Thermodynamics EAS 204 Spring 2004

Class	Month	Day	Chapter	Topic	Reading	Due
1	January	12 M	Introduction			
2		14 W	Chapter 1 Concepts		Chapter 1	
		19 M	MLK Holiday	no class		
3		21 W	Chapter 2 Properties		Chapter 2	PS1
4		26 M	Chapter 2 Properties			PS 2
5		28 W	Chapter 2 Properties			
6	February	2 M	Chapter 3 Heat&Work			PS 3
7		4 W	Chapter 3 Heat&Work			
8		9 M	Chapter 4 First Law		Chapter 4	PS 4
9		11 W	Chapter 4 First Law			
10		16 M	Chapter 4 First Law			PS 5
11		18 W	Chapter 4 First Law			
12		23 M		Review	Chapter 5	PS 6
13		25 W		Exam 1-4		
14	March	1 M	Chapter 5 Second Law		Chapter 5	PS 7
15		3 W	Chapter 5 Second Law			
16		8 M	Chapter 5 Second Law			
17		10 W	Chapter 6 Entropy		Chapter 6	
		15 M	Spring Recess	no class		PS 8
		17 W	Spring Recess	no class		
18		22 M	Chapter 6 Entropy			PS 9
19		24 W		Review		
20		29 M		Exam 5-6		PS 10
21		31 W	Chapter 8 Gas Power		Chapter 8	
22	April	5 M	Chapter 8 Gas Power			PS 11
23		7 W	Chapter 9 Vapor Power		Chapter 9	
24		12 M	Chapter 9 Vapor Power			PS 12
25		14 W	Chapter 9 Vapor Power			
26		19 M	Refrigeration Cycles		Chapter 10	PS 13
27		21 W	Refrigeration Cycles			
28		26 M		Review		PS 14
		TBA		FINAL		

Course Summary

Chapter 1 Concepts

Thermodynamic system, properties, state point, process, cycle, heat and work.

Thermodynamic problem solving technique.

Chapter 2 Fluid Properties

Real gases - steam, air, refrigerants tables

Ideal gases

Equations of state - EES CD

Chapter 3 Heat and Work

Work in non-flow, steady flow and unsteady flow systems.

Adiabatic Process

Chapter 4 First Law

First Law for processes and cycles

Heat and work in closed non-flow, open flow and unsteady flow systems.

Chapter 5 Second Law

Statement and Corollaries

Heat Engines

Reversible engines and refrigerators

Carnot Cycle

Chapter 6 Entropy

Second Law and heat engines

The Entropy property

Isentropic process

Entropy change calculation

Chapter 8 Gas Power Cycles

Brayton (gas turbine) cycle

Otto (spark ignition engine) cycle

Diesel cycle

Chapter 9 Vapor Power Cycles

Rankine (steam power) reheat, superheat and regeneration cycles

Chapter 10 Refrigeration Cycles

Vapor Compression Cycle

Heat Pumps

Reversed Brayton Cycle

THERMODYNAMICS OVERVIEW

Thermodynamics

Thermodynamics is the study of the relationship between all forms of Energy beginning historically with the relationship between Heat and Work.

Laws of Thermodynamics (fundamental observations)

Mass Balance (should be a law)

Mass can not be created or destroyed and is conserved.

First Law

Heat and work are equivalent
Property energy is defined
Energy can change form, can not be destroyed, and is conserved

Second Law

Heat can not be converted completely to work.
Property entropy defined.
Ideal and actual heat engine efficiency.

THERMODYNAMICS IN DESIGN

Thermodynamic Analysis – Process Analysis

Thermodynamic analysis is the first step in energy system design.

Through Thermodynamic Analysis the required mass flows, volume flows, temperatures and pressures are established. Performance is determined.

ENERGY SYSTEMS

Gasoline Engines	Food Processing Plants
Diesel Engines	Rocket Engines
Steam Power Plants	Air Conditioning Systems
Chemical Plants	Refrigeration Systems
Compression Systems	Heating Systems
Gas Liquefaction	Gas Turbine Engines

Thermodynamics Concepts

Thermodynamic System

Properties

State Point

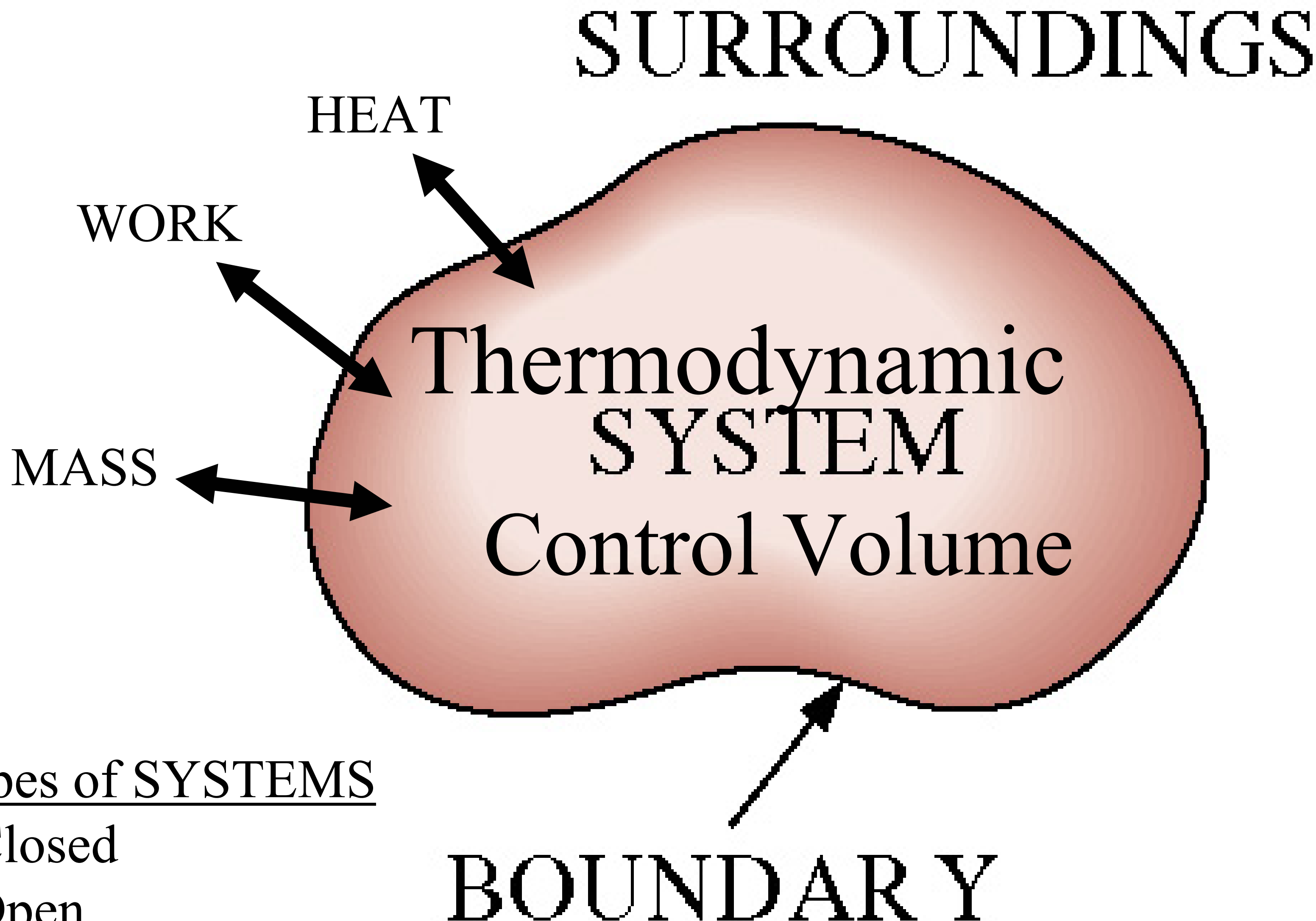
Process

Cycle

Heat

Work

Energy



<u>3 Types of SYSTEMS</u>

- Closed
- Open
- Unsteady

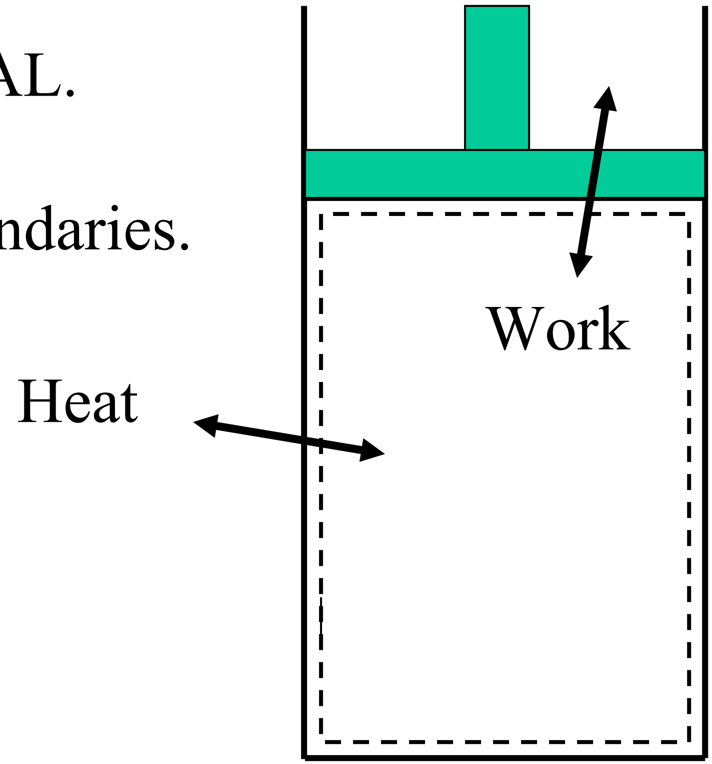
Concepts
System
Properties
State Point
Process
Cycle

CLOSED THERMODYNAMIC SYSTEM
NON FLOW SYSTEM

A MASS OF MATERIAL.

Heat and Work can cross the system boundaries.

Mass can not.



Examples:

- A closed tank.
- A piston cylinder.
- A balloon

OPEN THERMODYNAMIC SYSTEM
STEADY FLOW THERMODYNAMIC SYSTEM

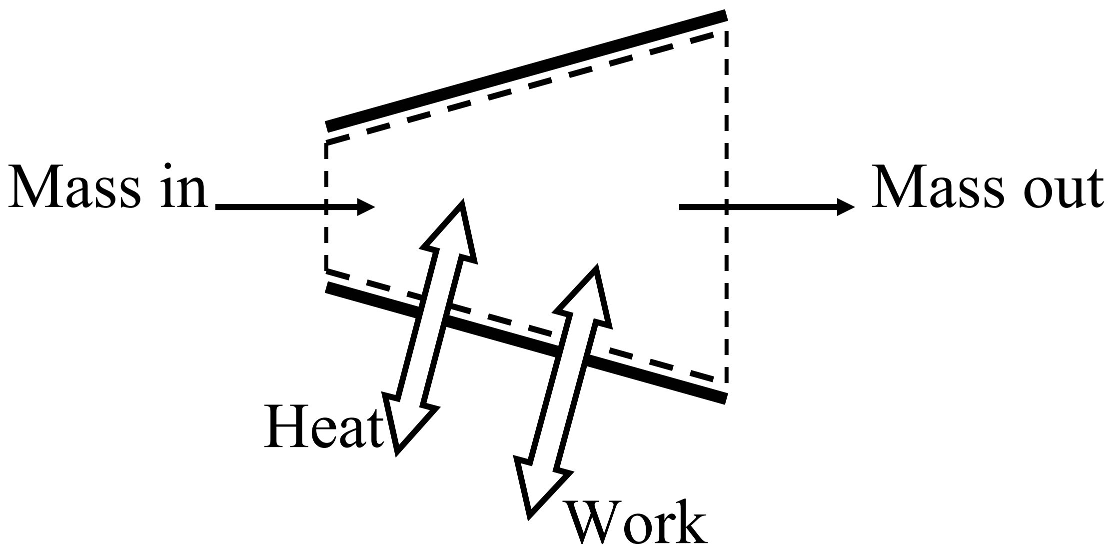
Concepts
- System
- Properties
- State Point
- Process
- Cycle

A FIXED REGION IN SPACE

Mass, heat and work can cross the system boundaries.

Examples:

turbine, compressors, boilers, heat exchangers



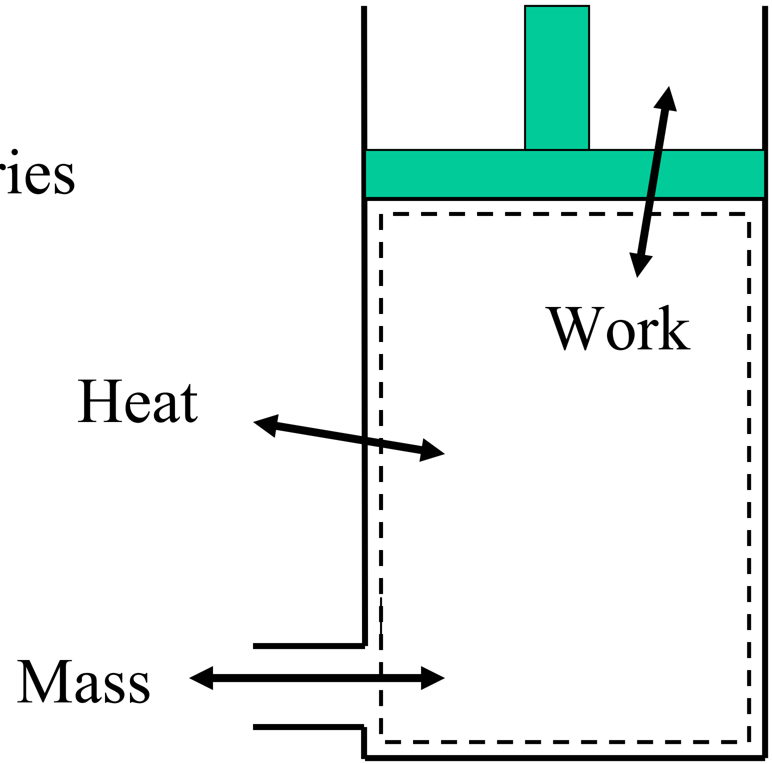
Concepts
- System
- Properties
- State Point
- Process
- Cycle

UNSTEADY FLOW THERMODYNAMIC SYSTEM

A VARIABLE MASS

Mass, heat and work can cross the system boundaries

Examples:
- A filling tank.
- An emptying tank
- Piston-Cylinder Filling



Concepts

- System
- Properties
- State Point
- Process
- Cycle

Identify the thermodynamic system,

1) open,steady flow thermodynamic system
2) closed,non-flow thermodynamic system
3) unsteady flow thermodynamic system

in the following problems.

2-48 closed system, mass of water in the piston cylinder.
2-123 closed system, mass of hydrogen in both tanks
3-50 open system, region in space occupied by the nozzle
3-74 closed system, mass of ball
4-11 closed system, mass of steam in the radiator
4-84 open system, region in space occupied by the turbine
4-155 unsteady system, mass initially in the tank
5-84 open system, region in space occupied by the heat engine
6-100 open system, region in space occupied by the compressor
6-132 open system, region in space occupied by the mixing chamber

Thermodynamic Properties

Concepts
- System
- Properties
- State Point
- Process
- Cycle

Temperature $-{}^{o}F,\ {}^{o}C$, absolute, ${}^{o}K,\ {}^{o}R$

$${}^{o}F = 1.8 \times {}^{o}C + 32.$$

$${}^{o}K = {}^{o}C + 273.15$$

$${}^{o}R = {}^{o}F + 459.69$$

p Pressure – kPa, atmospheres, bar, lb/in^2

Absolute pressure = Gage pressure + Ambient pressure

v SpecificVolume – m^3/kg, ft^3/lb

ρ Density – kg/m^3, lbm/ft^3

V Volume – m^3, ft^3

$$V = mass \times v$$

u SpecificInternalEnergy – kJ/kg, BTU/lb

$$du = c_v dT$$

c_v – specifc heat at constant volume, kG/jg, $m^3/kg\,{}^{o}C$, BTU/lbm ${}^{o}F$

U InternalEnergy – kJ, BTU

Thermodynamic Properties

Concepts
- System
- Properties
- State Point
- Process
- Cycle

h **Specific Enthalpy** – kJ/kg, BTU/lbm

$$h = u + pv$$

$$dh = c_p dT$$

c_p specific heat at constant pressure, kJ/kg°C, BTU/lbm°F

H **Enthalpy** – kJ, BTU

$$H = m \times h$$

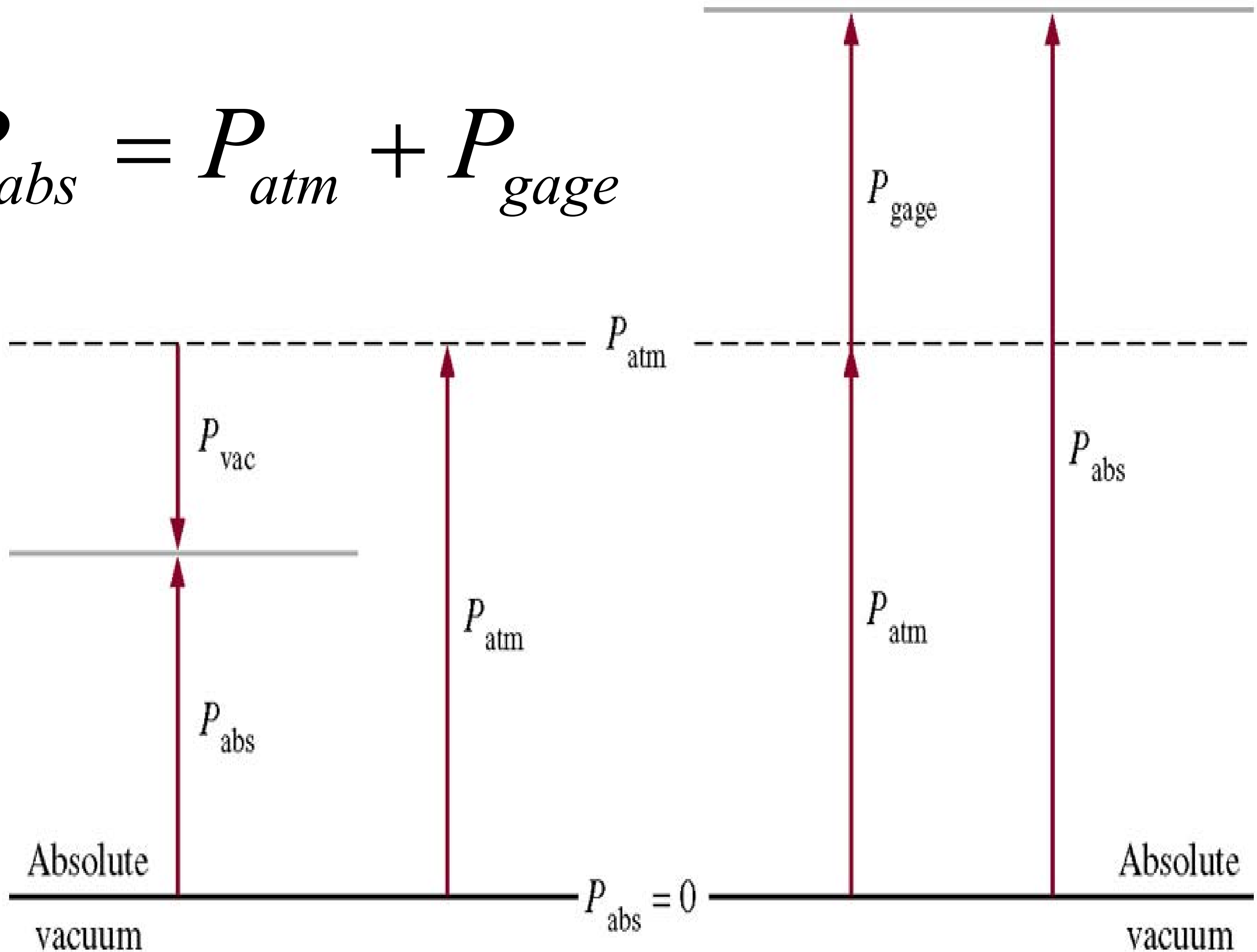
s **Specific Entropy** – kJ/kg°C, BTU/lbm°F

S **Entropy** – kJ/°K

$$S = m \times s$$

PRESSURE

$$P_{abs} = P_{atm} + P_{gage}$$



Force Units - force = mass x acceleration

$1\ \text{N} = 1\ \text{kg} \bullet 1\ \text{m/sec}^2$

$9.807\ \text{N} = 1\ \text{kg} \bullet 9.807\ \text{m/sec}^2$

Mass is measured indirectly by measuring the gravitational force it exerts. 1 kg mass weighs 9.807 N at an acceleration of $9.807\ \text{m/sec}^2$

$1\ \text{lb}_f = \text{lb}_m \bullet g_c\ \text{ft/sec}^2$

$1\ \text{lb}_f = \text{lb}_m \bullet 32.174\ \text{ft/sec}^2$

$1\ \text{lb}_m = \frac{1}{32.174}\text{slugs}$

$1\ \text{lb}_f = 1\ \text{slug} \bullet 1\ \text{ft/sec}^2$

1 lb_m weighs 1 lb_f at an acceleration of 32.174ft/sec^2

Energy Units - force x distance, mass and temperature change

$1\ \text{J} = 1\text{N} \bullet 1\text{m}$

Calorie – 1 g water at 15° C raised 15° C

$1\ \text{J} = 4.1868$ calories

1 kJ = 4.1816 kg water at 15° C raised 15° C

$1\ \text{ftlb}_f = 1\text{lb}_f \bullet 1\text{ft}$

BTU – 1 lb_m water at 60° F raised 1° F

$1\text{BTU} = 778\ \text{ftlb}_f$

Power Units - energy per time

1watt – 1J/sec

1kw – 1kJ/sec

$1\text{HP} = 550\text{ftlb}_f/\text{sec}$

$1\text{kw} = .7457\text{HP}$

THERMODYNAMIC STATE POINT

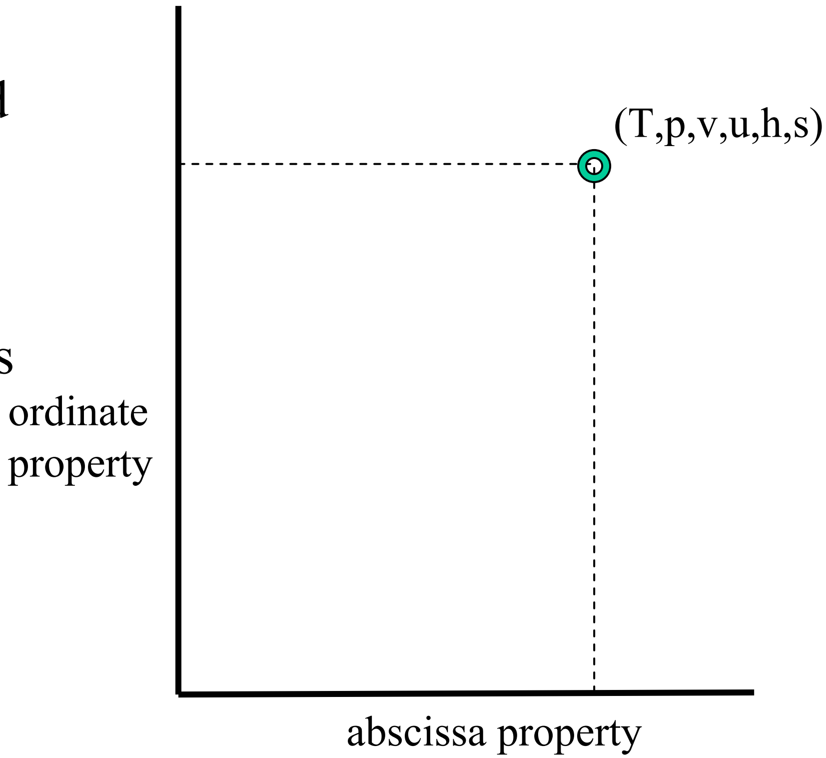
Properties are measured.

Equations and models are fitted to the data resulting in :

- Tables of Property Values
- Equations of State
- Computer property modules

Two properties define the state point of a single phase fluid.

One property defines the state point of a multiphase fluid.



THERMODYNAMIC PROCESS

A thermodynamic process is an interaction between a thermodynamic system and its surroundings which results in a change in the state point of the system

Concepts

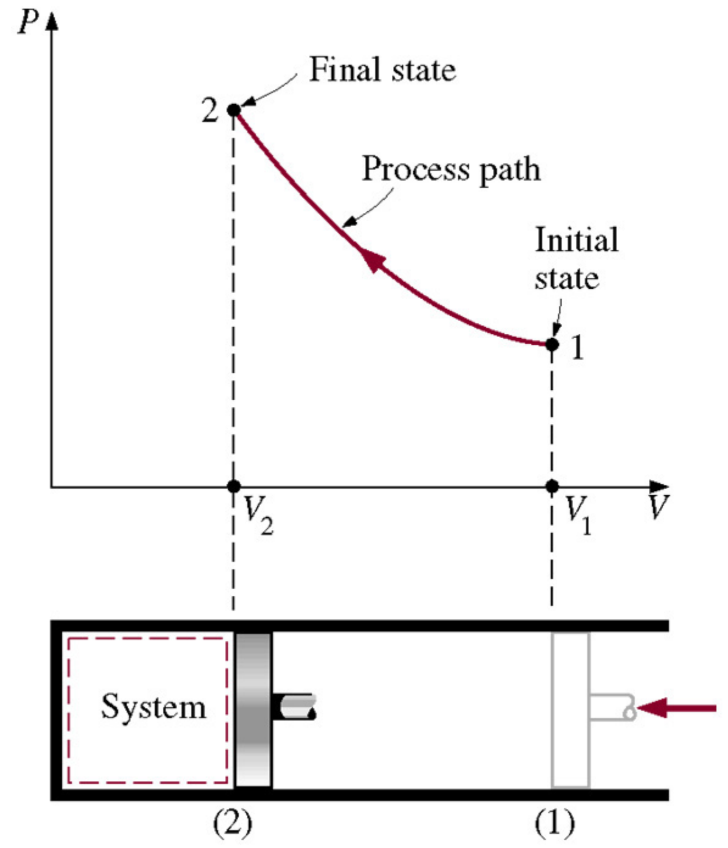
- System
- Properties
- State Point
- Process
- Cycle

Reversible Process

A process is reversible if the state points of all affected thermodynamic systems, including the external system or surroundings, are returned to their original state point values.

Examples:

- movement of a frictionless pendulum
- transfer of work to potential energy without loss
- movement of a frictionless spring



Irreversible Process

A process which can not be reversing bringing all the affected thermodynamic properties back to their original values is irreversible.

Examples:

- applying brakes to a moving wheel
- mixing hot and cold water
- transfer of heat through a finite temperature difference

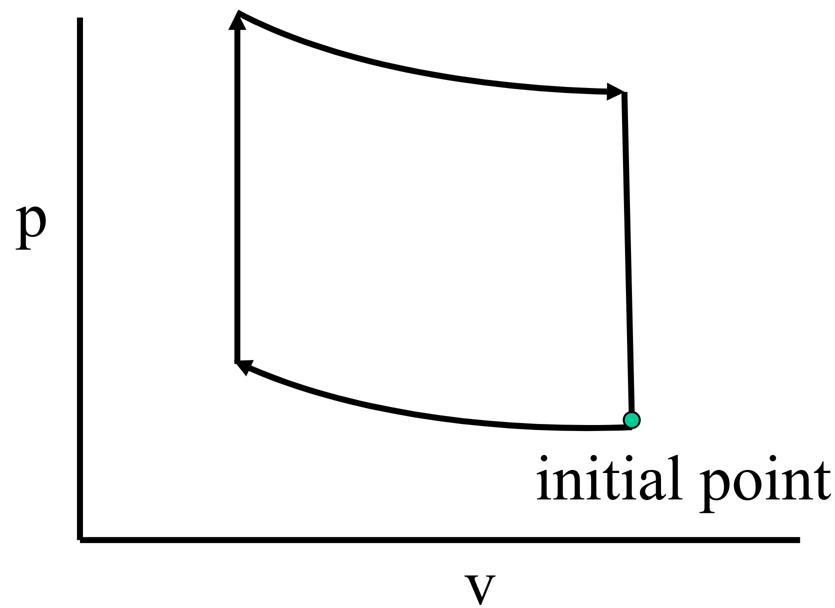
THERMODYNAMIC CYCLE

Concepts
System
Properties
State Point
Process
Cycle

A thermodynamic system undergoes a cycle when the system is subjected to a series of processes and all of the state point properties of the system are returned to their initial values.

$$\underset{cycle\ net}{Q} = \sum_{cycle} Q_{process}$$

$$\underset{cycle\ net}{W} = \sum_{cycle} W_{process}$$



First Law

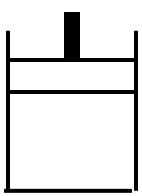
$$\oint \delta Q = \oint \delta W$$

Thermodynamic Problem Solving Technique

1. Problem Statement

Carbon dioxide is contained in a cylinder with a piston. The carbon dioxide is compressed with heat removal from T1,p1 to T2,p2. The gas is then heated from T2, p2 to T3, p3 at constant volume and then expanded without heat transfer to the original state point.

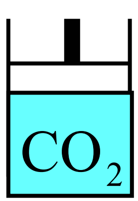
2. Schematic



3. Select Thermodynamic System

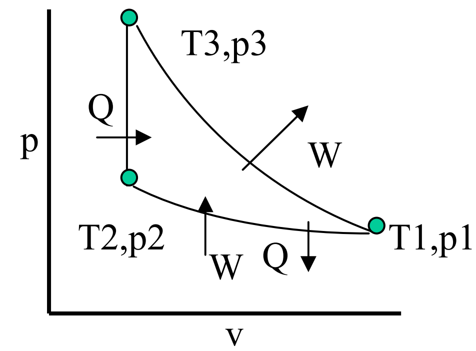
open - closed - control volume

a closed thermodynamic system composed to the mass of carbon dioxide in the cylinder

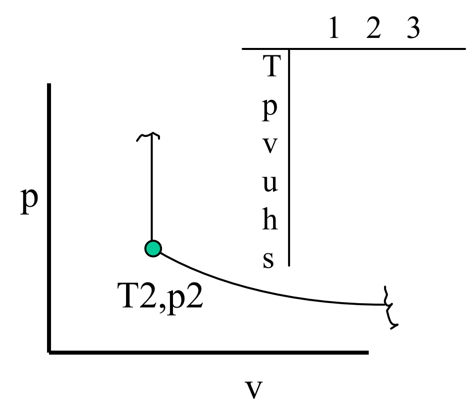


4. Property Diagram

state points - processes - cycle



5. Property Determination



6. Laws of Thermodynamics

Q=? W=? E=? material flows=?