ME 209
Basic Thermodynamics (Lecture-5)

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Review

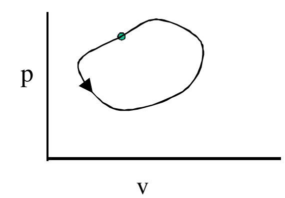
- We had argued axiomatically that Temperature is nothing but labels of isotherms.
- Isotherms were sequence of states for a system to have no heat interaction with a surrounding whose state was fixed.
- Such system states for which there are no heat interactions with surroundings are said to be in thermal equilibrium with surroundings

Temperature - I

- Humans could sense temperature long before development of thermometers. However, judgement cannot be quantified.
- Bodies at different temperature, when brought in contact and left isolated, undergo changes in physical properties before they attain equilibrium, called **thermal equilibrium**
- The energy interaction by virtue of change in temperature is called **heat interaction** and will be studied later

Temperature - II

- By executing a cyclic process (after knowing how to measure it), it can be deduced that temperature is a property



- Zeroth law of thermodynamics helps us to invent temperature scales
- To develop scales and measure temperature, we use some physical property of the sensing element
- Volume of liquid, electrical resistance, pressure/volume of a gas, thermo emf, etc., are some properties that are used

Temperature - III

Zeroth Law

- It states that If a body A is in thermal equilibrium with body B (sensing element) and the body B is in thermal equilibrium with body C, then body A is in thermal equilibrium with body C
- What this implies is that both bodies A and C when in thermal equilibrium, will make body B have the same value of a physical property, which can be used to create a temperature scale
- Let us first look at two point reference temperature scales

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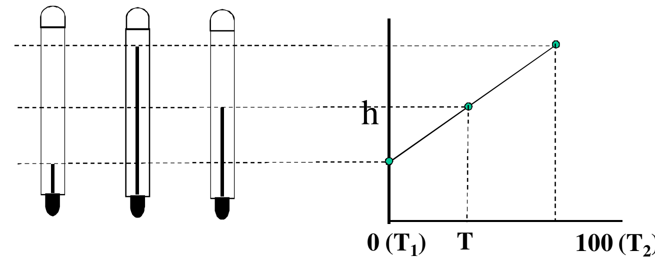
Temperature - III



- The scale is assumed linear

$$\frac{h - h_1}{h_2 - h_1} = \frac{T - T_1}{T_2 - T_1}$$

- In the above scale, we have assumed $T_1 = 0$ and $T_2 = 100$ and these assignments are arbitrary

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Temperature - IV

Two Point scales

- In Celsius scale, the first state corresponds to melting ice and the second state corresponds to boiling steam at 1 standard atmosphere

Other Scales

Scale	Melting ice value	Boiling steam value
Kelvin	273.15	373.15
Fahrenheit	32	212
Rankine	491.67	671.67

- Inter conversion is fairly straight forward

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Temperature - IV

- As the interest of temperature spread to higher temperatures, thermometric substance other than mercury had to be looked into
- Gas turned out to be convenient option as it can be used at widely varying temperatures
- Gas at lower pressures obey Boyle's law

$$pV = Constant$$

- Ideal gas is one that obeys Boyle's law everywhere
- Using Boyle's and Charles Law, the ideal gas equation of state can be expressed as

$$pV = mRT$$

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Temperature - IV

One Point scale

- The triple point of water, where solid, liquid and gas phases of water coexist is chosen as the reference and is assigned a value 273.16
- The relation used to find the other temperature values are

$$\frac{\phi}{\phi_R} = \frac{T}{T_R} \quad \textbf{Or} \quad T = 273.16\frac{\phi}{\phi_R}$$

In the above ϕ and ϕ_R are the property values at T and T_R

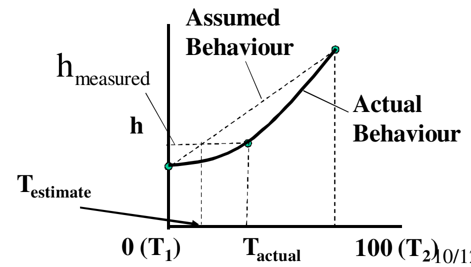
- If we use a fixed mass of gas as a thermometric substance

$$T = 273.16\frac{(pV)}{(pV)_R}$$

Temperature - V

Errors in temperature scales

- All scales assume a linear behaviour between the temperature and the sensing property
- While gas thermometers (constant p or constant V) at low pressures are linear, most properties do not vary linearly



Temperature - VI

International Practical Scale

- It is clumsy to use gas thermometer in practical environment
- To facilitate calibration a practical scale has been evolved. It is summarized in the next slide

Reference	Value (K)
Triple Point of H_2	13.8033
Triple Point of Ne	24.5561
Triple point of O_2	54.3584
Triple point of Ar	83.8058
Triple point of Hg	234.316
Triple point of Water	273.16
Melting Point of Ga	302.915
Freezing Point of In	429.749
Freezing point of Sn	505.078
Freezing point of Zn	692.677
Freezing point of Al	933.473
Freezing point of Ag	1234.93
Freezing point of Au	1337.33
Freezing point of Cu	1357.77

Source http://en.wikipedia.org/wiki/International_Temperature_Scale_of_1990