1.17. Reversible and Irreversible Processes

Reversible process: *A reversible process (also sometimes known as a quasi-static process) is one that can be stopped at any stage and reversed so that the system and surroundings are exactly restored to their initial states.*

عملية قابلة للعكس)تعرف أحيانا باسم عملية شبه ثابتة (هي عملية يمكن أيقافها في أي مرحلة وعكسها بحيث يتم استعادة النظام والمناطق المحيطة به الى حالتها الأولية

This process has the following *characteristics:*

1. It must pass through the same states on the reversed path as were initially visited on the forward path.

الاجراء يجب ان يمر عبر نفس الحالات states على المسار المعكوس كما تم المرور عليه في البداية على المسار الامامي

2.It must pass through a continuous series of equilibrium states.

يجب ان يمر عبر سلسلة مستمرة من حالات التوازن

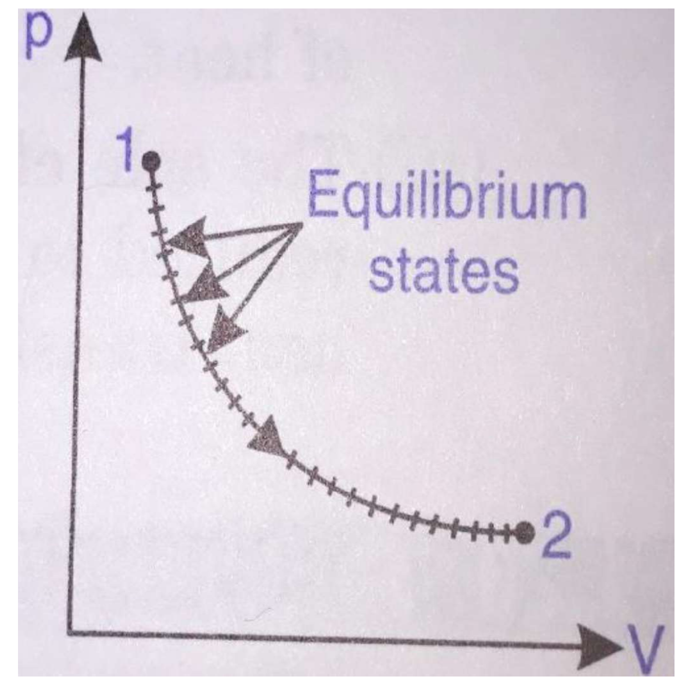


Fig.1.9 .Reversible process

Examples. Some examples of nearly reversible processes are:

(i) Frictionless relative motion.
(ii) Expansion and compression of spring
(iii) Frictionless adiabatic expansion or compression of fluid.
(iv) Polytropic expansion or compression of fluid.
(v) Isothermal expansion or compression
(vi) Electrolysis التحليل الكهربائي

Irreversible process: *An irreversible process is one in which heat is transferred through a finite temperature.*

العملية التي لا رجعة فيها هي العملية التي تنتقل فيها الحرارة من خلال درجة حرارة محدودة

Examples.

(i)Relative motion with friction
(ii)Combustion
(iii)Diffusion
(iv)Free Expansion
(v)Throttling
(vi) Electricity flows through a resistance
(vii)Heat transfer
(viii)Plastic deformation

An irreversible process is usually represented by a dotted(or discontinuous)line joining the end states to indicate that the intermediate states are indeterminate(Fig.1.10).

عادة ما يتم تمثيل عملية لا رجعة بخط منقط ينظم الى الحالات النهائية للاشارة الى ن الحالات الوسطية غير محددة

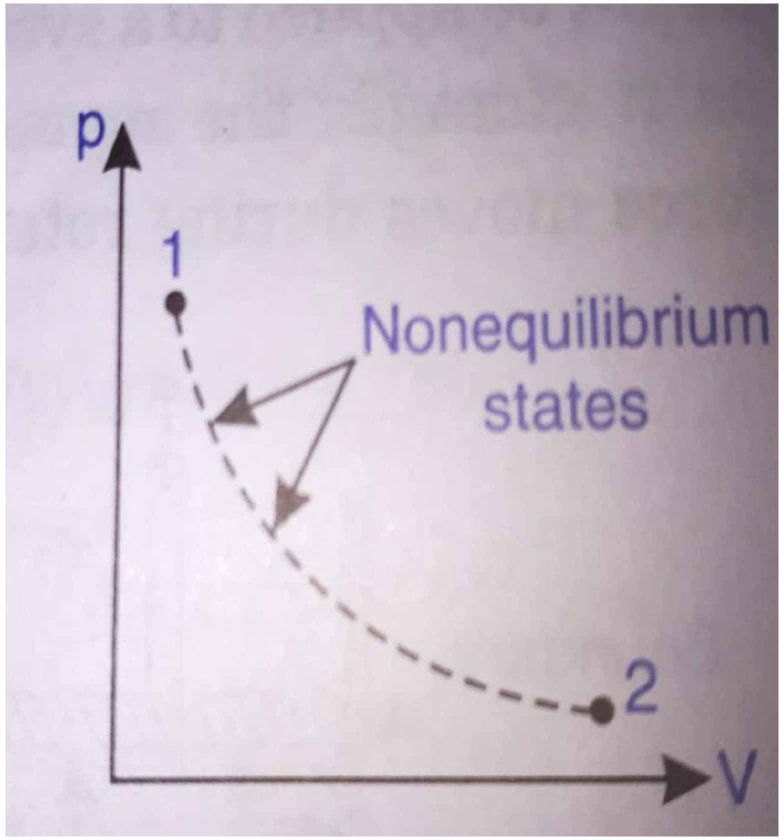


Fig.1.10.Irreversible process

Irreversibilities are of *two types:*

1. External Irreversibilities. *These are associated with dissipating effects outside the working fluid.*

هذه ترتبط بتأثيرات تبديد(dissipating) خارج مائع التشغيل النظام

2. Internal irreversibilities. *These are associated with dissipating effects within the working fluid.*

هذه ترتبط بتأثيرات تبديد داخل مائع التشغيل (النظام)

1.18 Energy, Work and Heat

1.18.1. Energy

Energy is a general term embracing energy in transition and stored energy.

الطاقة مصطلح عام يشمل الطاقة التي تمر بمرحلة انتقالية والطاقة المخزنة

The stored energy of a substance may be in the forms of *mechanical energy* and *internal energy* (other forms of stored energy may be chemical energy and electrical energy).

Part of the stored energy may take the form of either potential energy (due to high above a chosen datum line) or kinetic energy (due to velocity).

*in a **non-flow process** usually there is no change in potential or kinetic energy hence mechanical energy will not enter the calculations.*

In a flow process, however, they may changes in both potential and kinetic energy and these must be taken into account.

***Heat and work** are the forms of energy in transition.*

ملاحظة : الطاقة عندما تنتقل (تعبر جدار النظام system boundary) يكون شكلها اما شغل او حرارة

1.18.2 Work and Heat

$$Work = Force \times distance = F \times L$$

عادةً في ديناميك الحرارة يدرس النظام وللنظام جدار يسمى boundary of system وعندما يحدث لهذا الجدار ازاحة نتيجة القوة المسلطة عليه والناتجة عادتا من الضغط المسلط على جدران النظام وهذه الازاحة تكون باتجاة القوة المسلطة وكما موضح في الشكل (1-11)(أ) والذي يوضح اسطوانة يتحرك داخلها مكبس piston وتسمى هذه المنظومة piston-cylinder arrangement وهو نفس ما موجود في محرك احتراق داخلي(محرك السيارة)، يسمى الشغل الناتج من الازاحة لجدران النظام boundary work ويكون موجب عندما تكون الازاحة موجبة(حالة التمدد expansion process) وسالب عندما تكون الازاحة سالبة (compression process)

Sign convention:

(i) if the work is done by the system on the surroundings , the work is said to be positive

(ii) if the work is done on the system by the surroundings, the work is said to be negative.

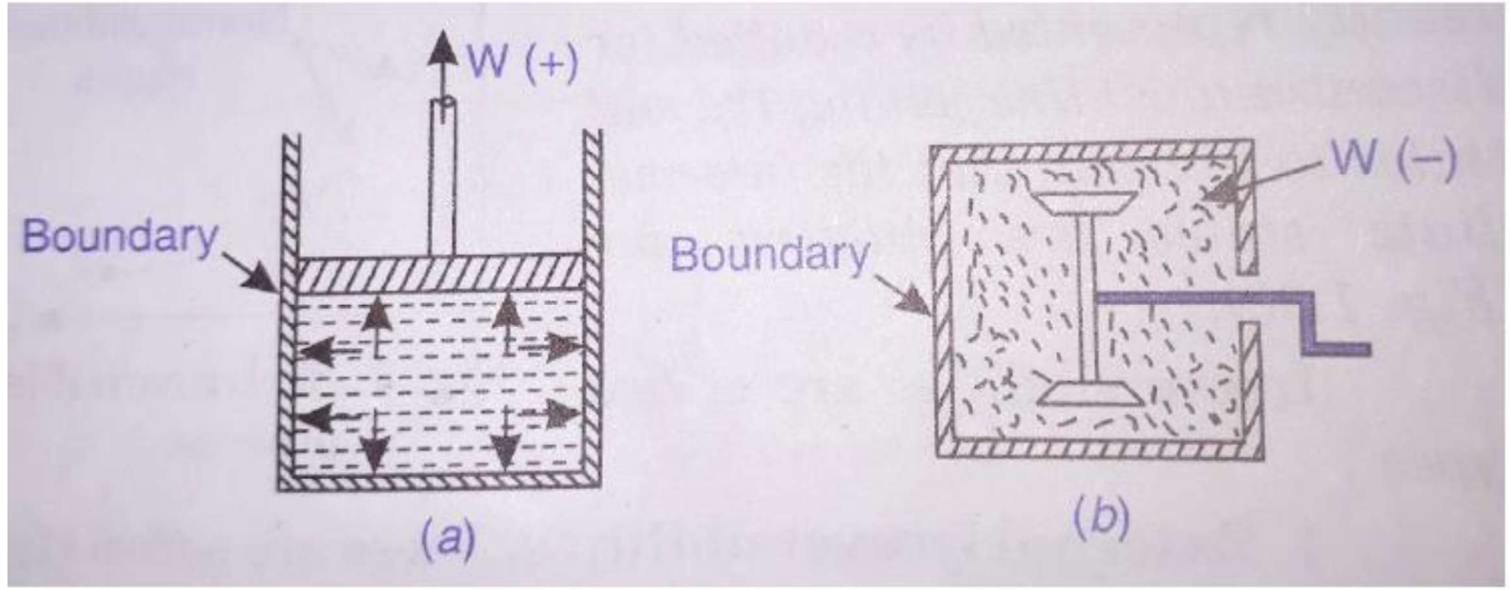


Fig.1.11

الشكل (a) النظام يسلط ضغط على المكبس ويحركه الى الاعلى وينتج تمدد في الحجم وبالتالي يكون الشغل موجب كونه مسلط من قبل النظام (خارج من النظام)

الشكل (b) شغل ميكانيكي مصدره من الخارج surroundingsمسلط على النظام ، الشغل في هذه الحالة يكون سالب

Heat

Heat denoted by the symbol Q. may be. defined in an analogous way to work as follows:

" Heat is 'something' which appears at the boundary when a system changes its state due to a difference in temperature between the system and its surroundings".

Heat, like work, is a transient quantity, which only appears at the boundary while a change is taking place within a system.

الشغل والحرارة ليس exact differentials وتكاملهما يجب ان يكون بهذه الصيغة:

$\int_1^2 \delta W = W_{1-2}$ Or ${}_1W_2$ (or W) and

$\int_1^2 \delta Q = Q_{1-2}$ or ${}_1Q_2$ (or Q)

Sign convention :

(i) if the heat flows into a system from the surroundings, the quantity is said to be positive

(ii) if the heat flows from the system to the surrounding it is said to be negative.

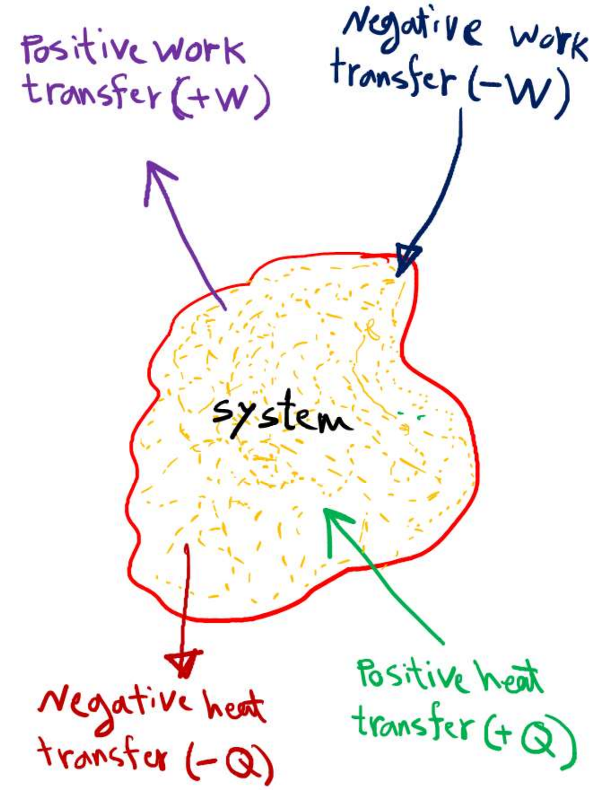


Fig.1.12.Sign convention for work and heat

Comparison of Work and Heat

Similarities:

(i) Both are path functions and inexact differentials.

(ii) Both are boundary phenomenon i.e. both are recognized at the boundaries of the system as they cross them.

(iii) Both are associated with a process, not a state. Unlike properties , work and heat has no meaning at a state.

(iv) systems possess energy, but not work or heat.

تمتلك الأنظمة الطاقة ولا تمتلك شغل او حرارة

Dissimilarities:

(i) In heat transfer temperature difference is required.

(ii) In a stable system there cannot be work transfer, however, there is no restriction for the transfer of heat.

في نظام مستقر لا يمكن ان يكون هناك نقل شغل، ومع ذلك، لا توجد قيود على نقل الحرارة

1.19 Reversible Work

ع)-(1.13) افترضناه يحتوي على مائع مثالي بدون احتكاك اثناء الجريان ، والشكل عبارة عن مكبس يتحرك داخل من دون احتكاك عملية ارجاعية(reversible process) وتسمى ايضا frictionless process، لتكن :

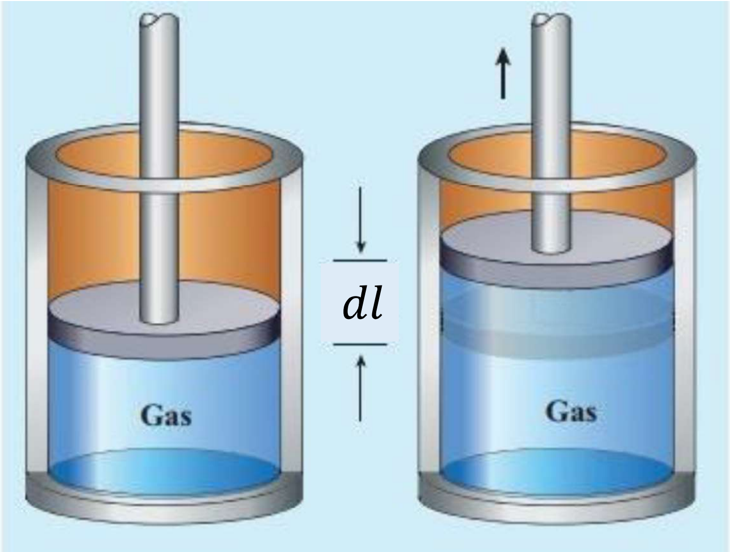


Fig.1.13(a)

A= Cross-sectional area of the piston,

P= pressure of the fluid at any instant,

dl= the distance moved by the piston under the action of the force exerted.

$$p = \frac{F}{A} \quad or \quad F = pA$$

Work done by the fluid=$(pA) \times dl = pdV$

Where dV = a small increase in volume, or considering unit mass

$$Work\ done = pdv$$

Where $v = specific\ volume$

Note that $specific\ volume = \frac{Total\ volume}{mass}$

Or $v = \frac{V}{m}$ $\quad \therefore V = mv$

This is only true when

(a) the process is frictionless

(b) the difference in pressure between the fluid(or system) and its surroundings during the process is infinitely small. Hence when a reversible process takes place between state 1 and state 2 , we have

$$work\ done\ by\ the\ unit\ mass\ of\ fluid = \int_1^2 pdv$$

The work done by the fluid during any reversible process is therefore given by the area under the line of process plotted on a $p - v$ diagram [Fig.1.13(b)].

$i.e\ Work\ done = Shaded\ area\ on\ Fig 1{\cdot}13(b)$

$$= \int_1^2 p\,dv$$

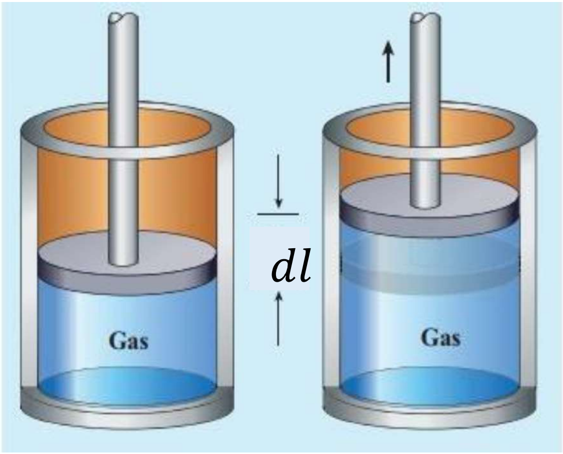
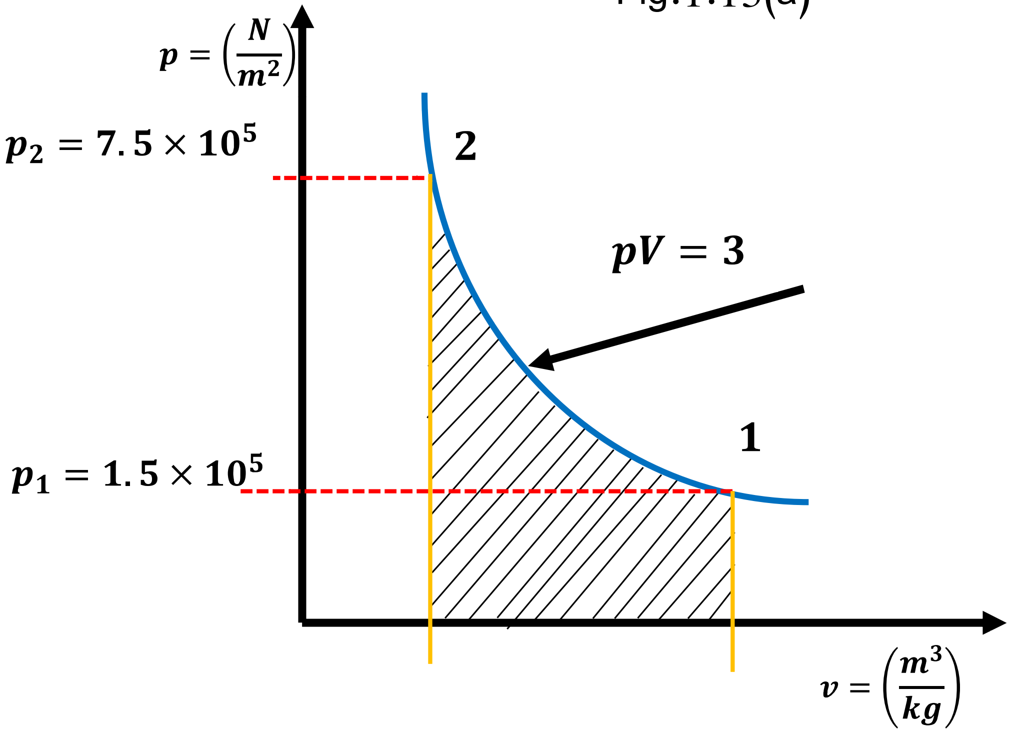


Fig.1.13(a)



Example 1.5. **The properties of a closed system change following the relation between pressure and volume as pV=3, where p is in bar V is in m^3. Calculate the work done when the pressure increases from 1.5 bar to 7.5 bar.**

Solution.

Initial pressure, p_1=1.5 bar

Finial pressure, p_2= 7.5 bar

Relation between p and V, pV=3.0

Work done, W=?

The work done during the process is given by

$$W = \int_{V_1}^{V_2} p dV$$

From the above relation $V_1 = \frac{3}{p_1} = \frac{3}{1.5} = 2\, m^3$

$$V_2 = \frac{3}{2} = \frac{3}{7.5} = 0 \cdot 4\, m^3$$

From the relation pv=3 , we find $p = \frac{3}{V}$

$$W = 10^5 \times \int_2^{0\cdot 4} \frac{3}{V} dV = 10^5 \times 3[LnV]_2^{0.4}$$

$$= 10^5 \times 3[Ln0 \cdot 4 - Ln2]$$

$$= -3 \times 10^5\, Ln\left(\frac{2}{0 \cdot 4}\right)$$

$$= -3 \times 10^5\, Ln\, 5$$

$$= -3 \times 10^5 \times 1.61$$

$$= -4 \cdot 83 \times 10^5\, Nm$$

$$= -4 \cdot 83 \times 10^5 J = -4 \cdot 83 \frac{10^5}{10^3} = -4 \cdot 83 \times 10^2 kJ = -483 kJ$$

Example 1.6. *To a closed system $150\ kJ$ of work is supplied. If the initial volume is $0 \cdot 6\ m^3$ and pressure of the system changes as $p = 8 - 4V$, where p is in bar and V is in m^3, determine the final volume and pressure of the system.*

Solution.

Amount of work supplied to a closed system = 150 kJ

Initial volume, V_1=0.6 m^3

Pressure–volume relationship, p=8 − 4V

The work done during the process is given by

From the relation p=8−4V , substitute from p in this relation:

$$W = \int_{V_1}^{V_2} p dV = 10^5 \int_{0 \cdot 6}^{V_2} (8 - 4V) dV$$

$$W = 10^5[8V - 4\frac{V^2}{2}]_{0\cdot6}^{V_2}$$

$$= 10^5[8(V_2 - 0\cdot6) - 2(V_2^2 - 0\cdot6^2)]$$

$$= 10^5[8V_2 - 4\cdot8 - 2V_2^2 + 0\cdot72]$$

$$= 10^5[8V_2 - 2V_2^2 - 4\cdot08]$$

But this work is equal to -150kJ, as this work is supplied to the system

Note: 1kJ = 10^3 J

$$\therefore \quad -150 \times 10^3 J = 10^5[8V_2 - 2V_2^2 - 4\cdot08]$$

$$-150 = 10^2[8V2 - 2V_2^2 - 4\cdot08$$

$$or \quad 2V_2^2 - 8V_2 + 2\cdot58 = 0$$

الحل بطريقة الدستور لايجاد الحجم المطلوب

$$V_2 = \frac{8 \pm \sqrt{64 - 4\times2\times2\cdot58}}{4}$$

$$= \frac{8 \pm 6\cdot585}{4} = 0\cdot354\, m^3$$

اشارة الجمع تهمل في هذا المثال ، وضح لماذا ؟

Final volume, $V_2 = 0\cdot354m^3$ $(Ans\cdot)$

And, Final pressure, $p_2 = 8 - 4V = 8 - 4\times0\cdot354 = 6\cdot584\, bar$ (Ans)

Example 1.7. A fluid at a pressure of 3 bar, and with a specific volume of 0.18 $\frac{m^3}{kg}$, contained in a cylinder behind a piston expands reversibly to a pressure of 0.6 bar according to a law, $p = C/v^2$, where C is a constant. Calculate the work done by the fluid on the piston.

$P_1 \cdot V_1^2 = C = P_2 \cdot V_2^2$

$3 \cdot (0.18)^2 = 0.6 * V_2^2 \Rightarrow V_2^2 = 0.162$

$\therefore V_2 = 0.402$

$C = P_1 \cdot V_1^2 = 3 * 10^5 (0.18)^2 = 0.0972 * 10^5$

$\bar{W} = \int_1^2 P \cdot dV$ = shaded Area = Area under curve.

$= \int_{V_1}^{V_2} \frac{C}{V^2} \cdot dV = C\left[-V^{-1}\right]_{V_1}^{V_2} = C\left[\frac{1}{V_1} - \frac{1}{V_2}\right]$

$= 0.0972 * 10^5 \left[\frac{1}{0.18} - \frac{1}{0.402}\right] = 29840\ J/kg = 29.842\ KJ/kg$