10 Temperature and Heat

10-1 Temperature and Expansion

Vocabulary **Temperature:** A quantity that you can measure with a thermometer.

There are many different scales for measuring the temperature of an object. The SI unit for temperature is the **kelvin (K)**. The Kelvin scale is based on absolute zero, a point at which the internal movement of an object's atoms or molecules is a minimum and no heat can be removed. An increase of one kelvin on the Kelvin scale is equal to an increase of one degree Celsius on the Celsius scale. Respectively, the freezing and boiling temperatures of water on these two scales are 0°C = 273 K and 100°C = 373 K.

Notice that the Kelvin scale does not use the degree symbol, °. We say, "Zero degrees Celsius equals two hundred seventy-three kelvins."

However, the Fahrenheit scale is most common on household thermometers. Degrees Fahrenheit can be changed to degrees Celsius by writing.

$$T_C = \frac{5}{9}(T_F - 32.0)$$

Degrees Celsius can be changed to degrees Fahrenheit by writing

$$T_F = \left(\frac{9}{5}T_C\right) + 32.0$$

Heating an object will generally make its atoms or molecules move faster and cause the object to increase in size.

Linear Expansion

When a solid object experiences a temperature change, its length will increase by a certain amount depending upon the nature of the material.

change in length =

(original length)(coefficient of expansion)(change in temperature)

or $\Delta L = L_0 \alpha \Delta T$

where α, the **coefficient of linear expansion,** is a characteristic property of the material. The SI unit for the coefficient of linear expansion is $°C^{-1}$ (which is the same as $1/°C$).

Area Expansion

An object may also expand in area when heated. The equation for area expansion is

change in area =

2(original area)(coefficient of linear expansion)(change in temperature)

or $\Delta A = 2A_0\alpha\Delta T$

Volume Expansion

If the volume of a solid or liquid expands, the equation is written as

change in volume =

(original volume)(coefficient of volume expansion)(change in temperature)

or $\Delta V = V_0\beta\Delta T$

where β is the coefficient of volume expansion.

Solved Examples

Example 1: Justin is trying to convince his mother that he has a fever and should stay home from school. However, he has a thermometer that will measure his temperature in degrees Celsius. If Justin's temperature is 39.0°C and "normal" is 98.6°F, is Justin's temperature high enough to keep him home?

Given: $T_C = 39.0°C$

Unknown: $T_F = ?$

Original equation: $T_F = \left(\frac{9}{5}T_C\right) + 32.0$

Solve: $T_F = \left(\frac{9}{5}T_C\right) + 32.0 = \frac{9}{5}(39.0°C) + 32.0 = \mathbf{102°F}$

Yes. He should stay home.

Example 2: The layer of the sun that we see is called the photosphere. It has a temperature of 5600 K. What is the sun's temperature a) in degrees Celsius? b) in degrees Fahrenheit?

a. *Given:* $T_K = 5600\ K$

Unknown: $T_C = ?$

Original equation: $T_C = T_K - 273$

Solve: $T_C = T_K - 273 = 5600 - 273 = \mathbf{5327°C}$

b. *Given:* $T_C = 5327°C$

Unknown: $T_F = ?$

Original equation: $T_F = \left(\frac{9}{5}T_C\right) + 32.0$

Solve: $T_F = \left(\frac{9}{5}T_C\right) + 32.0 = \frac{9}{5}(5327°C) + 32.0 = \mathbf{9621°F}$ Pretty hot!

Example 3: Ernesto is knitting his wife a sweater in his 18°C air-conditioned living room with 0.30-m-long aluminum knitting needles, when he decides to knit outside in the 27°C air. How much will the knitting needles expand when Ernesto takes them outside? ($\alpha_{aluminum} = 24 \times 10^{-6}\,°C^{-1}$)

Given: $L_o = 0.30$ m
$\alpha = 24 \times 10^{-6}\,°C^{-1}$
$T_o = 18°C$
$T_f = 27°C$

Unknown: $\Delta L = ?$

Original equation: $\Delta L = L_o\alpha\Delta T$

Solve: $\Delta L = L_o\alpha\Delta T = L_o\alpha(T_f - T_o) = (0.30\text{ m})(24 \times 10^{-6}\,°C^{-1})(27°C - 18°C)$
$= \mathbf{6.5 \times 10^{-5}\ m}$

Example 4: Jacques, the French chef, is kneading the dough for French bread in his 21°C kitchen. He places the dough on a 0.40-m × 0.60-m aluminum cookie sheet. If the oven temperature is 177°C, how much does the cookie sheet expand in area while it is in the oven? ($\alpha_{aluminum} = 24 \times 10^{-6}\,°C^{-1}$)

Solution: Because the cookie sheet will expand in two directions, it is necessary to use the equation for area expansion. The area of the cookie sheet is 0.40 m × 0.60 m = 0.24 m^2.

Given: $A_o = 0.24\text{ m}^2$
$\alpha = 24 \times 10^{-6}\,°C^{-1}$
$T_o = 21°C$
$T_f = 177°C$

Unknown: $\Delta A = ?$

Original equation: $\Delta A = 2A_o\alpha\Delta T$

Solve: $\Delta A = 2A_o\alpha\Delta T = 2(0.24\text{ m}^2)(24 \times 10^{-6}\,°C^{-1})(177°C - 21°C)$
$= \mathbf{0.0018\ m^2}$

Example 5: A thermometer contains 0.50 cm^3 of mercury at room temperature (21°C) when Pilar takes it into the physics lab for an experiment. By how much does the volume of mercury in the thermometer change after it sits in an 80.°C beaker of water? ($\beta_{mercury} = 18 \times 10^{-5}\,°C^{-1}$)

Given: $V = 0.50\text{ cm}^3$
$\beta_{mercury} = 18 \times 10^{-5}\,°C^{-1}$
$T_o = 21°C$
$T_f = 80.°C$

Unknown: $\Delta V = ?$

Original equation: $\Delta V = V_o\beta\Delta T$

Solve: $\Delta V = V_o\beta\Delta T = V_o\beta(T_f - T_o) = (0.50\text{ cm}^3)(18 \times 10^{-5}\,°C^{-1})(80.°C - 21°C)$
$= \mathbf{0.0053\ cm^3}$

Practice Exercises

Exercise 1: On a summer day at the equator on Mars, the temperature never rises higher than 50.0°C. Find this temperature in degrees Fahrenheit in order to determine if this would be a comfortable temperature for a human visiting Mars.

Answer: ____________________

Exercise 2: The highest temperature ever recorded on Earth was 136.4°F at Al' Aziziyah, Libya, on September 13, 1922. The lowest temperature ever recorded was −128.6°F at Vostok, Antarctica, on July 22, 1983. Calculate both of these temperatures in degrees Celsius.

Answer: ____________________

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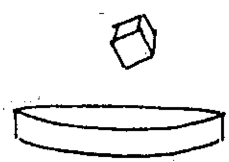
Exercise 3: The barium-yttrium ceramic compound used to demonstrate superconductivity will work only if supercooled to a temperature of 125 K. What is the equivalent temperature a) in °C? b) in °F?



Answer: ____________________

Exercise 4: Most bridges contain interlocking grates that allow the bridge to expand and contract with the change in temperature. The Golden Gate Bridge in San Francisco is about 1350 m long. a) The seasonal temperature variation in San Francisco ranges from about 0°C to 30.°C. How much will the bridge expand between these extremes? ($\alpha_{steel} = 12 \times 10^{-6}\,°C^{-1}$) b) Approximately how wide is this gap compared to the length of an automobile?

Answer: **a.** ____________________

Answer: **b.** ____________________

Exercise 5: Selena has a fire in the fireplace to warm her 20.°C apartment. She realizes that she has left the iron poker in the fire. How hot is the fire if the 0.60-m poker lengthens 0.30 cm? ($\alpha_{iron} = 12 \times 10^{-6}\,°C^{-1}$)

Answer: ____________________

Exercise 6: Leila is building an aluminum-roofed shed in her backyard to store her garden tools. The flat roof will measure 2.0 m × 3.0 m in area during the coldest winter months,when the temperature is −10°C, but temperatures in Leila's neighborhood can reach as high as 38°C in the summer. What is the area of the roof that should stick out from the shed in the summer so that the roof just fits the structure during cold winter nights?
($\alpha_{aluminum} = 24 \times 10^{-6}\,°C^{-1}$)

Answer: ____________________

Exercise 7: Just before midnight, when the air temperature is 10.0°C, Karl stops and fills the 0.0600-m^3 gas tank of his car. At noon the next day, when the temperature has risen to 32.0°C, Karl finds a puddle of gasoline beneath his car. a) What do you think happened? b) How much gasoline spilled out of Karl's car (assuming no change in the volume of the tank)? ($\beta_{gasoline} = 3.00 \times 10^{-4}\,°C^{-1}$)

Answer: **a.** ____________________

Answer: **b.** ____________________

10-2 Heat

Vocabulary **Heat:** The transfer of energy between two objects that differ in temperature.

Vocabulary **Specific heat:** A measure of the amount of heat needed to raise the temperature of 1 kg of a substance by 1°C.

The common unit for specific heat is the **joule per kilogram degree celsius (J/kg°C).**

The transfer of heat from an object depends upon the object's mass, the specific heat, and the difference in temperature between the object and its surroundings.

change in heat = (mass)(specific heat)(change in temperature)
or $\Delta Q = mc\Delta T$

The SI unit for heat is the **joule (J)**. This is the same unit used for mechanical energy in Chapter 5.

The heat lost by one object equals the heat gained by another object.

Heat lost = Heat gained or $(mc\Delta T)_{lost} = (mc\Delta T)_{gained}$

For each object in the system, an $mc\Delta T$ term is needed.

Water has a very high specific heat. It makes a good cooling agent because it takes a long time for water to absorb enough heat to greatly increase its temperature. In the following exercises, you will need to know the specific heat of water and of ice.

$$c_{\text{water}} = 4187\ \text{J/kg°C} \qquad c_{\text{ice}} = 2090\ \text{J/kg°C}$$

All other values for specific heat will be given in the exercises.

Heat of Fusion

Vocabulary

Heat of Fusion: The quantity of heat needed per kilogram to melt a solid (or solidify a liquid) at a constant temperature and atmospheric pressure.

The amount of heat needed to melt a solid is

$$\textbf{change in heat} = \textbf{(mass)(heat of fusion)} \qquad \text{or} \qquad \Delta Q = mh_f$$

The SI unit for the heat of fusion is the **joule per kilogram (J/kg).**

For water, which will be used most frequently in the exercises, the heat of fusion is $\mathbf{3.35 \times 10^5}$ **J/kg.** This means that 3.35×10^5 J of heat is required to turn 1 kg of ice into water. The same amount of heat is given off when 1 kg of water turns into ice.

Heat of Vaporization

Vocabulary

Heat of Vaporization: The quantity of heat needed per kilogram to vaporize a liquid (or liquify a gas) at a constant temperature and atmospheric pressure.

The amount of heat needed to vaporize a liquid is

$$\textbf{change in heat} = \textbf{(mass)(heat of vaporization)} \qquad \text{or} \qquad \Delta Q = mh_v$$

The SI unit for the heat of vaporization is the **joule per kilogram (J/kg).**

For water, the heat of vaporization is $\mathbf{2.26 \times 10^6}$ **J/kg.** This is more than six times the heat of fusion for water.

Note that "steam" is not the same thing as water vapor. Water vapor is an invisible gas that results when water boils or evaporates. Steam is what you see when water vapor is cooled and condenses back into water droplets.

Solved Examples

Example 6: Hypothermia can occur if the body temperature drops to 35.0°C, although people have been known to survive much lower temperatures. On January 19, 1985, 2-year-old Michael Trode was found in the snow near his Milwaukee home with a body temperature of 16.0°C. If Michael's mass was 10.0 kg, how much heat did his body lose, assuming his normal body temperature was 37.0°C? ($c_{\text{human body}} = 3470\ \text{J/kg°C}$)

Given: $m = 10.0\ \text{kg}$
$c = 3470\ \text{J/kg°C}$
$T_f = 16.0°\text{C}$
$T_o = 37.0°\text{C}$

Unknown: $\Delta Q = ?$
Original equation: $\Delta Q = mc\Delta T$

Solve: $\Delta Q = mc\Delta T = mc(T_f - T_o) = (10.0\ \text{kg})(3470\ \text{J/kg°C})(16.0°\text{C} - 37.0°\text{C})$
$= \mathbf{-729\ 000\ J}$

The negative answer implies that there was a heat loss. The encouraging (and amazing) end to this example is that Michael survived!

Example 7: Gwyn's bowl is filled with 0.175 kg of 60.0°C soup (mostly water) that she stirs with a 20.0°C silver spoon of mass 0.0400 kg. The spoon slips out of her hand and slides into the soup. What equilibrium temperature will be reached if the spoon is allowed to remain in the soup and no heat is lost to the outside air? ($c_{\text{spoon}} = 240.\ \text{J/kg°C}$) Assume that the temperature of the bowl does not change.

Given: $m_{\text{water}} = 0.175\ \text{kg}$
$c_{\text{water}} = 4187\ \text{J/kg°C}$
$T_{\text{water}} = 60.0°\text{C}$
$m_{\text{spoon}} = 0.0400\ \text{kg}$
$c_{\text{spoon}} = 240.\ \text{J/kg°C}$
$T_{\text{spoon}} = 20.0°\text{C}$

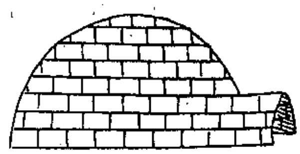
Unknown: $T_f = ?$
Original equation: Heat lost = Heat gained

Solve: $mc\Delta T_{\text{water}} = mc\Delta T_{\text{spoon}}$

$$(0.175\ \text{kg})(4187\ \text{J/kg°C})(60.0°\text{C} - T_f) = (0.0400\ \text{kg})(240.\ \text{J/kg°C})(T_f - 20.0°\text{C})$$
$$43\ 963\ \text{J} - (732.7\ T_f)\text{J/°C} = (9.6\ T_f)\text{J/°C} - 192\ \text{J}$$
$$44\ 155\ \text{J} = (742.3\ T_f)\text{J/°C}$$
$$T_f = \frac{44\ 155\ \text{J}}{742.3\ \text{J/°C}} = \mathbf{59.5°C}$$

Therefore, the temperature of the spoon and soup both reach equilibrium at 59.5°C, so the spoon has become much hotter but the soup has only cooled by 0.5°C.

Example 8: An igloo is made of 224 blocks of ice at 0°C, each with a mass of 12.0 kg. How much heat must be gained by the ice to melt the entire igloo?



Solution: The total mass of the ice is 224 (12.0 kg) = 2690 kg

Given: $m = 2690$ kg
$h_f = 3.35 \times 10^5$ J/kg

Unknown: $\Delta Q = ?$
Original equation: $\Delta Q = mh_f$

Solve: $\Delta Q = mh_f = (2690 \text{ kg})(3.35 \times 10^5 \text{ J/kg}) = \mathbf{9.01 \times 10^8 \text{ J}}$

Example 9: Gus is cooking soup in his hot pot and finds that he has added too much water. If Gus needs to boil off 0.200 kg of water in order for his soup to have the correct consistency, how much additional heat must Gus add once the soup is boiling?

Given: $m = 0.200$ kg
$h_v = 2.26 \times 10^6$ J/kg

Unknown: $\Delta Q = ?$
Original equation: $\Delta Q = mh_v$

Solve: $\Delta Q = mh_v = (0.200 \text{ kg})(2.26 \times 10^6 \text{ J/kg}) = \mathbf{4.52 \times 10^6 \text{ J}}$

Example 10: To cool her 0.200-kg cup of 75.0°C hot chocolate (mostly water), Heidi drops a 0.0300-kg ice cube at 0°C into her insulated foam cup. What is the temperature of the hot chocolate after all the ice is melted?

Solution: The relationship "Heat lost = Heat gained" can take on many forms depending upon what is happening in the exercise. In this exercise, heat is lost from the hot chocolate ($mc\Delta T_{water}$) and gained by the ice cube, first melting it (mh_f) and then raising its temperature ($mc\Delta T_{water}$).

Given: $m_{ice} = 0.0300$ kg
$m_{water} = 0.200$ kg
$h_f = 3.35 \times 10^5$ J/kg
$c_{water} = 4187$ J/kg°C
$T_{water} = 75.0$°C
$T_{ice} = 0$°C

Unknown: $T_f = ?$
Original equation: Heat lost = Heat gained

Solve: $mc\Delta T_{water} = mh_{f(ice)} + mc\Delta T_{water} = (0.200 \text{ kg})(4187 \text{ J/kg°C})(75.0\text{°C} - T_f)$

$= (0.0300 \text{ kg})(3.35 \times 10^5 \text{ J/kg}) + (0.0300 \text{ kg})(4187 \text{ J/kg°C})(T_f - 0\text{°C})$

$= 62\,805 \text{ J} - (837.4\, T_f)\text{J/°C} = 10\,050 \text{ J} + 125.6\, T_f(\text{J/°C})$

$= 52\,755 \text{ J} = (963.0\, T_f)\text{J/°C}$ so $T_f = \dfrac{52\,755 \text{ J}}{963.0 \text{ J/°C}} = \mathbf{54.8°C}$

Practice Exercises

Exercise 8: Peter is heating water on the stove to boil eggs for a picnic. How much heat is required to raise the temperature of his 10.0-kg vat of water from 20.0°C to 100.0°C?

Answer: ____________________

Exercise 9: Nova, whose mass is 50.0 kg, stays out skiing for too long and her body temperature drops by 2.00°C. What is the amount of heat lost from Nova's body? ($c_{\text{human body}} = 3470\ \text{J/kg°C}$)

Answer: ____________________

Exercise 10: Phoebe's insulated foam cup is filled with 0.150 kg of the coffee (mostly water) that is too hot to drink, so she adds 0.010 kg of milk at 5.0°C. If the coffee has an initial temperature of 70.0°C and the specific heat of milk is 3800 J/kg°C, how hot is the coffee after the milk is added? (Assume that no heat leaks out through the cup.)

Answer: ____________________

Exercise 11: Emily is testing her baby's bath water and finds that it is too cold, so she adds some hot water from a kettle on the stove. If Emily adds 2.00 kg of water at 80.0°C to 20.0 kg of bath water at 27.0°C, what is the final temperature of the bath water?

Answer: ____________________

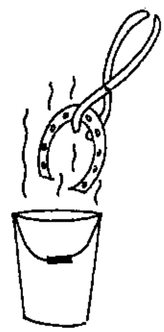
Exercise 12: Finishing his ginger ale, Ramesh stands at a party holding his insulated foam cup that has nothing in it but 0.100 kg of ice at 0°C. How much heat must be gained by the ice in order for all of it to melt?

Answer: ____________________

Exercise 13: In Exercise 12, how much more heat must be gained to raise the temperature of the melted ice to room temperature of 23.0°C?

Answer: ____________________

Exercise 14: Under the spreading chestnut tree the village blacksmith dunks a red-hot horseshoe into a large bucket of 22.0°C water. How much heat was lost by the horseshoe in vaporizing 0.0100 kg of water?

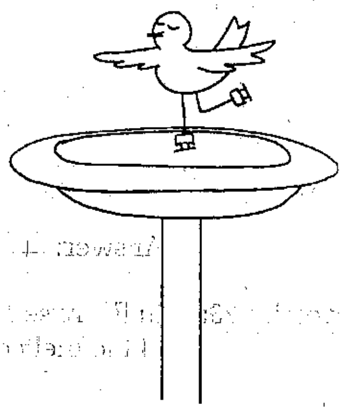


Answer: ____________________

Exercise 15: While Laurie is boiling water to cook spaghetti, the phone rings, and all 1.5 kg of water boils away during her conversation. If the water was initially at 15°C, how much heat must have been gained for all of it to turn into water vapor?

Answer: ____________________

Exercise 16: By January, the 3.0 kg of water in the birdbath in Robyn's backyard has frozen to a temperature of −7.0°C. As the season changes, how much heat must be added to the water to make it a comfortable 25°C for the birds?



Answer: ____________________

Additional Exercises

A-1: The hottest temperature on a planet was 864°F recorded on Venus by the Soviet *Venera* probe and the U.S. *Pioneer* probe. The coldest place in the solar system is Pluto where the temperature is estimated at −360.0°F. Calculate each of these temperatures in degrees Celsius.

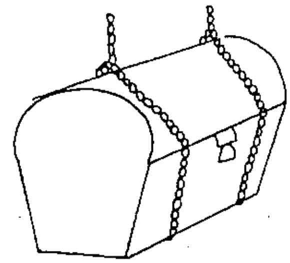
A-2: The temperature of background radiation left over from the Big Bang during the creation of the universe is 3 K. What is the temperature of the universe a) in °C? b) in °F?

A-3: As he rides the train to work on a −4.0°C winter day, Mr. Trump notices that he can hear the click of the train going over spaces between the rails. Six months later, on a 30.0-°C summer day, the rails are pushed tightly together and he hears no click. If the rails are 5.00 m long, how large a gap is left between the rails on the cold winter day? ($\alpha_{steel} = 12 \times 10^{-6}\,°C^{-1}$)

A-4: Bradley, working in his 23°C kitchen, is cooking himself a crepe in an iron skillet that has a circular bottom with a diameter of 30.00 cm. How hot must the skillet be in order for Bradley to make a 710.3-cm^2 crepe that just fills the bottom of the pan? ($\alpha_{iron} = 12 \times 10^{-6}\,°C^{-1}$)

A-5: A popular winter activity of many college students is "traying," or sliding down a snow-covered hill on a tray borrowed from the dining hall. If Joanne removes a 0.35-m × 0.65-m aluminum tray from the 20.°C dining hall to go traying in the brisk −8°C winter air, how much will the tray shrink when taken outside? ($\alpha_{aluminum} = 24 \times 10^{-6}\,°C^{-1}$)

A-6: A 0.50-m^3 brass treasure chest is pulled out of the cold 15°C ocean and onto the deck of a ship, where the air temperature is 40°C. How much does the volume of the treasure chest expand? ($\beta_{brass} = 56 \times 10^{-6}\,°C^{-1}$)



A-7: Leslie takes a full bottle of benzene from the 25.0°C chemistry lab into the 10.0°C refrigerated storage locker. Later, Leslie enters the storage locker and finds that 37.0 cm^3 of benzene is missing from the bottle. What was the original volume of benzene in the bottle? ($\beta_{benzene} = 1240 \times 10^{-6}\,°C^{-1}$)

A-8: Sidney is home from school with a cold, so Mom has made him a bowl of chicken soup (mostly water), which she ladles from a pot into a glass bowl. If 0.600 kg of soup at 90.0°C is placed in a 0.200-kg bowl that is initially at 20.0°C, what will be the temperature of the soup when the bowl and soup have reached equilibrium? (c_{glass} = 840. J/kg°C)

A-9: In A-8 above, when the soup and bowl are at 80.0°C, a chilled dumpling with a mass of 0.100 kg and a temperature of 10.0°C is added. What will be the temperature of the dumpling, soup, and bowl when the three have reached equilibrium? ($c_{dumpling}$ = 110. J/kg°C)

A-10: Nils is emptying the dishwasher. He removes a 0.200-kg glass that has a temperature of 30.0°C. Into it he pours 0.100 kg of diet soda (mostly water), which comes out of the refrigerator with a temperature of 5.00°C. Assuming no external heat loss, what will be the final equilibrium temperature of the glass of diet soda? (c_{glass} = 840. J/kg°C)

A-11: In Exercise A-10, Nils doesn't feel that his drink is cold enough, so he throws in an ice cube whose temperature is −3.0°C. What is the mass of the ice cube if his drink (and glass) are now cooled to 1.0°C?

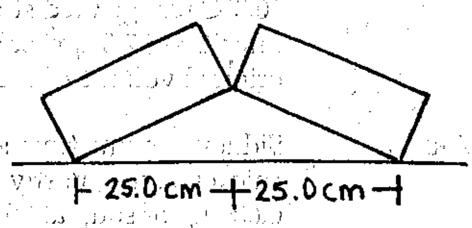
A-12: A puddle filled with 20. kg of water is completely frozen to −6.0°C in the middle of the winter. How much heat must be absorbed by the puddle to melt the ice and warm the water up to 20.°C during the spring thaw?

A-13: Before ironing his shirt for work, Nathaniel drops some water on his iron to test whether it is hot enough to iron his clothes. How much heat is needed to vaporize a 5.0×10^{-4}-kg drop of 20.°C water?

Challenge Exercises for Further Study

B-1: Lawrence, a civil engineer, uses a steel tape measure to figure the dimensions of the Emersons' property. When the temperature is 37°C, he determines the property line to be 152.000 m long. However, the length of the property seems to have changed when Lawrence returns on a 5.0°C winter day. a) Does the property appear to be longer in the warm weather or the cold? Explain why you think this is so. b) How long is the property when measured by his steel tape in the winter? ($\alpha_{steel} = 12 \times 10^{-6}\,°C^{-1}$)

B-2: One cool 5.0°C spring morning, Mason lays a brick sidewalk up to his house, placing the 25.0-cm-long bricks end to end against each other. However, Mason forgets to leave a space for expansion and when the temperature reaches 36.0°C, the bricks buckle. How high will the bricks rise? ($\alpha_{brick} = 10.0 \times 10^{-6}\,°C^{-1}$)



B-3: Phil is making a sandwich and he is having trouble getting the lid off the jar of mayonnaise. a) If the steel lid and the glass jar each have a diameter of 10. cm at a room temperature of 21°C, should Phil run the lid under water that is 20.°C warmer or 20.°C cooler to remove the lid? b) When he completes the correct procedure to free the lid, what is the size of the space between the lid and the jar? ($\alpha_{aluminum} = 24 \times 10^{-6}\,°C^{-1}$ and $\alpha_{glass} = 8.5 \times 10^{-6}\,°C^{-1}$)

B-4: Pablo brings a 6000.-cm^3 aluminum can filled all the way to the top with turpentine up from the 20.0°C basement and sets it outside where he is painting. The noonday sun heats the turpentine and the aluminum container to 45.0°C. Will the turpentine overflow the container? If so, how much will spill out? If not, how much more could be added to the empty space created? ($\beta_{aluminum} = 77 \times 10^{-6}\,°C^{-1}$ and $\beta_{turpentine} = 900. \times 10^{-6}\,°C^{-1}$)

B-5: In a physics experiment, a 0.100-kg aluminum calorimeter cup holding 0.200 kg of ice is removed from a freezer, where both ice and cup have been cooled to −5.00°C. Next, 0.0500 kg of steam at 100.°C is added to the ice in the cup. What will be the equilibrium temperature of the system after the ice has melted? ($c_{aluminum} = 920.\ J/kg°C$)