. in the Southern Hemisphere only.
        c. in both the Northern and Southern Hemispheres at high latitudes.
        d. in both the Northern and Southern Hemispheres near the equator.
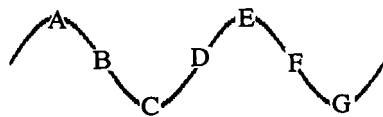
ANSWER: c

87.   Suppose you are outside in very cold temperatures, wearing a winter coat that is quite effective at
        keeping you warm. Which of the following is true?
        a. The coat is the source of the heat that keeps you warm.
        b. Your body generates the heat that keeps you warm.
        c. The coat prevents your body's heat from escaping to the surrounding air.
        d. Both a and c are true.
        e. Both b and c are true.

ANSWER: e
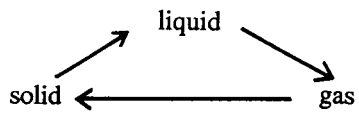
88.   _____ of the phase changes shown above release(s) energy to the surroundings.
         a. None
         b. One
         c. Two
         d. All

ANSWER: b

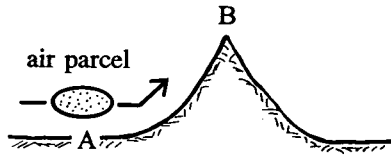
89.   Points A and C are _____ wavelength apart.
         a. 1
         b. 1/2
         c. 1/3
         d. 1/4

ANSWER: b
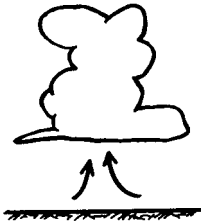

90.   In the figure above, energy is being transported _____.
         a. upward
         b. downward

ANSWER: a

91.   As air in the figure above moves from A to B, its volume will _____, and its temperature will
       _____.
       a. remain the same, decrease
       b. increase, remain the same
       c. decrease, increase
       d. increase, decrease
       e. remain the same, increase

ANSWER: d

92.   Warm air rising in the figure above illustrates which *two* energy transport processes?
       a. advection, latent heat energy transport
       b. convection, electromagnetic radiation
       c. convection, latent heat energy transport
       d. electromagnetic radiation, advection

ANSWER: c

93.   Sunlight passes through a thicker portion of the atmosphere at:
       a. sunrise.
       b. noon.
       c. sunset.
       d. night.
       e. both sunrise and sunset.

ANSWER: e

94. When a plate of hot food is left on the table for awhile, it cools by:
    a. advection.
    b. radiation.
    c. latent heat energy release.
    d. specific heat.

ANSWER: b

95. A red shirt:
    a. selectively absorbs red wavelenghts of visible light and scatters the rest.
    b. selectively scatters red wavelenghts of visible light and absorbs the rest.

ANSWER: b

Essay Questions

1. In the discussion of the earth's annual energy balance, we saw that the earth absorbed approximately 51 units of solar energy but emitted 117 units of infrared energy. What prevents the earth from getting colder and colder?

2. Will a rising parcel of air always expand? Why? Does this expansion cause the air temperature to increase or decrease? Why?

3. Explain how energy in the form of sunlight absorbed at the ground could be transferred upward in the atmosphere in the form of latent heat. How or when is the latent heat energy released in the air above the ground?

4. Describe and give examples of the various ways that heat can be transported in the atmosphere.

5. Describe the atmospheric greenhouse effect. Is there any difference between the way the atmospheric greenhouse effect works on a clear night and on a cloudy night?

6. Several of the planets in our solar system are further from the sun and cooler than the earth. Do they emit electromagnetic radiation? Why are we able to see the planets in the sky at night?

7. How could increased cloud cover cause an increase in the average surface temperature? How could increased cloudiness cause a decrease in average surface temperatures?

8. When you remove a cold beverage from a refrigerator in a humid room, water vapor will condense on the sides of the container. Would this act to warm or cool the beverage, or would the condensation have no effect on the beverage's temperature?

9. Imagine that the temperature of the sun were to change. Describe or discuss some of the effects that this might have on the earth's energy budget and the earth's climate.

10. Many automobile engines are cooled by water which flows in a closed circuit through the engine block and the car's radiator. How many different heat transport processes do you find in operation here?

11. Many people will blow on a bowl of hot soup to try to cool it. In your view, what are the two most important heat transport processes being used to cool the soup?

12. In what ways is the atmospheric greenhouse different from an agricultural greenhouse?

13. What are the other factors, besides increasing CO_2 concentrations, that affect global warming?