

Chapter One

Introduction and basic concepts of
thermodynamics

Objectives

- Identify the unique vocabulary associated with thermodynamics through the precise definition of basic concepts to form a sound foundation for the development of the principles of thermodynamics.
- To identify the application area of thermodynamic
- Review the metric SI and the English unit systems that will be used throughout the text.
- Explain the basic concepts of thermodynamics such as system, state, equilibrium, process, and cycle.
- Review concepts of temperature, temperature scales.

Discussion

What is the difference between physics and engineering science?
What is engineering thermodynamics?
Why we learn engineering thermodynamics?
What is the application areas of engineering thermodynamics?
(List and describe)

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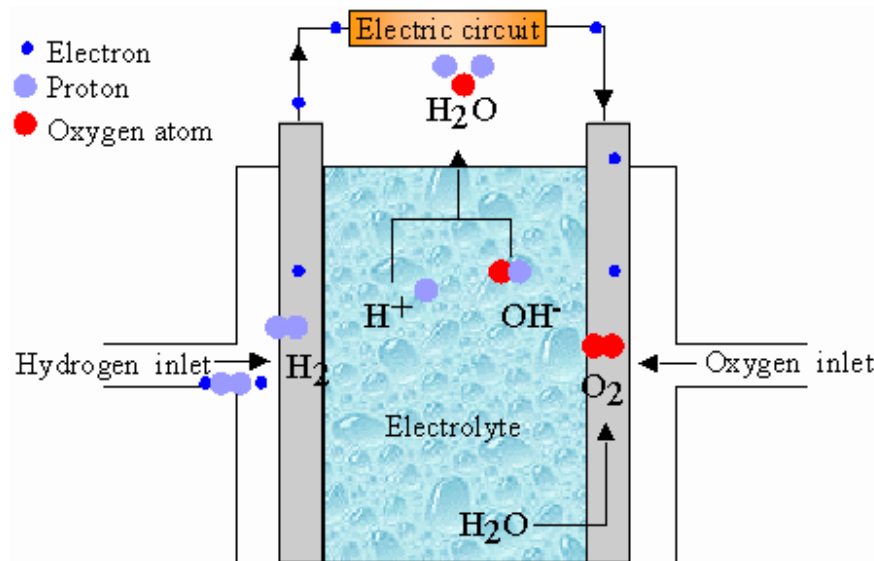
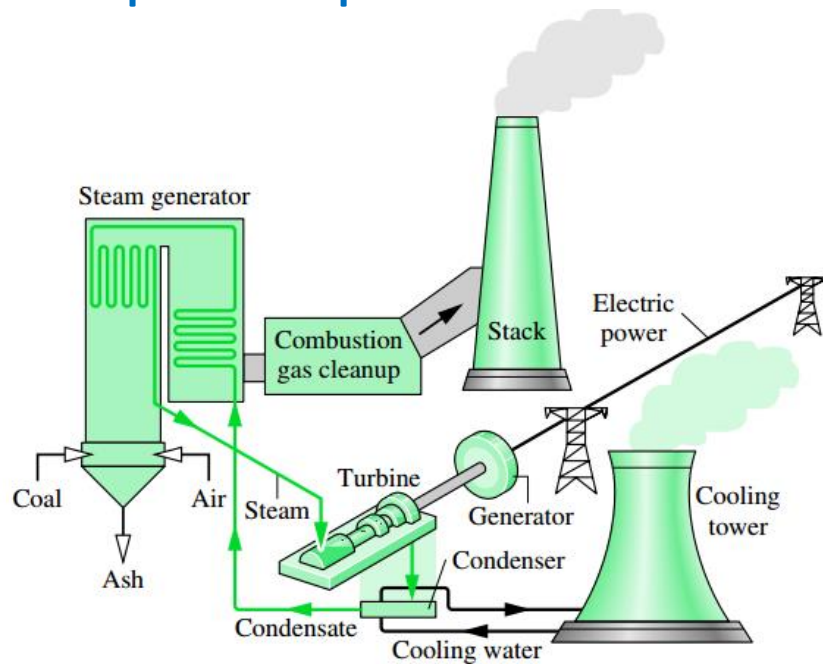
- Physics is pure science studies the way how the universe work while engineering is a discipline uses the principles of the pure science to solve problems and to improve life for other.
- thermodynamics is branch of physics and engineering science.
- Engineering thermodynamics dealing generally with *energy* and relationships among the *properties* of matter
- Engineers seek to achieve improved designs and better performance, as measured by factors such as an increase in the output of some desired product, a reduced input of a scarce resource, a reduction in total costs, or a lesser environmental impact.
- The principles of engineering thermodynamics play an important part in achieving these goals.

Application areas of engineering thermodynamics

- Automobile engines
- Turbines
- Compressors, pumps
- Fossil- and nuclear-fueled power stations
- Combustion systems
- Heating, ventilating, and air-conditioning systems
- Vapor compression and absorption refrigeration
- Heat pumps
- Cooling of electronic equipment
- Fuel cells
- Thermoelectric and thermionic devices
- Solar-activated heating, cooling, and power generation
- Geothermal systems
- Ocean thermal, wave, and tidal power generation
- Wind power
- Artificial organs

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Steam power plant



Fuel cells

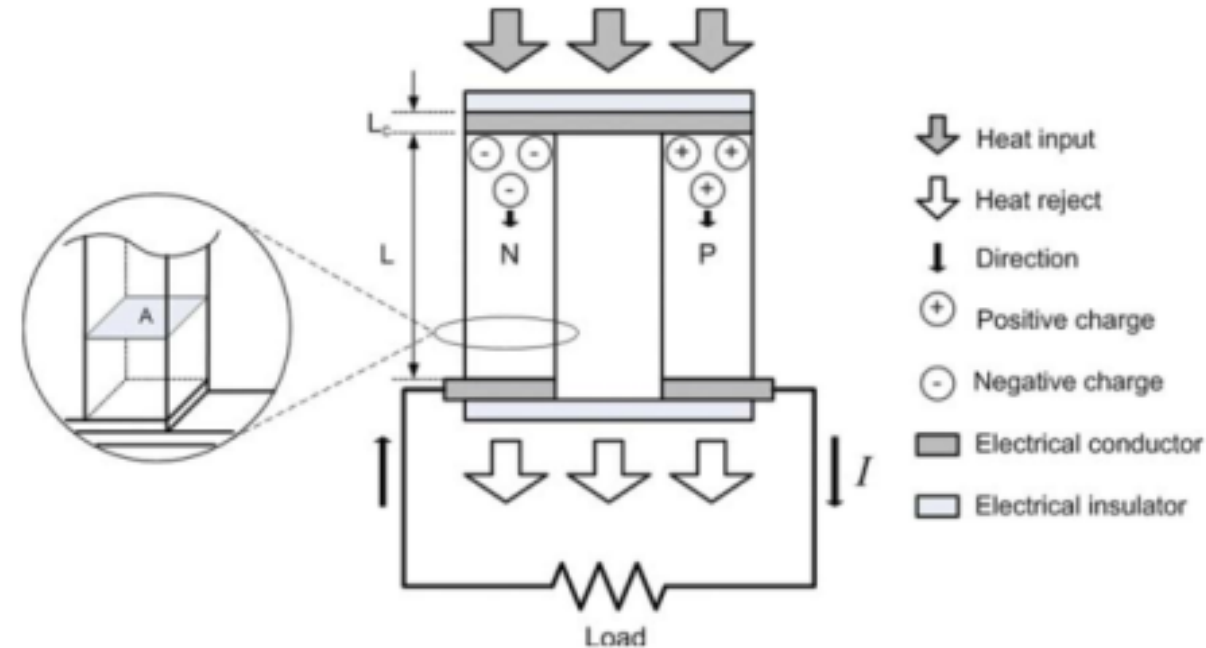
- A fuel cell is an energy conversion device that converts the chemical energy of a fuel directly into electricity without any intermediate thermal or mechanical processes.
- Energy is released whenever a fuel reacts chemically with the oxygen in air.
- In a fuel cell, the reaction occurs electrochemically and the energy is released as a combination of low-voltage DC electrical energy and heat.
- The electrical energy can be used to do useful work directly while the heat is either wasted or used for other purposes.

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Thermoelectric generator

- A thermoelectric generator is a device that consists of a p-type and n-type semiconductors connected in series.
- This structure can be used to convert heat energy to electricity by using a principle known as the Seebeck effect.
- When heat is applied to one surface of the thermoelectric generator, the electrons in the n-type semiconductor and the holes in the p-type semiconductor will move away from the heat source.
- This movement of electrons and holes gives rise to an electrical current.
- The direction of the current is opposite to the movement of the electrons, and in the same direction as the movement of the holes.

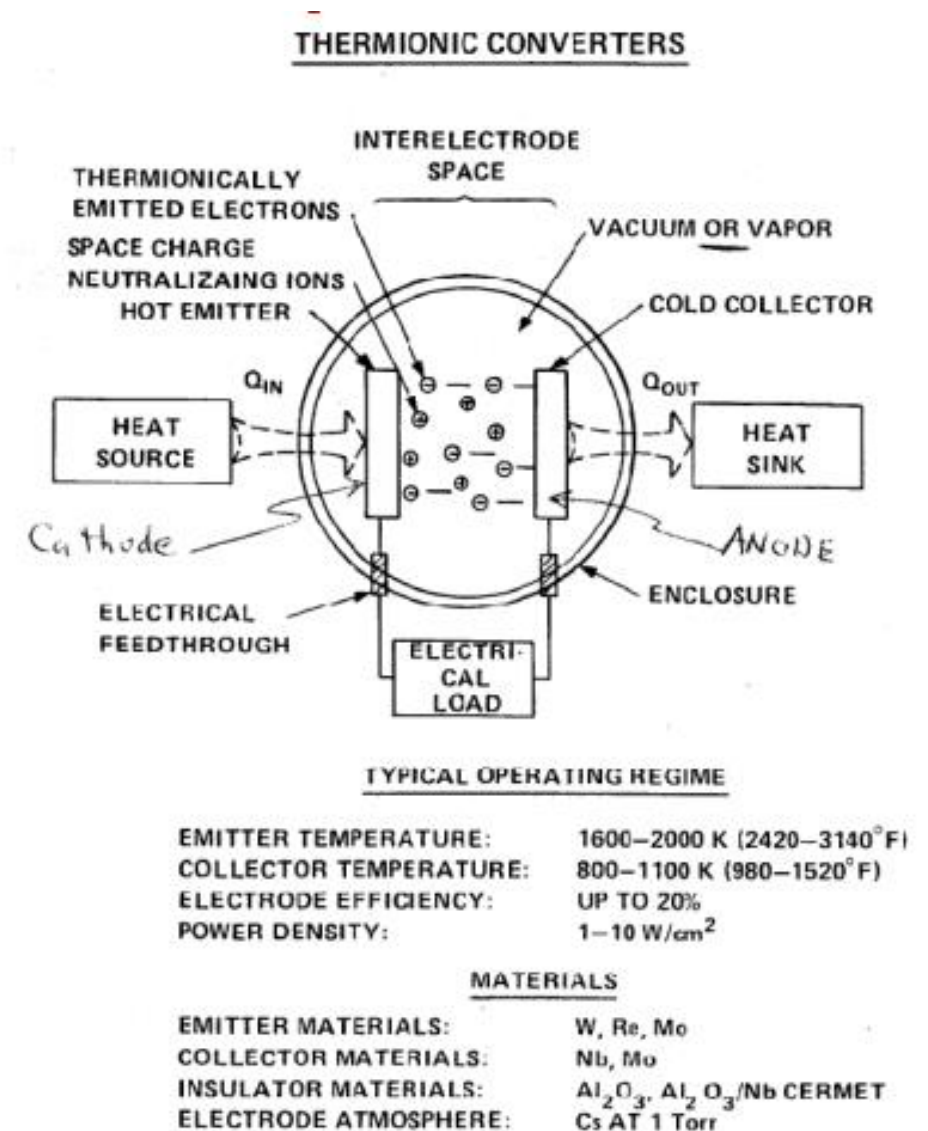
- Schematic of single Thermoelectric Couple



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Thermionic generator

- **Thermionic Power Converter** is a static device that converts heat into electricity by boiling electrons from a hot emitter surface (approx. 1800 K) across a small inter electrode gap (< 0.5 mm) to a cooler collector surface (approx. 1000 K)
- A **Thermionic Generator** consists of one or more of these converters coupled to give desired power output
- Thermionic generators can be operated from any primary heat source.
- For low power level (3 kW or less) solar energy can be used
- For high power level (50 kW or more) nuclear heat source can be used



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Refrigeration

- Refrigeration: it is the process of continuous cooling or extraction of heat to below that of the atmosphere from a substance with a help of the external work.
- Principle of refrigeration: It is based on the second law of thermodynamics that the heat can made to flow from cold body to a hot body with the help of external source.
- Refrigerator: it is a machine which produces cold. It is used to remove heat from the refrigerated space and reject it to atmosphere. Hence it maintains the temperature below the surrounding atmosphere.
- Refrigerant: it is the working fluid used in the refrigerator. E.g. Ammonia, Methyl chloride, Freon etc.
- Ton of refrigeration: It is the standard unit of the refrigerator. It is the freezing capacity of the one American short ton of water from 0 c in 24 hrs.
- One ton of the refrigeration = $3.5\text{kW} = 3.5\text{kJ/s} = 210\text{kJ/min}$

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Thermoelectric refrigeration

- Thermoelectric cooling is a way to remove thermal energy from a medium, device or component by applying a voltage of constant polarity to a junction between dissimilar electrical conductors or semiconductors.
- Thermoelectric Refrigeration provides cooling effect by using thermoelectric effect i.e. Peltier effect rather than the more prevalent conventional methods like those using the ‘vapor compression cycle’ or the ‘gas compression cycle’.
- Thermoelectric Refrigeration finds applications in electronic systems and computers to cool sensitive components such as power amplifiers and microprocessors.
- TER can also be used in a satellite or space application to control the extreme temperatures that occur in components on the sunlit side and to warm the components on the dark side.
- In scientific applications like digital cameras and charge coupled devices (CCDs) TER is used to minimize thermal noise, thereby optimizing the sensitivity and image contrast.

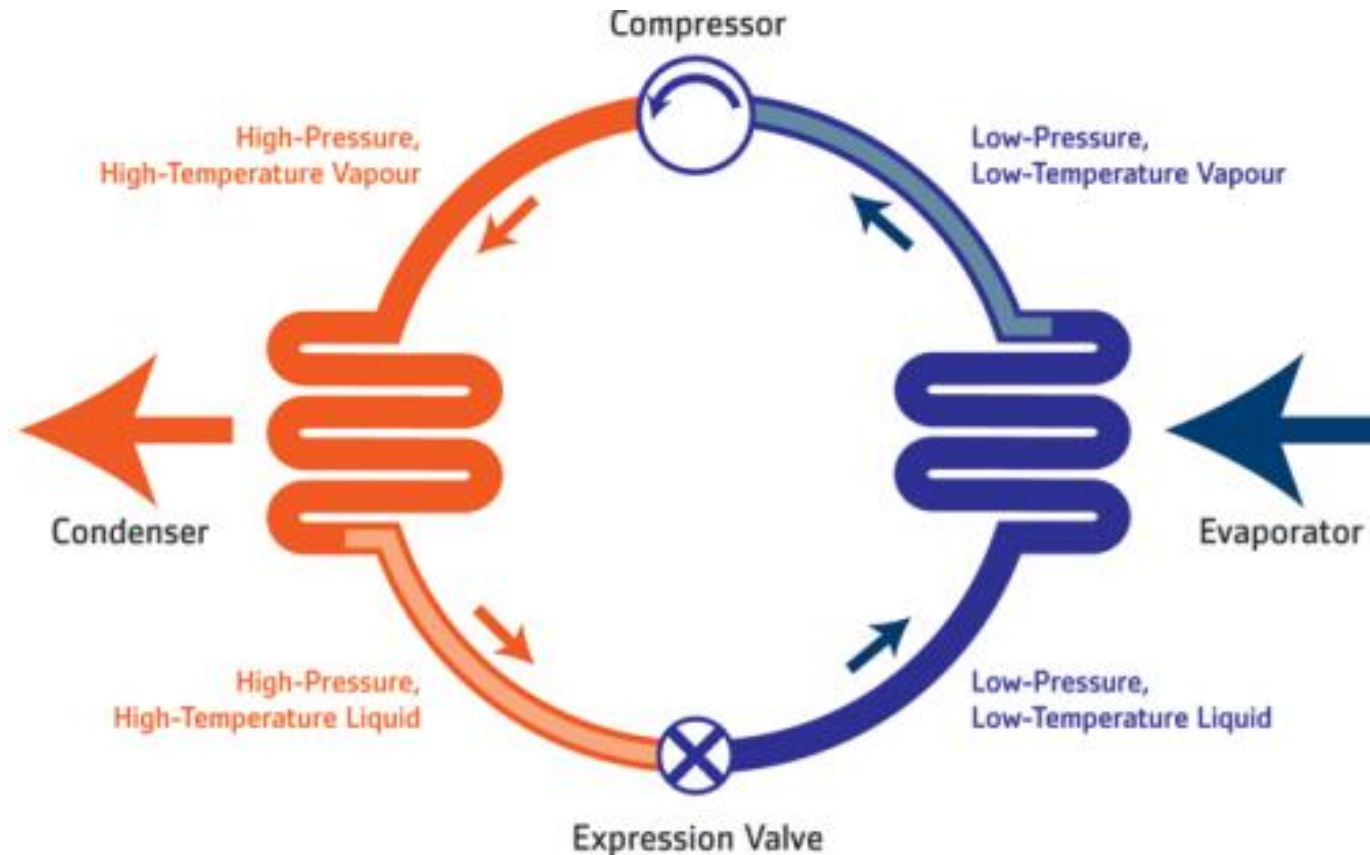
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Heat pump

- Heat pump is a device which pumps heat from, one or more low temperature sources to one or more high temperature sinks simultaneously, with the help of an external source of energy.
- Heat pumps are designed to move thermal energy opposite to the direction of spontaneous heat flow by absorbing heat from a cold space and releasing it to a warmer one.
- Heat pumps are very efficient for heating and cooling systems and they can significantly reduce the energy costs.
- "Heat" is not conserved in this process because it requires some amount of external energy, such as electricity.
- Heat pumps also work extremely efficiently, because they simply transfer heat, rather than burn fuel to create it and also help in the reduction of greenhouse emission in various industry applications.

Cont..

- The most common examples of heat pumps are air conditioners and freezers etc.
- All the heat pumps use a refrigerant as a transitional fluid to absorb heat where it vaporizes, in the evaporator, and then to release heat where the refrigerant condenses, in the condenser.
- The refrigerant flows through the insulated pipes between the evaporator and the condenser, allowing for efficient thermal energy transfer.
- Heat Pump Cycle



Environmental concerns

- The relationship between humanity and the environment is a delicate balance.
- Since the industrial revolution, the world's population has increased exponentially, and with the population growth, the environment has been profoundly affected.
- There is direct relationship between environment and economy.
- Economic development without environmental considerations can cause serious environmental damage in turn impairing the quality of life of present and future generations.
- In the process of economic development, the environmental problems should be consider.
- Now, the need of the world is to concentrate on sustainable development.
- Sustainable development means, “Meeting the needs of present generation without compromising with the needs of future generations.”
- Deforestation, pollution and global climate changes are amongst the adverse effects that population and technological expansion has introduced.

Renewable energy

- **Renewable:** Renewable resources are unlimited natural resources that can be replenished in a short period of time.



- **Renewable energy** is energy generated from natural resources such as sunlight, wind, rain, tides and geothermal heat which are renewable (naturally replenished).
 - ☐ Solar energy
 - ☐ Wind
 - ☐ Hydropower
 - ☐ Biomass
 - ☐ Ocean energy
 - ☐ Geothermal
 - ☐ Waste to Energy

Dimension and unit system

- Any physical quantity can be characterized by dimensions.
- The magnitudes assigned to the dimensions are called units.
- Some basic dimensions such as mass m , length L , time t , and temperature T are selected as primary or fundamental dimensions, while others such as velocity V , energy E , and volume V are expressed in terms of the primary dimensions and are called secondary dimensions, or derived dimensions.

TABLE 1–1

The seven fundamental (or primary) dimensions and their units in SI

Dimension	Unit
Length	meter (m)
Mass	kilogram (kg)
Time	second (s)
Temperature	kelvin (K)
Electric current	ampere (A)
Amount of light	candela (cd)
Amount of matter	mole (mol)

TABLE 1–2

Standard prefixes in SI units

Multiple	Prefix
10^{12}	tera, T
10^9	giga, G
10^6	mega, M
10^3	kilo, k
10^2	hecto, h
10^1	deka, da
10^{-1}	deci, d
10^{-2}	centi, c
10^{-3}	milli, m
10^{-6}	micro, μ
10^{-9}	nano, n
10^{-12}	pico, p

Systems

Thermodynamic System

- is defined as a quantity of matter or a region in space chosen for study.

Surroundings

- Everything external to the system (the mass or region outside the system).

Boundary

- ✓ is Surface that separates the system from the surroundings. It may be **fixed** or **movable, real or imaginary**.
- ✓ is contact surface shared by both the system and the surroundings.
- ✓ Mathematically speaking, the boundary has zero thickness, and thus it can neither contain any mass nor occupy any volume in space.

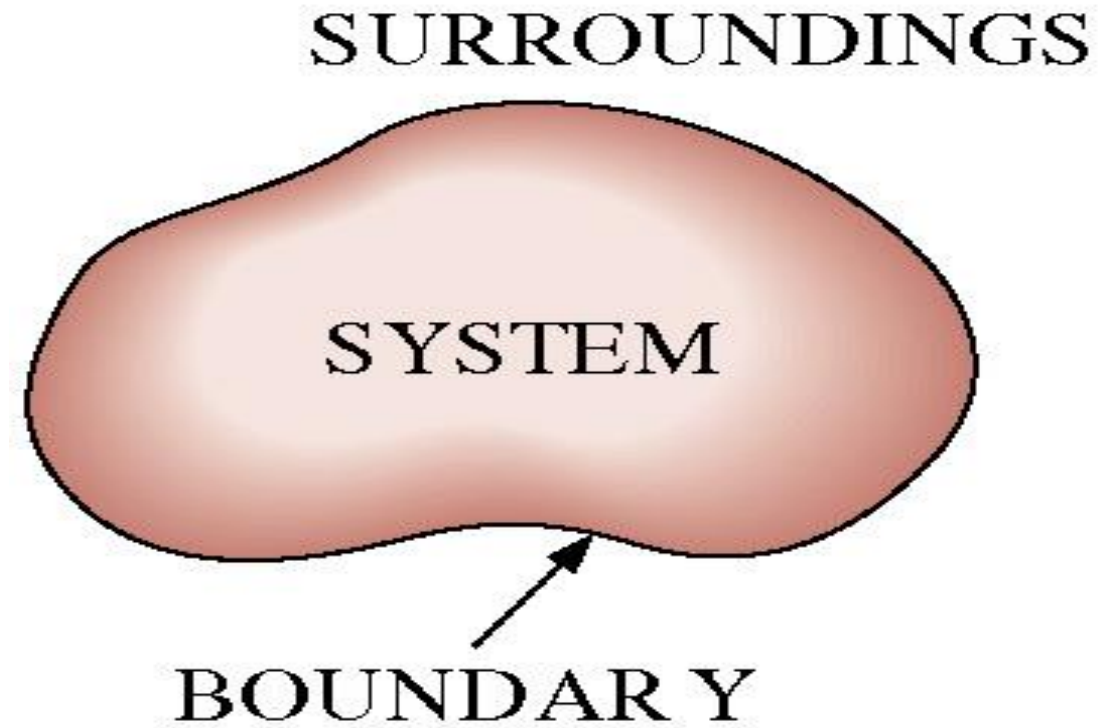


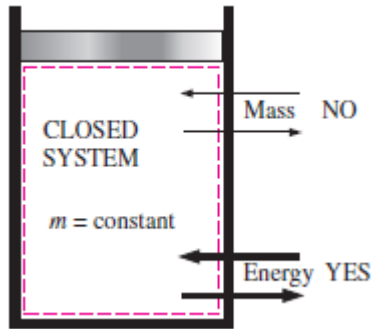
Fig. System, surroundings, and boundary.

Type of system

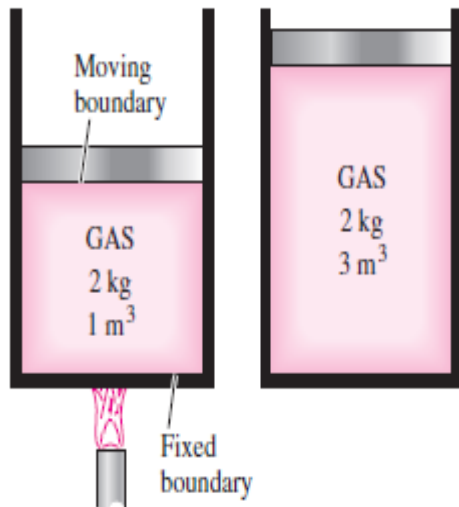
- Systems may be considered as
 - ❖ closed system(control mass)
 - ❖ open system (control volume)
- depending on whether a fixed mass or a fixed volume in space is chosen for study.
- A (also known as a **control mass**) **consists of a fixed amount of mass, and no** mass can cross its boundary.
- That is, no mass can enter or leave a closed system, as shown in fig. below. But energy, in the form of heat or work, can cross the boundary; and the volume of a closed system does not have to be fixed.
- If, as a special case, even energy is not allowed to cross the boundary, that system is called an **isolated system**.

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- closed system



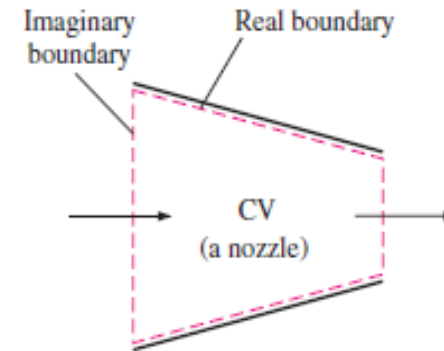
Mass cannot cross the boundaries of a closed system, but energy can.



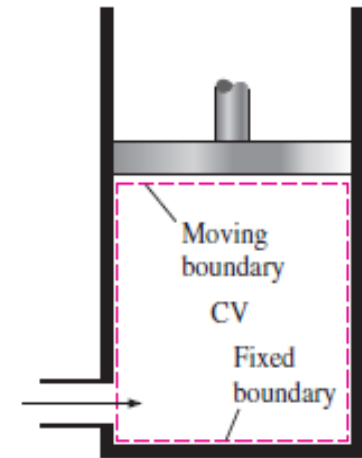
A closed system with a moving boundary.

- open system (a control volume)

- ✓ Both mass and energy can cross the boundary of control volume.
- ✓ It usually encloses a device that involves mass flow such as a compressor, turbine, or nozzle.



(a) A control volume with real and imaginary boundaries



(b) A control volume with fixed and moving boundaries

A control volume can involve fixed, moving, real, and imaginary boundaries.

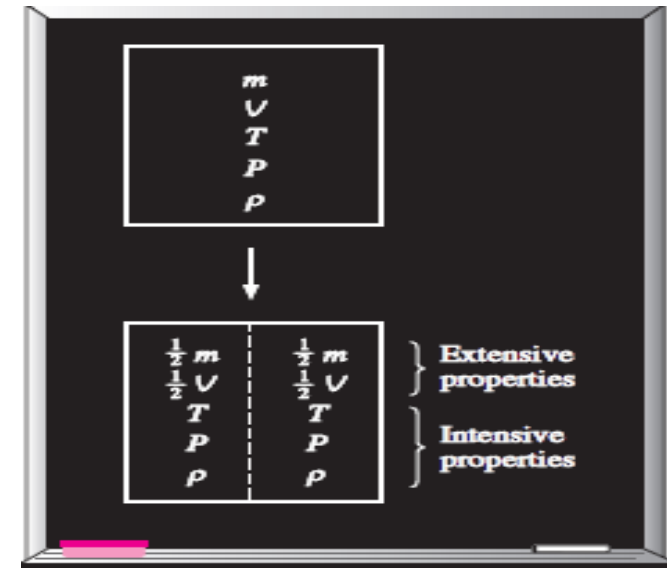
Properties of a system

- Any characteristic of a system is called a **property**.

Example: pressure (P), temperature (T), volume (V), and mass (m)

- Properties** are considered to be either **intensive or extensive**
- Intensive properties** are those that are independent of the mass of a system, such as temperature, pressure, and density.
- Extensive properties** are those whose values depend on the size-or extent-of the system, such as total mass, total volume, and total momentum.
- An easy way to determine whether a property is intensive or extensive is to divide the system into two equal parts with an imaginary partition, as shown in Fig below.

- Each part will have the same value of intensive properties as the original system, but half the value of the extensive properties.
- Extensive properties per unit mass are called specific properties.**
- Some examples of specific properties are specific volume ($v = V/m$) and specific total energy ($e = E/m$).



Criterion to differentiate intensive and extensive properties.

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DENSITY AND SPECIFIC GRAVITY

- Density is defined as mass per unit volume

$$\rho = \frac{m}{V} \quad (\text{kg/m}^3)$$

- The reciprocal of density is the **specific volume v**, which is defined as volume per unit mass.

$$v = \frac{V}{m} = \frac{1}{\rho}$$

Sometimes the density of a substance is given relative to the density of a well-known substance. Then it is called **specific gravity**, or **relative density**, and is defined as *the ratio of the density of a substance to the density of some standard substance at a specified temperature* (usually water at 4°C, for which $\rho_{\text{H}_2\text{O}} = 1000 \text{ kg/m}^3$). That is,

Specific gravity:

$$\text{SG} = \frac{\rho}{\rho_{\text{H}_2\text{O}}} \quad (1-6)$$

Note that the specific gravity of a substance is a dimensionless quantity.

cont..

- Note that substances with specific gravities less than 1 are lighter than water, and thus they would float on water.

TABLE 1–3

Specific gravities of some substances at 0°C

Substance	SG
Water	1.0
Blood	1.05
Seawater	1.025
Gasoline	0.7
Ethyl alcohol	0.79
Mercury	13.6
Wood	0.3–0.9
Gold	19.2
Bones	1.7–2.0
Ice	0.92
Air (at 1 atm)	0.0013

- The weight of a unit volume of a substance is called **specific weight** and is expressed as

$$\text{Specific weight:} \quad \gamma_s = \rho g \quad (\text{N/m}^3)$$

where g is the gravitational acceleration.

State And Equilibrium

State: is the condition of the system which is described by a set of properties (e.g. Temperature, pressure...).

- ✓ At a given state, all the properties of a system have fixed values.
- ✓ If the value of even one property changes, the state will change to a different one

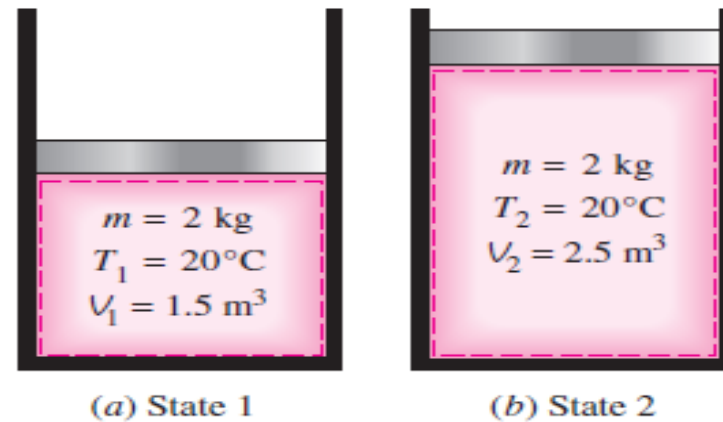


Fig. A system at two different states.

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Thermodynamics deals with equilibrium states.

Equilibrium

- ✓ implies a state of balance.
- ✓ no unbalanced potentials (or driving forces) within the system.
- There are many types of equilibrium, example

Thermal equilibrium

- A system is in thermal equilibrium if the temperature is the same throughout the entire system

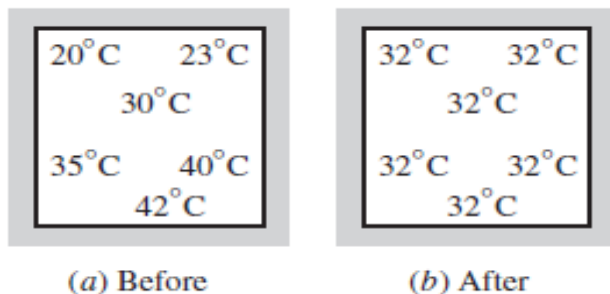


fig. A closed system reaching thermal equilibrium.

Mechanical equilibrium

A system is in mechanical equilibrium if there is no change in pressure at any point of the system with time.

chemical equilibrium

A system is in chemical equilibrium if its chemical composition does not change with time, that is, no chemical reactions occur.

N.B. A system will not be in equilibrium unless all the relevant equilibrium criteria are satisfied.

Processes And Cycles

Process

- any change that a system undergoes from one equilibrium state to another.

Path

- the series of states through which a system passes during a process
- To describe a process completely, one should specify the initial and final states of the process, as well as the path it follows, and the interactions with the surroundings.

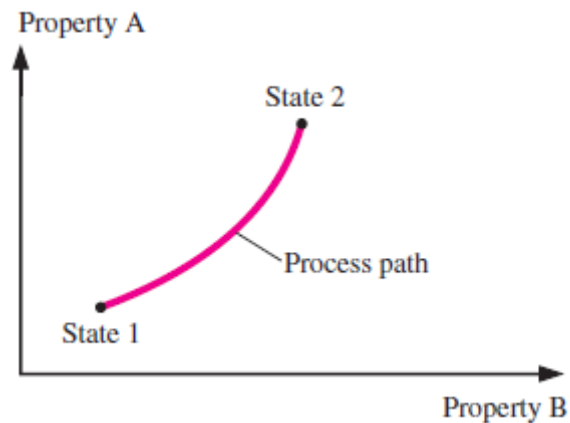


Fig. A process between states 1 and 2 and the process path.

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- The state of a system is defined when it is in equilibrium.

non-quasi-equilibrium process

- If we change the state very fast it is not in equilibrium during the process (**non-quasi-equilibrium process**)
- States during the process are undefined.
- We can only define the initial and final states.

quasi-static process or quasi-equilibrium process(is an ideal process)

- If we change state slowly then the system is in equilibrium during the process (**quasi-static process or quasi-equilibrium process**)
- The system is very near to equilibrium in all successive states during the process.

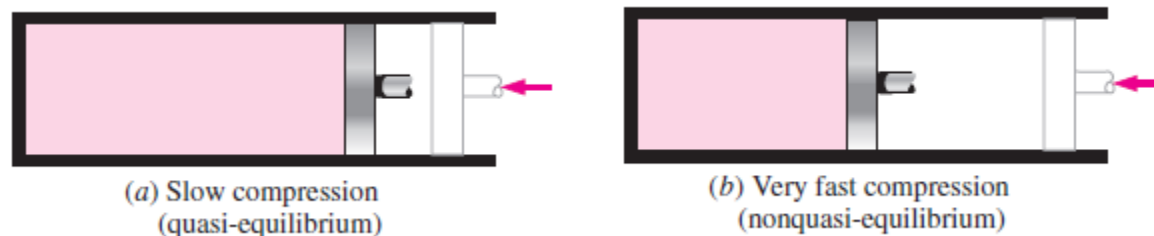


Fig. Quasi-equilibrium and non quasi-equilibrium compression processes.

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- In thermodynamics, we have different processes, such as

Isothermal process

- is a process during which the temperature T remains constant

Isobaric process

- is a process during which the pressure P remains constant

Isochoric (or isometric) process

- is a process during which the specific volume v remains constant.

➤NOTE: The prefix iso- is often used to designate a process for which a particular property remains constant

- A system is said to have undergone a cycle if it returns to its initial state at the end of the process.
- That is, for a cycle the initial and final states are identical.

Steady-Flow Process

- The terms steady and uniform are used frequently in engineering, **The term steady implies no change with time.**
- The opposite of steady is unsteady, or transient.
- The term uniform, however, implies no change with time over a specified region.
- A large number of engineering devices operate for long periods of time under the same conditions, and they are classified as steady-flow devices.
- Processes involving such devices can be represented reasonably well by a somewhat idealized process, called **the steady-flow process**, which can be defined as a process during which a fluid flows through a control volume steadily.

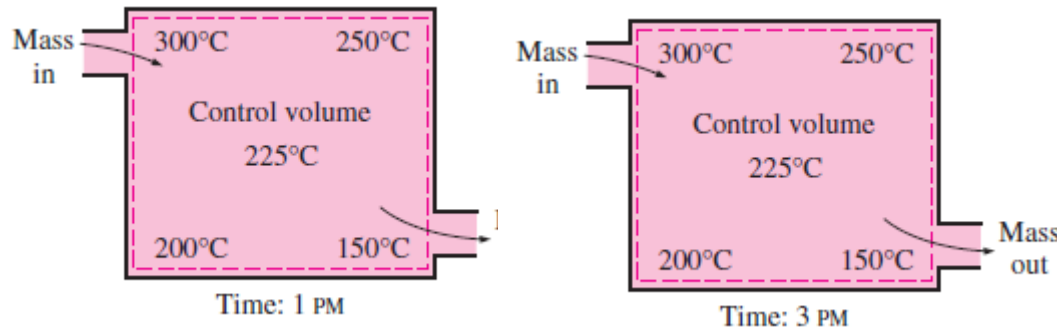
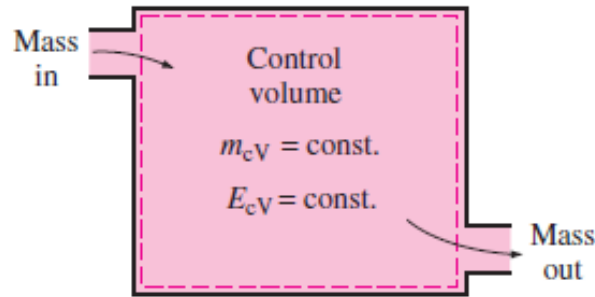


Fig. During a steady-flow process, fluid properties within the control volume may change with position but not with time.

Cont..

- In steady flow device, the fluid properties can change from point to point within the control volume, but at any fixed point they remain the same during the entire process. Therefore, the volume V , the mass m , and the total energy content E of the control volume remain constant during a steady flow process as shown in the fig below.



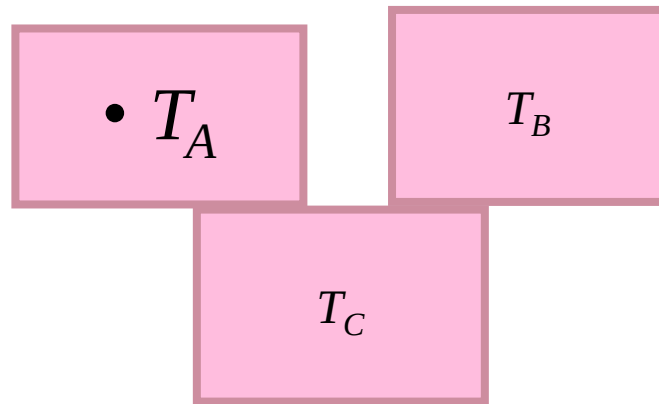
- Fig. Under steady-flow conditions, the mass and energy contents of a control volume remain constant.

Temperature And The Zeroth Law of Thermodynamics

Temperature: Degree of hotness or coldness

The zeroth law of thermodynamics: states that if two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other.

- It is one of the basic laws of thermodynamics.
- It cannot be concluded from the other laws of thermodynamics, and it serves as a basis for the validity of temperature measurement.
- By replacing the third body with a thermometer, The zeroth law can be restated as two bodies are in thermal equilibrium if both have the same temperature reading even if they are not in contact.



- if $T_A = T_C$ & $T_B = T_C$
 then $T_A = T_B$

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Temperature Scales

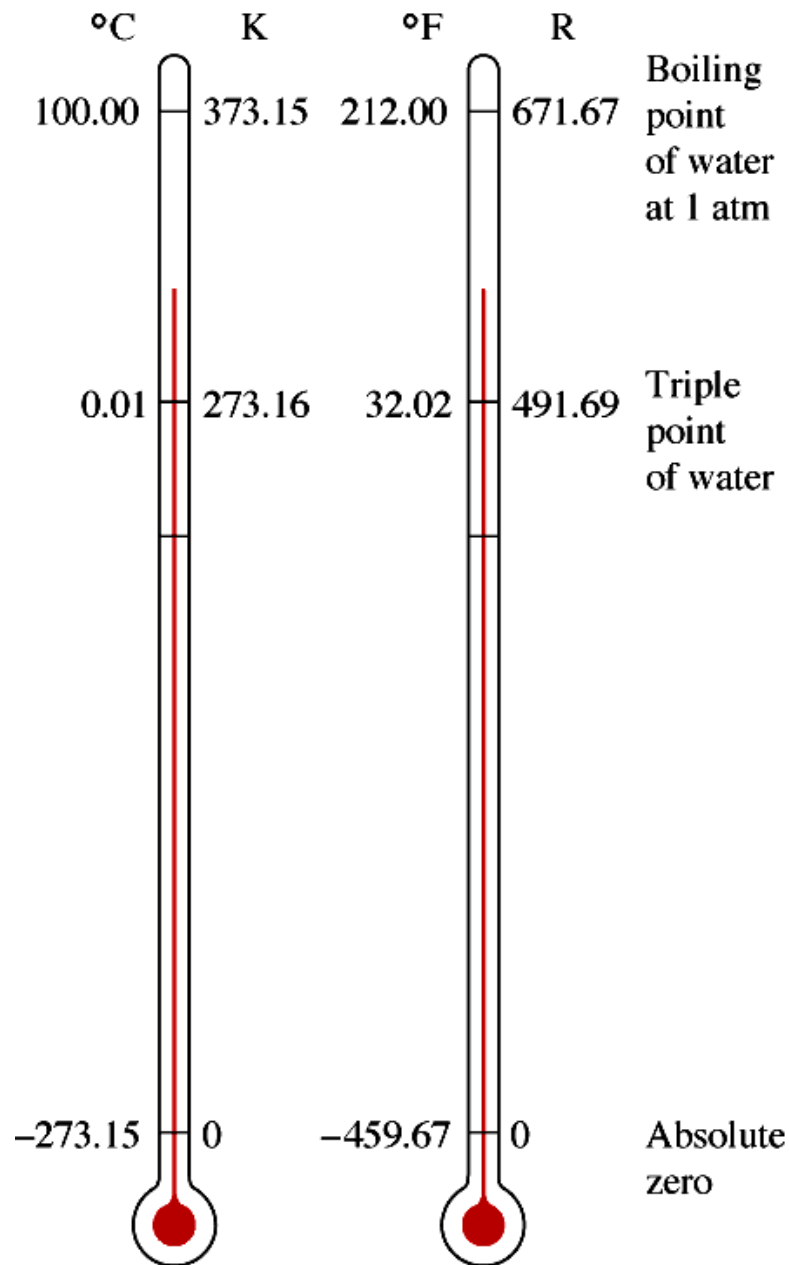
- To relate temperatures that we read from different devices we need a standard scale of temperature
- The temperature scales used in the SI and in the English system today are
 - ✓ **Celsius scale**
 - ✓ **Fahrenheit scale**
- On the Celsius scale, the ice and steam points were originally assigned the values of 0 and 100°C, respectively.
- The corresponding values on the Fahrenheit scale are 32 and 212°F.
- These are often referred to as two-point scales since temperature values are assigned at two different points.

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Thermodynamic(absolute) temperature scale

- is temperature scale that is independent of the properties of any substance or substances.
- The thermodynamic temperature scale in the English system is the **Rankine scale**, named after William Rankine (1820–1872). The temperature unit on this scale is the **Rankine**, which is designated by R.
- The thermodynamic temperature scale in the SI is the Kelvin scale. The temperature unit on this scale is the Kelvin, which is designated by K (not °K).
- The lowest temperature on the Kelvin scale is absolute zero, or 0 K.
- The reference temperature chosen in the original Kelvin scale was 273.15 K (or 0°C), which is the temperature at which water freezes (or ice melts) and water exists as a solid–liquid mixture in equilibrium under standard atmospheric pressure (the ice point).
- The triple point of water (the state at which all three phases of water coexist in equilibrium), which is assigned the value 273.16 K(0.01°C).
- The boiling temperature of water (the steam point) was experimentally determined to be again 100.00°C.

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The Kelvin scale is related to the Celsius scale by

$$T(\text{K}) = T(^{\circ}\text{C}) + 273.15$$

The Rankine scale is related to the Fahrenheit scale by

$$T(\text{R}) = T(^{\circ}\text{F}) + 459.67$$

The temperature scales in the two unit systems are related by

$$T(\text{R}) = 1.8T(\text{K})$$

$$T(^{\circ}\text{F}) = 1.8T(^{\circ}\text{C}) + 32$$

- When we are dealing with temperature differences T , the temperature interval on both scales is the same.

$$\Delta T(\text{K}) = \Delta T(^{\circ}\text{C})$$

$$\Delta T(\text{R}) = \Delta T(^{\circ}\text{F})$$

- it is always safe to use K because there are virtually no situations in which the use of K is incorrect, but there are many thermodynamic relations that will yield an erroneous result if $^{\circ}\text{C}$ is used.

Cont..

Example

- During a heating process, the temperature of a system rises by 10°C . Express this rise in temperature in K, $^{\circ}\text{F}$, and R.

PRESSURE

- Pressure is defined as *a normal force exerted by a fluid per unit area*.
- We speak of pressure only when we deal with a gas or a liquid.
- The counterpart of pressure in solids is *normal stress*.
- Since pressure is defined as force per unit area, it has the unit of Newton's per square meter (N/m²), which is called a **Pascal (Pa)**. That is,
$$1 \text{ Pa} = 1 \text{ N/m}^2$$
- The pressure unit Pascal is too small for pressures encountered in practice.
- Therefore, its multiples *kilopascal* ($1 \text{ kPa} = 10^3 \text{ Pa}$) and *Mega pascal* ($1 \text{ MPa} = 10^6 \text{ Pa}$) are commonly used.
- The other pressure units commonly used in practice, especially in Europe, are *bar and standard atmosphere*.
- The actual pressure at a given position is called the **absolute pressure**, and it is measured relative to absolute vacuum (i.e., absolute zero pressure).

$$1 \text{ bar} = 10^5 \text{ Pa} = 0.1 \text{ MPa} = 100 \text{ kPa}$$

$$1 \text{ atm} = 101,325 \text{ Pa} = 101.325 \text{ kPa} = 1.01325 \text{ bars}$$

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- Most pressure-measuring devices, however, are calibrated to read zero in the atmosphere, and so they indicate the difference between the absolute pressure and the local atmospheric pressure. This difference is called the **gage pressure**.
- Pressures below atmospheric pressure are called **vacuum pressures** and are measured by vacuum gages that indicate the difference between the atmospheric pressure and the absolute pressure.



Some basic pressure gages.

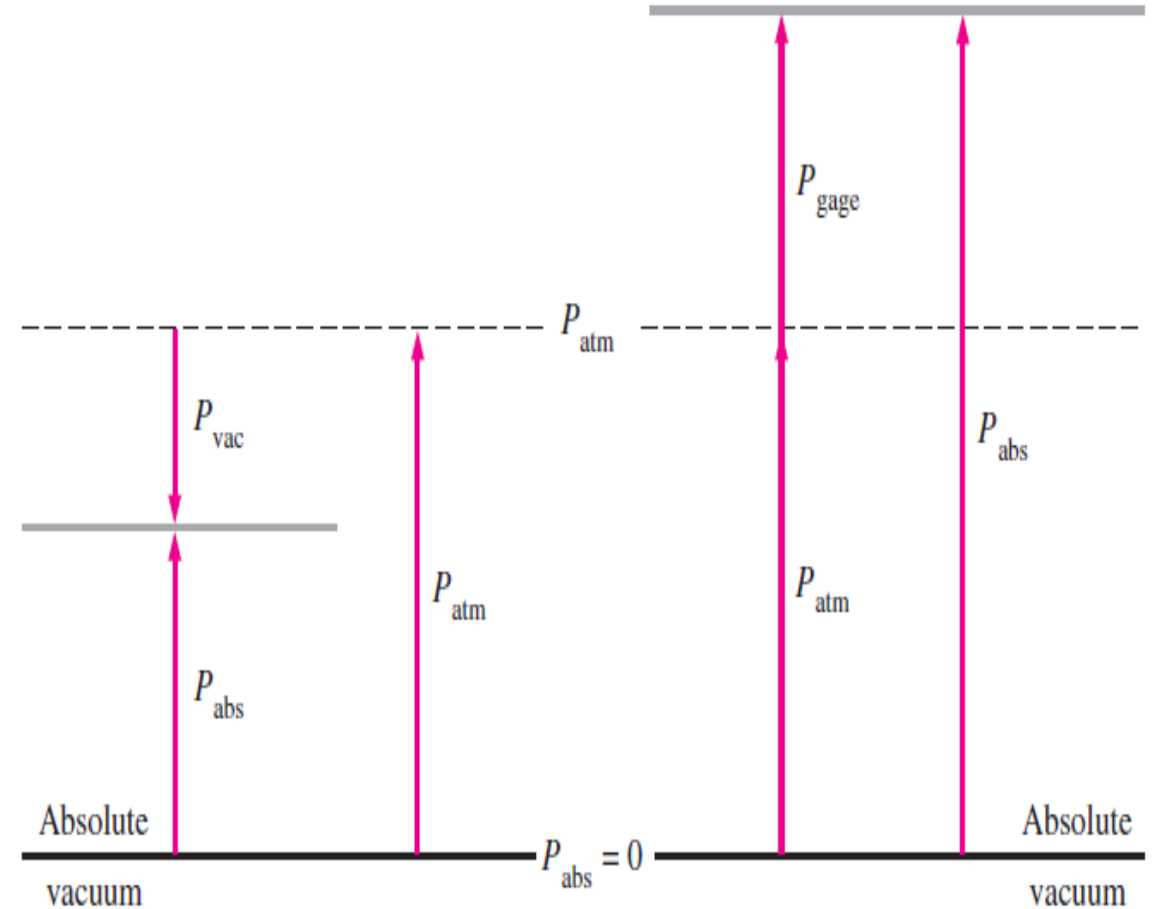
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- Absolute, gage, and vacuum pressures are all positive quantities and are related to each other by:-

$$P_{\text{gage}} = P_{\text{abs}} - P_{\text{atm}}$$

$$P_{\text{vac}} = P_{\text{atm}} - P_{\text{abs}}$$

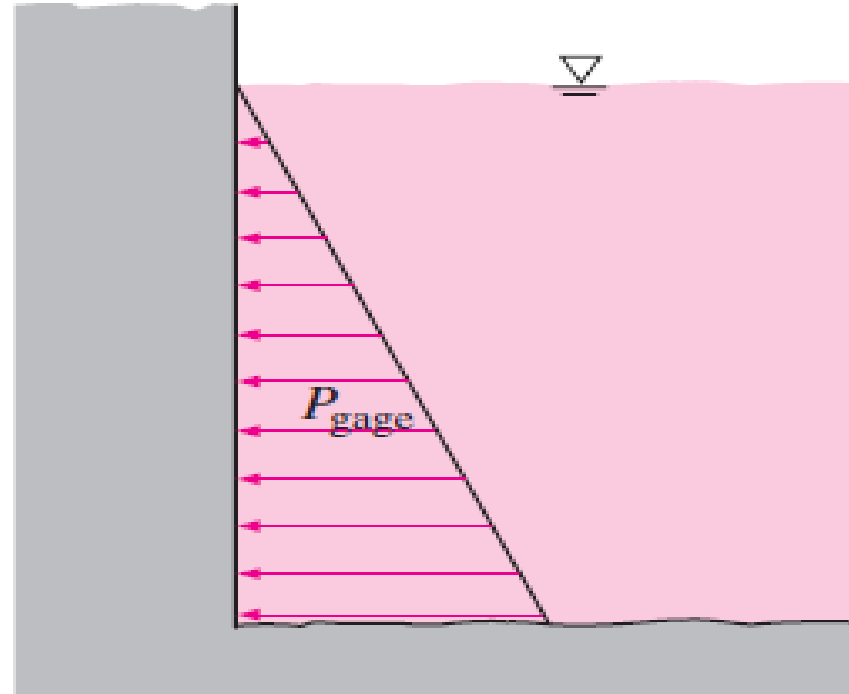
- Like other pressure gages, the gage used to measure the air pressure in an automobile tire reads the gage pressure.



Absolute, gage, and vacuum pressures.

Variation of Pressure with Depth

- Pressure in a fluid increases with depth because more fluid rests on deeper layers, and the effect of this “extra weight” on a deeper layer is balanced by an increase in pressure.



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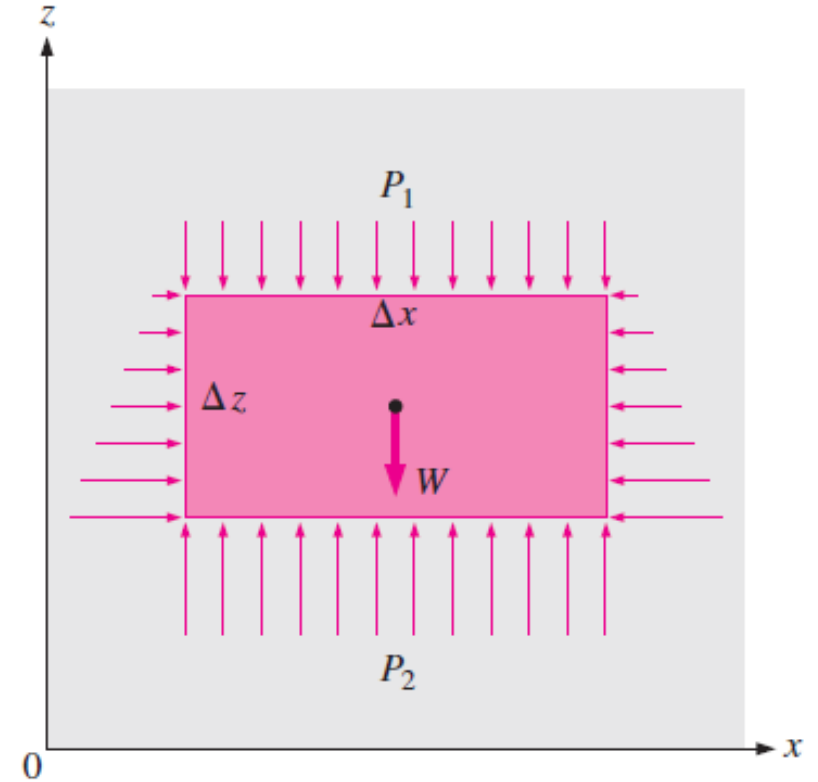
- To obtain a relation for the variation of pressure with depth, consider a rectangular fluid element of height z , length x , and unit depth (into the page) in equilibrium, as shown in the Fig.
- Assuming the density ρ of the fluid to be constant, a force balance in the vertical z -direction gives.

$$\sum F_z = ma_z = 0: \quad P_2 \Delta x - P_1 \Delta x - \rho g \Delta x \Delta z = 0$$

- Where $W = mg = \rho g \Delta x \Delta z$ is the weight of the fluid element. Dividing by Δx and rearranging gives

$$\Delta P = P_2 - P_1 = \rho g \Delta z = \gamma_s \Delta z$$

- Where: $\gamma_s = \rho g$ is the specific weight of the fluid.



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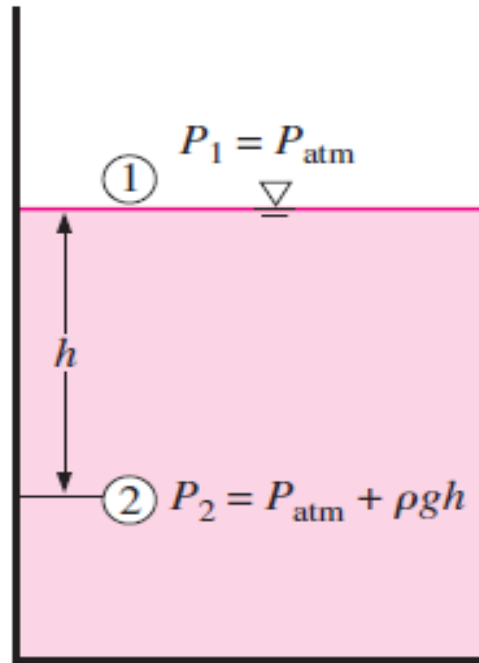
- Thus, we conclude that the pressure difference between two points in a constant density fluid is proportional to the vertical distance z *between the points and the density ρ of the fluid*.
- In other words, pressure in a fluid increases linearly with depth.
- For a given fluid, the vertical distance z *is sometimes used as a measure of pressure, and it is called the pressure head*.
- We also conclude that for small to moderate distances, the variation of pressure with height is negligible for gases because of their low density.
- The pressure in a tank containing a gas, for example, can be considered to be uniform since the weight of the gas is too small to make a significant difference.
- Also, the pressure in a room filled with air can be assumed to be constant.

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- If we take point 1 to be at the free surface of a liquid open to the atmosphere, where the pressure is the atmospheric pressure P_{atm} , then the pressure at a depth h from the free surface becomes

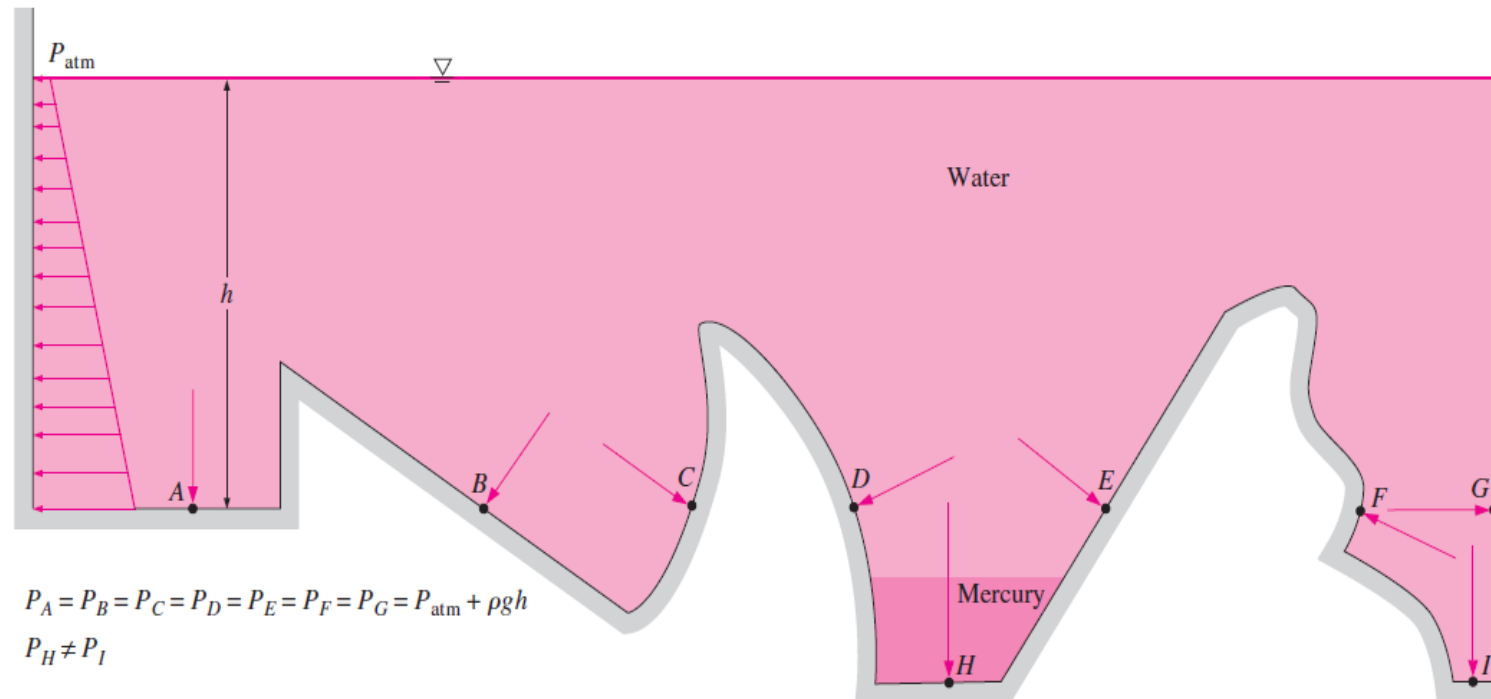
$$P = P_{atm} + \rho gh \quad \text{or} \quad P_{gage} = \rho gh$$

- Liquids are essentially incompressible substances, and thus the variation of density with depth is negligible. This is also the case for gases when the elevation change is not very large.



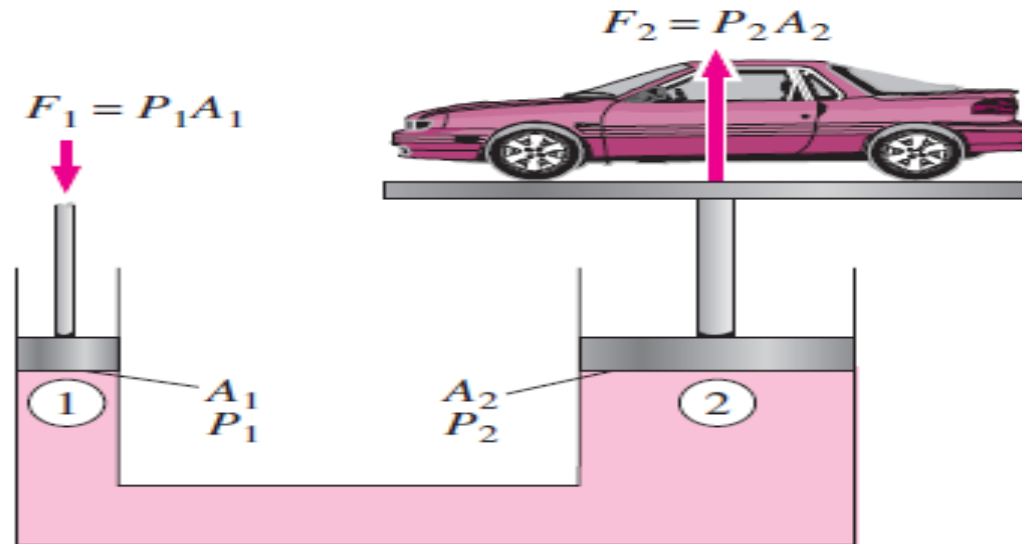
Cont...

- the pressure is the same at all points on a horizontal plane in a given fluid.
- A consequence of the pressure in a fluid remaining constant in the horizontal direction is that the pressure applied to a confined fluid increases the pressure throughout by the same amount. This is called **Pascal's law**.



Cont...

- Pascal also knew that the force applied by a fluid is proportional to the surface area.
- He realized that two hydraulic cylinders of different areas could be connected, and the larger could be used to exert a proportionally greater force than that applied to the smaller.
- This is what enables us to lift a car easily by one arm, as shown in the Fig.



Cont...

- Noting that $P_1 = P_2$ since both pistons are at the same level (the effect of small height differences is negligible, especially at high pressures), the ratio of output force to input force is determined to be:-

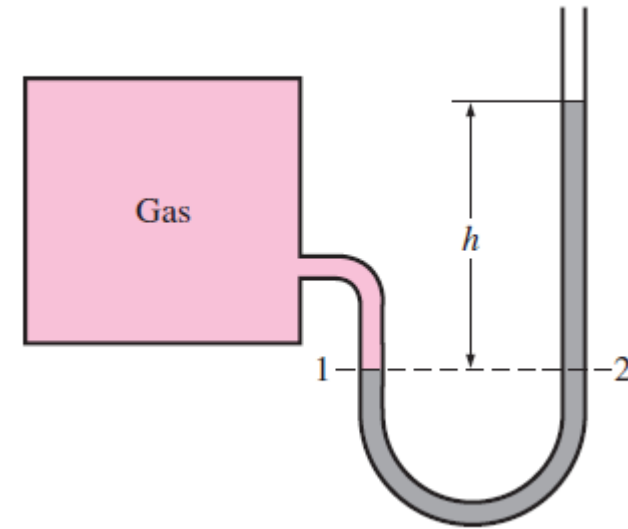
$$P_1 = P_2 \rightarrow \frac{F_1}{A_1} = \frac{F_2}{A_2} \rightarrow \frac{F_2}{F_1} = \frac{A_2}{A_1}$$

- The area ratio A_2/A_1 is called the *ideal mechanical advantage* of the hydraulic lift.

THE MANOMETER

- **manometer** is a device which is commonly used to measure small and moderate pressure differences.
- Consider the manometer shown in the Fig that is used to measure the pressure in the tank.
- Since the gravitational effects of gases are negligible, the pressure anywhere in the tank and at position 1 has the same value.

The basic manometer.



Cont..

- Furthermore, since pressure in a fluid does not vary in the horizontal direction within a fluid, the pressure at point 2 is the same as the pressure at point 1, $P_2 = P_1$.
- The differential fluid column of height h is *in static equilibrium*, and it is open to the atmosphere. Then the pressure at point 2 is determined directly from the eqn.:

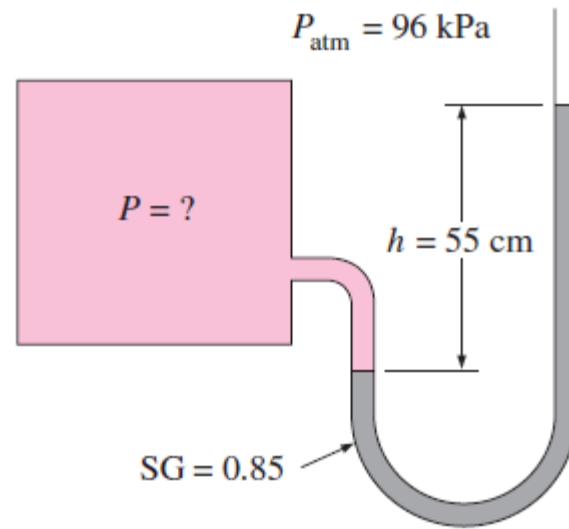
$$P_2 = P_{\text{atm}} + \rho gh$$

- Where ρ is the density of the fluid in the tube.

Example:

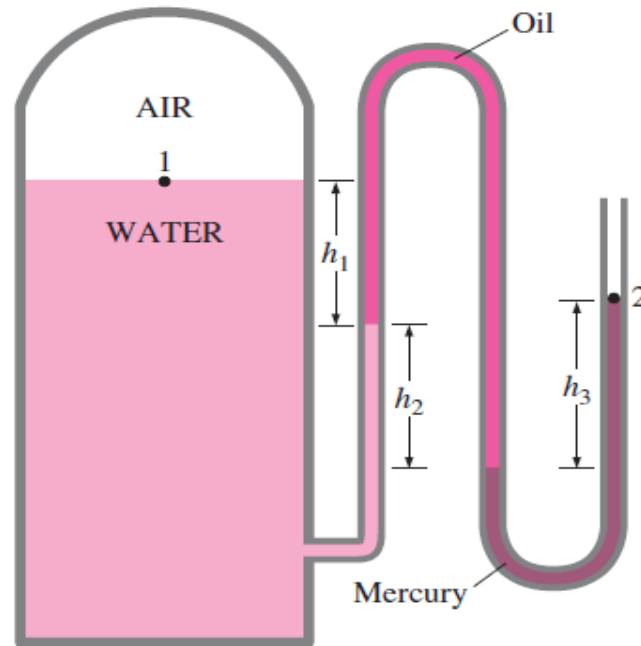
- Measuring Pressure with a Manometer

A manometer is used to measure the pressure in a tank. The fluid used has a specific gravity of 0.85, and the manometer column height is 55 cm, as shown in Fig. 1–46. If the local atmospheric pressure is 96 kPa, determine the absolute pressure within the tank.



Example:-

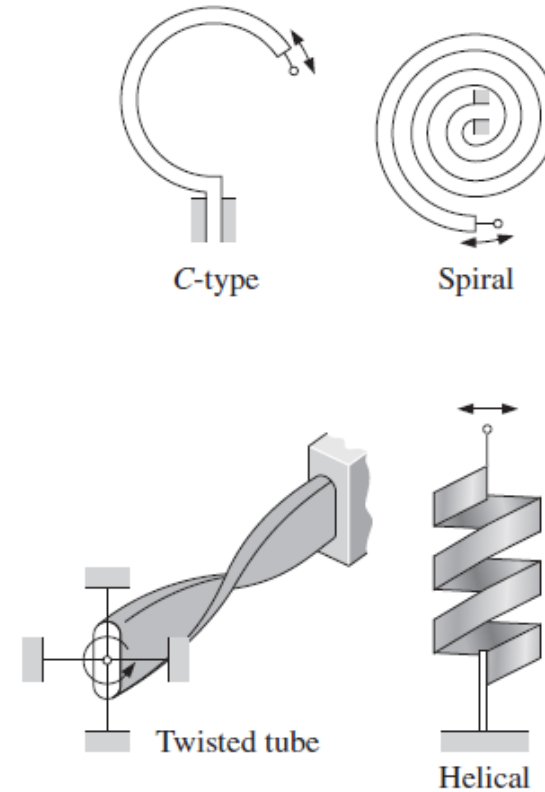
The water in a tank is pressurized by air, and the pressure is measured by a multifluid manometer as shown in Fig. 1–49. The tank is located on a mountain at an altitude of 1400 m where the atmospheric pressure is 85.6 kPa. Determine the air pressure in the tank if $h_1 = 0.1$ m, $h_2 = 0.2$ m, and $h_3 = 0.35$ m. Take the densities of water, oil, and mercury to be 1000 kg/m^3 , 850 kg/m^3 , and $13,600 \text{ kg/m}^3$, respectively.



Other Pressure Measurement Devices

- Another type of commonly used mechanical pressure measurement device is the **Bourdon tube**, which consists of a hollow metal tube bent like a hook whose end is closed and connected to a dial indicator needle.
- When the tube is open to the atmosphere, the tube is undeflected, and the needle on the dial at this state is calibrated to read zero (gage pressure). When the fluid inside the tube is pressurized, the tube stretches and moves the needle in proportion to the pressure applied.

Various types of Bourdon tubes used to measure pressure.



Cont...

- Modern pressure sensors, called **pressure transducers**, use various techniques to convert the pressure effect to an electrical effect such as a change in voltage, resistance, or capacitance.
- Pressure transducers are smaller and faster, and they can be more sensitive, reliable, and precise than their mechanical counterparts.
- They can measure pressures from less than a millionth of 1 atm to several thousands of atm.
- A wide variety of pressure transducers is available to measure gage, absolute, and differential pressures in a wide range of applications. For example:-
 1. Gage pressure transducers
 2. Strain-gage pressure transducers
 3. Piezoelectric transducers
- Atmospheric pressure is measured by a device called a **barometer**; thus, the atmospheric pressure is often referred to as the barometric pressure.