Overview

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

Examples :

(i) Heating of a water in a pan

work : work done on atmosphere due to expansion

Heat : heat transfer from flame to pan + heat lost to surroundings

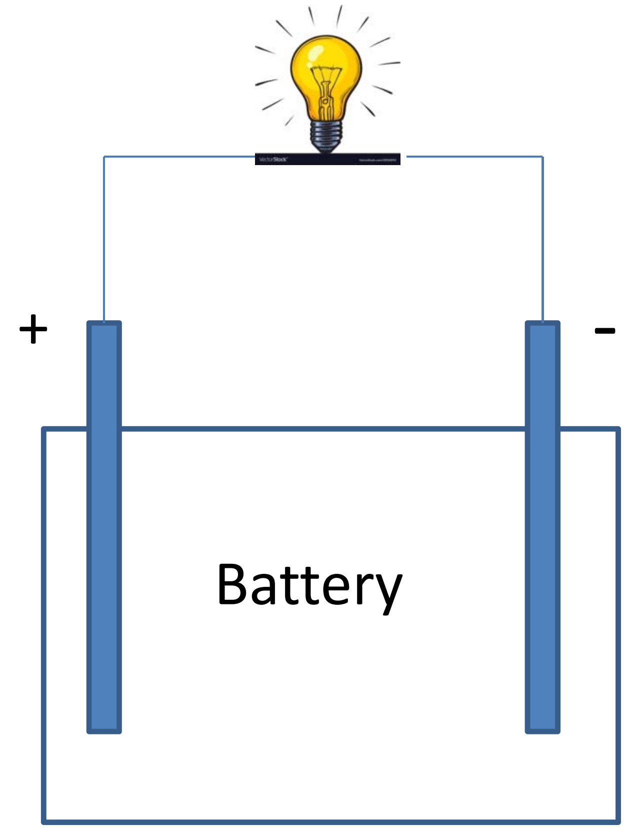
(ii) Ceiling fan

work : electrical work

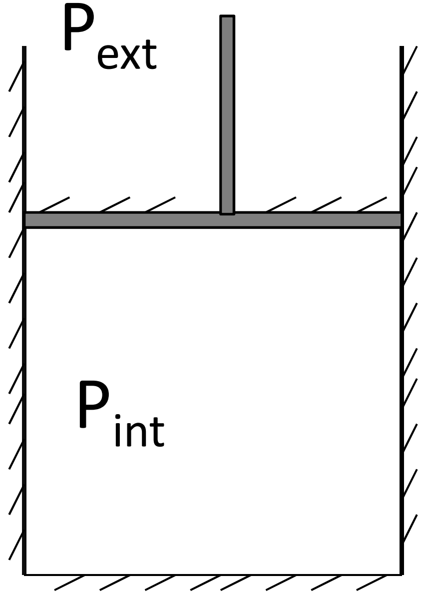
heat : heat lost to surrounding due to friction

Work done in a process can be <u>estimated</u>

Non-mechanical work



Mechanical work



$$W = -V.I.dt$$

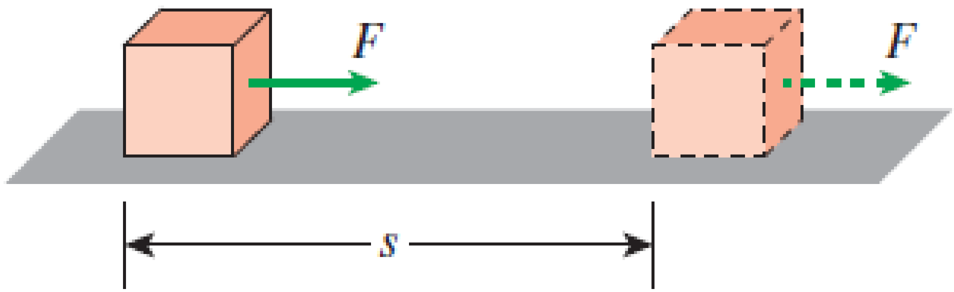
$$W = -P_{ext}\, dV$$

Negative sign is because work is done by the system

Mechanical work = (Force)(Displacement)

If the force F is constant (as in the picture below) and displacment is in the direction of the force, then work done on the block by the force is

$$W = Fs$$



In general, if force varies with displacement, work done on the block is

$$W = \int_{1}^{2} \vec{F}.d\vec{s}$$

Mechanical work :

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$$W = \int_1^2 \vec{F}.d\vec{s}$$

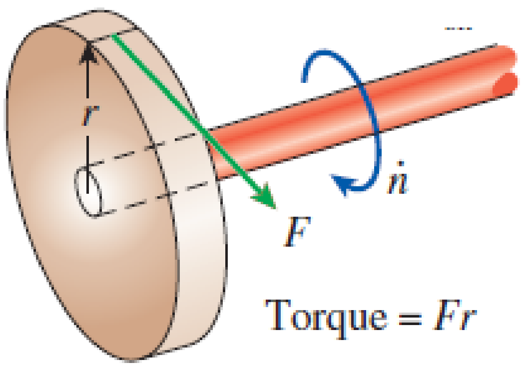
$$W = \frac{1}{2} M (V_2^2 - V_1^2)$$

Work done to increase potential energy :

When a block is raised through height h, work done on the combined system (block + earth) is

$$W = M g h$$

Mechanical work :

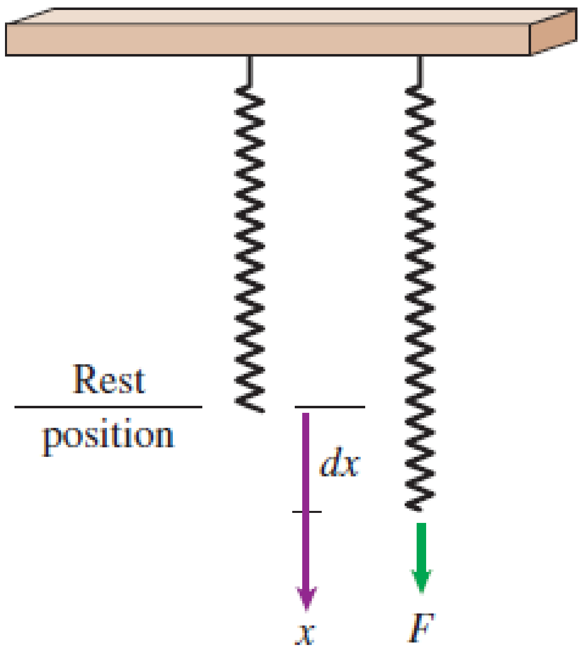


Shaft work

$$W(\text{for a single rotation}) = F(2\pi r)$$

$$\dot{W} = F(2\pi r)\dot{n}$$

$$\dot{W} = 2\pi T\dot{n}$$



Spring work

$$W = \int_1^2 \vec{F}.d\vec{x}$$

For a linear spring, F = k x

$$W = \frac{1}{2}k(x_2^2 - x_1^2)$$

Overview

First Law :

- deals with relation between heat and work

- it introduces a quantity called “Internal Energy”

- it enables us to estimate amount of heat transferred in a process

Overview

Why Second Law is important ?

- It is observed that processes happen in a specific direction.

- Efficiency associated with a process

Efficiency = (Desired output)/(required input)

Overview

First and Second Laws combined:

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

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

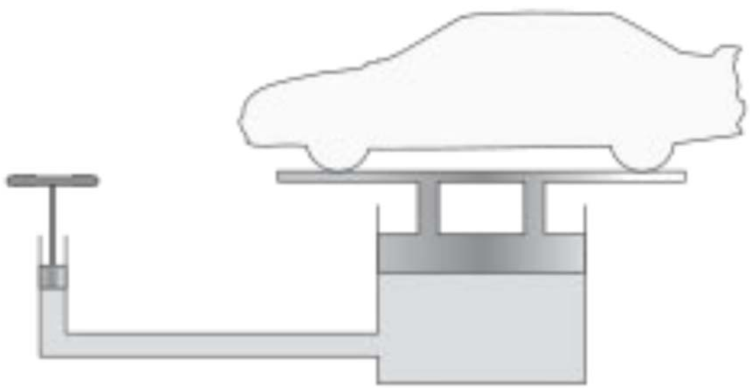
Average Force experienced by hand divided by area = Pressure

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

Atmospheric pressure = 101.325 kPa = 101325 Pa

Pascal’s law

A change in pressure at any point in an enclosed incompressible fluid at rest is transmitted equally and undiminished to all points in all directions throughout the fluid, and the force due to the pressure acts at right angles to the enclosing walls.

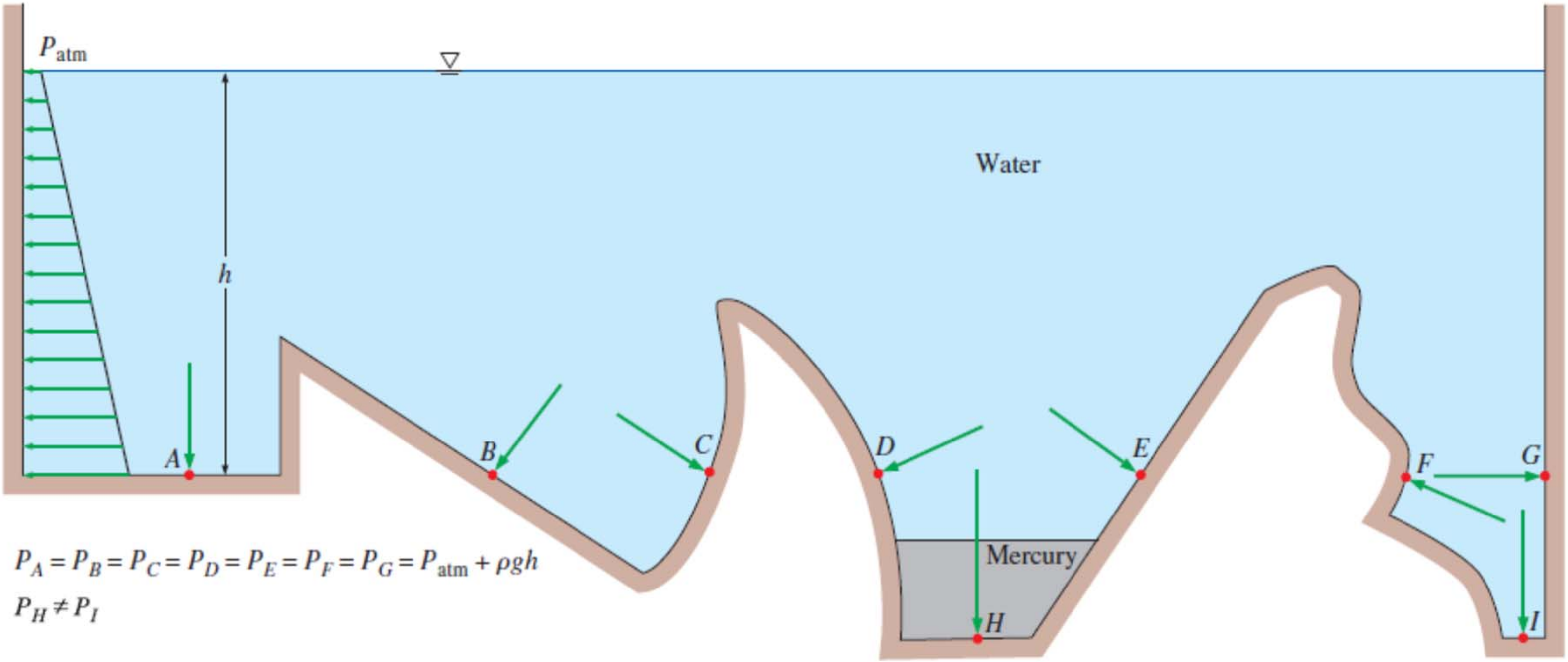


$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

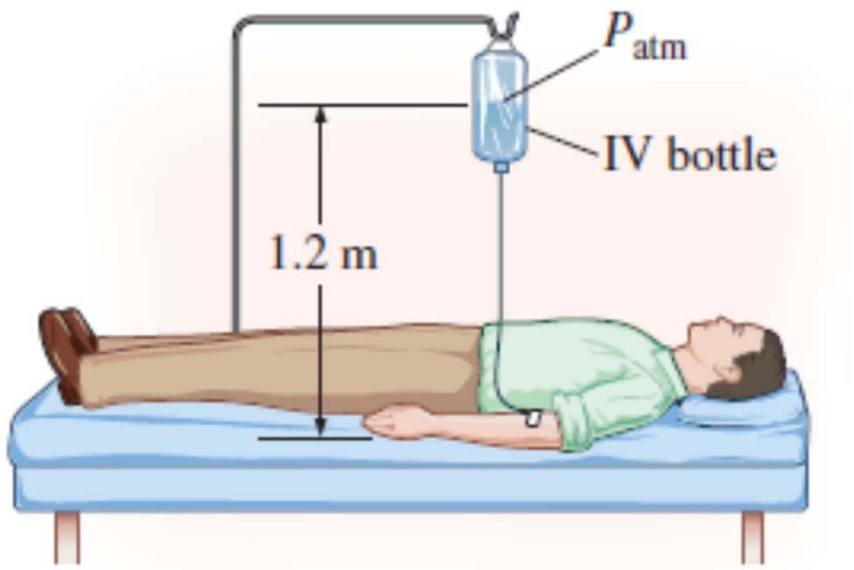
Hydraulic lift

(source : Wikipedia)

Pascal’s law


P_{atm}
Water
h
A
B
C
D
E
F
G
Mercury
H
I
$P_A = P_B = P_C = P_D = P_E = P_F = P_G = P_{atm} + \rho g h$
$P_H \neq P_I$

Gage pressure of blood :

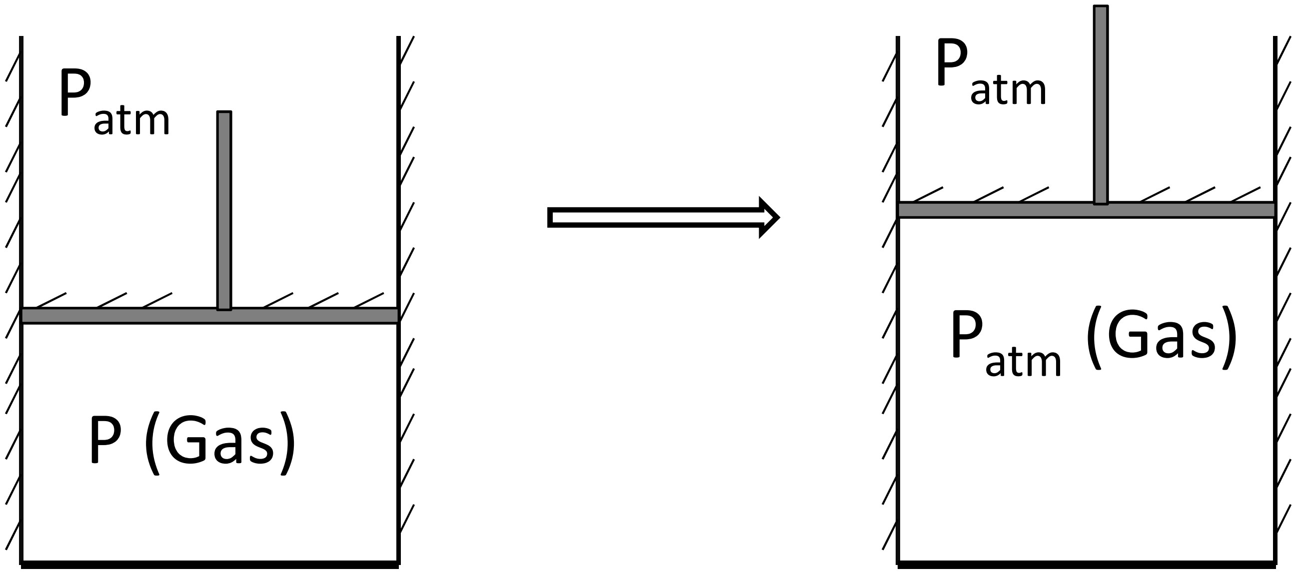


$$P_{abs} = Pat_m + Pg$$

$$P_{abs} = Pat_m + \rho g\ (1.2\ m)$$

$$P_g = 12\ \text{kPa}$$

Mechanical equilibrium



$P > P_{atm}$

Mechanical Equilibrium

Time required to achieve mechanical equilibrium is usually extremely small