SPH 302
THERMODYNAMICS

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Lecture Hrs: **Mon 2 – 4 pm**
Thur 12 – 1pm

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Course Objectives

- Explain the Laws of thermodynamics & their significance
- Apply laws of thermodynamics to solve problems relating to energy conversion processes

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Course Outline

Lecture 1: Thermodynamic concepts & Zeroth Law

Lecture 2: 1^{ST} Law of Thermodynamics

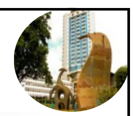
Lecture 3: 2^{ND} Law

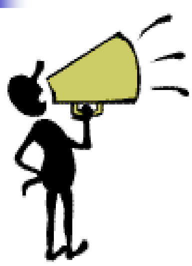
Lecture 4: Entropy & 2^{ND} Law, 3^{rd} Law

Lecture 5: Thermodynamic Potentials & Maxwell's Equations

Lecture 6: Phase Changes & Equilibria

Prerequisites

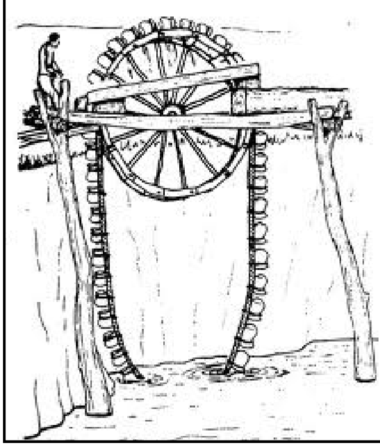




- SPH 203
- Calculus & ODE

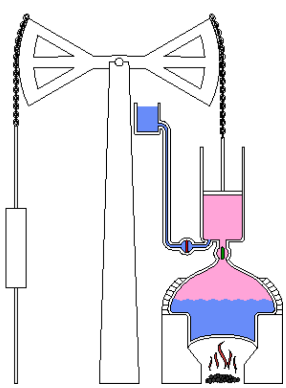
INTRODUCTION

Before industrial revolution, "machinery" were powered by animals



James watt Steam Engine

- 1ST Engine (invented 1790) to convert steam (Heat) to mechanical work
- Lead to industrial revolution



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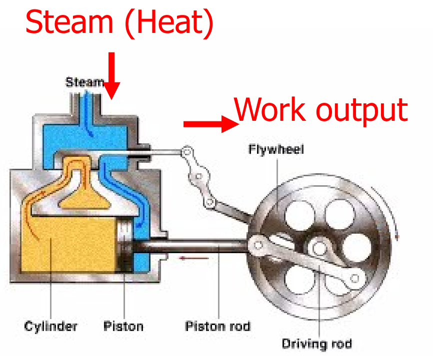
Steam Engines of Industrial Revolution

Steam powered cars

Steam powered bicycles

Steam powered Industries

- By 19th cent, a new science was born – **THERMODYNAMICS**
- **GOAL**: Study & improve efficiency of devices that convert heat ↔ work i.e., heat engines



1930s - 1ST Diesel Engines (internal combustion) developed

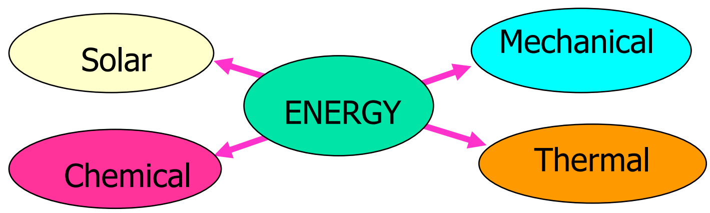
2000 - Hybrids & gas turbines

What is Thermodynamics?

- Thermo $\Rightarrow$ Energy transfer in form of heat
- Dynamics $\Rightarrow$ Motion in form of mechanical work
- **Thermodynamics** = science that govern energy conversions processes (heat $\rightarrow$ work and vice versa)

Why Thermodynamics ?

- It provides the Laws of nature that govern energy conversion processes



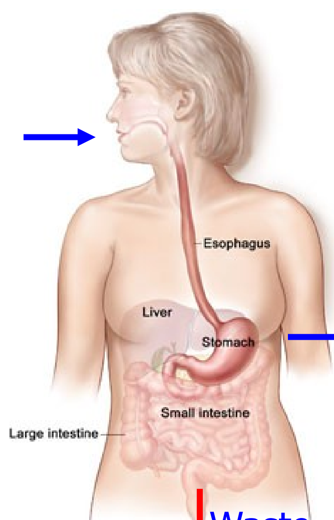
Energy 1 (heat) $\rightleftarrows$ Energy 2 (work)

Relationship?

Laws of Thermodynamics

Examples – Digestive system

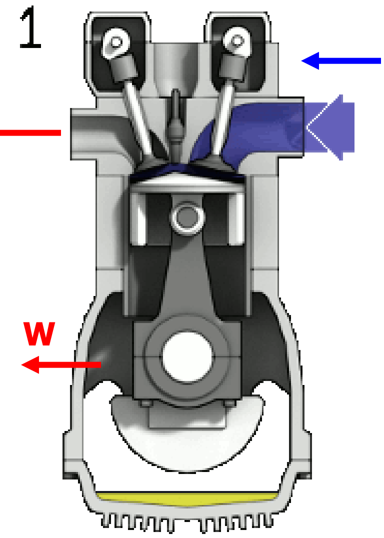
Food (Energy) input →



→ Work out

Waste

- Mechanical devices



- Heat pumps

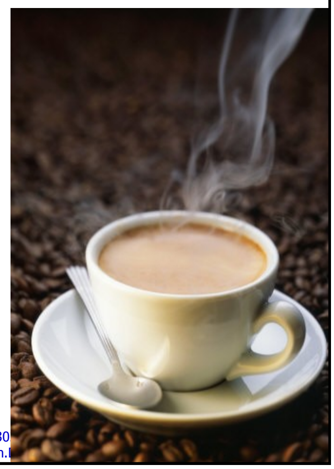
Work in

Heat out

Laws of Thermodynamics

- Energy conversions processes are governed by **4 Laws (of Nature)**

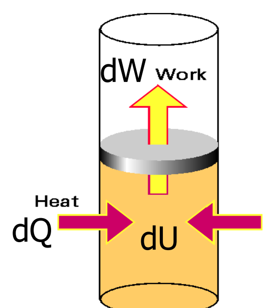
- **Zeroth Law**
  Gives condition for heat exchange between bodies in contact



1ST Law

- Gives relationship between Heat input (dQ) into system, gain in internal energy (dU) and work output (dW)

$$dQ = dU + dW$$



- "No animal works continously without eating or wearing out"

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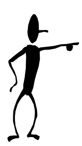
Second Law:

(i) Defines efficiency of processes that convert heat ⇔ work.

- No heat engine or animal has 100% efficiency.

- ⇒ **"If you eat, you must shit".**



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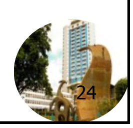

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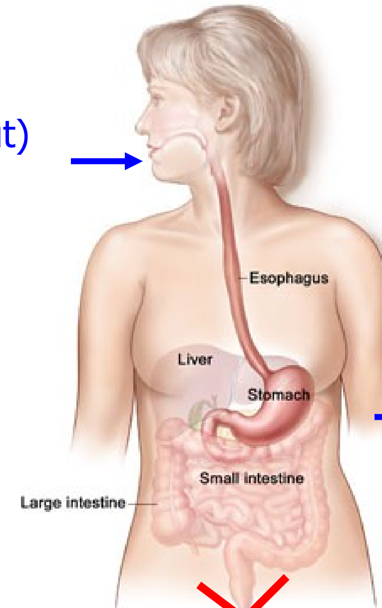
Food input)

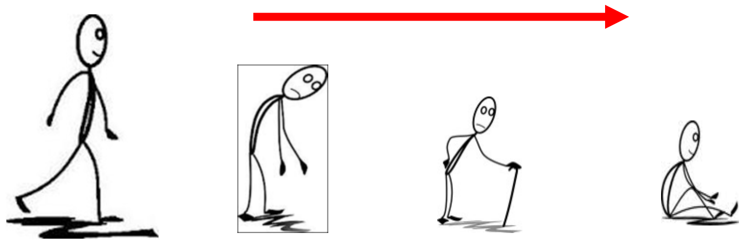


Work out

Impossible

(ii) Gives direction of natural occurring processes - "**Arrow of time**"

Nature is irreversible & Systems become Disorderly with time



d(disorder)/dt > 0 →

Third Law:

- Explains behaviour of systems as T → absolute zero (0K).
  - NB Systems become orderly as T → 0. E.g, water → ice, where ice is more orderly (hence less dense) compared to water.

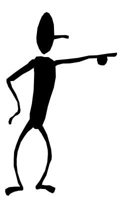
Ice crystal

Lecture 1

Thermodynamic Concepts & Zeroth Law

- ✓ Ideal Gas Laws
- ✓ Zeroth Law

Objectives

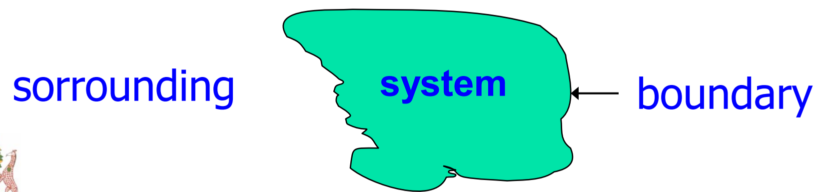


- Explain ideal gas Laws
- Explain Zeroth Law and its significance

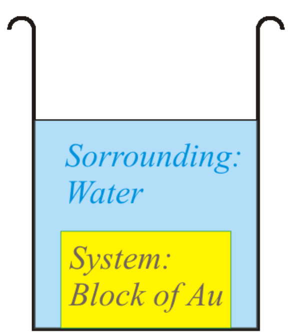
Thermodynamic concepts

- Energy conversion processes are studied using a **thermodynamic system**
- **System** – Part of material universe that can be isolated completely from the rest for investigation

SYSTEM + SURROUNDING = UNIVERSE



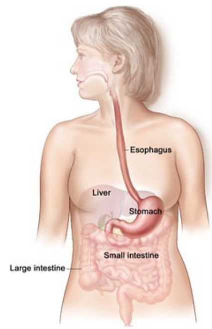
- **Surrounding** - The rest of the universe in the neighbourhood of the system.
- To a thermodynamic system two 'things' may be added/removed:
  - **energy** (in the form of heat &/or work)
  - **matter**



Types of systems

- 3 types

(a) Open systems:- Allows exchange of both heat and matter through the boundary. E.g. digestive system.



(b) Closed systems:- Allows only exchange of heat with surrounding but not matter.

- E.g. refrigerator

(c) Isolated System:- No heat or matter exchange occurs with surrounding. The walls are **Adiabatic (Adiathermal)**

- E.g. Vacuum flask.

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- **Thermodynamic Variables:-** Are parameters that describe behavior or state of system i.e., **P, T, V** & composition (μ)

- **Extensive variable**:- Dependent on mass/size of the substance present in the system e.g., internal energy U.

- **Intensive variable**:- independent on size of system

- **Heat**:- Transfer of thermal energy between systems by virtue of a temp difference
- **Work**:-Transfer of mechanical energy
- Both Heat & Work = ways of transferring energy

"Bodies contain internal energy (U) and not heat"

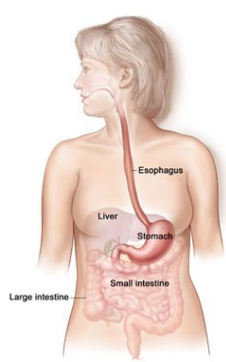
- **Thermodynamic equilibrium:-** State where system experiences thermal, mechanical and chemical equilibrium S.T. P, V, T & μ are const in time.

- **Working substance**:- Fluid enclosed in the system that either receives or transfers energy to the surrounding in the form of heat or work.

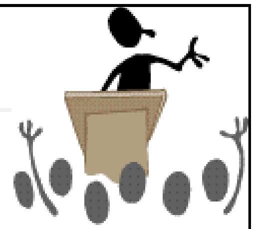
- In Thermodynamics, we use the **ideal gas** as the working substance. WHY?

Activity

- Name the working substance in these systems



Lecture Evaluation



- Explain the following
  - Open & Closed system
  - Adiabatic & Diathermal Wall
  - Extensive & Intensive variables
  - Heat and work
  - Thermodynamic Equilibrium

Behavior of Ideal gases

- An ideal gas is an abstraction (i.e., theoretical gas) that obeys **Ideal gas laws** (Eqn of state).
- Assumptions

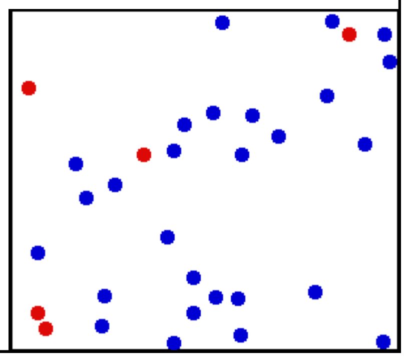
  (i) It is composed of randomly moving point particles that only interact through elastic collisions.

  (ii) The particles occupy negligible volume compared to the bulk volume of the gas

- In Thermodynamics, we use the concept of the ideal gas because:
  - It satisfactorily models behaviour of real gases under classical mechanics
  - it obeys Simple Gas Laws.
- Real gases (N_2, O_2, H_2 and fluids) fail to obey the ideal gas model because:
  - Gas molecules occupy finite volume and liquefy at low **T** and at high **P**
  - $\exists$ intermolecular attractions and collisions are not elastic

Ideal Gas Laws

- Consider an ideal gas enclosed in a container with movable piston
- Behavior of ideal gas depends on **T, P** and **V** and obey the **gas laws**:

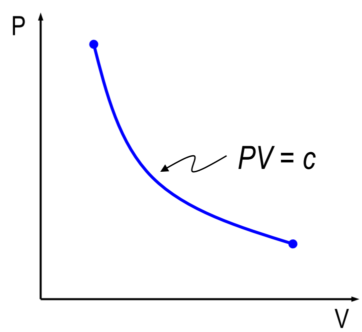


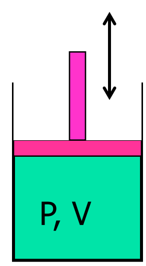
(a) Boyle's law:

- For const T, Compressing a gas, increases P

$$P \propto \frac{1}{V}$$

$$\Rightarrow \quad PV = C$$

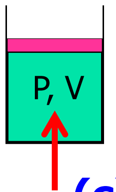


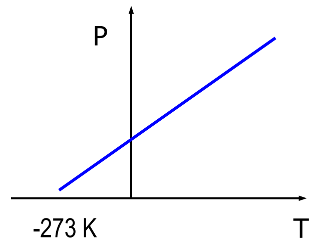


(b) Pressure law:

- For const Vol, Heating a gas increases P

$$P \propto T \quad \Rightarrow \frac{P}{T} = C$$

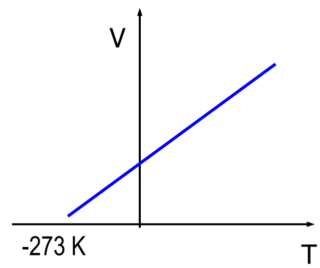




(c) Charles' Law:

- For Const P, Heating a gas increases V

$$V \propto T \quad \Rightarrow \frac{V}{T} = C$$



Cooking under constant Volume (closed sufuria)

Cooking under constant pressure (open Sufuria)

(d) **Avogadros Law**: V α No. of moles (*n*) of the gas i.e.

$$V \alpha \ n$$

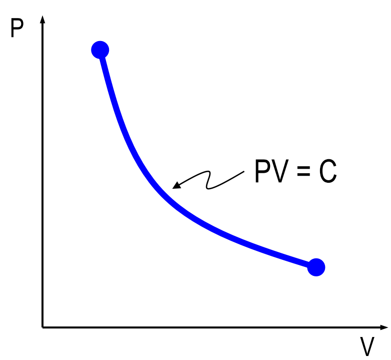
- Combining (a) to (d) gives

PV = nRT Equation of state ……………………….(1.1)

- Eqn (1) defines the State of a system

P-V Diagram

- From PV = nRT $\Rightarrow$ Behaviour/processes of ideal gas can be represented on **PV diagrams**



Real Gases

- Real gases (N_2, O_2, H_2 etc and fluids) behave like ideal gas only at high temps and low pressures where there is less intermolecular attractions.

- At low temps or higher pressures, real gases condense to liquid and fail to obey the ideal gas model.

- Eqn of state of real gas is given by

$$\left(P + \frac{a}{v^2}\right)\left(V - nb\right) = nRT$$

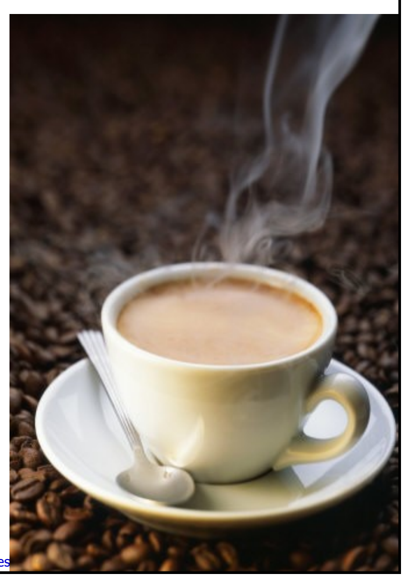
  - Where a & $b \propto$ molecular attractions & v = molecular volume

Activity

- Explain an ideal gas
- Why do we use ideal gas in the study of thermodynamics
- Explain conditions under which real gases approach the ideal gas behaviour

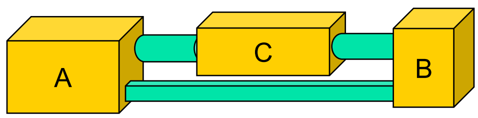
Zeroth law of Thermodynamics

- Naturally, a hot object looses heat to attain thermal equilibrium with surrounding
- **Zeroth Law Gives condition for heat exchange between bodies in contact**



"Statement of Zeroth Law"

"If objects A and B are separately in thermal equilibrium with third object C, then A and B are in thermal equilibrium with each other".



Significance of Zeroth Law

- Defines condition for thermal equilibrium between bodies
- Introduces concept of temperature and how it is determined – Through thermal equilibrium

$\Rightarrow$Temperature = measure of degree of hotness

Thermodynamics and Laws of nature
Rule of Nature: We eat to live

Laws of Nature	Laws of Thermodynamics
1. We eat when hungry	**Zeroth Law**: Heat flows from hot to Cold

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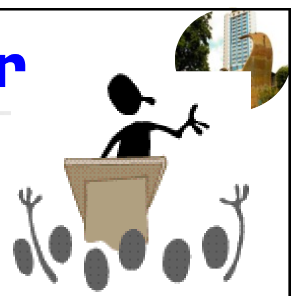
Lecture -Evaluation



1. State Equation of State
2. State Zeroth Law and its significance

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