CHAPTER FOUR

HEAT AND THERMODYNAMICS (TDs)

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HEAT AND THERMODYNAMICS

Introducion

➢ Thermodynamics is a science of the relationship between heat, work, temperature, and energy.

➢ In broad terms, thermodynamics is the study of energy conversion b/n heat and other forms of energy.

➢ In thermodynamics, one usually considers both thermodynamic systems and their surrounding (environments).

➢ System is a definite quantity of gas enclosed in a cylinder with a sliding piston that allows the volume of gas to vary.

➢ System is the subject of the study in TDS. I.e.; Solid, liquid or gas.

➢ thermodynamic system is defined by its temperature, volume, pressure, and chemical composition

➢ A system is in equilibrium when each of these variables has the same value at all points.

➢ Surrounding is the environment that is around a system and in thermal contact with it.
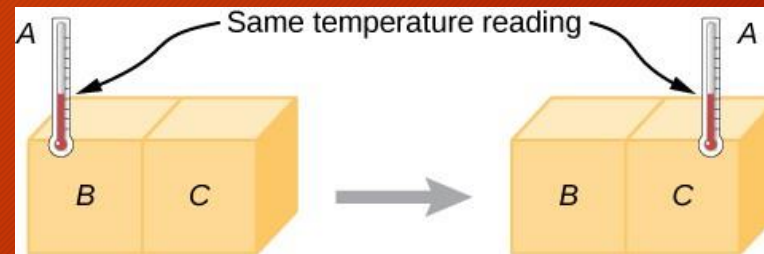
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4.1. The concept of temperature and zeroth law of TDs

➢ Heat is defined as the flow of energy from one object to another. This flow of energy is caused by a difference in temperature.

➢ Temperatue is the measure of average KE of the particles in a body

➢ Heat can flow between objects if they are in thermal contact.

➢ An important concept related to temperature is thermal equilibrium.

➢ Two objects are in thermal equilibrium if they are in close contact that allows either to gain energy from the other, but nevertheless, no net energy is transferred between them.

Zeroth's Law of TDs: States that:

➢ Experimentally, if object A is in thermal

equilibrium with object B, and objectB is in

thermal equilibrium with object C, then object A is in thermal equilibrium with object C.

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Temperature Scales

➢ Any physical property that depends consistently and reproducibly on temperature can be used as the basis of a thermometer.

➢ Thermometers measure temperature according to well-defined scales of measurement.

➢ The SI unit of Temperature is Kelvin(K)

➢ Other temperature scales are Celsius, Fahrenheit and Rankin.

4.2. Thermal Expansion

➢ Is the increase in length of a substance due to heating.

➢ Could be: (I).**Linear Thermal Expansion**

         (II). Areal Expansion

         (III). Volume Expansion

	°F	°C	K
Boiling point of water	212	100	373
Freezing point of water	32	0	273
Freezing point of dry ice (CO_2)	−109	−78	195
Boiling point of nitrogen	−321	−196	77
Absolute zero	−460	−273	0

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I. Linear Thermal Expansion

➢ The increase in length Δl of a solid is proportional to its initial length l_0 and the change in its temperature ΔT .The proportionality constant is called the coefficient of linear expansion α.

$$\Delta l = \alpha l_0 \Delta T$$

$$l = l0 + \Delta l = l0 + \alpha l0\Delta T, \text{ or } l = l0(1 + \alpha \Delta T)$$

II. Areal Expansion

➢ The change in area ΔA of a solid is proportional to its initial area A_0 and the change in its temperature ΔT . That is;

$$\text{➢ } \Delta A = \beta A_0 \Delta T$$

$$A = A_0 (1 + \beta \Delta T)$$

Where $\beta = 2\alpha$

III. Volume Expansion

➢ The change in volume of a material which undergoes a temperature change is given by a relation;

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

$$V = V_0 (1 + \gamma \Delta T)$$

Where: $\gamma = 3\alpha$

Substance	Coefficient of linear expansion, $\alpha (K^{-1})$
Lead	29×10^{-6}
Aluminum	24×10^{-6}
Brass	19×10^{-6}
Copper	17×10^{-6}
Iron (steel)	12×10^{-6}
Concrete	12×10^{-6}
Window glass	11×10^{-6}
Pyrex glass	3.3×10^{-6}
Quartz	0.50×10^{-6}

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4.3. The Concept of Heat, Work and Internal Energy

➢ *Heat and work are two possible ways of transferring energy from one system to another.*

➢ Heat, symbol Q and unit Joule (J), is the spontaneous flow of energy into or out of a system caused by a difference in temperature between the system and its surroundings, or between two objects whose temperatures are different.

➢ Heat is a transient phenomenon.

➢ Heat transfer obeys the law of conservation of energy (if no heat is lost to the surroundings): Qlost by hotter object = Qgained by cooler object

$$Q=mc\Delta T$$

➢ Work, symbol W and unit Joule (J), is a non-spontaneous energy transfer into or out of a system due to force acting through a displacement.

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4.4. Specific Heat and Latent Heat

➤ Heat flowing into or out of a body (or system) changes the temperature of the body (or system) except during phase changes the temperature remains constant.

➤ The quantity of heat, Q, required to change the temperature of a body of mass m by ΔT is proportional to both the mass and the change in temperature.

$$Q = mc\Delta T$$

➤ The heat capacity(C) is defined as the amount of heat energy required to raise the temperature of a substance by 1^0C.

Latent Heats

➤ Latent Heat the heat required per unit mass of a substance to produce a phase change at constant temperature

$$L = \frac{Q}{m}$$

➤ SI-unit of L J/kg

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Types of Latent Heat Transfer

Latent Heat of Fusion (Lf): is the heat absorbed or released when matter melts, changing phase from solid to liquid form at constant temperature

Latent Heat of Vaporization (L_V): is the heat absorbed or released when matter vaporizes, changing phase from liquid to gas phase

at constant temperature

Eg.; For water Lf= 333.7kJ/kg and so L_V = 2256 kJ.

Substance	Specific heat c	
	J/kg·°C	cal/g·°C
Elemental solids		
Aluminum	900	0.215
Beryllium	1 830	0.436
Cadmium	230	0.055
Copper	387	0.092 4
Germanium	322	0.077
Gold	129	0.030 8
Iron	448	0.107
Lead	128	0.030 5
Silicon	703	0.168
Silver	234	0.056
Other solids		
Brass	380	0.092
Glass	837	0.200
Ice (-5°C)	2 090	0.50
Marble	860	0.21
Wood	1 700	0.41
Liquids		
Alcohol (ethyl)	2 400	0.58
Mercury	140	0.033
Water (15°C)	4 186	1.00
Gas		
Steam (100°C)	2 010	0.48

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➢ Work takes many forms, moving a piston, or stirring, or running an electrical current through a resistance. Work is the non-spontaneous transfer of energy.

➢ Internal Energy, symbol U, is defined as the energy associated with the random, disordered motion of the microscopic components-atoms and molecules.

➢ Internal energy is all the energy of a system that is associated with its microscopic components, atoms and/or molecules, when viewed from a reference frame at rest with respect to the center of mass of the system.

➢ Internal energy includes kinetic energy of random translational, rotational, and vibrational motion of molecules; vibrational potential energy associated with forces between atoms in molecules; and electric potential energy associated with forces between molecules.

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4.5. The First Law of Thermodynamics

➢ The first law of thermodynamics states that: ―*The change in internal energy of a system is equal to the sum of the heat flow into the system and the work done on the system.*"

$$\Delta U = Q + W$$

The First Law for different thermodynamic systems:

i.   Isobaric process : $\Delta U = Q + W$

ii. **Isochoric process:** $\Delta U = Q$

iii. **Isothermal Process:** $Q = \pm W$

iv. Adiabatic Process: $\Delta U = W$

Water as an Extinguishing :When sand and water are exposed to the same amount of heat energy from the sun, you will have observed that sand gets much ―hotter‖ (attains a higher temperature) than water. This is because water has a much higher specific heat than sand.

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4.6.Heat Transfer Mechanisms

- Heat may be transferred from one place to another in three ways:
- conduction
- convection
- radiation
- direct burning

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Chapter Summery

- Two objects are in thermal equilibrium with each other if they do not exchange energy when in thermal contact.

- The zeroth law of thermodynamics states that if objects A and B are separately in thermal equilibrium with a third object C, then objects A and B are in thermal equilibrium with each other.

- Temperature is the property that determines whether an object is in thermal equilibrium with other objects. Two objects in thermal equilibrium with each other area the same temperature.

- T he SI unit of absolute temperature is the Kelvin, which is defined to be the fraction 1/273.16 of the temperature of the triple point of water.

- When the temperature of an object is changed by an amount ΔT , its length changes by an amount Δl that is proportional to $\Delta l = \alpha l_0 \Delta T$ and to its final length $l = \Delta l = l_0(1 + \alpha \Delta T)$.

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- Where, the constant α is the average coefficient of linear expansion. The average coefficient of areal and volume expansions respectively are $\beta=2\alpha$ and $= 3\alpha$.

- Internal energy is all of a system's energy that is associated with the system's microscopic components. Internal energy includes kinetic energy of random translation, rotation, and vibration of molecules, potential energy within molecules, and potential energy between molecules.

- Heat is the transfer of energy across the boundary of a system resulting from a temperature difference between the system and its surroundings. We use the symbol Q for the amount of energy transferred by this process.

- The heat capacity C of any sample is the amount of energy needed to raise the temperature of the sample by 1°C.

- The energy Q required to change the temperature of a mass m of a substance by an amount ΔT is $Q=mc\Delta T$, where c is the specific heat of the substance.

- The energy required to change the phase of a pure substance of mass m is $Q= \pm mL$, where L is the latent heat of the substance and depends on the nature of the phase change and the

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- *L* is the latent heat of the substance and depends on the nature of the phase change and the properties of the substance. The positive sign is used if energy is entering the system, and the negative sign is used if energy is leaving.

- The first law of thermodynamics states that when a system undergoes a change from one state to another, the change in its internal energy is $\Delta U = Q + W$, where *Q* is the energy transferred into the system by heat and *W* is the work done on the system.

- Although *Q* and *W* both depend on the path taken from the initial state to the final state, the quantity ΔU is path-independent.

- In a **cyclic process** (one that originates and terminates at the same state), $\Delta U = 0$ and, therefore, $Q + W = 0 \implies Q = -W$. That is, the energy transferred into the system by heat equals the negative of the work done on the system during the process.

- In an **adiabatic process**, no energy is transferred by heat between the system and its surroundings ($Q = 0$). this case, the first law gives $\Delta U = W$.

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...Continued(Δ U= W)

- That is, the internal energy changes as a consequence of work being done on the system.

- In the adiabatic free expansion of a gas Q= 0and W = 0, and so Δ = 0. That is, the internalenergy of the gas does not change in such a process.

- An **isobaric process** is one that occurs at constant pressure. The work done on a gas in such a process is W = − (V_f −V $_i$).

- An **isovolumetric process** is one that occurs at constant volume. No work is done in such a process, so ΔU =Q .

- An isothermal process is one that occurs at constant temperature. The work done on an ideal gas during an isothermal process is:

$$W = nRT \ln \frac{V_f}{V_i}$$

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