TOPIC V - Gas Cycles

Air Standard Cycles (Lecture 1/4)

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Objectives

Understand steps in deriving Otto cycle efficiency, and implications.

TOPIC V - Gas Cycles

Air Standard Cycles (Lecture 1/4)

1) Preamble

Engines.

- working fluid … ideal gas,
- closed cycles … gas is recirculated
- open cycles … gas enters and exits

Internal combustion– fuel + air

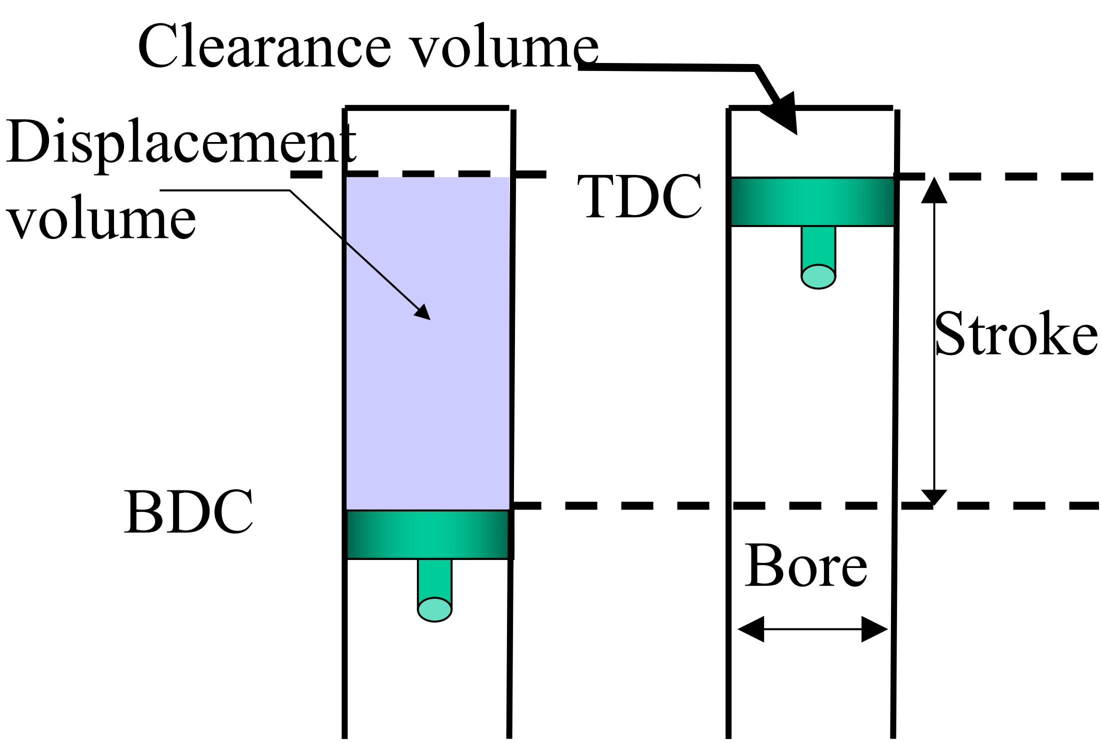
External combustion - heat transfer

Here … idealised cycles with no internal irreversibilities

2) Air standard cycles – assumptions:

- ideal gas with air properties;
- gas circulates in a closed loop;
- heat inputs approximates combustion;
- heat rejection approximates exhaust;
- constant heat capacities (optional)

Piston cylinder -



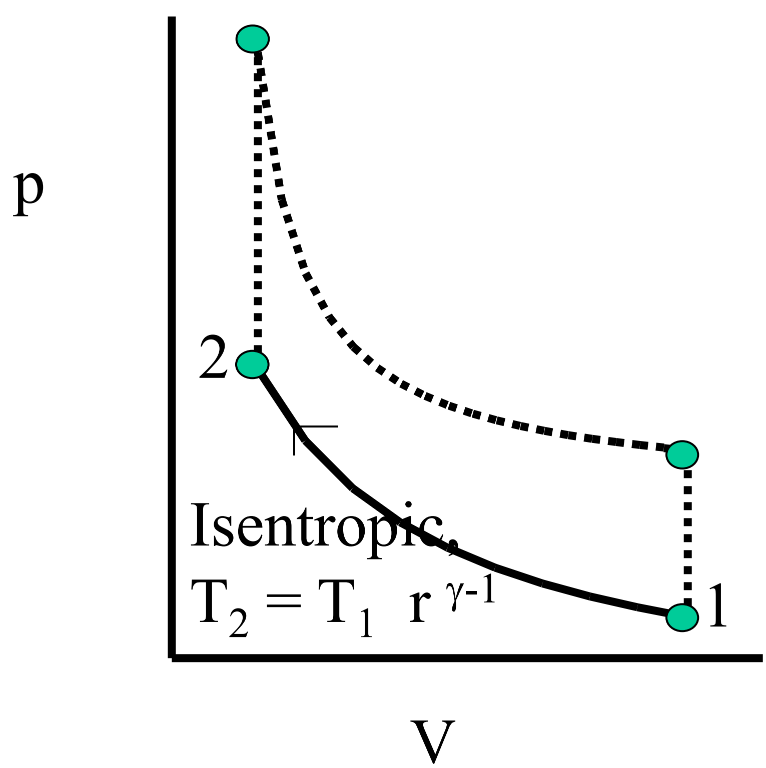
Compression ratio,

$$r = \frac{V_{max}}{V_{min}} \qquad (1)$$

2) Otto Cycle (4-stroke, Spark ignition)

<u>Compression stroke (1-to-2)</u>

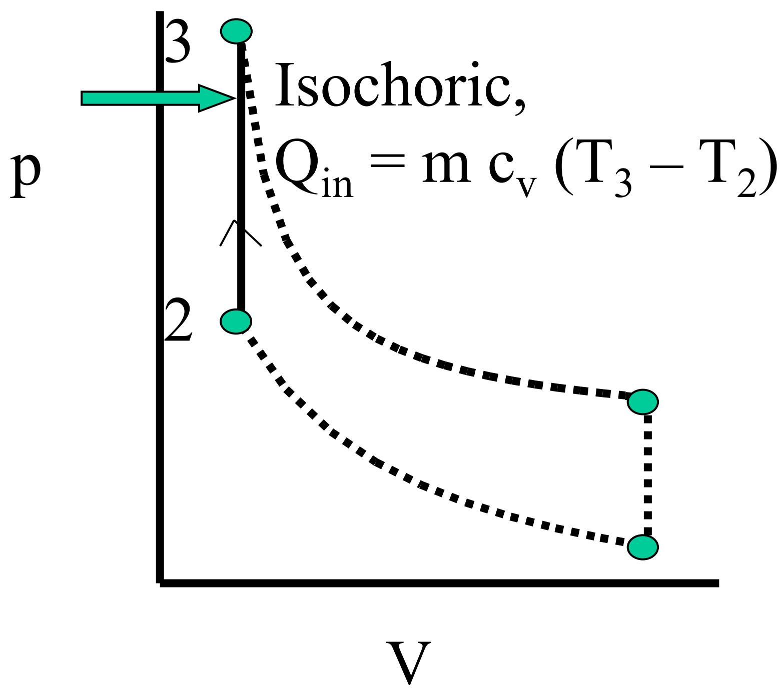
Piston moves BDC to TDC, isentropic compression

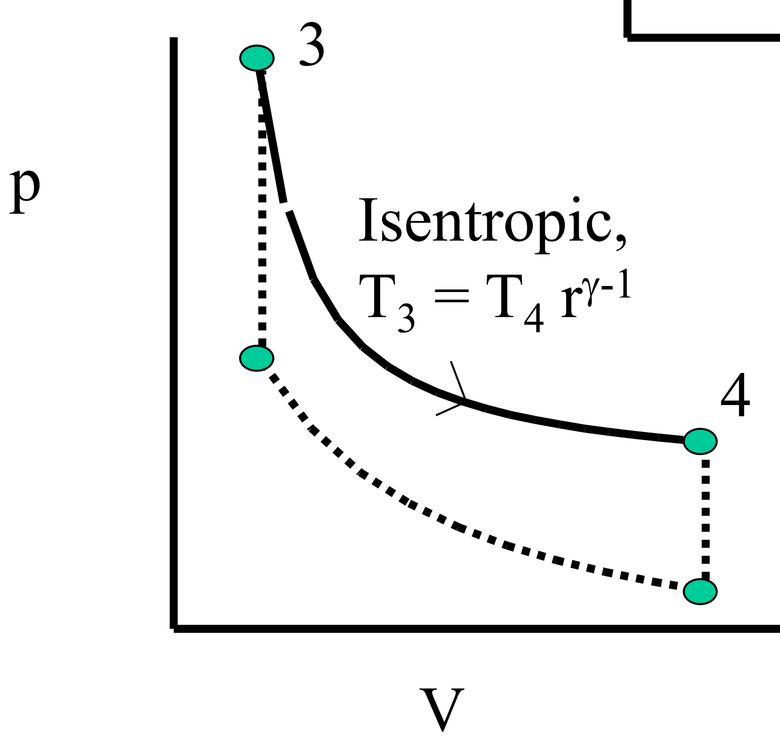


Power stroke (2-to-3 and 3-to-4)

- Ignition, then piston moves TDC to BDC

2-3, constant volume heating (isochoric)

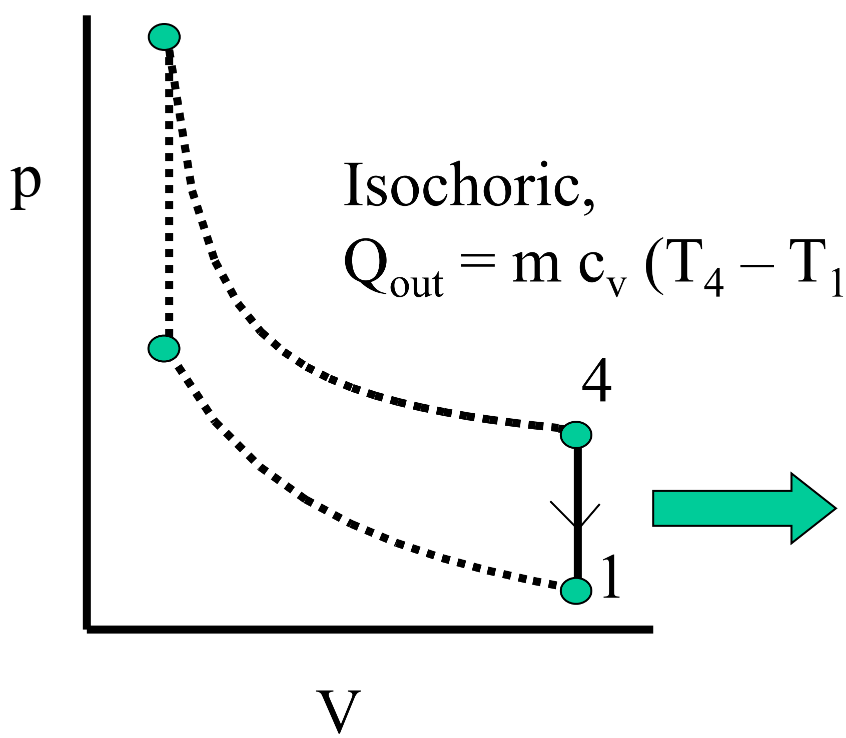




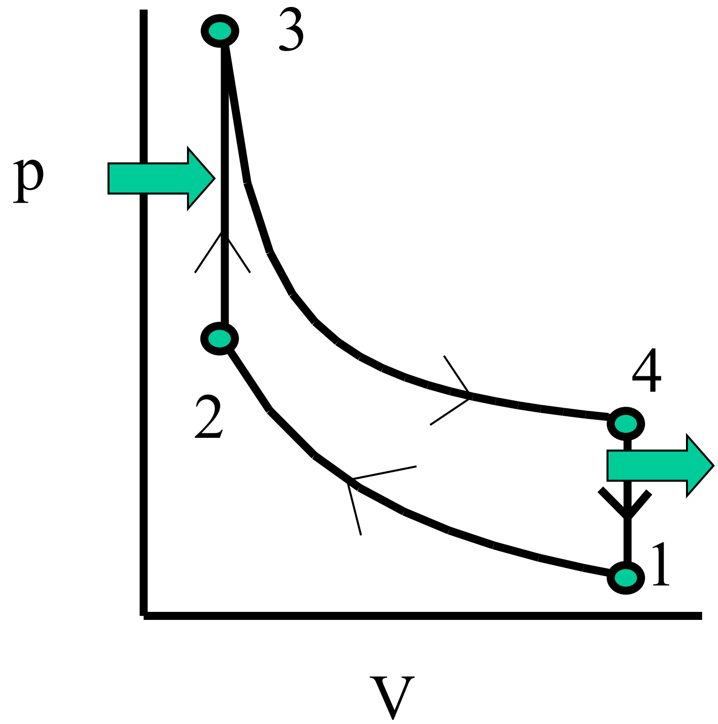
3-4, isentropic expansion

Exhaust stroke and intake stroke (4-to-1)

- Expel combustion gas (BDC to TDC)
- Air induction (TDC to BDC)
- Represent the two strokes with a single isochoric cooling process



Complete cycle



$$\eta = 1 - \frac{Q_{out}}{Q_{in}} = 1 - \frac{m\,c_v\left(T_4 - T_1\right)}{m\,c_v\left(T_3 - T_2\right)} = 1 - \frac{\left(T_4 - T_1\right)}{\left(T_3 - T_2\right)} \quad (2)$$

Isentropic eqns yield temps at TDC, T2 & T3

$$\eta = 1 - \frac{T_4 - T_1}{T_3 - T_2} = 1 - \frac{T_4 - T_1}{T_4\, r^{\gamma-1} - T_1\, r^{\gamma-1}} = 1 - \frac{1}{r^{\gamma-1}} \quad (3)$$

The efficiency depends only on the compression ratio, r.

Large compression ratios yield better efficiency, but … "knocking“

Exam + coursework –often W, Q for each process. Derived efficiency as a check (discussion part)

Conclusions

Complex engine processes simplified (grossly) with air standard assumptions.

Otto represented by two isentropic and two isochoric processes.