1 Introduction and the First Law of thermodynamics

In this lecture we will cover these following topic:

1.1 Heat, work, and the system

In this topic we will cover basic concept of the Heat and system.

1. **Heat:**

A heat engine is the name given to a system which by operating in a cyclic manner produces net-work from a supply of heat. The laws of thermodynamics are natural hypotheses based on observations of the world in which we live. **It is observed that heat and work are two mutually convertible forms of energy, and this is the basis of the First Law of Thermodynamics.**

"Applied thermodynamics is the science of the relationship between heat, work, and the properties of systems."

First law of thermodynamics:

The first law of thermodynamics is a version of the law of conservation of energy, adapted for thermodynamic processes, distinguishing two kinds of transfer of energy, as heat and as thermodynamic work, and relating them to a function of a body's state, called Internal energy. The law of conservation of energy states that the total energy of an isolated system is constant; energy can be transformed from one form to another, but can be neither created nor destroyed.

Example of the first law of thermodynamics:

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Thermodynamic work, and relating them to a function of a body's state, called Internal energy. The law of conservation of energy states that the total energy of an isolated system is constant; energy can be transformed from one form to another, but can be neither created nor destroyed.
In other words, it is concerned with the means necessary to convert heat energy from available sources such as fossil fuels into mechanical work.
It is also observed that heat never flows unaided from an object at a low temperature to one at a high temperature, in the same way that a river never flows unaided uphill. This observation is the basis of the **Second Law of Thermodynamics, *which can be used to show that a heat engine cannot convert all the heat supplied to it into mechanical work but must always reject some heat at a lower temperature.***
For example, when a body A at a certain temperature, say 20C, is brought into contact with a body B at a higher temperature, say 21C, then there will be a transfer of heat from B to A until the temperatures of A and B are equal.

Thermal equilibrium:
When the temperature of A is the same as the temperature of B no heat transfer takes place between the bodies, and they are said to be in thermal equilibrium. **Heat can never be contained in a body or possessed by a body.**

2. **Systems:**

A system may be defined as a collection of matter within prescribed and identifiable boundaries. There are two types of systems, those are discuss in the below section:

1. Closed system

In **thermodynamics**, a **closed system** can exchange energy (as heat or work) but not matter, with its surroundings. An isolated **system** cannot exchange any heat, work, or matter with the surroundings, while an open **system** can exchange energy and matter. Example of the closed system is hot bottle water and Fluid in a cylinder as closed system.

2. Open system

Open System: **An open system is a thermodynamic system which** allows both mass and energy to flow in and out of it, across its boundary. Other example of this system is fluid in a turbine as an open system.

For study of gauges, check out this link in below:
https://www.bing.com/images/search?q=bourdon+gauge&id=50D6AF2363474F61828D2BAA7D2D53CF31D3CA27&s=1&view=detailv2&idpp=imgqna&vt=1&idpview=singleimage&idpbck=1&rtpu=%2fsearch%3fq%3dbourdon+gauge&FORM=IEQNAI

And most importantly, Mercury (Hg) is very often used in gauges. Taking the relative density of mercury as 13.6, then

$$1mmHg = \frac{1}{10^3} * 13.6 * \frac{9810N}{m^2} = \frac{133.4N}{m^2} = 133.4Pa$$

For a simple introduction to manometers and pressure measurements, see ref.1.2. In the book, read page no.25.

Specific volume

The specific volume of a system is the volume occupied by unit mass of the system. The symbol used is v and the units are, for example, m^3/kg. The symbol V will be used for volume. (Note that the specific volume is the reciprocal of density.)

3. **WORK:**
   Work is defined as the product of a force and the distance moved in the direction of the force.
   Explanation:
   Now, when a boundary of a closed system moves in the direction of the force acting on it, then the surroundings do work on the system. When the boundary is moved outwards the work is done by the system on its surroundings.
   - ➔ Units:
     If work is done on unit mass of a fluid, then the work done per kilogram of fluid has units of Nm/kg.
   - ➔ Properties:
     Work is observed to be energy in transition. It is never contained in a body or possessed by a body. There are many example of this topic, like Paddle wheel work input. Kindly see the page on 5 on the book for more explanation.
4. **Convention**
   The sign convention used in this book assumes that all external inputs to a system are positive. That is

Heat supplied to a system, Q, is positive.
Work input to system, W, is positive.

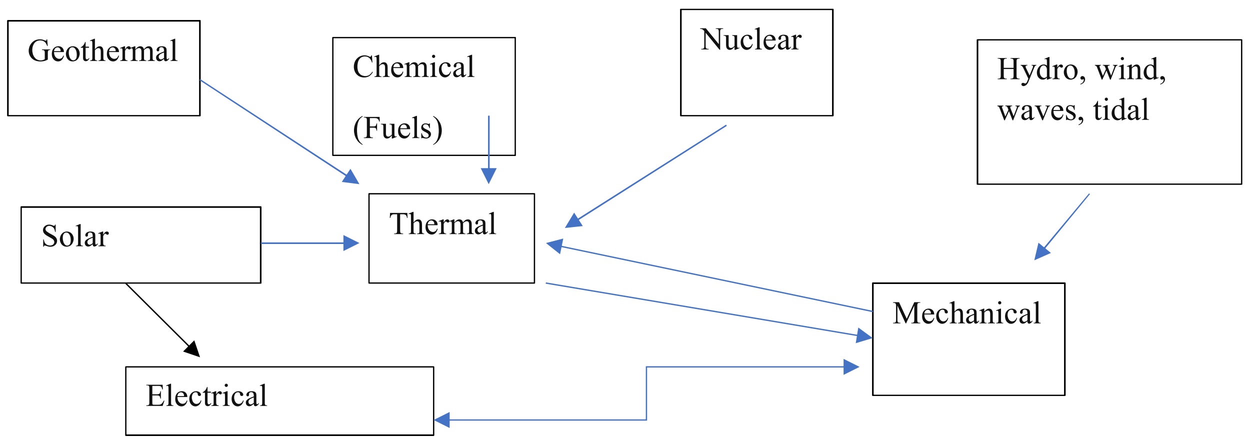
Points:

- ➔ **In algebraic equations,** it will be quite clear when numbers are substituted whether the value of Q and / or W is positive or negative; a negative value for Q will indicate that heat is rejected from the system; a negative value for W will indicate that work is done by the system on its surroundings.
- ➔ **In many cases,** it would cause unnecessary confusion by referring throughout to negative quantities; for example, it is clear that for a device designed to produce power, such as an internal combustion engine or turbine, the work input to the system is always negative. Although the above sign convention will be used for all algebraic equations it will made clear in the wording that system is producing a work output. For example

$$\boldsymbol{Work\ done\ by\ the\ system = -W}$$

Similarly, for the case of a system designed specifically to cool a fluid, such as a condenser for example, it is clear that the heat supplied to the system is always negative. Hence we can write

$$Heat\ rejected\ by\ the\ system = -Q$$



1.2 Units:

For more explanation, kindly check page no.6

Force, energy, and power

Pressure, temperature page no.7

Multiples and sub-multiples page no.8

1.3 The state of the working fluid:

What is working fluid?

In all problems in applied thermodynamics we are concerned with energy transfers to or from a system. In practice the matter contained within the boundaries of the system can be liquid, vapors, or gas, and is known as the **working fluid.**

We will discuss the working of fluid in chapter 2 in detail.

What is pure working fluid?.

- ➔ It has been found that, for any pure working fluid, only two independent properties are necessary to define completely the state of the fluid.

1.4 Reversibility

The criteria of reversibility are as follows:

(a) The process must be frictionless. The fluid itself must have no internal friction and there must be no mechanical friction (e.g. between cylinder and piston).

(b) The difference in pressure between the fluid and its surrounding during the process must be infinitely small. This means that the process must take place infinitely slowly, since the force to accelerate the boundaries of the system is infinitely small.

(c) The difference in temperature between the fluid and its surroundings during the process must be infinitely small. This means that the heat supplied of rejected to or from the fluid must be transferred infinitely slowly.

- ➔ From above mention criteria that no process in practice is truly reversible. However, in many practical processes a very close approximation to an **internal reversibility may be obtained.**
- ➔ **What is an internal reversibility?**
  - In an internal reversible process, although the surroundings can never be restored to their original state, the fluid itself is at all times in an equilibrium state and the path of the process can be exactly retraced to the initial state.
- ➔ In general purpose, processes in cylinders with a reciprocating, but processes in rotary machinery (e.g. turbines are known to be irreversible due to the high degree of turbulence and scrubbing of thee fluid.

Section 1.5 Reversible work

Section 1.6 Conversation of energy and the First Law of Thermodynamics

The concept of energy and the hypothesis that it can neither be created nor destroyed were developed by scientists in the early part of the 19th century, and became known as the *principle of the Conversation of Energy.*

- ➔ *The first law of thermodynamics is merely one statement of this general principle with particular reference to thermal energy, (i.e. heat), and mechanical energy, (i.e. work).*

- ➔ *When a system undergoes complete thermodynamic cycle the intrinsic energy of the system is the same at the beginning and end of the cycle.*

➔ *During the various processes that make up the cycle work is done on or by the fluid and heat is supplied or rejected; the network input can be defined as ΣW, and the net heat supplied as ΣQ, where the symbol Σ represents the sum for a complete cycle.*

➔ ***Since the intrinsic energy of the system is unchanged the first law of thermodynamics states that:***
"When a system undergoes a thermodynamic cycle then the net heat supplied to the system from its surroundings plus the net -work input to the system from its surroundings must equal zero."

$$\Sigma Q + \Sigma W = 0$$

Section 1.7 the non-flow equation

In conversation of energy and the first law of thermodynamics, it is stated that when a system possessing a certain intrinsic energy is made to undergo a cycle by heat and work transfer, then the net heat supplied plus the net-work input is zero.

➔ This is true for a complete cycle when the final intrinsic energy of the system is equal to its initial value.

<u>Explanation of the non-flow equation:</u>

Consider now a process in which the intrinsic energy of the system is finally greater than the initial intrinsic energy. The sum of the net-heat supplied and the Net-work input has increased the intrinsic energy of the system, i.e.

Gain in intrinsic energy = Net heat supplied + Net -work input

When the net effect is to transfer energy from the system, then there will be a loss in the intrinsic energy of the system.

- Specific internal energy:
  When a fluid is not in motion then its intrinsic energy per unit mass is known as the specific internal energy of the fluid and is given the symbol u.
  Explanation:
  The specific internal energy of a fluid depends on its pressure and temperature, and is itself a property.
  Units:
  The internal energy of mass, m, of a fluid is written as U, i.e. mu = U.
  The units of internal energy, U, are usually written as kJ.
- Since internal energy is a property, then gain in internal energy in changing from state 1 to state 2: U2-U1.
  Also , gain in internal energy = net-heat supplied + net-work input,

Section 1.8 The steady-flow equation

Total example are 7, 1.1 to 1.7

Total problems are 14

Above section 1.5 to 1.8 include numerical with theory.