Thermodynamics – Lecture 1:

<u>Introduction to the course, 08.305 Thermodynamics</u>

Thermodynamics is the science of

- **Energy** and **energy transformations**,(including power generation, refrigeration) and
- Relationships among the **properties** of matter.

Thermo = heat and dynamics = power. Thermodynamics emerged as a science when people tried to learn how to efficiently convert heat into work.

Human beings always wanted to generate power, to run factories, to run automobiles, to send rockets to outer space, to run our computers, mobile phones.

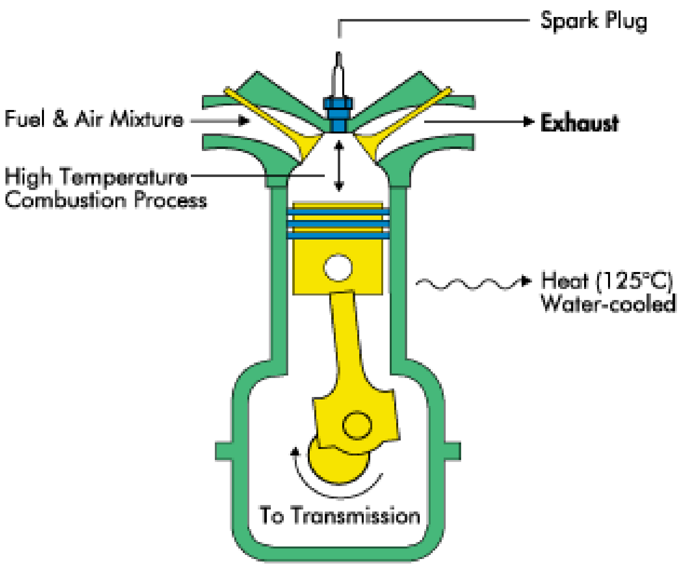
Everything around us involves energy transfers, whether it's a mechanical system, electrical system or a biological system.

In thermodynamics we classify the energy transfers broadly into two, **heat** and **work**. Heat is the transfer of energy by virtue of temperature difference. All the other energy transfers are termed as work.

<u>Why should we learn thermodynamics?</u>

Thermodynamics gives us relationships between these energy quantities. So we will be able to know how much work we will get for a particular heat input in an IC engine.

Thermodynamics also gives us relationships among properties of matter. For example we will be able to calculate what is the temperature or pressure inside the engine so that an appropriate material can be selected that withstands the conditions.



Single Cylinder Internal Combustion engine

How will we know the relationships to calculate these quantities?

Thermodynamics is a mature science. Scientists have synthesized the experimental findings into four laws which help us in these calculations.

Each of these laws defines a property

1. Zeroth law – Temperature (T)
2. First law – Energy (U) (1. Energy conservation law. 2. Gives the relationships between energy quantities)
3. Second law – Entropy (S) (1. Is called the arrow of time, 2. Helps in finding the efficiency of energy conversion)
4. Third law – Gives a numerical value to entropy

There are two *approaches* in thermodynamics, **macroscopic** and **microscopic**. Thermodynamics was developed before the knowledge of atoms and molecules. So it was based on macroscopic properties like pressure, temperature, volume etc. That is to find the energy transfers and properties of matter in terms of measurable macroscopic properties like temperature, pressure etc. This is the macroscopic approach and this branch is known as **classical thermodynamics**.

When atoms and molecules were discovered the behavior of these particles were used in thermodynamic analysis. This is the microscopic approach and this is called **statistical thermodynamics**.

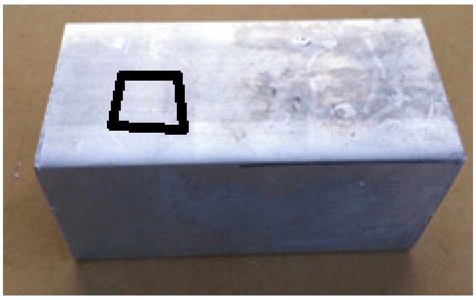
Exercise: Find out where the **energy transfers** are in the IC engine (figure above). Identify the important **properties** of the **working fluid. ***

*The working fluid or a **working substance** is a liquid or gas that *transfers energy* and undergoes *changes in properties*.

Basic concepts

System

A system is a quantity of matter or a region in space chosen for study. A system is defined by its boundary, which can be real or imaginary.



The surface of the aluminium block (real) can be the boundary of a system. Or a system can be defined in the aluminium block by considering a small portion of it (imaginary).

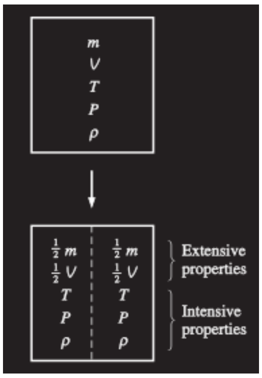
There are three types of systems: open system, closed system and isolated system

Type	Across the boundary	
	Mass Transfer	Energy Transfer
Open System	Yes	Yes
Closed System	No	Yes
Isolated System	No	No

The closed system is a **fixed mass** system or known as **control mass.** Open system is also known as a **control volume.** The boundaries of a control volume are called a **control surface.**

Properties

Any characteristic of a system is called a **property**. Some familiar properties are pressure P, temperature T, volume V, and mass m. Properties are considered to be **intensive** or **extensive.** Extensive properties depends on the extent (size) of the system. If we divide the system into two equal parts with an imaginary boundary each part will have the same value of intensive properties as the original system, but half the value of the extensive properties



State (Describing a system)

The **state** of a system is described by its

- macroscopic properties,
- no of components
- whether homogeneous or heterogeneous (multi phase)
- whether its in equilibrium

For eg: The state of air inside a balloon can be described as, m=10g, P=1atm, T= 35^{o}C

At a given state, all the properties of a system have fixed values. If the value of even one property changes, a **change of state** of the system has happened.

<u>Two property rule:</u> A single phase one component system requires only two **independent properties** and its mass to fully describe it. Once a system is fully described all the other properties could be found out.

Equilibrium

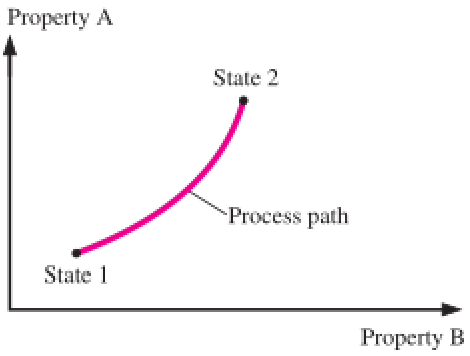
Thermodynamics deals with **equilibrium** states. The word equilibrium implies a state of balance. In an equilibrium state there are no unbalanced potentials (or driving forces) within the system.

A system in equilibrium experiences no changes in properties through **space** (x,y,z) and **time** (t), when it is isolated from its surroundings.

There are many types of equilibrium, and a system is not in thermodynamic equilibrium unless the conditions of mechanical equilibrium, thermal equilibrium and chemical equilibrium are satisfied.

Mechanical equilibrium	No change in pressure within the system
Thermal equilibrium	No change in temperature within the system
Chemical equilibrium	No change in chemical composition within the system

Process and **Path**



Any change that a system undergoes from one equilibrium state to another is called a **process**, and the series of states through which a system passes during a process is called the **path** of the process

To describe a process the **initial state**, **final state** and the path are required.

Quasi-static process

When a process proceeds in such a manner that the system remains infinitesimally close to an equilibrium state at all times, it is called a **quasi-static**, or **quasi-equilibrium process**. A quasi-equilibrium process can be viewed as a sufficiently slow process that allows the system to adjust itself internally so that properties in one part of the system do not change any faster than those at other parts.

A quasi-equilibrium process is an idealized process and is not a true representation of an actual process. Significance of a quasi-equilibrium process is that

- they are easy to analyze (so an actual process can be approximated as a quasi-equilibrium process for easy analysis)
- work-producing devices deliver the most work when they operate on quasi-equilibrium processes.

Therefore, quasi-equilibrium processes serve as standards to which actual processes can be compared.

Thermodynamic Cycle

A system is said to have undergone a **cycle** if it returns to its initial state at the end of the process. For a cycle the initial and final states are the same.

Summary

In this lecture, the basic concepts of thermodynamics are introduced and discussed.

Thermodynamics is a science that deals with energy.

Thermodynamics deals with equilibrium states, and in a thermodynamic analysis we try to find out the

- **property values** at the equilibrium states
- **energy transfers** and **changes in properties** when a system moves from **one equilibrium state to the other**.