

# THERMODYNAMICS

Faculty	: Mathematics and Natural Sciences
Study Program	: Physics Education
Subject Matter and Code	: Thermodynamics (FIC 325)
Sum SCS	: Theory 3 SCS, pract 0 SCS, Sum 3 SCS
Semester	: III
Prerequisite Subject Matter	: Introduction to Mechanics, Heat, and Sound
Sum Meeting	: 16 meeting (@ 150 minutes)

There are three important ways that heat energy can be transported or transferred, called *conduction*, *convection*, and *radiation*.

The first two refer to transfer of the thermal energy, whereas the last is really a *conversion* of energy to a different form, (photons of light) and the subsequent travel (transport) of those photons.

Can you explain mechanism of conduction, convection and radiation? Task 1(3)

## Work

Work is not a thermodynamic property, but can change them  
All forms of work are theoretically interconvertible

Work can be done by system  
Work can be done on system

Can you explain the forms of work which were done by system?

Can you explain the forms of work which were done on system?

} Task 1(4)

The language of thermodynamics

*System* : the material in the portion of space to be analyzed

*Surroundings* : exterior environment

*Boundary* : A separator, real or imaginary, between system and surroundings

## Thermodynamic *properties* single-component (pure substance)

- characteristics that fix the condition of a system
- *microscopic* properties: average of the quantum numbers of all atoms or molecules in a system – ***statistical thermodynamics***
- *macroscopic* properties (also called *state variable*) : a few characteristics that determine the measurable gross condition of the system - ***classical thermodynamics***

## Classification of thermodynamic properties (for a pure or 1-component substance)

Fundamental :  $p, T, V, U, S$

Auxiliary : (derived from fundamental)  $H, F, G$

Absolute :  $p, T, V, S, C_P, C_V$

Relative (to a reference state) :  $U, H, F, G$

**Extensive ( $\propto$  amount):  $V, S, U, H, F, G$**

**Intensive :  $p, T, v, u, s, h, f, g$**

Derivative :  $C_P, C_V, a, b$

## Fundamental macroscopic properties

- pressure*** ( $p$ )
  - momentum transferred to walls by molecular impacts
- temperature*** ( $T$ )
  - molecular speeds (gas) or amplitudes of atomic vibrations (solids)
- volume*** ( $V$ )
  - The space occupied by the system
- internal energy*** ( $U$ )
  - kinetic and potential energy contained in molecules or atoms
- entropy*** ( $S$ )
  - measure of the degree of order of a system (disorder  $\sim$  high  $S$ )

## Auxiliary Properties

**Enthalpy:**  $\Delta H \equiv \Delta U + p \cdot \Delta V$

- like internal energy, but automatically accounts for pV work
- $\Delta H$  (change in enthalpy) is the heat added in a constant-p process

**Helmholz free energy** :  $F \equiv U - TS$

Is a thermodynamic potential which measures the “useful” work obtainable from a closed thermodynamic system at a constant temperature and volume  
F is the link between statistical and classical thermodynamics  
(F is rarely used in purely classical approach)

**Gibbs free energy:**  $G \equiv H - TS$

Is a thermodynamic potential that measures the “useful” or process-initiating work obtainable from a thermodynamic system at a constant temperature and pressure

- G is the criterion of equilibrium in chemical reactions
- $\Delta G$  is the maximum work done (or needed) in a flow process.

## Absolute and Relative Properties

$p$ ,  $T$ ,  $V$ ,  $S$ ,  $C_p$  and  $C_v$  are *absolute* : zero values are unique;

- Absolute zero temperature: 0 K
- The absolute zeros of  $p$  and  $V$  are obvious
- $C_p$  and  $C_v$  are derivatives of relative properties
- The absolute value of  $S$  comes from the 3<sup>rd</sup> Law:

***The entropy of a solid is zero at 0 K***

(all substances are solid at this temperature)

$U$ ,  $H$ ,  $F$ ,  $G$  are *relative* : i.e., they must be assigned a zero value at an arbitrary “reference state”  
(the same state for all four)



## Extensive and Intensive Properties

***Extensive*** : value proportional to amount in system

V, S, M, En, A, L, U, H, F, G

***Intensive*** : value independent of the amount of material

p, T, v, u, s, h, f, g

For a one-component system (pure substance) extensive properties can be made intensive by dividing by the amount ( $n$  = moles of substance)

- $v = V/n$ ;  $v =$  *molar volume*, or reciprocal of the molar density
- $u = U/n$ ;  $s = S/n$ ;  $h = H/n$ ;  $g = G/n$

## Derivative Properties

Specific heats (heat capacities):

$$C_P = (\partial h / \partial T)_P \text{ - constant-pressure}$$

$$C_V = (\partial u / \partial T)_V \text{ - constant-volume}$$

Coefficients of expansion:

$$\alpha = (1/v)(\partial v / \partial T)_P \text{ - thermal expansion}$$

$\alpha(\text{Hg})$  used for mercury thermometer

$$\beta = -(1/v)(\partial v / \partial p)_T \text{ - compressibility}$$

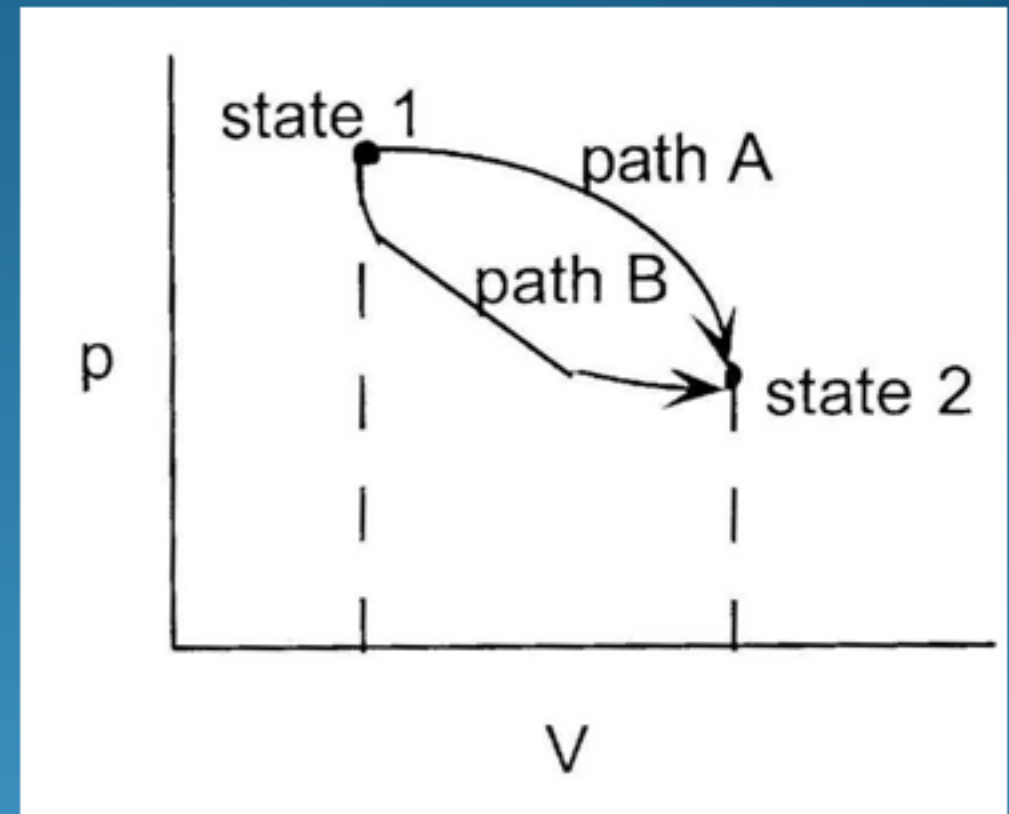
## Thermodynamics Process

**Process** : change in p-V-T state of system due to exchange of heat and/or work with the surroundings.

Plot process **path** on a pressure-volume graph state of system at 2 is :

- independent of path (A or B)
- but, Q and W are different for each path

$$W = \int_{V_1}^{V_2} p(V)dV$$



- Cannot infer Q from this diagram
- Path depends on how T varies with V.

## REFERENCES

### A. REQUIREMENT

Sears, F.W.& Gerhart L. Salinger, 1975, ***Termodinamics, Kinetyc Theory and Statistical Thermodynamic***, Sydney : Addison Wesley Publishing Company.

### B. SUGGESTION / RECOMMENDATION

1. Holman J.P., 1988, *Thermodynamics*, Fourt Edition, New York: Mc Graw- Hill Book Company
2. Ahmad Abu Hamid, 2007, *Kalor dan Termodinamika*, Diktat Kuliah, Yogyakarta: Jurusan Pendidikan Fisika FMIPA UNY.
3. B. Darmawan, 1990, *Termodinamika*, Diktat Kuliah, Bandung: Jurusan Fisika FMIPA ITB.
4. Budi Purwanto, 2009, ***Teori Soal dan Penyelesaian Termodinamika***, Yogyakarta, Jurdik Fisika, FMIPA UNY.

## Thermodynamics Coordinates

Thermodynamics coordinate : Pressure (P), Temperature (T), V(Volume)

### Pressure (P)

Pressure is an effect that occurs when a *force* is applied on a surface.

Pressure (P) is the force per unit area applied in a direction perpendicular to the surface of an object.

Mathematically:

$$P = \frac{F}{A} \quad \text{or} \quad P = \frac{dF_n}{dA}$$

where:

$P$  is the pressure,  $F$  is the normal force,  $A$  is the area.

## Temperature (T)

**Temperature** is a physical property of matter that quantitatively expresses the common notions of hot and cold. Objects of low temperature are cold, while various degrees of higher temperatures are referred to as warm or hot.

**Microscopic \_\_\_\_ Temperature** : a relative term reflecting how vigorously the atoms of a substance are moving and colliding. The temperature of a body varies with the speed of the fundamental particles that it contains, raised to the second power

Temperature is a measurement of the average kinetic energy of the molecules in an object or system and can be measured with a thermometer or a calorimeter.

It is a means of determining the internal energy contained within the system.

## Volume

**Volume** is the quantity of three-dimensional space enclosed by some closed boundary, for example, the space that a substance (solid, liquid, gas, or plasma) or shape occupies or contains.

Volume and *capacity* are sometimes distinguished :

- Capacity being used for how much a container can hold (with contents measured commonly in litres or its derived units)
- Volume being how much space an object displaces (commonly measured in cubic metres or its derived units).

## Summary

The study of Thermodynamics is important because understanding how thermodynamics works helps you understand how machines that use thermodynamics work.

Thermodynamics is the study of energy relationships that involve heat, mechanical work, and other aspects of energy and heat transfer.

There are three important aspects of thermodynamics : energy, heat and work.



Thermodynamics properties : - statistical thermodynamics  
- classical thermodynamics

Classical thermodynamics properties :

Fundamental :  $p, T, V, U, S$

Auxiliary : (derived from fundamental)  $H, F, G$

**Absolute** :  $p, T, V, S, C_p, C_v$

**Relative (to a reference state)** :  $U, H, F, G$

**Extensive ( $\propto$  amount)**:  $V, S, U, H, F, G$

**Intensive** :  $p, T, v, u, s, h, f, g$

Derivative :  $C_p, C_v, a, b$

***Thermodynamics Process*** : change in p-V-T state of system due to exchange of heat and/or work with the surroundings.

Thermodynamics coordinate :  $P, T, V$

## Home study 1

Please study the derivatives exact and non exact, and integral derivative exact and non exact.

Give examples of thermodynamics problems which use them

Next meeting :

Temperature and Pressure

Conduction is the transfer of heat between substances that are in direct contact with each other

The better the conductor, the more rapidly heat will transfer

Example : We touch hot iron

Convection is up or down movement of gases and liquids caused by heat transfer

Example : warmer water at the surface of a lake or swimming pool

- wind currents

- hot air balloon

- lower floors of a building being cooler than the top floor

Radiation is electromagnetic waves travel through space

When electromagnetic waves come in contact with an object, the waves transfer the heat to the object.

EM waves travel through empty space.

Example : a camp fire

- a microwave oven

- a light bulb

## EVALUATION

No	Component	Heavy (%)
1	Lecture Participation	20
2	The Tasks	40
3	The Inserted Examination	20
4	The End Examination	20
	Sum	100

### THE LECTURE STRATEGY

1. Lecture
2. Discuss
3. Task

## INTRODUCTION

Why is the study of Thermodynamics important?

The study of thermodynamics is important because many machines and modern devices change heat into work, such as an automobile engine or turn work into heat or cooling, such as with a refrigerator.

Understanding how thermodynamics works helps you understand how machines that use thermodynamics work.

**Investigate and determine the answer to these questions:**

- 1. How can I take the energy from a camp fire and use it to cool my ice chest?**
- 2. How does a jet engine move an airplane?**
- 3. How does energy from fire make water boiling?**

## Definition of thermodynamics

Thermodynamics is the study of energy relationships that involve heat, mechanical work, and other aspects of energy and heat transfer.

Thermodynamics is the study of the movement of heat from one body to another , and the relations between heat and other forms of energy.

Thermodynamics is the study of the connection between heat and work and the conversion of one into the other.

Key Words :

- Energy
- Heat
- Work

What is energy?

What is heat?

What is work?

Energy ~ ability to do work.

Heat ~ A form of energy that flows from a warmer object to a cooler object.

Work ~ Force exerted over a distance.

What are the units for Energy?

What are the units for Heat?

What are the units for Work?

Task 1 (1)

## Energy

Energy has a number of different forms, all of which measure the ability of an object or system to do work on another object or system.

In other words, there are *different ways* that an object or a system can possess energy.

Can you explain basic forms of energy? --- Task 1(2)

How is energy transported from place to place and transferred between objects?



The most obvious and trivial way in which energy is transported is when an object that possesses energy simply moves from one place to another. For example, a baseball flying through the air is a simple form of energy transport..

Kinetic energy can also be transferred from one object to another when objects collide. This is also trivial, except that we also know that the total energy, including any heat or other forms of energy generated during the collision, is conserved in this process, regardless of the relative sizes, shapes, and materials of the objects

## Heat

**Heat** — A form of energy that flows from a warmer object to a cooler object

**Heat** ---- Energy exchanged between system and surroundings (reservoirs) due to a  $\Delta T$

Heat is not a thermodynamic property: it causes changes in them

**Calorie** — The amount of heat energy needed to raise the temperature of one gram of water one degree Celsius in temperature

**Temperature** — A relative term reflecting how vigorously the atoms of a substance are moving and colliding