Basic Concepts

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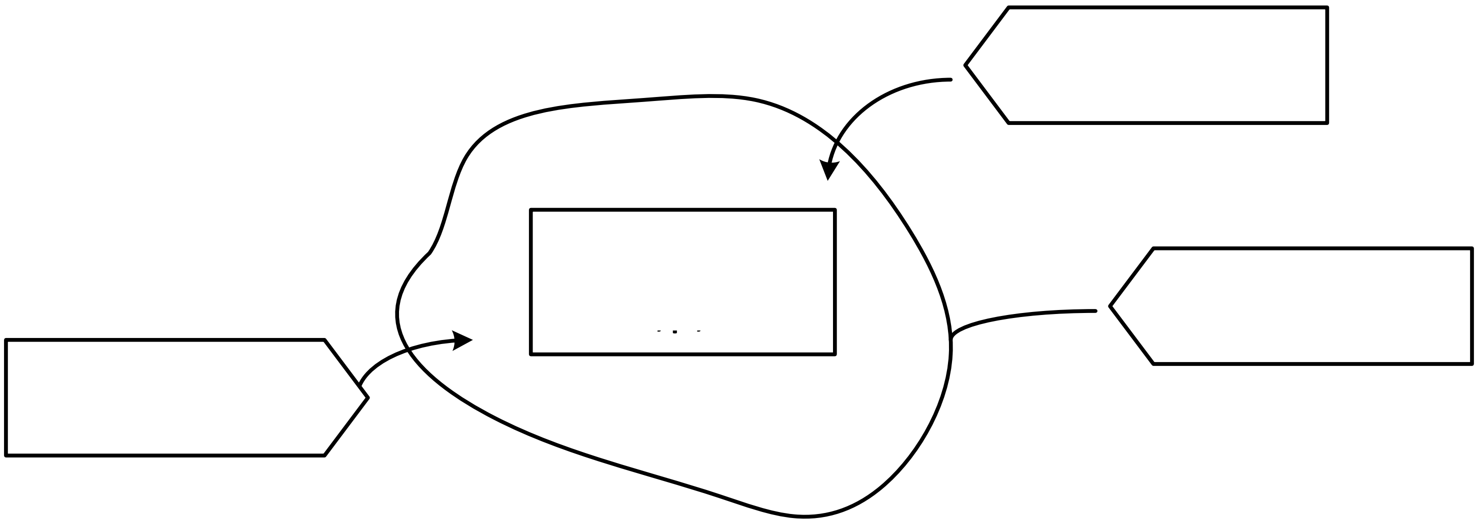
System, boundary and surroundings

A **system** is the collection of matter identified as the subject of the analysis.

The **boundary** of the system may be real or imaginary, rigid or flexible, adiabatic or diathermal. All matter outside the boundary is termed the **surroundings**.

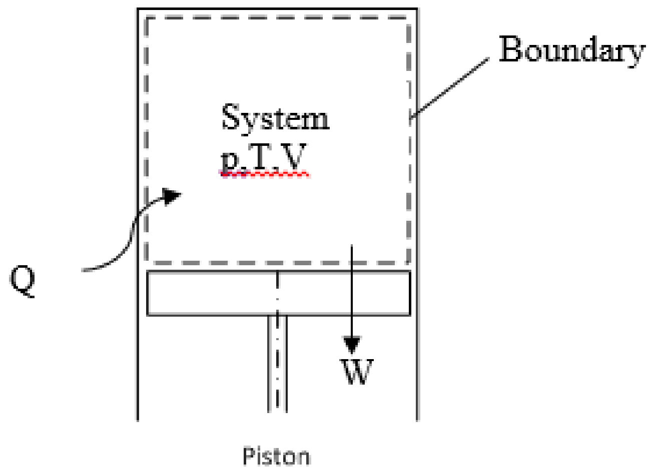


Basic concepts

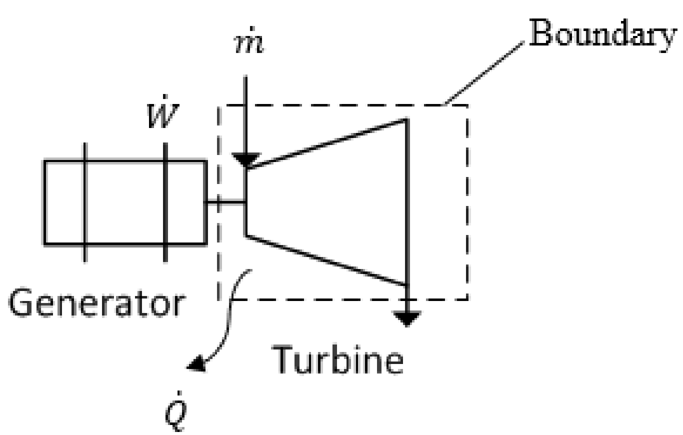
Control mass system and control volume system

A **control mass** (**closed**) system contains the same amount of matter all the time (boundary may change)

m is constant



A **control volume** (**open**) system contains the matter and devices inside a control (fixed) surface (the matter may change)



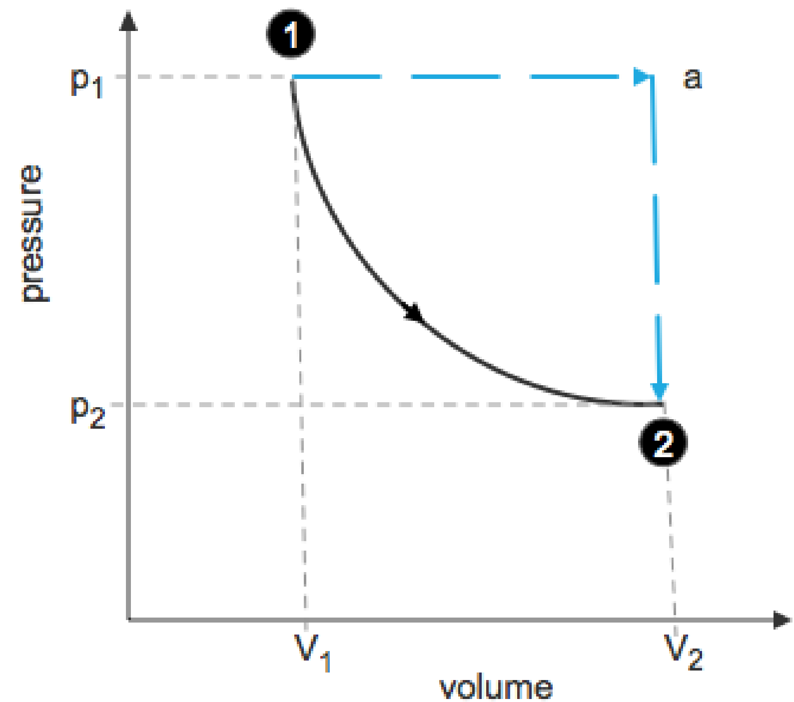
Further concepts

State - The condition of the working substance in the system is known as the state. In order to use the concept of state in an analysis it is necessary to define the state in terms of measurable **properties**, for example pressure, volume and temperature. Change in state is **independent** of the process path.

Equation of state: e.g. pV=mRT

Equation of process: e.g. pV=constant

Property - Property is defined as an identifiable characteristic of the substance within the system. When a mass of gas in a cylinder expands from state ❶ to state ❷, the volume changes from V_1 to V_2, the pressure from p_1 to p_2, etc. A change in properties is **independent** of the **process** path. For example, in Fig 2.3 the change $\Delta p = p_2 - p_1$ is identical whether the process follows path ❶-❷ directly or ❶-a-❷.



Extensive Properties A property that depends upon the (extent) magnitude of the system is an extensive property.

- For example volume (V in m^3), internal energy (U in kJ) or Entropy (S in kJ/K).

Capital for extensive properties

Intensive Properties A property that is independent of the magnitude of the system is called an intensive property.

- For example pressure (p in Pa) or temperature (T in K)

Specific Properties A specific property is the average value of an extensive property per unit mass when the system is in **thermodynamic equilibrium**. Specific properties are intensive.

Lower case for specific properties

Specific volume $v = \frac{V}{m}$ (in m^3/kg)

Specific entropy $s = \frac{S}{m}$ (in kJ/kg K)

Two property postulate

Two Property Rule (State postulate) The equilibrium state of a pure substance, for example air (air is usually considered a pure substance as the components keep constant through a wide temperature and pressure range), oxygen or steam, may be specified by only **two independent** properties. The specific volume of steam may be defined by the pressure and temperature. For a non-pure substance, however, for example a mixture of steam (vapour) and liquid more than two properties are required. In the case of wet steam we need to know the percentage of liquid present to establish a dryness fraction. This is because the pressure and temperature are not independent for two phases in equilibrium.

	v (m^3/kg)			
Temperature (°C)	200	250	300	350
Pressure (bar)				
5	0.4252	0.4745	0.5226	0.5701
6	0.3522	0.3940	0.4344	0.4743
7	0.3001	0.3364	0.3714	0.4058
8	0.26110	0.2933	0.3242	0.3544
9	0.2305	0.2597	0.2874	0.3144

Specific volume of superheated steam

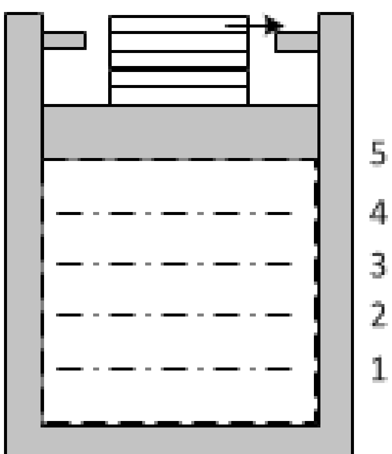
Process and cycle

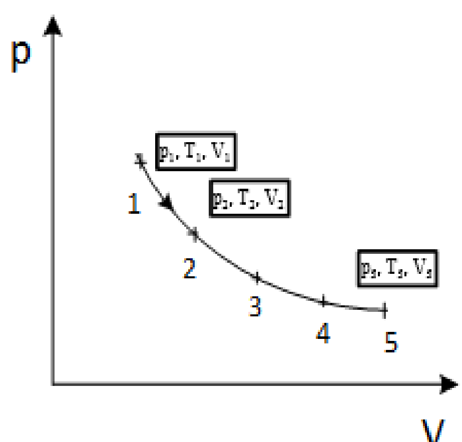
Equilibrium - A state of equilibrium exists if there is no change in any property when the system is isolated from its surroundings. In general this course will concentrate on the analysis of processes between equilibrium end states.

Process – A system undergoes a process when the state changes from one equilibrium to another.

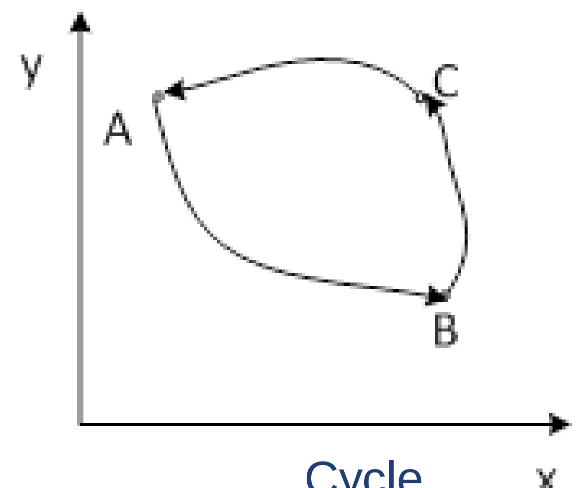
A **quasi-equilibrium process** takes place sufficiently slowly for the properties to be related in an equilibrium manner at each instant.

When a system in an initial state goes through a number of processes and finally returns to its initial state, the system has undergone a **cycle**.





Process



Cycle

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Energy and energy forms

Energy (J) is the ability of a system to do work or transfer heat, i.e. to produce physical effects outside the system. Energy is a scalar property in many interchangeable forms.

- **Kinetic energy** (KE) energy due to bulk motion: KE**=** ½ mc^2 where c is velocity
- **Potential energy** (PE) energy due to elevation in a gravitational field PE**=** mgz
- **Electrical energy =** voltage x charge = voltage x current x time
- **Chemical Energy =** energy released by combustion or a chemical reaction
- **Electromagnetic energy** = radiant energy of the electromagnetic spectrum
- **Internal energy** (U) = energy related to absolute temperate T (K) (sensible and latent heat) due to random molecule motion

Energy will be more rigorously defined later when the First Law is introduced

$$\boldsymbol{E = mgz + \frac{1}{2}mc^2 + U + etc.}$$

Energy transfer: heat and work

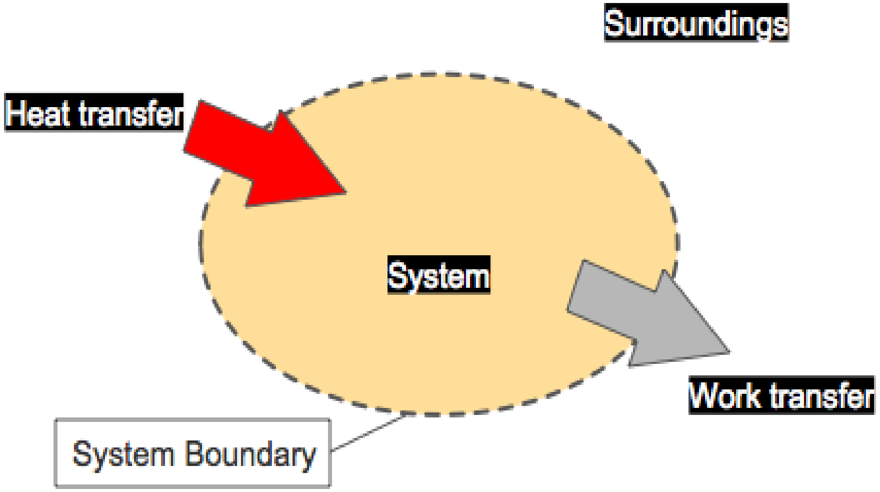
There are only two forms of energy transfer: **Heat** and **Work**.

Heat (Q in J): The energy transfer caused by a temperature difference between a system and its surroundings.

Work (W in J): The energy transfer from a system when done by moving a force, F, through a distance, ds.

Power (P in W): rate of work

1 W = 1 J/s = 1 Nm/s



Basic concepts

Heat temperature

Heat

- is positive value ("+ve") when flows into the system and vice versa.
- is NOT a property (path dependant)
- is transfer from high temperature system to the low temperature system, and heat transfer occurs solely because of the temperature difference between two systems.

Temperature (T in K): two bodies have equality of temperature, if when they are in thermal communication, no change in any observable property occurs. It is directly related to the internal energy, and is a measure of average kinetic energy of molecular motion. Temperature is a property (intensive).

Temperature scales and absolute temperature

K (Kelvin) = °C (Celsius) +273.15

Do distinguish heat and hot, heat and temperature

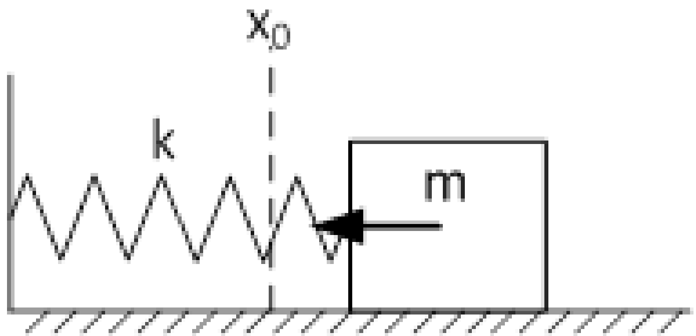
Work (in association with movement)

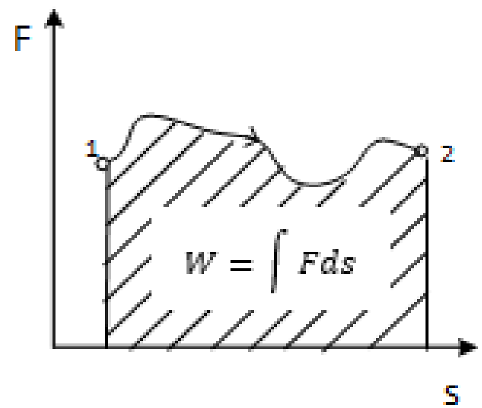
Electric work (electron movement)

- Electrical Work (J)= [potential difference E (V≡J/C)]×[charge Q (C)]
- Power (W) = E×Q/t=E×I where I=Q/t=electric current (A)

Displacement work

- $dW = F \times ds$
- Power = rate of work = $F \times ds/dt$ = force (N) × velocity (m/s)





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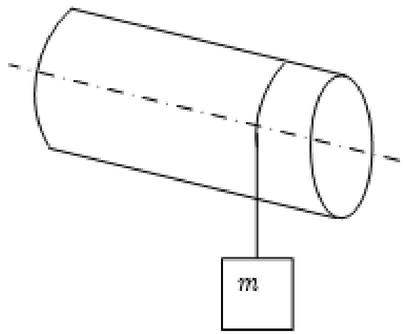
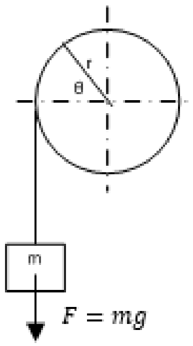
Basic concepts

Work (in association with movement)

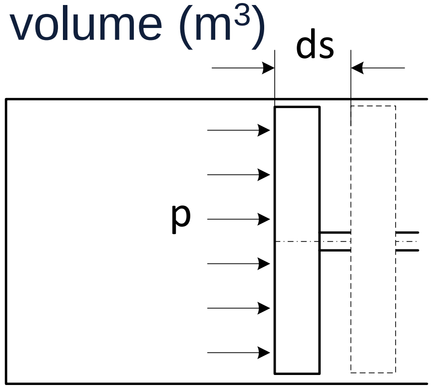
Shaft work $dW = T.d\theta = torque(Nm) \times rotaional\ angle(\ rad)$

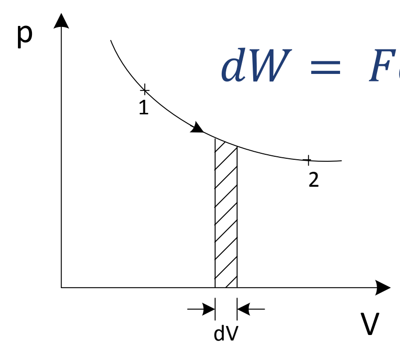
Power = rate of work = $T.\omega = torque(Nm) \times angular\ velocity(\ rad/s)$





Work for a closed (compressible) system, $dW = p.dV$ = pressure (N/m^2) × change in volume (m^3)





$$dW = Fds = pAds = pdV$$

$$W_{12} = \int_1^2 pdV$$

Work is "+ve" when system does work on the surroundings, "-ve" when surroundings does work on the system.

Summary

- System (close system and open system), boundary and surroundings (understanding)
- State, process and cycle, equilibrium and quasi-equilibrium (understanding)
- Properties (intensive, extensive and specific properties), two property rule (understanding)
- Energy transfer – heat and work (understanding)
- Different types of work (calculation)