CH365 Chemical Engineering Thermodynamics

Lesson 5
Reversible Processes

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Equilibrium

Hidden Material – Take Notes!

Equilibrium is the absence of any tendency toward change in a macroscopic scale

The Reversible Process

A process is reversible when its direction can be changed at any point by an infinitesimal change in external conditions.

- frictionless piston
- no heat transfer to surroundings
- no gravity

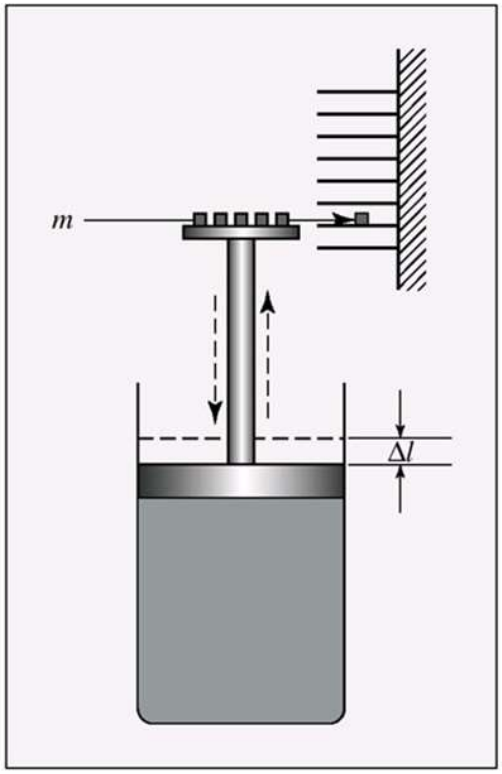

Figure 2.2: Expansion of a gas.

Note: $P_{external} \approx P_{internal}$

Attributes of a Reversible Process

A reversible process:

- can be reversed at any point by an infinitesimal change in external conditions
- is never more than minutely removed from equilibrium
- traverses a succession of (infinitesimally different) equilibrium states
- is frictionless
- is driven by forces whose imbalance is infinitesimal in magnitude
- proceeds infinitely slowly
- when reversed, retraces its path, restoring the initial state of the system and the surroundings

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$$dW = -PdV \quad \Rightarrow \quad W = -\int_{V_1^t}^{V_2^t} PdV \qquad \text{or} \qquad W = -P\Delta V$$

Eq 1.3 Eq 1.4 When?

Example 2.5

Hidden Material – Take Notes!

A horizontal piston/cylinder arrangement is placed in a constant-temperature bath. The piston slides in the cylinder with negligible friction, and an external force holds it in place against an initial pressure of 14 bar. The initial gas volume is 0.03 m^3. The external force on the piston is reduced gradually, and the gas expands isothermally as its volume doubles. If the volume of gas is related to its pressure so that the product PV^t is constant, what is the work done by the gas in moving the external force?

Example 2.5, continued

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How much work would be done if the external force were suddenly reduced to half its initial value (7 bar) instead of being gradually reduced?

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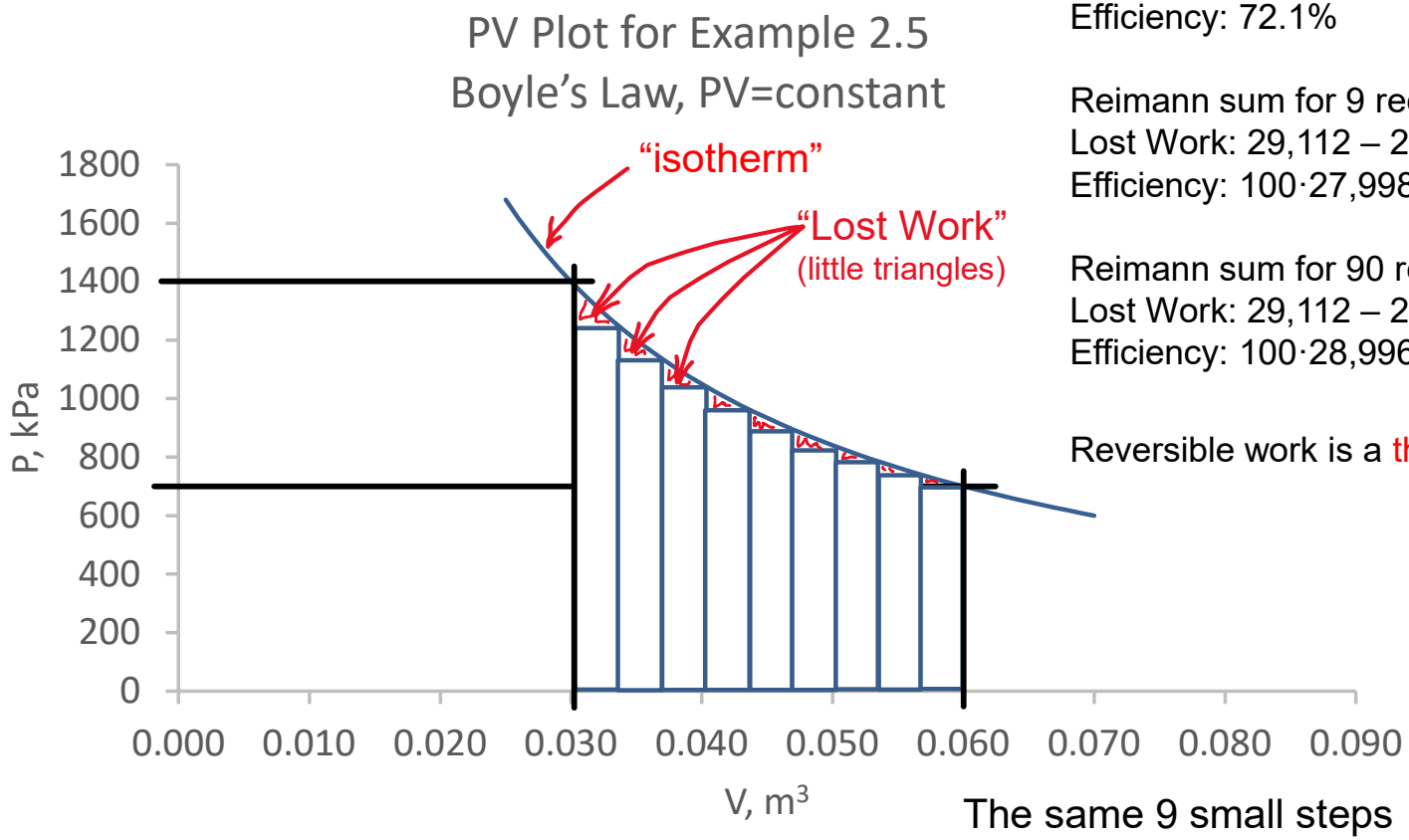

Reimann sum for 1 rectangle: -21,000 J
Lost Work: 29,112 – 21,000 = 8,112 J
Efficiency: 72.1%

Reimann sum for 9 rectangles: -27,998 J
Lost Work: 29,112 – 27,998 = 1,134 J
Efficiency: 100·27,998/29,112 = 96%

Reimann sum for 90 rectangles: 28,996 J
Lost Work: 29,112 – 28,996 = 116 J
Efficiency: 100·28,996/29,112 = 99.6%

Reversible work is a theoretical limit.

The same 9 small steps

Questions?