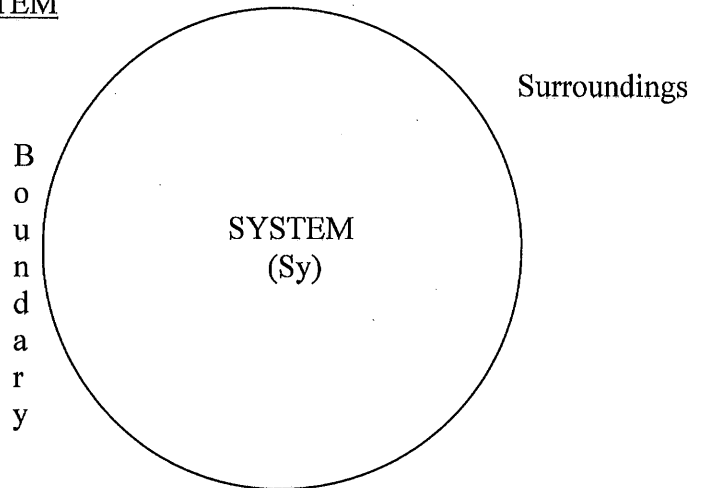


Thermodynamics- Dynamics + One Thermal Parameter

THERMODYNAMIC SYSTEM

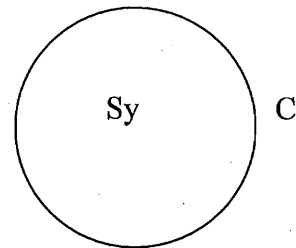
Consists of some amount of solid, liquid, gas separated from the surroundings by a "Boundary" Wall.



TWO KINDS OF BOUNDARIES ARE OF INTEREST

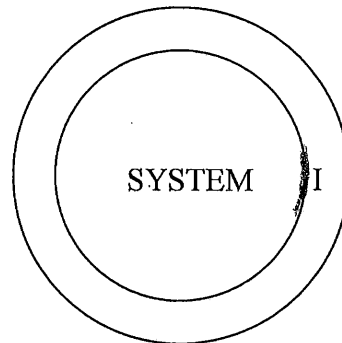
Conducting Boundary (C)

In this case the system is very sensitive to its surroundings.



Insulating Boundary (I)

The system is totally isolated from its surroundings.



PROPERTIES OF A THERMODYNAMIC SYSTEM

To start with, Sy has an extent so the very first property is the amount of space it occupies:

Volume V

This, of course, includes the special cases of length ℓ and area A .

Any attempt to change V makes us immediately aware that the material inside (even a gas) exerts a force on the wall. This leads us to the definition of the second property- PESSURE

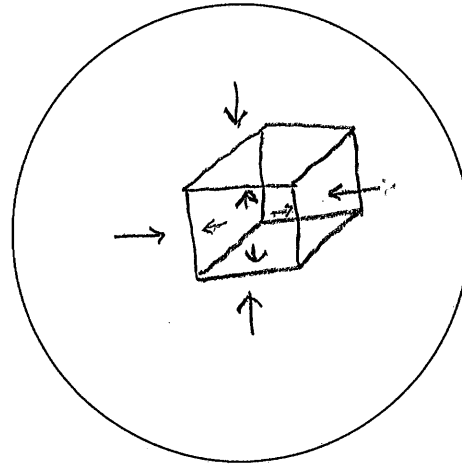
P = Force per unit area on wall

$$= \frac{F}{A}$$

[Pressure $ML^{-1}T^{-2}$ N/m^2 Scalar (for us)]

Next, if system has no external force acting on it, there must be equilibrium everywhere.

If we imagine “looking” at a small cube inside, it is realized that for $\equiv m$ to prevail the pressure must be isotropic (same in all directions) and uniform (same at all points). So for an isolated system V and P are single valued.



If we bring our system close to the Earth the picture changes because every mass point m inside experiences a force $-mg\hat{y}$ so if pressure were the same at all values of y (height above surface of Earth) the system would not be in $\equiv m$.

VARIATION OF PRESSURE IN A FLUID (GAS/LIQUID) NEAR EARTH

Pressure is force per unit area. If we have fluid in a container far away from Earth then in equilibrium the pressure has to be isotropic and uniform otherwise there will be unbalanced forces and the fluid particles will not be stationary. If you bring the fluid near Earth, the situation changes because the earth pulls every mass toward its center with the force

$$\underline{W}_g = -Mg\hat{y}$$

So the fluid pressure must adjust itself if a layer of fluid located between y and $(y + \Delta y)$ is to be in equilibrium.

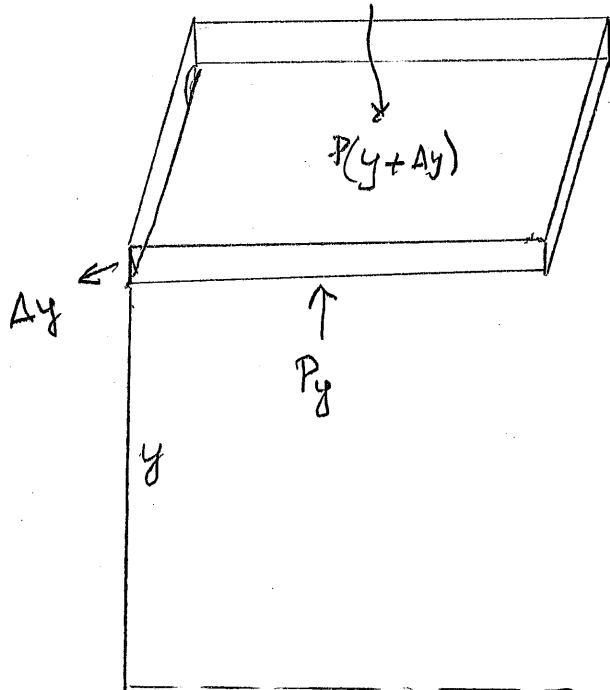
Consider the layer of Area A

Let the pressures be

$$P(y) \text{ at } y$$

and

$$P(y + \Delta y) \text{ at } (y + \Delta y)$$



If density of fluid is ρ

$$\text{Mass of fluid in layer} = \rho A \Delta y.$$

There are three forces on the layer

$$\underline{F}_1 = P(y)A \hat{y}$$

$$\underline{F}_2 = -P(y + \Delta y)A \hat{y}$$

$$\underline{W}_g = -P A \Delta y g \hat{y}$$

For $\equiv m$ $\quad \underline{F}_1 + \underline{F}_2 + \underline{W}_g = 0$

$$P(y)A - P(y + \Delta y)A - \rho A \Delta y g = 0$$

$$P(y + \Delta y) - P(y) = -\rho g \Delta y \quad \text{-- (1)}$$

That is, pressure must reduce as y increases so that the weight of the layer is supported. Liquids are incompressible, $\rho = \text{constant}$ hence pressure difference between top and bottom of a column of liquid of height h becomes

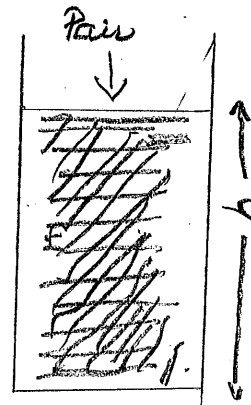
$$P_{\text{top}} - P_{\text{bottom}} = -\rho g h$$

or

$$P_{\text{bottom}} = P_{\text{top}} + \rho g h$$

Further, because of all the air above the liquid column $P_{\text{top}} = P_{\text{air}}$ and hence

$$P_{\text{bottom}} = P_{\text{top}} + \rho g h \quad \text{(Liquid)}$$

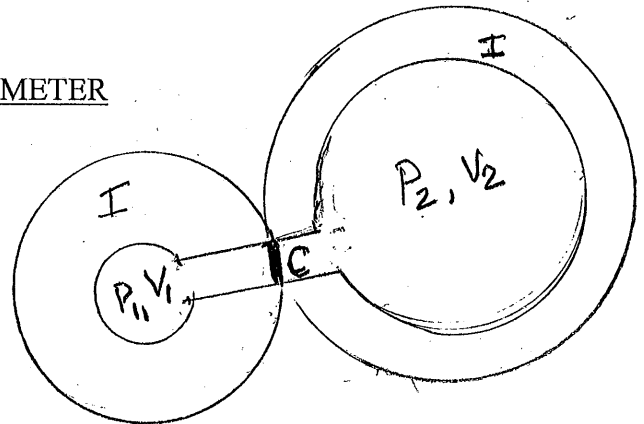


Note \rightarrow In a gas the situation is more complicated because the density is a function of pressure.

Note \rightarrow The important point about Eq (1) is that if Δy is small one can still pretend that a single value of P is adequate to describe the system.

THERMAL PARAMETER

To proceed further we need two systems with a conducting wall between them. That is, they can "talk" to one another but are isolated from all other surroundings.



Before we bring them together, let their parameters be P_1, V_1 and P_2, V_2 , respectively. Two things can happen:

- I. There is no change in either system even though

$$P_1 \neq P_2$$

$$V_1 \neq V_2$$

II. Both systems change but if we are patient, all changes stop

$$P_1, V_1 \rightarrow P_1', V_1'$$

$$P_2, V_2 \rightarrow P_2', V_2'$$

but again

$$P_2' \neq P_1'$$

$$V_2' \neq V_1'$$

CONCLUSIONS TO BE DRAWN

A. If there is no change it is reasonable to claim that the systems are in equilibrium. This is a new kind of $\equiv m$ called:

THERMAL $\equiv m$

In case I above systems were in $\equiv m$ when we began. In case II they got to $\equiv m$ after a while.

The crucial observation is that equilibrium prevails WHEN NEITHER THE PRESSURES NOR THE VOLUMES ARE EQUAL. INDEED, THE EXPERIMENT TEACHES US THAT P and V ARE IRRELEVANT FOR THERMAL $\equiv m$.

B. Even more important we are leaning that there must exist another property besides P and V whose value must be the same for both the systems to ensure $\equiv m$.

THIS NEW PROPERTY IS CALLED:

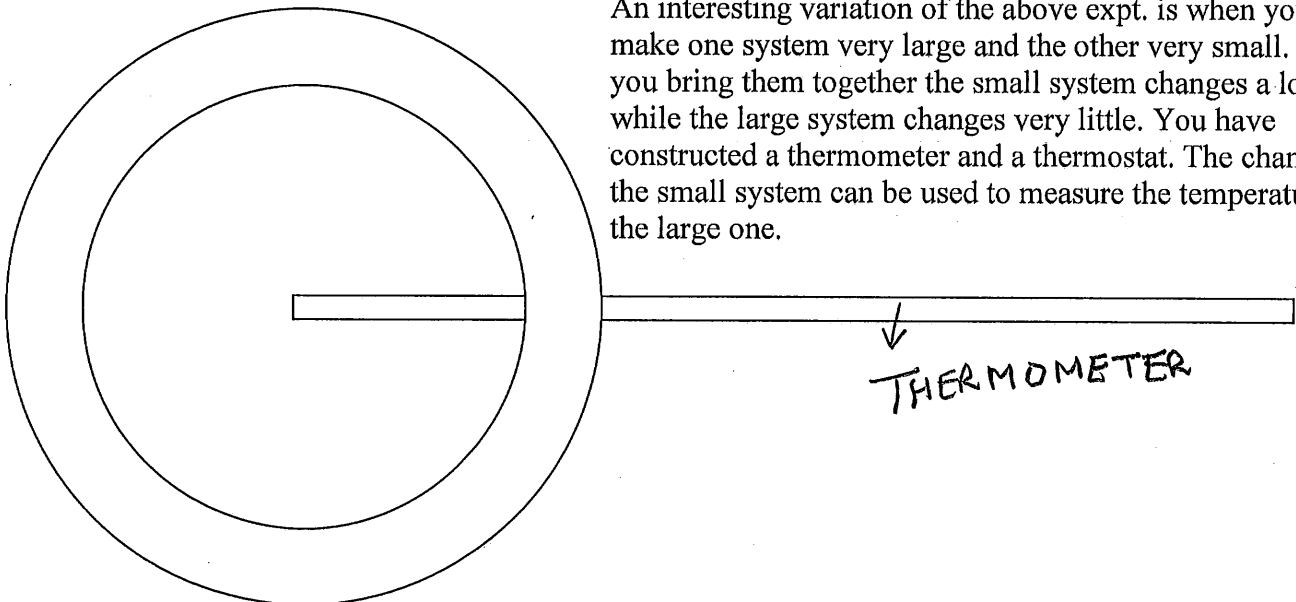
TEMPERATURE

TWO THERMODYNAMIC SYSTEMS CAN BE IN EQUILIBRIUM IF AND ONLY IF THEIR TEMPERATURES ARE EQUAL.

COROLLARY: A SINGLE SYSTEM CAN BE IN $\equiv m$ ONLY IF THE TEMPERATURE IS THE SAME AT ALL POINTS IN THE SYSTEM.

[TEMPERATURE IS A DIMENSION IN ITS OWN RIGHT Temp θ^1 Degree SCALAR.]

THERMOMETER – THERMOSTAT



An interesting variation of the above expt. is when you make one system very large and the other very small. When you bring them together the small system changes a lot while the large system changes very little. You have constructed a thermometer and a thermostat. The change in the small system can be used to measure the temperature of the large one.