TOPIC III - Energy Balances

Work done by moving boundaries (Lecture 1/4)

Contents

1. Preamble – piston-cylinders and moving boundary work
2. Constant volume process
3. Constant pressure process
4. Isothermal process

Objectives

Understand the physics underpinning formulae for (reversible) moving boundary work. Feeds into **Non-Flow Energy Eqn**

Applications:

Processes listed here apply to engine cycles (Topic V)

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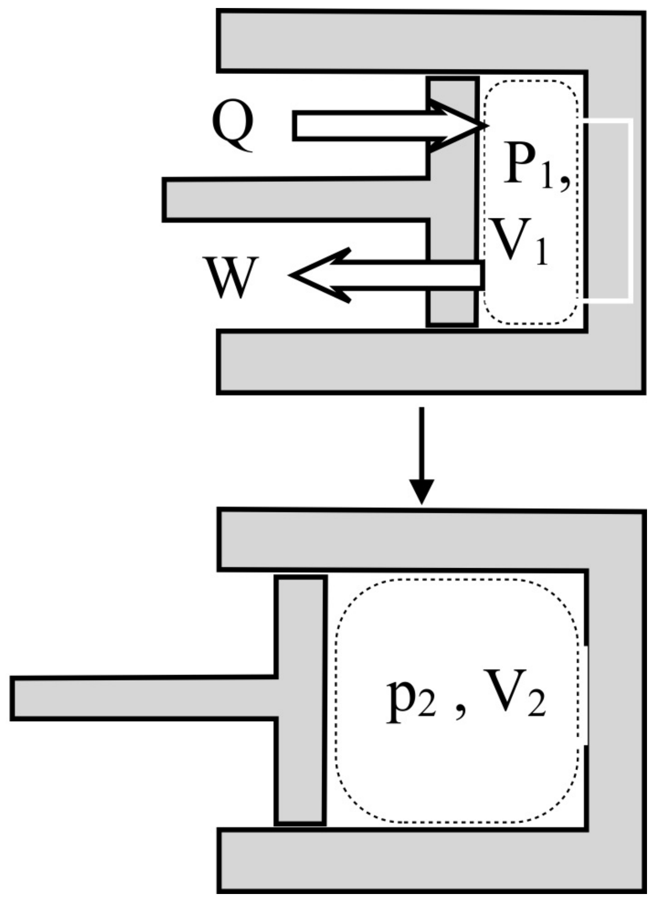
1) Preamble:

- NFEE relates W, Q, ΔU
- Piston-cylinders
- ”Best case", quasi - equilibrium paths.
- Gas-to-solid interface is system boundary

$$\delta W_b = -F\, \delta s$$

or $\delta W_b = -p\, \delta V$ (1)



W_b is area under p-V curve

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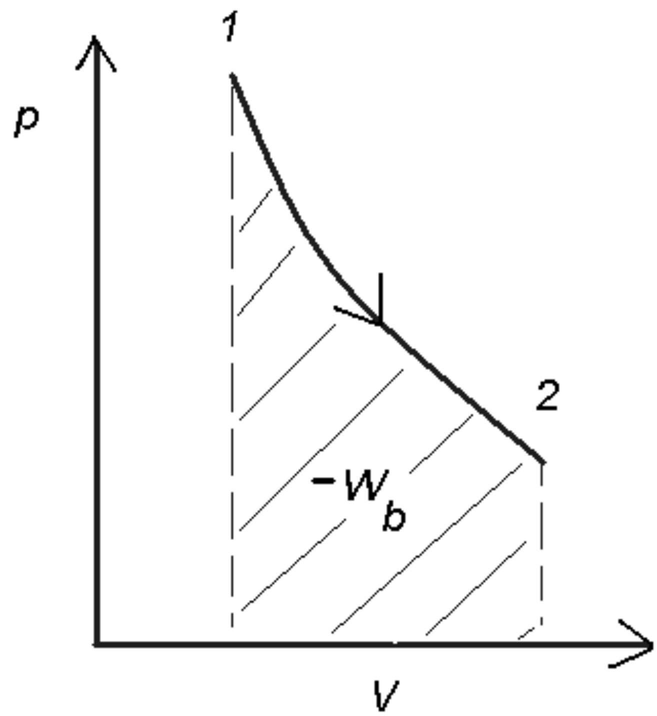
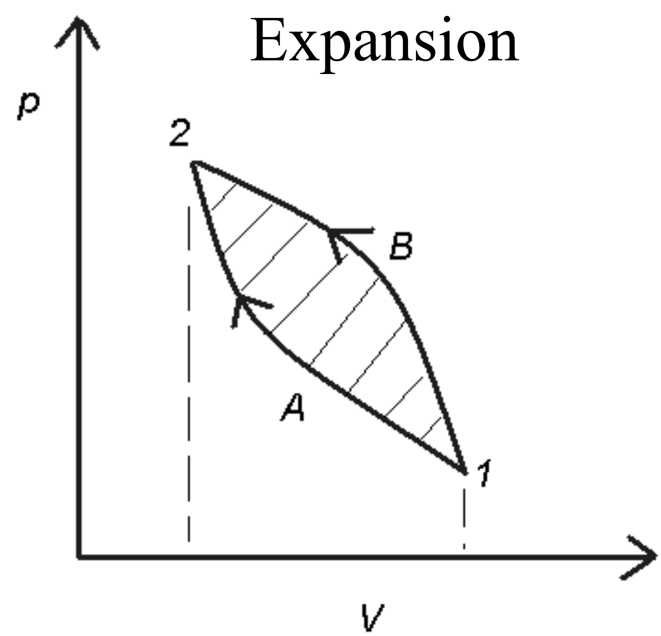
$$W_b = -\int_1^2 p\, dV \quad (2)$$

Note friction losses.
Many paths 1-to-2.
Thus many possible values of W_b.



Expansion

Path (b) demands more work than (a).
Difference is shaded area

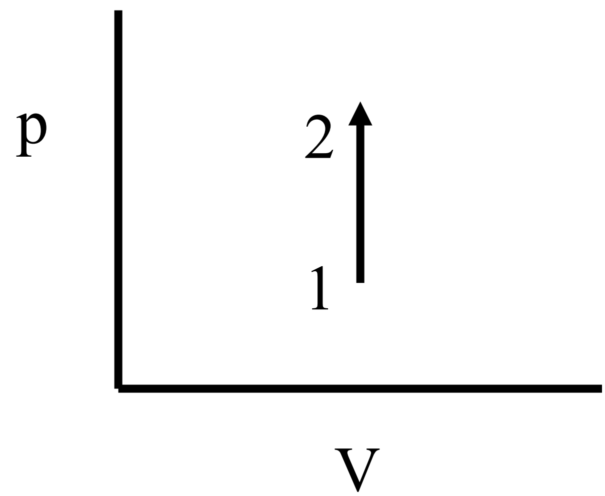


Compression

2) The Constant Volume Process

No work done:

$$Q_v + \cancel{W} = \Delta U$$

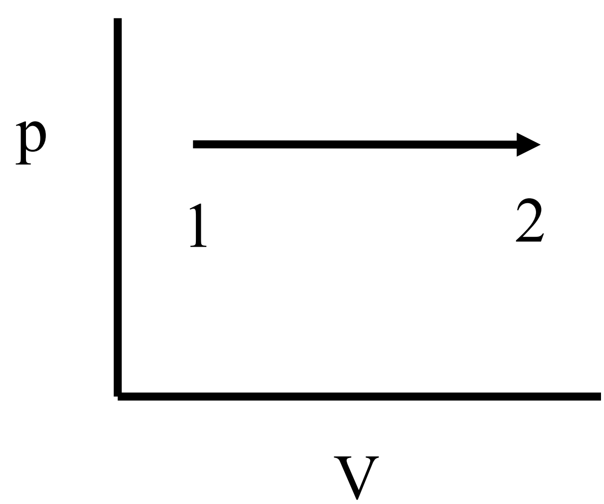


3) The Constant Pressure Process

E.g. piston acting against a weight,

$$Q_p = \Delta U - W \ \ldots$$

NFEE



$$Q_p = \Delta U + p\,\Delta V \ \ldots$$

reversible

$p = \text{const}$

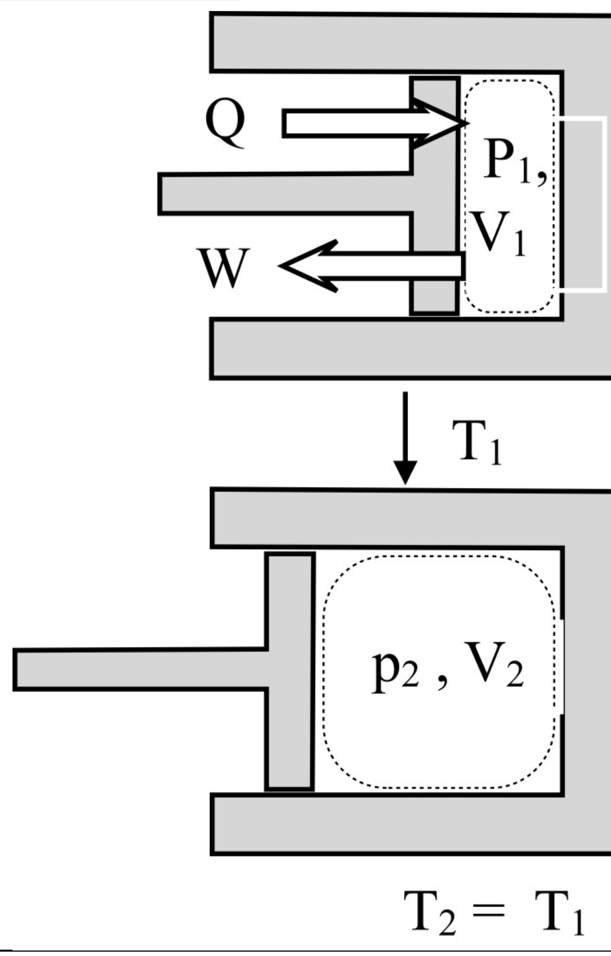
$$Q_p = \Delta\,(U + pV) = \Delta H$$

3) The Constant Pressure Process

Integrate p dV to get:

$$W_b = -\int_1^2 p\,dV = -p\left(V_2 - V_1\right) \quad (3)$$

4) The Isothermal Process



Applies later to Carnot cycle.

$Q + W = \Delta U = 0$

Substitute ideal gas law into (3),

$pV = m R T$

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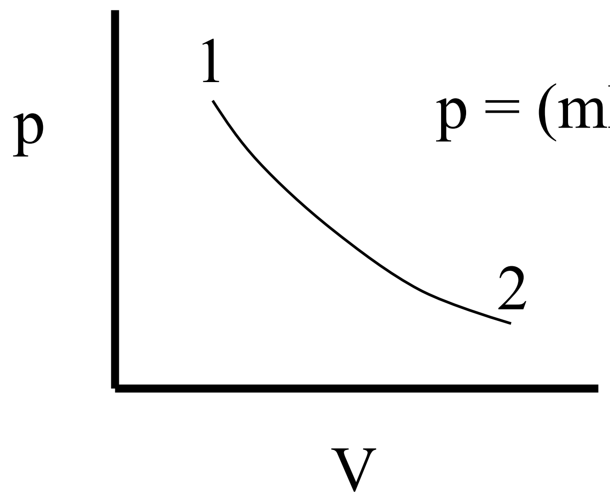

$p = (mRT) / V$

$$W_b = -\int_1^2 p\,dV = -mRT\int_1^2 \frac{dV}{V} =$$

$$-mRT\ln\left(\frac{V_2}{V_1}\right)$$

(4)

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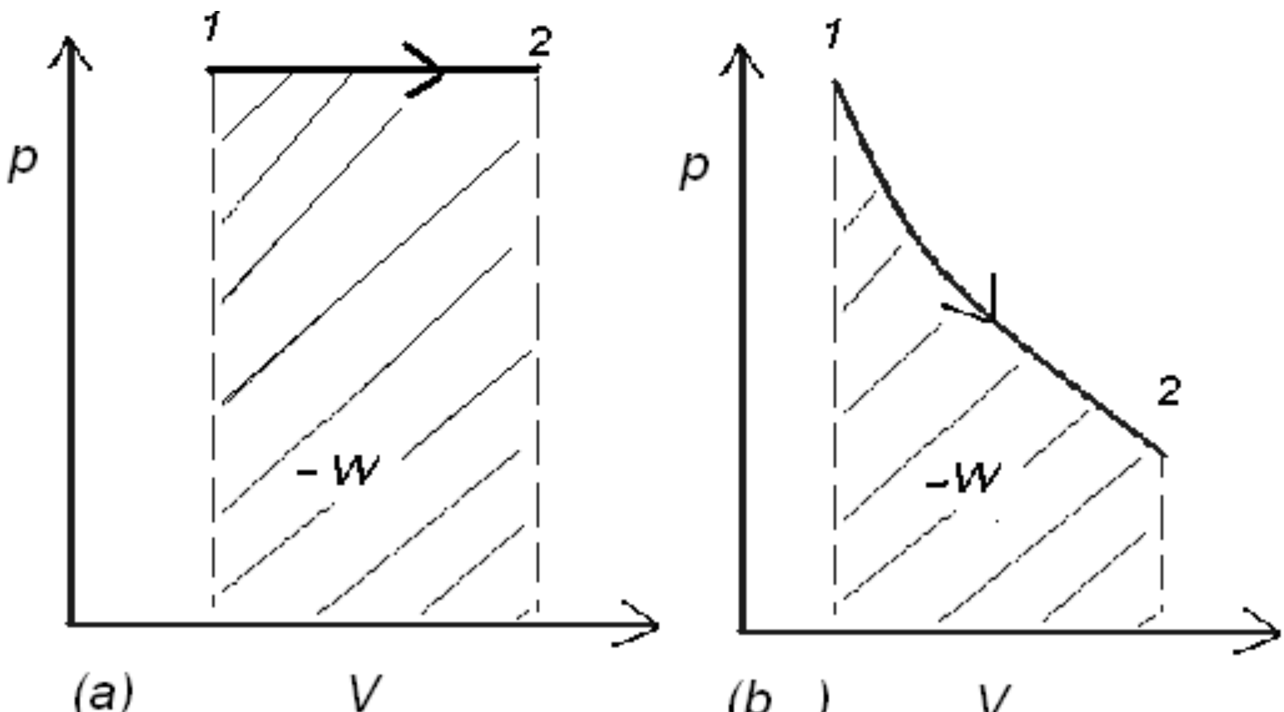
Work done by moving boundaries (Lecture 1/4)

<u>Example</u>: Consider a piston-cylinder for which the start conditions are $V_1 = 250$ cm^3, $p_1 = 6$ bar and the end volume is $V_2 = 1000$ cm^3. What is the boundary work for (a) constant pressure expansion (b) isothermal expansion? (See notes for solution)



Work done by moving boundaries (Lecture 1/4)

Conclusion

Integration of - p dV gives (reversible) moving boundary work, W_b

W_b depends on path

Show results for three paths:

* Constant volume ($Q_v = \Delta U$, $W = 0$)
* Constant pressure ($Q_p = \Delta H$, $W = -p\, \Delta V$)
* Constant temperature ($W = -\, Q_T$)

Often sub W into NFEE to get Q

$$Q = \Delta U - W = m\, c_v\, \Delta T - W$$