others grew. It took nature about 10,000 years to do that. That's the natural rate of change. We're talking about a 5 °C change from our climate models in one century."

Still with all this evidence many scientists are reluctant to make a definitive stand on the issue of global warming. As an example, "No 'smoking gun' evidence exists, however, to prove that the Earth's global climate is warming (versus a natural climate variability) or, if it is warming, whether that warming is caused by the increase in carbon dioxide. Recent estimates show a warming trend, but unfortunately many problems and limitations of observed data make difficult the exact determination of temperature trends."[6]

Still one concern remains. If we wait until we are certain that there is a global warming caused by the increase of carbon dioxide in the air, will we be too late to do anything about it?

6. "Computer Simulation of the Greenhouse Effect," Washington, Warren M. and Bettge, Thomas W., *Computers in Physics*, May/June 1990.

## The Language of Physics

**Convection**
The transfer of thermal energy by the actual motion of the medium itself (p. 451).

**Conduction**
The transfer of thermal energy by molecular action. Conduction occurs in solids, liquids, and gases, but the effect is most pronounced in solids (p. 451).

**Radiation**
The transfer of thermal energy by electromagnetic waves (p. 451).

**Isotherm**
A line along which the temperature is a constant (p. 451).

**Temperature gradient**
The rate at which the temperature changes with distance (p. 453).

**Coriolis effect**
On a rotating coordinate system, such as the earth, objects in straight line motion appear to be deflected to the right of their straight line path. Their actual motion in space is straight, but the earth rotates out from under them. The direction of the prevailing winds is a manifestation of the Coriolis effect (p. 455).

**Conductor**
A material that easily transmits heat by conduction. A conductor has a large value of thermal conductivity (p. 458).

**Insulator**
A material that is a poor conductor of heat. An insulator has a small value of thermal conductivity (p. 458).

**Thermal resistance, or *R* value of an insulator**
The ratio of the thickness of a piece of insulating material to its thermal conductivity (p. 463).

**Stefan-Boltzmann law**
Every body radiates energy that is proportional to the fourth power of the absolute temperature of the body (p. 465).

**Blackbody**
A body that absorbs all the radiation incident upon it. A blackbody is a perfect absorber and a perfect emitter. The substance lampblack, a finely powdered black soot, makes a very good approximation to a blackbody. The name is a misnomer, since many bodies, such as the sun, act like blackbodies and are not black (p. 465).

**Solar constant**
The power per unit area impinging on the edge of the earth's atmosphere. It is equal to $1.38 \times 10^3$ W/m$^2$ (p. 466).

**Planck's radiation law**
An equation that shows how the energy of a radiating body is distributed over the emitted wavelengths. Planck assumed that the radiated energy was quantized into little bundles of energy, eventually called quanta (p. 468).

**Wien displacement law**
The product of the wavelength that gives maximum radiation times the absolute temperature is a constant (p. 468).

## Summary of Important Equations

Heat transferred by convection

$$\Delta Q = vmc\frac{\Delta T}{\Delta x}\Delta t \qquad \textbf{(16.4)}$$

$$\Delta Q = v\rho Vc\frac{\Delta T}{\Delta x}\Delta t \qquad \textbf{(16.6)}$$

$$\frac{\Delta Q}{\Delta t} = \rho c\frac{\Delta V}{\Delta t}(T_h - T_c) \qquad \textbf{(16.8)}$$

Heat transferred by conduction

$$Q = \frac{kA(T_h - T_c)t}{d} \qquad \textbf{(16.10)}$$

Heat transferred by conduction through a compound wall

$$Q = \frac{A(T_h - T_c)t}{\sum_{i=1}^{n} d_i/k_i} \qquad \textbf{(16.19)}$$

$$Q = \frac{A(T_h - T_c)t}{\sum_{i=1}^{n} R_i} \qquad \textbf{(16.23)}$$

*R* value of insulation

$$R = \frac{d}{k} \qquad \textbf{(16.20)}$$

Stefan-Boltzmann law, heat transferred by radiation

$$Q = e\sigma AT^4t \qquad \textbf{(16.24)}$$

Radiation from a blackbody

$$Q = \sigma AT^4t \qquad \textbf{(16.25)}$$

Energy absorbed by radiation from environment

$$Q = \sigma A(e_E T_E^4 - e_B T_B^4)t \qquad \textbf{(16.27)}$$

Planck's radiation law

$$\frac{Q}{At\Delta\nu} = \frac{2\pi h\nu^3}{c^2}\left(\frac{1}{e^{h\nu/kT} - 1}\right) \qquad \textbf{(16.29)}$$

$$\frac{Q}{At\Delta\lambda} = \frac{2\pi hc^2}{\lambda^5}\left(\frac{1}{e^{hc/\lambda kT} - 1}\right) \qquad \textbf{(16.30)}$$

Wien displacement law

$$\lambda_{max}T = \text{constant} \qquad \textbf{(16.31)}$$

# Questions for Chapter 16

1. Explain the differences and similarities between convection, conduction, and radiation.
†2. Explain how the process of convection of ocean water is responsible for relatively mild winters in Ireland and the United Kingdom even though they are as far north as Hudson's Bay in Canada.
†3. Explain from the process of convection why the temperature of the Pacific Ocean off the west coast of the United States is colder than the temperature of the Atlantic Ocean off the east coast of the United States.
†4. Explain from the process of convection why it gets colder after the passing of a cold front and warmer at the approach and passing of a warm front.
5. Explain the process of heat conduction in a gas and a liquid.
6. Considering the process of heat conduction through the walls of your home, explain why there is a greater loss of thermal energy through the walls on a very windy day.
7. In the winter time, why does a metal door knob feel colder than the wooden door even though both are at the same temperature?
8. Explain the use of venetian blinds for the windows of the home as a temperature controlling device. What advantage do they have over shades?
9. Why are thermal lined drapes used to cover the windows of a home at night?
10. Why is it desirable to wear light colored clothing in very hot climates rather than dark colored clothing?
11. Explain how you can still feel cold while sitting in a room whose air temperature is 70 °F, if the temperature of the walls is very much lower.
12. From what you now know about the processes of heat transfer, discuss the insulation of a calorimeter.
†13. On a very clear night, radiation fog can develop if there is sufficient moisture in the air. Explain.
14. If the maximum radiation from the sun falls in the blue-green portion of the visible spectrum, why doesn't the sun appear blue-green?
†15. From the point of view of radiation, discuss the process of thermography, whereby a specialized camera takes pictures of an object in the infrared portion of the spectrum. Explain how this could be used in medicine to detect tumors in the human body. (The tumors are usually several degrees hotter than normal body tissue.)

# Problems for Chapter 16

## *16.2* Convection

1. How much thermal energy per unit mass is transferred by convection in 6.00 hr if air at the surface of the earth is moving at 15.0 mph? The temperature gradient is measured as 4.00 °C per 100 miles.
2. Air is moving over the surface of the earth at 30.0 km/hr. The temperature gradient is 2.50 °C per 100 km. How much thermal energy per unit mass is transferred by convection in an 8.00-hour period?
3. An air conditioner can cool 300 $ft^3$ of air per minute from 95.0 °F to 60.0 °F. How much thermal energy is removed from the room per hour?
4. An air conditioner can cool 10.5 $m^3$ of air per minute from 30.0 °C to 18.5 °C. How much thermal energy per hour is removed from the room in one hour?
5. In a hot air heating system, air at the furnace is heated to 200 °F. A window is open in the house and the house temperature remains at 55 °F. If the furnace can deliver 200 $ft^3$/min of air, how much thermal energy per hour is transferred from the furnace to the room?
6. A hot air heating system rated at 84,000 Btu/hr has an efficiency of 65.0%. The fan can move 225 $ft^3$ of air per minute. If air enters the furnace at 60.0 °F, what is the temperature of the outlet air?
7. A hot air heating system rated at $6.3 \times 10^7$ J/hr has an efficiency of 58.0%. The fan is capable of moving 5.30 $m^3$ of air per minute. If air enters the furnace at 17.0 °C, what is the temperature of the outlet air?

## *16.3* Conduction

8. How much thermal energy flows through a glass window 1/8 in. thick, 4.00 ft high, and 3.00 ft wide in 12.0 hr if the temperature on the outside of the window is 20.0 °F and the temperature on the inside of the window is 70.0 °F?
9. How much thermal energy flows through a glass window 0.350 cm thick, 1.20 m high, and 0.80 m wide in 12.0 hr if the temperature on the outside of the window is −8.00 °C and the temperature on the inside of the window is 20.0 °C?
10. Repeat problem 8, but now assume that there are strong gusty winds whose air temperature is 5.00 °F.
11. Find the amount of thermal energy that will flow through a concrete wall 10.0 m long, 2.80 m high, and 22.0 cm wide, in a period of 24.0 hr, if the inside temperature of the wall is 20.0 °C and the outside temperature of the wall is 5.00 °C.
12. Find the amount of thermal energy transferred through a pine wood door in 6.00 hr if the door is 0.91 m wide, 1.73 m high, and 5.00 cm thick. The inside temperature of the door is 20.0 °C and the outside temperature of the door is −5.00 °C.
13. How much thermal energy will flow per hour through a copper rod, 5.00 cm in diameter and 1.50 m long, if one end of the rod is maintained at a temperature of 225 °C and the other end at 20.0 °C?
14. One end of a copper rod has a temperature of 100 °C, whereas the other end has a temperature of 20.0 °C. The rod is 1.25 m long and 3.00 cm in diameter. Find the amount of thermal energy that flows through the rod in 5.00 min. Find the temperature of the rod at 45.0 cm from the hot end.

15. On a hot summer day the outside temperature is 98.0 °F. A home air conditioner is trying to maintain a temperature of 70.0 °F. If there are 10 windows in the house, each 1/8 in. thick and 12.0 $ft^2$ in area, how much thermal energy must the air conditioner remove per hour to eliminate the thermal energy transferred through the windows?

16. On a hot summer day the outside temperature is 35.0 °C. A home air conditioner is trying to maintain a temperature of 22.0 °C. If there are 12 windows in the house, each 0.350 cm thick and 0.960 $m^2$ in area, how much thermal energy must the air conditioner remove per hour to eliminate the thermal energy transferred through the windows?

†17. A styrofoam cooler ($k = 4.8 \times 10^{-5}$ kcal/m s °C) is filled with ice at 0 °C for a summertime party. The cooler is 40.0 cm high, 50.0 cm long, 40.0 cm wide, and 3.00 cm thick. The air temperature is 95.0 °F. Find (a) the mass of ice in the cooler, (b) how much thermal energy is needed to melt all the ice, and (c) how long it will take for all the ice to melt. Assume that the energy to melt the ice is only conducted through the four sides of the cooler. Also take the thickness of the cooler walls into account when computing the size of the walls of the container.

18. An aluminum rod 50.0 cm long and 3.00 cm in diameter has one end in a steam bath at 100 °C and the other end in an ice bath at 0.00 °C. How much ice melts per hour?

19. If the home thermostat is turned from 70.0 °F down to 60.0 °F for an 8-hr period at night when the outside temperature is 20.0 °F, what percentage saving in fuel can the home owner realize?

20. If the internal temperature of the human body is 37.0 °C, the surface temperature is 35.0 °C, and there is a separation of 4.00 cm of tissue between, how much thermal energy is conducted to the skin of the body each second? Take the thermal conductivity of human tissue to be $0.5 \times 10^{-4}$ kcal/s m °C and the area of the human skin to be 1.9 $m^2$.

21. What is the $R$ value of (a) 4.00 in. of glass wool and (b) 6.00 in. of glass wool?

22. How thick should a layer of plaster be in order to provide the same $R$ value as a 5.00 cm of concrete?

23. A basement wall consists of 8.00 in. of concrete, 1 1/2 in. of glass wool, 3/8 in. of sheetrock (plaster), and 3/4 in. of knotty pine paneling. The wall is 7.00 ft high and 30.0 ft long. The outside temperature is 40.0 °F and we want to maintain the inside temperature at 70.0 °F. How much thermal energy will be lost through four such walls in a 24-hr period?

24. A basement wall consists of 20.0 cm of concrete, 3.00 cm of glass wool, 0.800 cm of sheetrock (plaster), and 2.00 cm of knotty pine paneling. The wall is 2.50 m high and 10.0 m long. The outside temperature is 1.00 °C, and we want to maintain the inside temperature of 22.0 °C. How much thermal energy will be lost through four such walls in a 24-hr period?

25. On a summer day the attic temperature of a house is 160 °F. The ceiling of the house is 8.00 m wide by 13.0 m long and 3/8-in. thick plasterboard. The house is cooled by an air conditioner and maintains a 70.0 °F temperature in the house. (a) Find the amount of thermal energy transferred from the attic to the house in 2.00 hr. (b) If 6.00 in. of glass wool is now placed in the attic floor, find the amount of thermal energy transferred into the house.

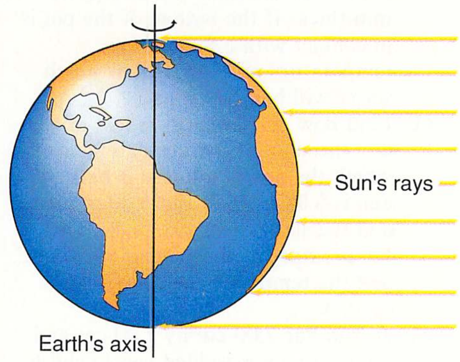
26. How much thermal energy is conducted through a thermopane window, in 8.00 hr if the window is 32.0 in. wide by 45.0 in. high, and consists of two sheets of glass 1/8 in. thick separated by an air gap of 1/2 in.? The temperature of the inside window is 68.0 °F and the temperature of the outside window is 20.0 °F. Treat the thermopane window as a compound wall.

27. How much thermal energy is conducted through a thermopane window in 8.00 hr if the window is 80.0 cm wide by 120 cm high, and it consists of two sheets of glass 0.350 cm thick separated by an air gap of 1.50 cm? The temperature of the inside window is 22.0 °C and the temperature of the outside window is −5.00 °C. Treat the thermopane window as a compound wall.

28. How much thermal energy is conducted through a combined glass window and storm window in 8.00 hr if the window is 32.0 in. wide by 45.0 in. high and 1/8 in. thick? The storm window is the same size but is separated from the inside window by an air gap of 2.00 in. The temperature of the inside window is 68.0 °F and the temperature of the outside window is 20.0 °F. Treat the combination as a compound wall.

## *16.4* Radiation

29. How much thermal energy from the sun falls on the surface of the earth during an 8-hr period? (Ignore reflected solar radiation from clouds that does not make it to the surface of the earth.)




30. If the mean temperature of the surface of the earth is 288 K, how much thermal energy is radiated into space per second?

31. Assuming the human body has an emissivity, $e = 1$, and an area of approximately 2.23 $m^2$, find the amount of thermal energy radiated by the body in 8 hr if the surface temperature is 95.0 °F.

32. If the surface temperature of the human body is 35.0 °C, find the wavelength of the maximum intensity of radiation from the human body. Compare this wavelength to the wavelengths of visible light.

33. How much energy is radiated per second by an aluminum sphere 5.00 cm in radius, at a temperature of (a) 20.0 °C, and (b) 200 °C? Assume that the sphere emits as a blackbody.

34. How much energy is radiated per second by an iron cylinder 5.00 cm in radius and 10.0 cm long, at a temperature of (a) 20.0 °C and (b) 200 °C? Assume blackbody radiation.

35. How much energy is radiated per second from a wall 2.50 m high and 3.00 m wide, at a temperature of 20.0 °C? What is the wavelength of the maximum intensity of radiation?

36. A blackbody initially at 100 °C is heated to 300 °C. How much more power is radiated at the higher temperature?

37. A blackbody is at a temperature of 200 °C. Find the wavelength of the maximum intensity of radiation.

38. A blackbody is radiating at a temperature of 300 K. To what temperature should the body be raised to double the amount of radiation?

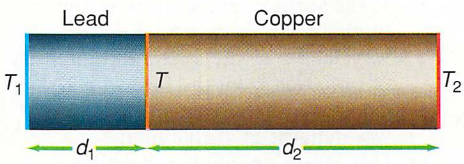
39. A distant star appears red, with a wavelength $7.000 \times 10^{-7}$ m. What is the surface temperature of that star?

## Additional Problems

40. An aluminum pot contains 10.0 kg of water at 100 °C. The bottom of the pot is 15.0 cm in radius and is 3.00 mm thick. If the bottom of the pot is in contact with a flame at a temperature of 170 °C, how much water will boil per minute?

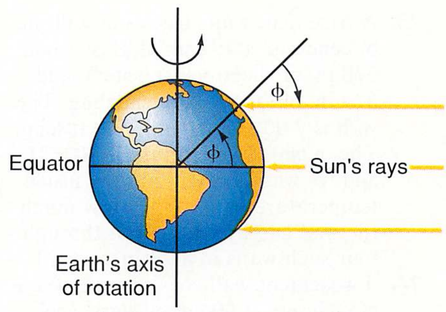
41. Find how much energy is lost in one day through a concrete slab floor on which the den of a house is built. The den is 5.00 m wide and 6.00 m long, and the slab is 15.0 cm thick. The temperature of the ground is 3.00 °C and the temperature of the room is 22.0 °C.

42. A lead bar 2.00 cm by 2.00 cm and 10.0 cm long is welded end to end to a copper bar 2.00 cm by 2.00 cm by 25.0 cm long. Both bars are insulated from the environment. The end of the copper bar is placed in a steam bath while the end of the lead bar is placed in an ice bath. What is the temperature $T$ at the interface of the copper-lead bar? How much thermal energy flows through the bar per minute?

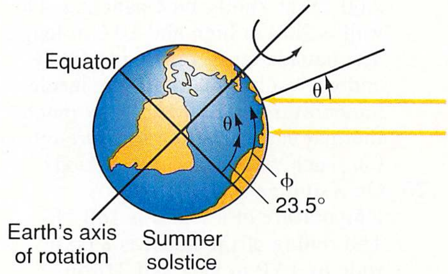



43. Find the amount of thermal energy conducted through a wall, 5.00 m high, 12.0 m long, and 5.00 cm thick, if the wall is made of (a) concrete, (b) brick, (c) wood, and (d) glass. The temperature of the hot wall is 25.0 °C and the cold wall −5.00 °C.

†44. Show that the distribution of solar energy over the surface of the earth is a function of the latitude angle $\phi$. Find the energy per unit area per unit time hitting the surface of the earth during the vernal equinox and during the summer solstice at (a) the equator, (b) 30.0° north latitude, (c) 45.0° north latitude, (d) 60.0° north latitude, and (e) 90.0° north latitude. At the vernal equinox the sun is directly overhead at the equator, whereas at the summer solstice the sun is directly overhead at 23.5° north latitude.




Vernal equinox




Summer solstice

45. An asphalt driveway, 50.0 m² in area and 6.00 cm thick, receives energy from the sun. Using the solar constant of $1.38 \times 10^3$ W/m², find the maximum change in temperature of the asphalt if (a) the radiation from the sun hits the driveway normally for a 2.00-hr period and (b) the radiation from the sun hits the driveway at an angle of 35° for the same 2.00-hr period. Take the density of asphalt to be 1219 kg/m³ and the specific heat of asphalt to be 1.02 kcal/kg °C.

†46. Find the amount of radiation from the sun that falls on the planets (a) Mercury, (b) Venus, (c) Mars, (d) Jupiter, and (e) Saturn in units of W/m².

47. If the Kelvin temperature of a blackbody is quadrupled, what happens to the rate of energy radiation?

†48. A house measures 40.0 ft by 30.0 ft by 8.00 ft high. The walls contain 4.00 in. of glass wool. Assume all the heat loss is through the walls of the house. The home thermostat is turned from 70.0 °F down to 60.0 °F for an 8-hr period at night when the outside temperature is 20.0 °F. (a) How much thermal energy can the home owner save by lowering the thermostat? (b) How much energy is used the next morning to bring the temperature of the air in the house back to 70.0 °F? (c) What is the savings in energy now?

†49. An insulated aluminum rod, 1.00 m long and 25.0 cm² in cross-sectional area, has one end in a steam bath at 100 °C and the other end in a cooling container. Water enters the cooling container at an input temperature of 10.0 °C and exits the cooling container at a temperature of 30.0 °C, leaving a mean temperature of 20.0 °C at the end of the aluminum rod. Find the mass of water that must flow through the cooling container per minute to maintain this equilibrium condition.

†50. An aluminum engine, operating at 300 °C is cooled by circulating water over the end of the engine where the water absorbs enough energy to boil. The cooling interface has a surface area of 0.525 m² and a thickness of 1.50 cm. If the water enters the cooling interface of the engine at 100 °C, how much water must boil per minute to cool the engine?

†51. When the surface through which thermal energy flows is not flat, such as in figure 16.6, the equation for heat transfer, equation 16.10, is no longer accurate. With the help of the calculus it can be shown that the amount of thermal energy that flows through the sides of a rectangular annular cylinder is given by

$$\frac{\Delta Q}{\Delta t} = \frac{2\pi k l \Delta T}{\ln(r_2/r_1)}$$

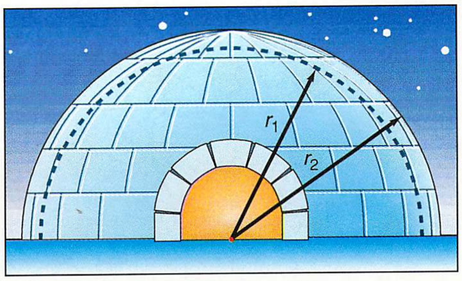
where $l$ is the length of the cylinder, $r_1$ is the inside radius of the cylinder, and $r_2$ is the outside radius of the cylinder. Steam at 100 °C flows in a cylindrical copper pipe 5.00 m long, with an inside radius of 10.0 cm and an outside radius of 15 cm. Find the energy lost through the pipe per hour if the outside temperature of the pipe is 30.0 °C.

†52. When the surface through which thermal energy flows is a spherical shell rather than a flat surface, the amount of thermal energy that flows through the spherical surface can be shown to be given by

$$\frac{\Delta Q}{\Delta t} = \frac{4\pi k \Delta T}{(r_2 - r_1)/r_1 r_2}$$

where $r_1$ is the inside radius of the sphere and $r_2$ is the outside radius of the sphere.

Consider an igloo as half of a spherical shell. The inside radius is 3.00 m and the outside radius is 3.20 m. If the temperature inside the igloo is 15.0 °C and the outside temperature is −40.0 °C, find the flow of thermal energy through the ice per hour. The thermal conductivity of ice is $4.00 \times 10^{-4}$ kcal/s m °C.




†53. Show that for large values of $r_1$ and $r_2$ the solution for thermal energy flow through a spherical shell (problem 52) reduces to the solution for the thermal energy flow through a flat slab.

†54. In problems 51 and 52 assume that you can use the formula for the thermal energy flow through a flat slab. Find $\Delta Q/\Delta t$ and find the percentage error involved by making this approximation.

55. A spherical body of 25.0-cm radius, has an emissivity of 0.45, and is at a temperature of 500.0 °C. How much power is radiated from the sphere?

†56. Newton's law of cooling states that the rate of change of temperature of a cooling body is proportional to the rate at which it gains or loses heat, which is approximately proportional to the difference between its temperature and the temperature of the environment. This is written mathematically as

$$\frac{\Delta T}{\Delta t} = -K(T_{avg} - T_e)$$

where $T_{avg}$ is the average temperature of the body, $T_e$ is the temperature of the environment, and $K$ is a constant. A cup of coffee cools from 98.0 °C to 90.0 °C in 1.5 min. The cup is in a room that has a temperature of 20.0 °C. Find (a) the value of $K$ and (b) how long it will take for the coffee to cool from 90.0 °C to 50.0 °C.

†57. A much more complicated example of heat transfer is one that combines conduction and convection. That is, we want to determine the thermal energy transferred from a hot level plate at 100 °C to air at a temperature of 20.0 °C. The thermal energy transferred is given by the equation

$$Q = hA\Delta T\, t$$

where $h$ is a constant, called the convection coefficient and is a function of the shape, size, and orientation of the surface, the type of fluid in contact with the surface and the type of motion of the fluid itself. Values of $h$ for various configurations can be found in handbooks. If $h$ is equal to $1.78 \times 10^{-3}$ kcal/s m² °C and $A$ is 2.00 m², find the amount of thermal energy transferred per minute.

†58. Using the same principle of combined conduction and convection used in problem 57, find the amount of thermal energy that will flow through an uninsulated wall 10.0 cm thick of a wood frame house in 1 hr. Assume that both the inside and outside wall have a thickness of 2.00 cm of pine wood and an area of 25.0 m². (*Hint:* First consider the thermal energy loss through the inside wall, then the thermal energy loss through the 10.0-cm air gap, then the thermal energy loss through the outside wall.) The temperatures at the first wall are 18.0 °C and 13.0 °C, and the temperatures at the second wall are 10.0 °C and −6.70 °C. The convection coefficient for a vertical wall is $h = 0.424 \times 10^{-4} (\Delta T)^{1/4}$ cal/s cm² °C.

†59. A thermograph is essentially a device that detects radiation in the infrared range of the electromagnetic spectrum. A thermograph can map the temperature distribution of the human body, showing regions of abnormally high temperatures such as found in tumors. Starting with the Stefan-Boltzmann law show that the ratio of the power emitted from tissue at a slightly higher temperature, $T + \Delta T$, to the power emitted from normal tissue at a temperature $T$ is

$$\frac{P_2}{P_1} = (1 + \Delta T/T)^4$$

Then show that a change of temperature of only 0.9 °C will give an approximate 1.00% increase in the power of the radiation transmitted. Assume that the body temperature is 37.0 °C.

## Interactive Tutorials

60. How much thermal energy flows through a glass window per second ($Q$/s) if the thickness of the window $d = 0.020$ m and its cross-sectional area $A = 2.00$ m². The temperature difference between the window's faces is $\Delta T = 65.0$ °C, and the thermal conductivity of glass is $k = 0.791$ J/(m s °C).

61. Convection. A hot air heating system heats air to a temperature of 125 °C and the return air is at a temperature of 17.5 °C. The fan is capable of moving a volume of 7.50 m³ of air in 1 min, $\Delta V/\Delta t$. The specific heat of air at constant pressure, $c$, is $1.05 \times 10^3$ J/kg °C and take the density of air, $\rho$ to be 1.29 kg/m³. Find the amount of thermal energy transfer per hour from the furnace to the room.

62. Conduction through a compound wall. Find the amount of heat conducted through a compound wall that has a length $L = 8.5$ m and a height $h = 4.33$ m. The wall consists of a thickness of $d_1 = 10.0$ cm of brick, $d_2 = 1.90$ cm of plywood, $d_3 = 10.2$ cm of glass wool, $d_4 = 1.25$ cm of plaster, and $d_5 = 0.635$ cm of oak wood paneling. The inside temperature of the wall is $T_h = 20.0$ °C and the outside temperature of the wall is $T_c = -9.00$ °C. How much thermal energy flows through this wall per day?

63. Radiation. How much energy is radiated in 1 s by an iron sphere 18.5 cm in radius at a temperature of 125 °C? Assume that the sphere radiates as a blackbody of emissivity $e = 1$. What is the wavelength of the maximum intensity of radiation?