

Thermodynamics
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Lecture 15
Zeroth law of thermodynamics

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- Thermodynamics: is the science that deals with energy and its conversion and transformation
 - Modes of energy transfer → Heat/ work

 - Which mode of energy transfer occurs may depend on choice of system/control volume



Thermodynamics is a science that deals with energy and its conversion and transformation. So far, we have looked at only one form of energy transformation which is work. Now, we will look at the other one, heat. So, there are two modes of energy transfer, work and heat.

Based on the choice of a system or a control volume, the energy transfer may be either in the form of heat or work or both.

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- Heat is an interaction between a system and surroundings which occurs solely by virtue of a temperature difference between the two
- Heat is energy transferred across a boundary by virtue of a temperature difference between two systems



Heat is an interaction between a system and its surroundings which takes place only because of a temperature difference between the two. It is energy transfer across a boundary.

We do not talk of heat transfer within the system. We only talk of heat transfer between a system and its surroundings. Heat is transferred across a boundary by virtue of temperature difference between two systems or a system and its surroundings. If there is no temperature difference between the system and the surroundings, there will be no net heat transfer.

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- Spontaneous heat transfer occurs between a system and surroundings at different temperatures
- Direction: higher temperature to lower temperature
- Heat transfer: path function, is an occurrence, not a property, not something stored
- $\int_A^B \delta Q = Q_{1-2} = \int_1^2 \delta Q$  $\int \delta W$
- $q = Q/m$
- $\dot{Q} = \delta Q/dt$ in the limit of $dt \rightarrow 0$



From experience, we know that a hot cup of coffee or tea cools down in a room at a temperature lower than the coffee or the tea. An ice cream, which is cold, starts melting in a room at higher temperature, i.e. the temperature of the ice cream increases. What we see is that the spontaneous heat transfer occurs between a system and the surroundings when the two are at different temperatures. Spontaneous heat transfer always occurs from a higher temperature to a lower temperature. Hence, the hot tea cools down. The cold ice cream warms up.

Similar to work transfer, heat transfer is also a path function. It also depends on what path we take in going from one state to another. Heat transfer is an occurrence. It's not a property. It is not something which is stored. It is something which happens while a process is going on.

We know that a small amount of work is represented as δW . To obtain the total work, we integrate δW . Similarly, a small amount of heat is represented as δQ . To obtain the total heat transfer during a process, we integrate δQ from state 1 to state 2 along a particular path. This total heat transfer during a process is represented as ${}_1Q_2$ or Q_{1-2} .

Heat transfer per unit mass is represented as q . It is not a property.

The rate of heat transfer is represented as $\dot{Q} = Q' = \lim_{dt \rightarrow 0} \frac{\delta Q}{dt}$

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- Unit: J, kcal
- Heat transferred into system +ve
- Heat transferred from system -ve
- Heat transfer in general leads to an increase in the temperature of the system



$$Q \text{ / } s = W$$



The SI unit of heat transfer is J (joule). Traditionally, the unit used for heat transfer is calorie. In this course, we are going to use the SI unit. There is a conversion factor of 4.2 between a calorie and a joule.

The unit of rate of heat transfer is J/s (joule per second) or W (watt).

In the case of work transfer, work done by the system on the surroundings is positive, whereas the work is negative if it is done on the system.

Heat transfer is positive if it is into the system, whereas it is negative if it is from the system to the surroundings.

In general, heat transfer leads to an increase or decrease of the temperature of the system. However, it is not true always. There are exceptions. During a phase change process, even though there is heat transfer from the system, the temperature of the system stays constant (e.g. melting of ice into water at 1 atmosphere).

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- Quiz
- A wooden block and a copper block are kept in an air conditioned room for a long time. Which is colder?
 - The wooden block
 - The copper block
 - Both are at the same temperature
 - Insufficient data



Figure 1

Answer of the question in Fig. 1:

If the blocks are kept in an air-conditioned room for a long time, we expect that the blocks attain the temperature of the room. Let's assume that the temperature of the room is constant.

However, from our experience, we feel the copper block is colder than the wooden block. We have a similar experience on a cold day when we touch the metal and the rubber/plastic parts of a cycle. We feel the metal parts are colder compared to the rubber/plastic parts.

Actually, the copper and the wooden blocks attain the same temperature as room when they are kept in that room (which is at constant temperature) for a sufficiently long time. We feel copper block colder compared to that of wood because the rate of heat transfer from our hand to copper block is higher than that for wooden block. This happens because the thermal conductivity of metals is higher compared to non-metals. More heat is taken away from our hand when we touch the copper block than when we touch the wooden block in the same period of time. It shows that we are not good at sensing temperatures of objects.

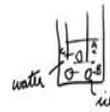
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- Zeroth Law of Thermodynamics



“ If system A is in equilibrium with system B and system B is in equilibrium with system C, then systems A and C must be in equilibrium with each other.”

Principle of thermometry



Correction: Equilibrium here refers to thermal equilibrium

We need special instruments to measure temperature. We need to calibrate these instruments using some fixed reference points. For example, the temperature of an ice and water mixture at atmospheric pressure can be a reference point. The temperature of such mixture measured by different instruments is given some constant value. If we don't have such common reference point, the temperatures measured by different instruments would be different.

We usually call the temperature of ice and water mixture at atmospheric pressure as 0 degree centigrade. When we insert our instrument (e.g. thermometer) into this ice and water mixture, and leave it there for a long time, we assume that the instrument attains the same temperature as the ice and water mixture. Similarly, when we put another instrument into the same ice and water mixture and leave it there for a long time, it also attains the temperature of the mixture. When these two instruments are brought in contact with each other, there would be no heat transfer between the two instruments as their temperatures are the same.

This is what the zeroth law of thermodynamics is all about. If a system A is in thermal equilibrium with system B and the system B is in thermal equilibrium with a system C, then the systems A and C are in thermal equilibrium with each other.

This law forms the basis of thermometry.