ESO201A : THERMODYNAMICS
2021-22 Ist semester
IIT Kanpur

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Lecture 1

Introduction

Thermodynamics deals with two forms of energy transfer : Work and Heat

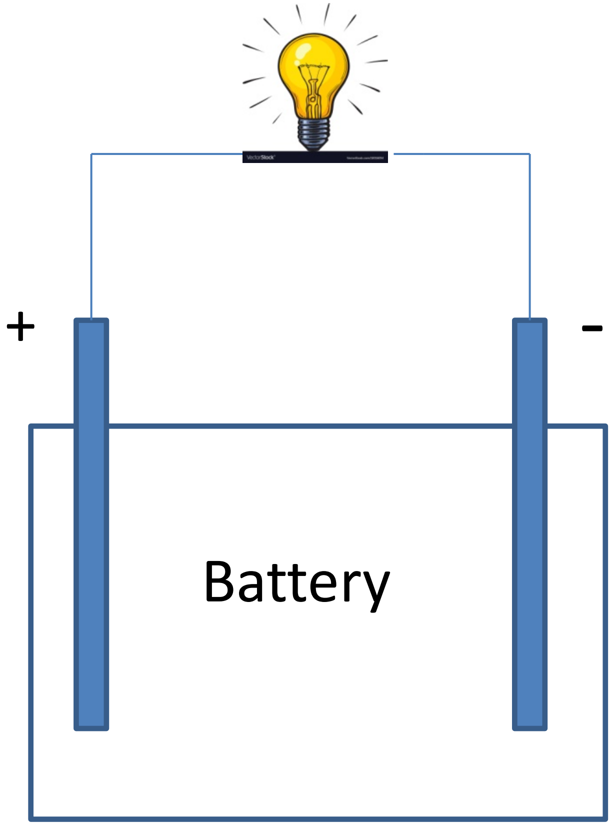
By work, we mean USEFUL work

First Law :

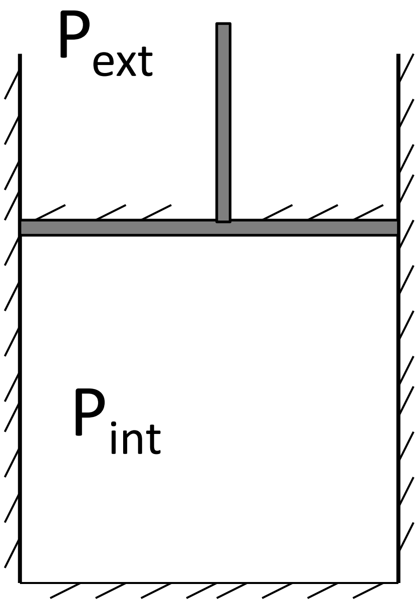
- deals with relation between heat and work

- It enables us to calculate amount of heat transferred in a process

Useful work
=light energy



Useful work
$=P_{ext}\, dV$



Introduction

First and Second Laws combined:

- It provides an estimate of how much MAXIMUM work we can extract from a given process or a machine

- It enables us to calculate efficiency of the devices such as Pumps, turbines, and even power plants

Introduction

First and Second Laws combined:

- It provides useful relations between various quantities such as pressure (P), temperature (T), volume (V), and compositions of a given phase.

- It also provides relations between phases in equilibrium

Basic quantities in Thermodynamics

Pressure:

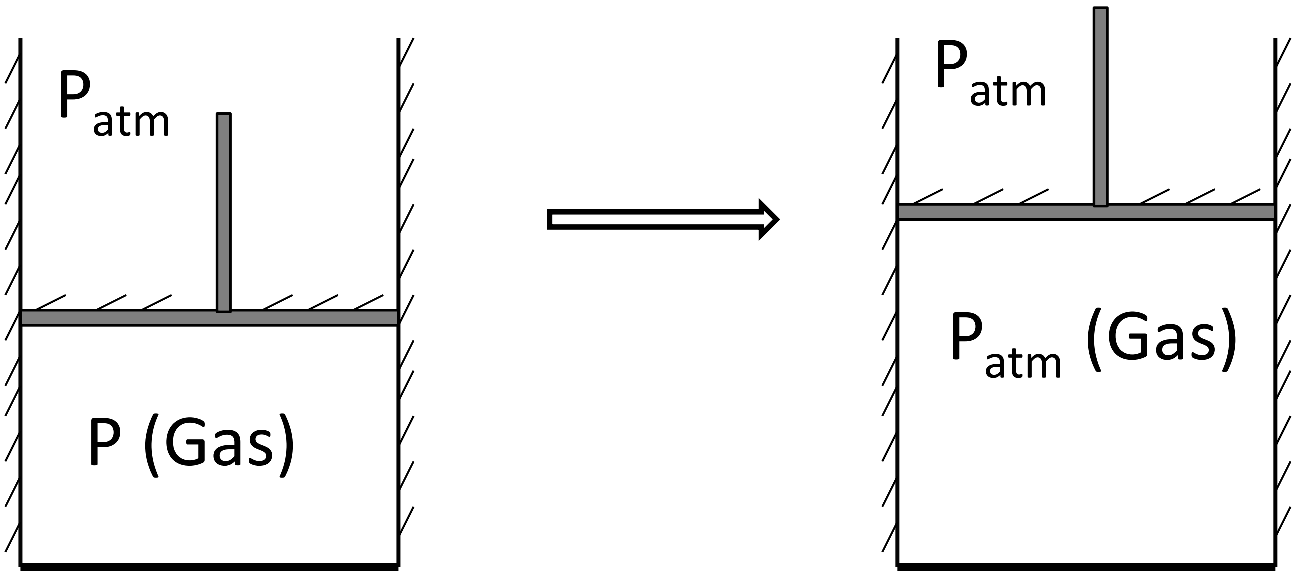
- It is a <u>statistical</u> property . i.e., a collective property of a large number of particles (atoms, molecules etc.).

Force experienced by hand divided by area = Pressure

SI unit of pressure is N/m^2 or Pa

Atmospheric pressure = 101.325 kPa = 101325 Pa

Mechanical equilibrium



$P > P_{atm}$

Mechanical Equilibrium

Basic quantities in Thermodynamics

Temperature:

- It is a statistical property . i.e., a collective property of a large number of particles (atoms, molecules etc.).

-Zeroth law of Thermodynamics enables us to develop the scientific concept of temperature as well as measurement of temperature

Temperature

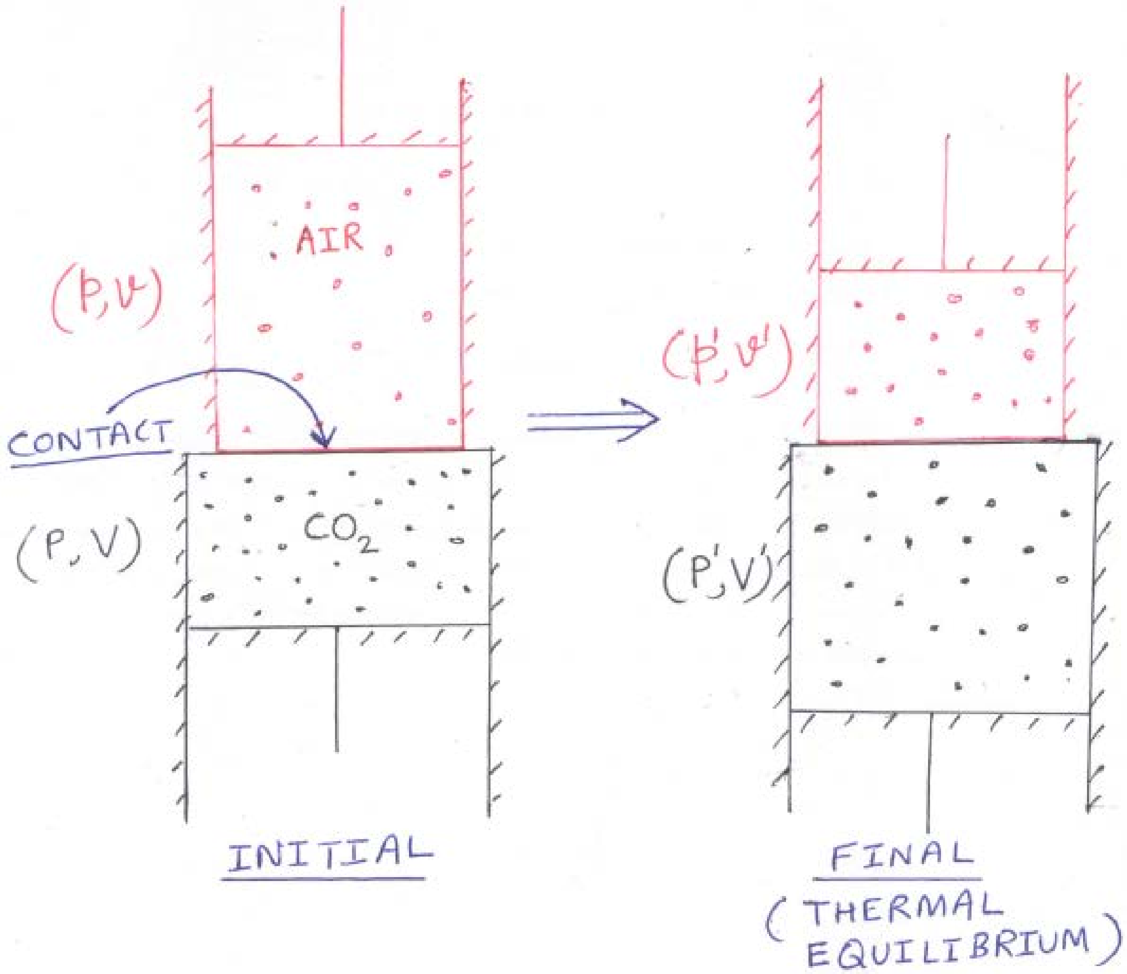
We can ‘feel’ the temperature, i.e., the degree of hotness or coldness of a given object

Can we define and measure the temperature ?

Answer is Yes !

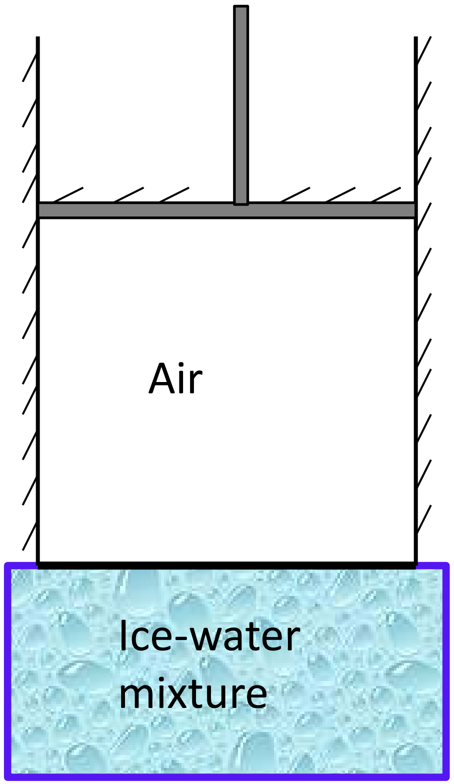
For that, we first need to understand the concept of thermal equilibrium

Thermal equilibrium



We expect that systems in thermal equilibrium have some property in common

Temperature and Zeroth law :

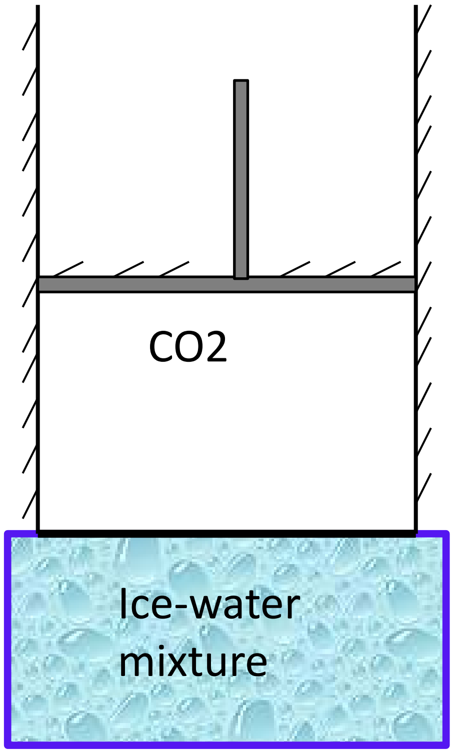


If Air is in thermal equilibrium with ice-water mixture, then air has a temperature of 0 ^{0}C

There is nothing special about Celcius scale !

0 ^{0}C is an arbitrarily assigned value.

Temperature and Zeroth law :

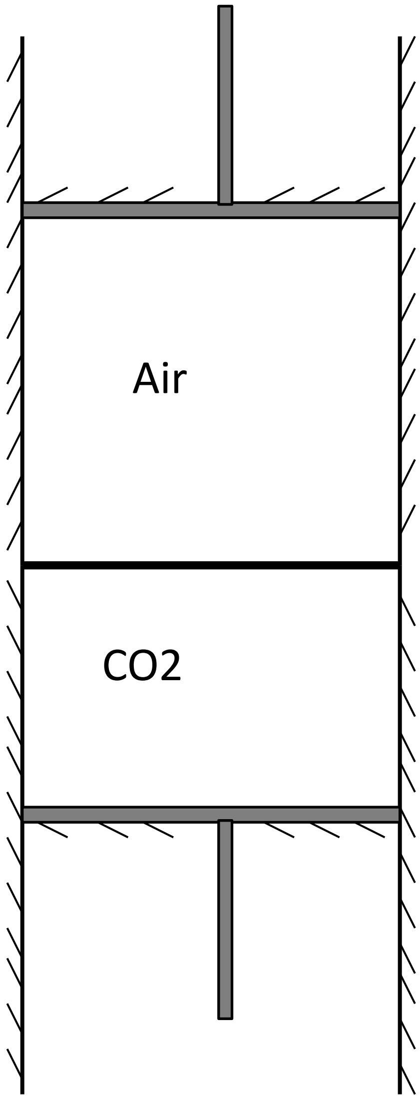


If CO_2 is in thermal equilibrium with ice-water mixture, then air has a temperature of 0 ^{0}C

Question 1: If Air and CO_2 are brought in thermal contact, will these be in equilibrium ?

Answer : Due to interactions between Air and CO_2 molecules (across the wall), it is not obvious to me !!

Temperature and Zeroth law :

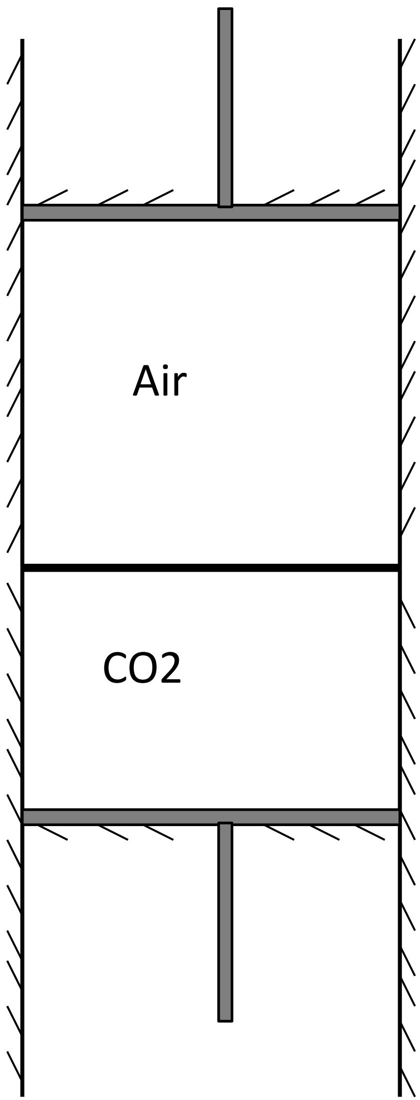


Question 2 : If we consider (hypothetically) that Air and CO2 will not be in thermal equilibrium, can be assign the same temperature to both ?

Answer : a firm **No !!**

Zeroth law guarantees (Answer to Question 1) that Air and CO2 will be in thermal equilibrium , if these are separately in equilibrium with ice-water mixture.

Zeroth law of Thermodynamics



"If two bodies are in thermal equilibrium with a third body, these are also in thermal equilibrium with each other"

As with other laws, this law is based on practical experience.

<u>Significance :</u>

Any body which is in thermal equilibrium with (say) ice-water mixture can be assigned the <u>same</u> value of Temperature (0 ^{0}C on the Celcius scale).

Temperature scales

These are based on easily reproducible states.

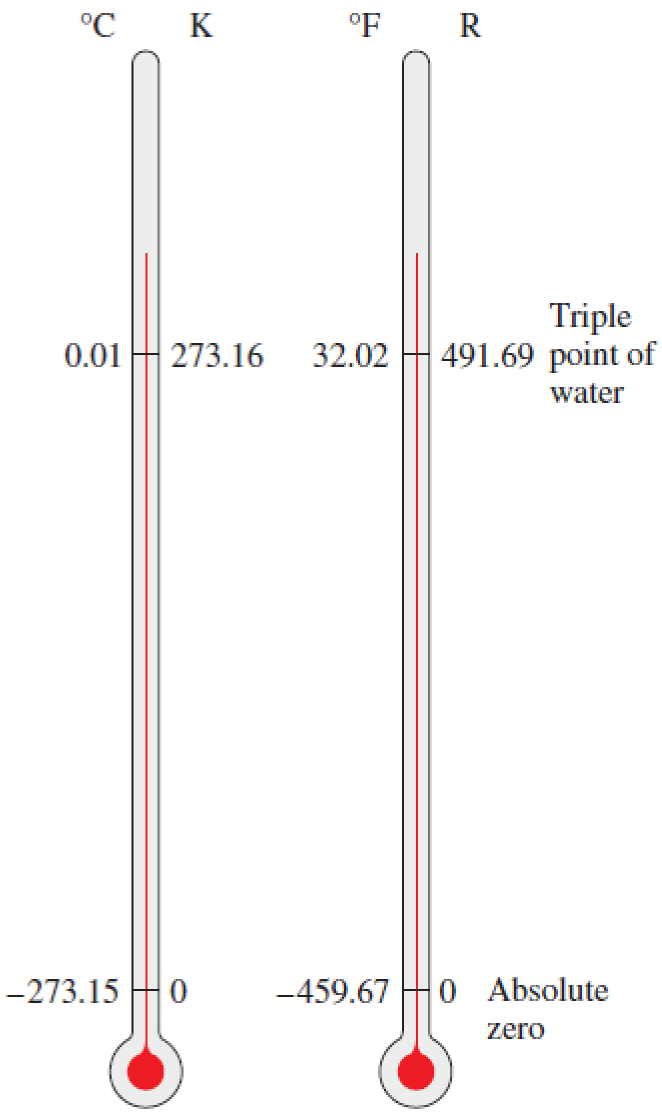
1. Ice point : A state in which ice and water are in equilibrium with air which is saturated with water vapor at a total pressure of 1 atmosphere

   On Celcius scale, ice point corresponds to 0 ^{0}C
   On Fahrenheit scale, ice point corresponds to 32 ^{0}F

2. Steam point : A state in which water is in equilibrium with steam (with no air) at a total pressure of 1 atmosphere.

   On Celcius scale, ice point corresponds to 100 ^{0}C
   On Fahrenheit scale, ice point corresponds to 212 ^{0}F

Temperature scales



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

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

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

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

Kelvin scale and Rankine scale are known as <u>Thermodynamic temperature scales</u> in SI and English Units, respectively.