

Gas Power Cycles

- Internal Combustion Engine
- Gas Turbine Power Plant

Internal Combustion Engine Types

- **Spark Ignition Engine:** Mixture of fuel and air is ignited by a spark plug
- **Compression Ignition Engine:** Air is compressed to a high enough pressure and temperature such that combustion occurs when the fuel is added

Compression Ratio

$$\text{Compression Ratio} = \frac{\text{Volume at bottom dead center}}{\text{Volume at top dead center}}$$

Four Stroke Engine

The piston executes four distinct strokes for every two revolutions of the crankshaft

**1.) Intake Stroke**

- Intake valve is open
- Charge is introduced (fuel-air mixture or air)

**2.) Compression Stroke**

- Both valves are closed
- Temperature and pressure increase
- Combustion occurs at the end of the Compression Stroke (spark occurs or the fuel is injected)

**3.) Power Stroke**

- Combustion causes expansion
- Work is done on the piston

**4.) Exhaust Stroke**

- Exhaust valve opens
- Burnt gases are purged from the cylinder

Mean Effective Pressure

$$mep = \frac{\text{net work for one cycle}}{\text{displacement volume}}$$

Air-Standard Analysis

- Simplifies the analysis of the four-stroke engine
- The working fluid is air as an ideal gas operating in a closed system
- Combustion is modeled as heat transfer from an external source
- The Exhaust and Intake Strokes are replaced by a single constant volume process with heat transfer
- All processes are internally reversible

Air-Standard Otto Cycle

Process 1-2

- Isentropic Compression (Compression Stroke)

$$\overset{0}{Q} - W = m(u_2 - u_1)$$

$$W = -W_{12}$$

$$\boxed{\frac{W_{12}}{m} = u_2 - u_1}$$

Process 2-3

- Combustion
- Heat transfer to the air
- Constant volume

$$\overset{0}{Q} - \cancel{W} = m(u_3 - u_2)$$

$$Q = Q_{23}$$

$$\boxed{\frac{Q_{23}}{m} = u_3 - u_2}$$

Process 3-4

- Power Stroke
- Isentropic Expansion

$$\overset{0}{Q} - W = m(u_4 - u_3)$$

$$W = W_{34}$$

$$\boxed{\frac{W_{34}}{m} = u_3 - u_4}$$

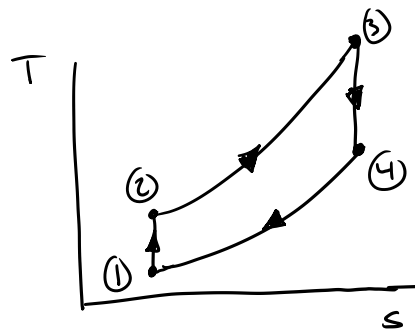
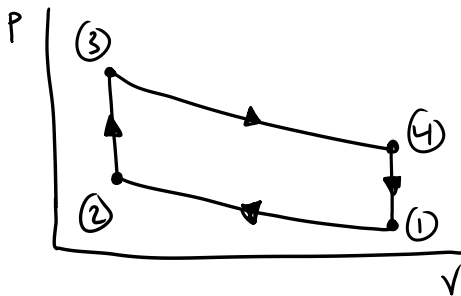
Process 4-1

- Exhaust and Intake Strokes
- Heat Transfer from the air
- Constant volume

$$Q - \overset{0}{W} = m(u_1 - u_4)$$

$$Q = -Q_{41}$$

$$\boxed{\frac{Q_{41}}{m} = u_4 - u_1}$$



Thermal Efficiency

$$\eta = \frac{W_{\text{cycle}}}{Q_{23}} = \frac{W_{34} - W_{12}}{Q_{23}}$$

Isentropic Processes (1-2 and 3-4)

$$\frac{T_2}{T_1} = \frac{v_{r2}}{v_{r1}}$$

$$r = \frac{T_1}{T_2} = \frac{T_4}{T_3}$$

Compression Ratio

$$\boxed{r = \frac{v_{r1}}{v_{r2}} = \frac{v_{r4}}{v_{r3}}}$$

$v_r = \text{Table A}$