8. Temperature and Heat – Tutorial 8

8.1 The SR-71 Blackbird, which is 107 feet 5 inches long, is the world’s fastest airplane. It can fly at three times the speed of sound (Mach 3) at altitudes of 80,000 ft. When it lands after a long flight, it is too hot to be touched for about 30 minutes, and is 6.0 inches longer than at takeoff. How hot is the Blackbird when it lands, assuming its coefficient of linear expansion is \(24 \times 10^{-6} \text{ K}^{-1}\) and its temperature at takeoff is 23 °C? (220°C)

8.2 The world’s longest suspension bridge is the Akashi Kaikyo Bridge in Japan. The bridge is 3910 m long and is constructed of steel. How much longer is the bridge on a warm summer day (30.0 °C) than on a cold winter day (-5.00 °C)? (1.6m)

8.3 A hole in an aluminium plate has a diameter of 1.178cm at 23.00 °C. (a) What is the diameter of the hole at 199.0 °C? (b) At what temperature is the diameter of the hole equal to 1.176cm? (1.183cm, -48°C)

8.4 It is desired to slip an aluminium ring over a steel bar (Figure 8.4). At 10.00 °C the inside diameter of the ring is 4.000 cm and the diameter of the rod is 4.040 cm. (a) In order for the ring to slip over the bar, should the ring be heated or cooled? Explain. (b) Find the temperature of the ring at which it fits over the bar. The bar remains at 10.0 °C. (430°C)

![Figure 8.4](image)

8.5 At 12.25 °C a brass sleeve has an inside diameter of 2.19625cm and a steel shaft has a diameter of 2.19893cm. It is desired to shrink-fit the sleeve over the steel shaft. (a) To what temperature must the sleeve be heated in order for it to slip over the shaft? (b) Alternatively, to what temperature must the shaft be cooled before it is able to slip through the sleeve? (76°C, -89°C)

8.6 Early in the morning, when the temperature is 5.0 °C, petrol is pumped into a car’s 51-L steel petrol tank until it is filled to the top. Later in the day the temperature rises to 25 °C. Since the volume of petrol increases more for a given temperature increase than the volume of the steel tank, petrol will spill out of the tank. How much petrol spills out in this case? (0.93L)

8.7 Some cookware has a stainless steel interior (\(\alpha = 17.3 \times 10^{-6} \text{ K}^{-1}\)) and a copper bottom (\(\alpha = 17.0 \times 10^{-6} \text{ K}^{-1}\)) for better heat distribution. Suppose an 8inch pot of this construction is heated to 610 °C on the stove. If the initial temperature of the pot is 22 °C, what is the difference in diameter change for the copper and the steel? (0.0014in)

8.8 You construct two wire-frame cubes, one using copper wire, the other using aluminium wire. At 21 °C the cubes enclose equal volumes of 0.016 m³. (a) If the temperature of the cubes is increased, which cube encloses the greater volume? (b) Find the difference in volume between the cubes when their temperature is 97 °C. (2.6x10⁻⁵m³)

8.9 A copper ball with a radius of 1.6 cm is heated until its diameter has increased by 0.18 mm. Assuming an initial temperature of 22 °C, find the final temperature of the ball. (680°C)
8.10 An aluminium saucepan with a diameter of 23 cm and a height of 6.0 cm is filled to the brim with water. The initial temperature of the pan and water is 19 °C. The pan is now placed on a stove burner and heated to 88 °C. (a) Will water overflow from the pan, or will the water level in the pan decrease? Explain. (b) Calculate the volume of water that overflows or the drop in water level in the pan, whichever is appropriate. (24cm³)

8.11 How much heat is required to raise the temperature of a 55-g glass ball by 15°C? (0.69kJ)

8.12 A 5.0-g lead bullet is fired into a fence post. The initial speed of the bullet is 250 m/s, and when it comes to rest, half its kinetic energy goes into heating the bullet. How much does the bullet’s temperature increase? (120K)

8.13 Silver pellets with a mass of 1.0 g and a temperature of 85 °C are added to 220 g of water at 14 °C. (a) How many pellets must be added to increase the equilibrium temperature of the system to 25 °C? Assume no heat is exchanged with the surroundings. (b) If copper pellets are used instead, does the required number of pellets increase, decrease, or stay the same? Explain. (c) Find the number of copper pellets that are required. (722, 436)

8.14 A 235-g lead ball at a temperature of 84.2 °C is placed in a light calorimeter containing 177 g of water at 21.5 °C. Find the equilibrium temperature of the system. (23.9°C)

8.15 If 2200 J of heat is added to a 190-g object, its temperature increases by 12 °C. (a) What is the heat capacity of this object? (b) What is the object’s specific heat? (0.18kJ/°C, 0.96kJ/kg.K)

8.16 An 87.6-g lead ball is dropped from rest from a height of 5.43 m. The collision between the ball and the ground is totally inelastic. Assuming all the ball’s kinetic energy goes into heating the ball, find its change in temperature. (0.416°C)

8.17 To determine the specific heat of an object, a student heats it to 100 °C in boiling water. She then places the 38.0-g object in a 155-g aluminium calorimeter containing 103 g of water. The aluminium and water are initially at a temperature of 20.0 °C, and are thermally insulated from their surroundings. If the final temperature is 22.0 °C, what is the specific heat of the object? Identify the material in the object. (385J/kg.K)

8.18 At the local county fair, you watch as a blacksmith drops a 0.50-kg iron horseshoe into a bucket containing 25 kg of water. (a) If the initial temperature of the horseshoe is 450 °C, and the initial temperature of the water is 23 °C, what is the equilibrium temperature of the system? Assume no heat is exchanged with the surroundings. (b) Suppose the 0.50-kg iron horseshoe had been a 1.0-kg lead horseshoe instead. Would the equilibrium temperature in this case be greater than, less than, or the same as in part (a)? Explain. (24°C)

8.19 The ceramic coffee cup in Figure 8.19, with m = 116 g and c = 1090J/(kg·K), is initially at room temperature (24.0 °C). If 225 g of 80.3 °C coffee and 12.2 g of 5.00 °C cream are added to the cup, what is the equilibrium temperature of the system? Assume that no heat is exchanged with the surroundings, and that the specific heat of coffee and cream are the same as the specific heat of water. (70.5°C)

Figure 8.19
8.20 Find the heat that flows in 1.0 s through a lead brick 15 cm long if the temperature difference between the ends of the brick is 8.5 °C. The cross-sectional area of the brick is 12 cm². (2.3 J)

8.21 Two metal rods of equal length—one aluminium, the other stainless steel—are connected in parallel with a temperature of 20.0 °C at one end and 118 °C at the other end. Both rods have a circular cross section with a diameter of 3.50 cm. (a) Determine the length the rods must have if the combined rate of heat flow through them is to be 27.5 J per second. (b) If the length of the rods is doubled, by what factor does the rate of heat flow change? (0.80 m)

8.22 Two cylindrical metal rods—one copper, the other lead—are connected in parallel with a temperature of 21.0 °C at one end and 112 °C at the other end. Both rods are 0.650 m in length, and the lead rod is 2.76 cm in diameter. If the combined rate of heat flow through the two rods is 33.2 J/s, what is the diameter of the copper rod? (2.64 cm)

8.23 Two metal rods—one lead, the other copper—are connected in series, as shown in Figure 8.23. Each rod is 0.525 m in length and has a square cross section 1.50 cm on a side. The temperature at the lead end of the rods is 2.00 °C; the temperature at the copper end is 106 °C. (a) The average temperature of the two ends is 54.0 °C. Is the temperature in the middle, at the lead-copper interface, greater than, less than, or equal to 54.0 °C? Explain. (b) Given that the heat flow through each of these rods in 1.00 s is 1.41 J, find the temperature at the lead-copper interface. (98 °C)

8.24 Consider two cylindrical metal rods with equal cross section—one lead, the other aluminium—connected in series. The temperature at the lead end of the rods is 20.0 °C; the temperature at the aluminium end is 80.0 °C. (a) Given that the temperature at the lead-aluminium interface is 50.0 °C, and that the lead rod is 14 cm long, what condition can you use to find the length of the aluminium rod? (b) Find the length of the aluminium rod. (89 cm)

8.25 A copper rod 85 cm long is used to poke a fire. The hot end of the rod is maintained at 105 °C and the cool end has a constant temperature of 21 °C. What is the temperature of the rod 23 cm from the cool end? (44 °C)

8.26 Two identical objects are placed in a room at 21 °C. Object 1 has a temperature of 95 °C and object 2 has a temperature of 25 °C. What is the ratio of the net power emitted by object 1 to that radiated by object 2? (26)

8.27 A block has the dimensions $L$, $2L$, and $3L$. When one of the $L \times 2L$ faces is maintained at the temperature $T_1$ and the other $L \times 2L$ face is held at the temperature $T_2$, the rate of heat conduction through the block is $P$. Answer the following questions in terms of $P$. (a) What is the rate of heat conduction in this block if one of the $L \times 3L$ faces is held at the temperature $T_1$ and the other $L \times 3L$ face is held at the temperature $T_2$? (b) What is the rate of heat conduction in this block if one of the $2L \times 3L$ faces is held at the temperature $T_1$ and the other $2L \times 3L$ face is held at the temperature $T_2$? (9/4 $P$, 9$P$)