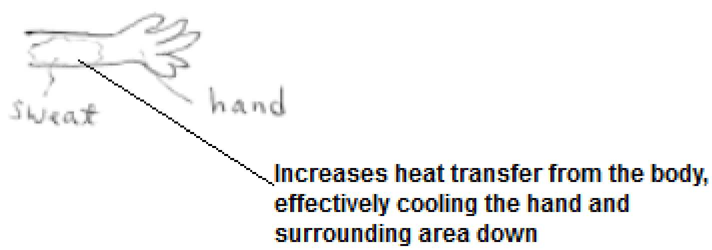
Q1. Can sweating cool you down?

(a) Please explain your answer using words.

Sweating can cool an individual down, because the addition of water to the skin surface increases the skin's thermal conductivity, allowing the physical hot to cold thermal diffusion to release heat from the body more effectively. Sweating provides an evolutionary advantage in this regard, as the amount of sweat generated from the body provides a proportional amount of cooling, effectively allowing individuals with sufficient sweating to continue vigorous activities amid a rising body temperature, with less concern for premature exhaustion or risks to their health.

Considering the thermodynamic processes in more detail, sweat emerges from your body while your body is attempting to adjust from the heat of the environment. This may be in response to physical activity, or a high environmental temperature. In either case, heat readily flows into the sweat, which either drops from the body or evaporate from rising kinetic energy. This speeds the process of heat leaving the body, and thus, sweating can cool you down.

(b) Please sketch on the diagram below to help your explanation. [Also show the necessary label(s)]



(c) Is (Are) there any formula(s) which can help your explanation? How can this (these) formula(s) help your explanation?

The basic principles can be explained using a formula for heat transfer. In the following equation, q denotes heat, c denotes heat capacity, and delta (T) denotes change in temperature.

delta(q) = c x delta(T)

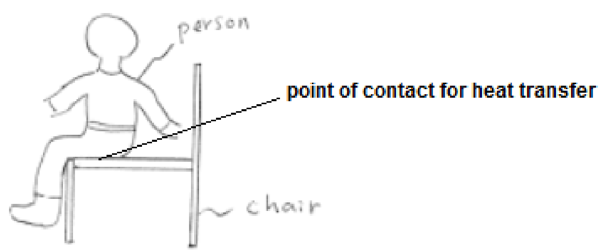
In the equation, considering that water has approximately four times the heat capacity of air, the change allows a proportional increase in heat loss amid the body's (and likely environment's) maintained temperature.

Q2. In winter, which makes you feel colder, sitting on a wooden chair or sitting on a metal chair?

(a) Please explain your answer using words.

In the winter (or otherwise on a cold day), one would feel significantly colder sitting on a metal chair, compared to a wooden chair. There are multiple factors responsible for this phenomenon. In short, one is density, while another is the surface contact, and these ultimately contribute to thermal conductivity and heat loss. Both the lower density and more porous surface of the wood contributes to a lower thermal conductivity, as even the most smooth wood surface would feel warmer than metal, because of the density difference.

(b) Please sketch on the diagram below to help your explanation. [Also show the necessary label(s)]



(c) Is (Are) there any formula(s) which can help your explanation? How can this (these) formula(s) help your explanation?

The basic principles can be explained using a formula for heat transfer. In the following equation, q denotes heat, c denotes heat capacity, and delta (T) denotes change in temperature.

delta(q) = c x delta(T)

Similar to the previous question, the higher density results in a higher heat capacity, allowing for a (undesirable in this case) greater transfer of heat in metal compared to wood.

Meanwhile, another equation assists in explaining the role of surface contact (assuming wood is more porous).

Q = (U)(A)(T), where q=heat, U=conductance, A=surface area, and T=temperature.

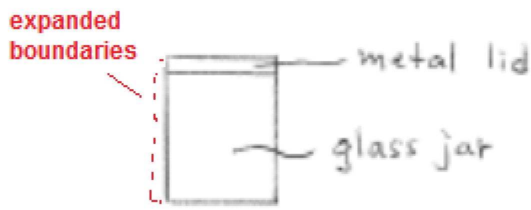
Here, the surface contact with the less porous surface would give rise to increased heat transfer (while the density of the metal contributes to the conductance, and therefore to the heat transfer also).

Q3. Mary takes a **glass jar** and wants to open the **metal lid** on it. She finds it is too tight to open the lid, so she decides to put the jar in the sink and turns on the hot water tap to heat the lid with running hot water. After doing that for a while (the temperature of the lid and jar becomes different), she opens the lid successfully. Why?

(a) Please explain your answer using words.

The heat from the hot water effectively caused the lid to expand, due to the transfer of energy resulting from the difference in heat, and the potential for the metal to expand in response to this energy. While the water was assumedly placed on the metal only, had it been placed on both the metal and the glass, the metal would have still expanded a greater distance (and therefore reducing its tightness on the jar) because of the greater capacity for metal to expand in response to heat transfer.

(b) On the diagram below, please use dotted lines to sketch the lid and jar after they are heated by running hot water. [Also show the necessary label(s)]

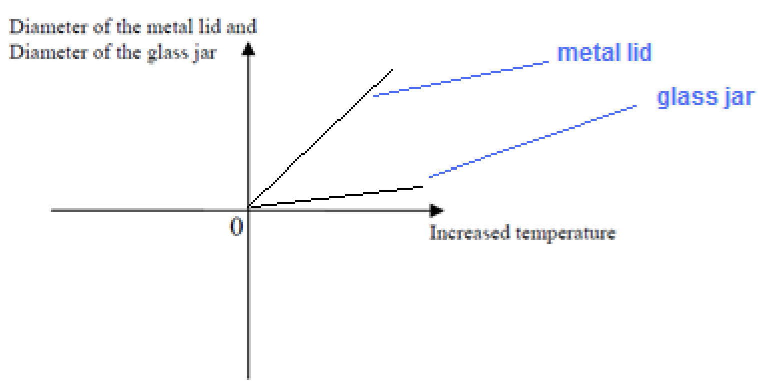


(c) Is (Are) there any formula(s) which can help your explanation? How can this (these) formula(s) help your explanation?

Thermal expansion can be calculated using $\Delta L = \alpha L_0 \Delta T$, where ΔL denotes a change in length, α denotes the coefficient of linear expansion, L_0 denotes the original length, and ΔT denotes a change in temperature. The coefficient for linear expansion of a metal, assuming tin, would be 23.4 in this case, while that of basic and average glass is only 8.5. Considering this, even if the water was transferring heat equally to the glass and the lid, the lid would expand at a greater rate (increasing the potential for the jar to be opened); placing the water on the lid somewhat would hasten this process.

(d) Please complete this coordinate graph.

The graph below displays a difference in slope of approximately 3:1, considering the difference between 23.4 and 8.5 as linear coefficients.



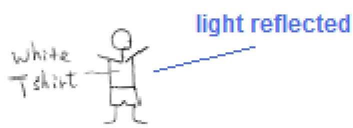
(Please label the graphs with "metal lid" and "glass jar")

Q4. On a hot day (your surrounding's temperature is higher than your skin's temperature). Which T-shirt makes you feel hotter, wearing a black T-shirt or wearing a white T-shirt? (Assume both are made of the same material.)

(a) Please explain your answer using words.

Assuming both the black and white T-shirts are constructed from the same material, the black T-shirt would make one feel hotter than the white T-shirt; this is due to the reflection and absorption properties of the actual colors, as white objects are known to reflect sunlight while black objects are known to absorb light. Essentially, more of the Sun's radiation is absorbed by the black T-shirt (which absorbs the full range of light wavelengths in the visible spectrum), while the white T-shirt reflects the light wavelengths with minimal heat absorbed from radiation (compared to all other colors).

(b) Please sketch on the diagrams below to help your explanation. [Also show the necessary label(s)]



(c) Is (Are) there any formula(s) which can help your explanation? How can this (these) formula(s) help your explanation?

q = e σ A [(ΔT)^4]; where q is heat, E is emissivity of system, σ is the f Stephan-Boltzmann constant (5.6697 x 10^-8 W/m^2.K^4), A is the area, and T is temperature.

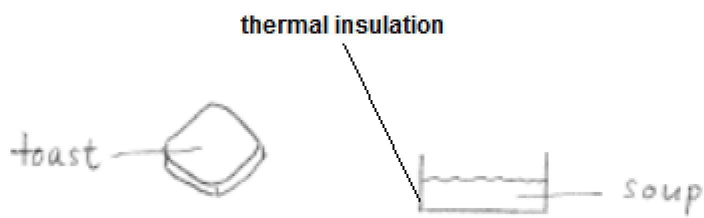
From the above equation, it is evident that the rise is emissivity is directly proportional to the rise in heat transfer, while the qualitative principle of the black T-shirt absorbing the full spectrum of wavelengths in the radiation versus the white T-shirt reflecting them will clearly give rise to a significantly greater heat transfer.

Q5. A piece of toast may be comfortably eaten a few seconds after coming from the hot toaster, whereas we must wait several minutes before eating soup from a stove as hot as the toaster. Do you agree? (The toast and the soup lose the same amount of heat per unit time, and they have the same mass.)

(a) Please explain your answer using words.

Despite a piece of toast and a bowl of soup (each having equal mass) having the same rate of heat loss, toast can cool off more quickly than soup, due to the insulating conditions present in the soup. While a piece of toast simply loses heat while its larger surface area is exposed, the bowl of soup has multiple advantages to retaining its heat. Firstly, the bowl of soup *is insulated by the bowl itself, while the toast has no insulation to protect it from heat loss. Meanwhile, the bowl of soup has a lesser surface area, which may potentially be true even if the bowl was not present. These two factors play a major role in the difference in actual heat loss, and while the materials in the soup may also contribute to variations in heat loss, the given equivalent rates of heat loss over time permits this factor to be negligible in this case; (this would be similar to the thermal conductivity considered in the previous question regarding wood versus metal toilet seats and conductivity with the air.)*

(b) Please sketch on the diagrams below to help your explanation. [Also show the necessary label(s)]



(c) Is (Are) there any formula(s) which can help your explanation? How can this (these) formula(s) help your explanation?

Q = (U)(A)(T), where q=heat, U=conductance, A=surface area, and T=temperature.

From the above equation, it is evident that a greater surface area and greater conductance will contribute to a greater heat transfer (loss in this case); the soup has a lesser surface area in direct contact with the air, while the bowl impacts the conductance (serving as an insulator), allowing the soup to retain the heat for a longer period of time.

Q6. Lee takes two cups of water at 40℃ and mixes them with one cup of water at 10℃ (each cup of water weighs 250g). What is the most likely temperature of the mixture?

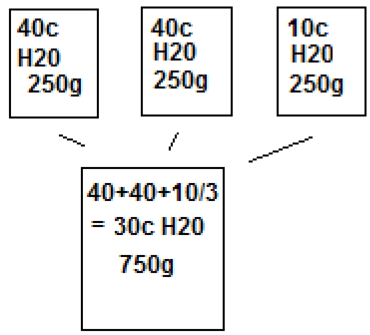
○a 20▯ ○b 25▯ ○c 30▯ ○d 50▯

(a) Please explain your answer using words.

C shows the correct approximate temperature. This can be explained conceptually due to the equal masses and specific heats, while it is also calculated quantitatively below. The equal masses of identical substances (therefore having identical specific heats) allow us to assume that the temperature will most likely be the mean of the three temperatures, or approximately 30deg. C.

(b) Please sketch a diagram(s) to help your explanation. [Also show the necessary label(s)]

Note that the following diagram is only accurate due to the equal masses and specific heats. A detailed calculation follows in the next section.



(c) Is (Are) there any formula(s) which can help your explanation? How can this (these) formula(s) help your explanation?

The thermal energy contained in the water for each cup can be calculated using the formula $E = mc_p(T_2 - T_1)$*, and this can then be used to calculate the energy of each cup, then these can be added for an energy total; following this, the final temperature can be calculated using the formula* $T_f=T_1+T_E/(m \times c_p)$*. In these equations, m denotes mass,* c_p *denotes the specific heat (of water), E denotes the thermal energy,* T_f *denotes final temperature,* T_1 *denotes the lower temperature (10deg. Celsius in this case) in the temperature difference, and* T_2 *denotes the higher temperature (40deg. Celsius in this case) in the temperature difference.*

Entering values into these formulas:

*(250g)(4.186j/gram*deg.C)x(40-10deg.C)=31385j*
*(250g)(4.186j/gram*deg.C)x(40-10deg.C)=31385j*
*(250g)(4.186j/gram*deg.C)x(10-10deg.C)=0j*
*X=10deg.C+(62770j/(750g x 4.186j/g*deg.C)); x=31.5~**<u>30deg.C</u>***

Q7. Pam asks one group of friends: “If I put 100 grams of ice at 0℃ and 100 grams of water at 0℃ into a freezer, which one will eventually lose the greatest amount of heat? (The temperature inside the freezer is -10℃)

○a Cat says: “The 100 grams of ice.”

○b Ben says: “The 100 grams of water.”

○c Jed says: “They both will eventually lose the same amount of heat.”

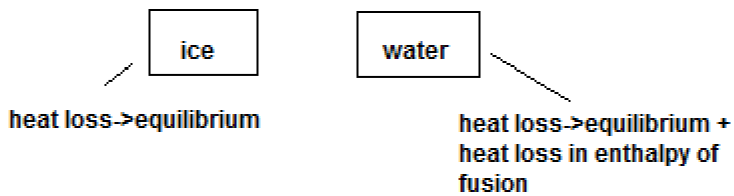
○d Nic says: “You all are wrong.”

Which of her friends do you most agree with?

(a) Please explain your answer using words.

*Ben (**b**) is ultimately correct, and while the amount of heat loss is comparable due to the mass, compound, and initial temperatures, the enthalpy of fusion has already taken place in the ice where it has not in the water; this will create a slightly greater net heat loss from the water as it freezes while approaching the freezer temperature. The ice has already lost this heat.*

(b) Please sketch a diagram(s) to help your explanation. [Also show the necessary label(s)]

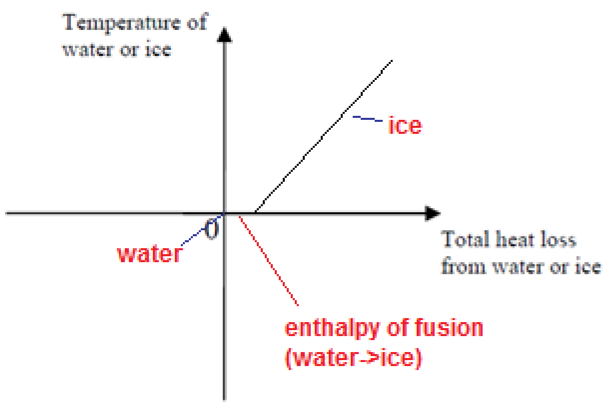


(c) Is (Are) there any formula(s) which can help your explanation? How can this (these) formula(s) help your explanation?

The heat equation $q=c_p$ x m x delta(T) can show the heat lost by each mass, while the specific heat of each variable can therefore assist with the solution; in the listed equation, q denotes heat, c_p denotes specific heat, m denotes mass, and delta(T) denotes change in temperature. Also, Q = (U)(A)(T), where q=heat, U=conductance, A=surface area, and T=temperature.

These equations show that the heat loss will be comparable past the freezing point, but they do not consider the enthalpy of fusion for water, which means that these otherwise comparable heat transfers will be unbalanced by this small amount of heat lost, as the water initially fuses into ice.

(d) Please complete this coordinate graph which **represents the situation after 0℃ water has been put in this freezer**. [Please label the phase (i.e. water, ice) on this graph)]



Q8. In constructing an expansion-type thermometer, it is necessary to use a material which

○a changes phase when heated.

○b has a coefficient of thermal expansion which increases with increasing temperature.

○c has a coefficient of thermal expansion which decreases with increasing temperature.

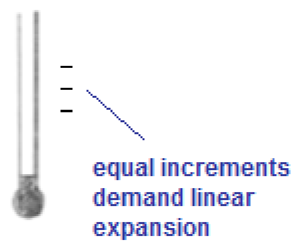
○d will expand linearly with increasing temperature.

Which one would you choose?

(a) Please explain your answer using words.

*Choice '**d**' is the ideal choice; this is because a change of phase would not produce results desirable for consistent display, changes in the coefficient of thermal expansion are not necessarily in incremental proportion to changes in temperature (and therefore may not fit to incremental scales), and a material which expands in proportion to temperature is ideal for using within a thermometer constructed with a linear scale.*

(b) Please sketch on the thermometer shown below to help your explanation.[Also show the necessary label(s)]



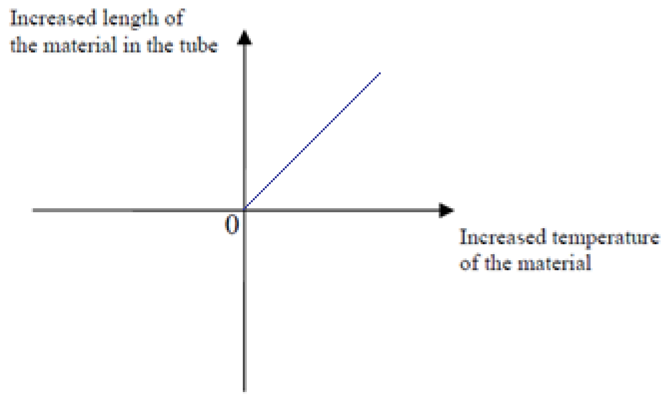
(c) Is (Are) there any formula(s) which can help your explanation? How can this (these) formula(s) help your explanation?

Thermal expansion can be calculated using $\Delta L = \alpha L_0 \Delta T$, where ΔL denotes a change in length, α denotes the coefficient of linear expansion, L_0 denotes the original length, and ΔT denotes a change in temperature.

This shows how an ideal compound, such as the commonly known mercury, would expand in a thermometer. The creators would have to pay special attention to the capacity for a volume of mercury, and the distance between increments, to create an effective and accurate thermometer; this equation would assist in making this possible.

(d) Please complete this coordinate graph.

The thermometer should be created so that the volume of the expanding compound would increase in direct proportion with the increments of temperature. Assuming a length in millimeters for an increase in Celsius (small thermometer), this could be a 1:1 ratio as shown, or much greater (depending on design).


Increased length of
the material in the tube
0
Increased temperature
of the material