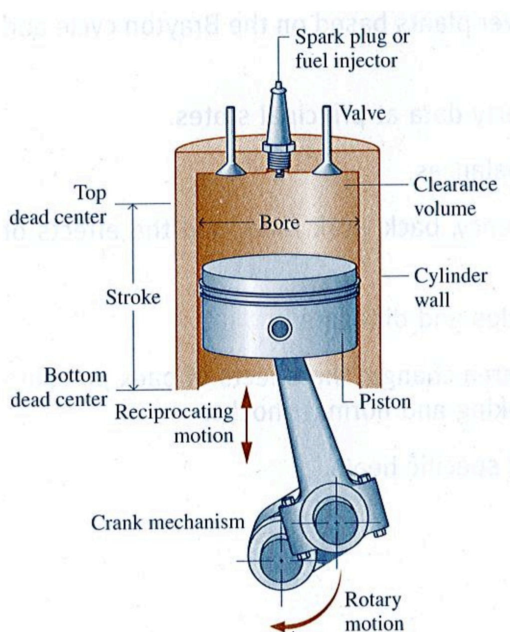
https://www.youtube.com/watch?v=vIJ50aUiBgM (old video, but shows the basics well)
https://www.youtube.com/watch?v=zA_19bHxEYg (newer technology, good animations)
https://www.youtube.com/watch?v=saPGX-1qC4M (hands-on video)

ME 200 (Thermodynamics I)

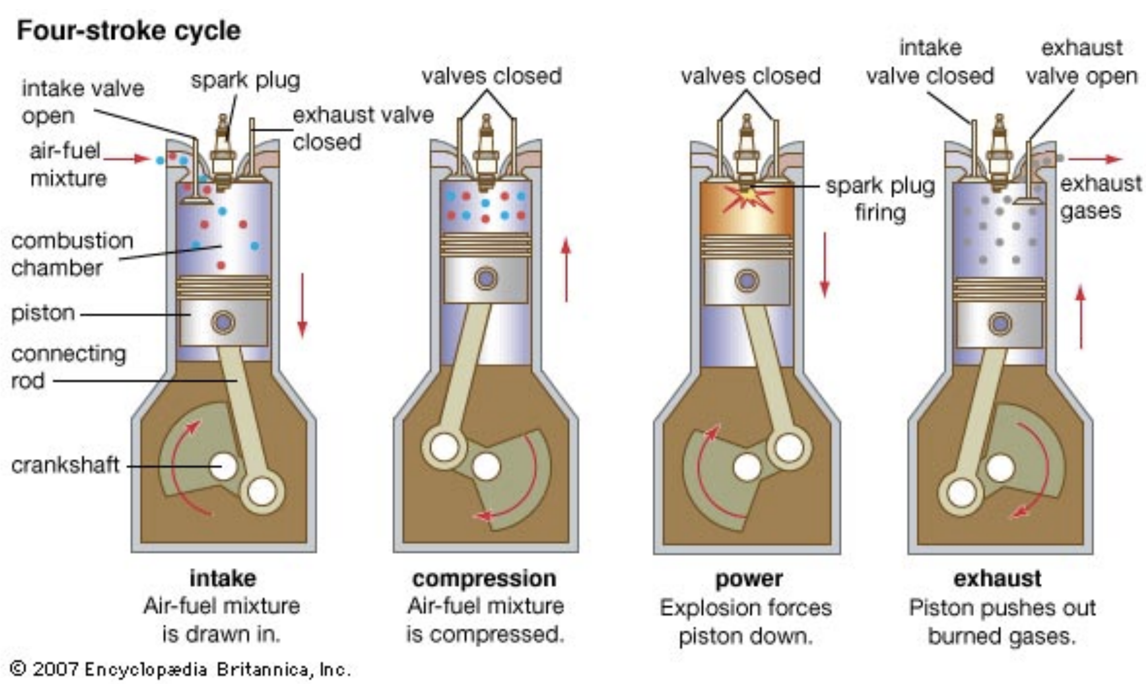
Air Standard Analysis

Two main types of reciprocating internal combustion engines

- spark-ignition engine
- compression-ignition engine



(Image from Moran et al., 7^{th} ed.)



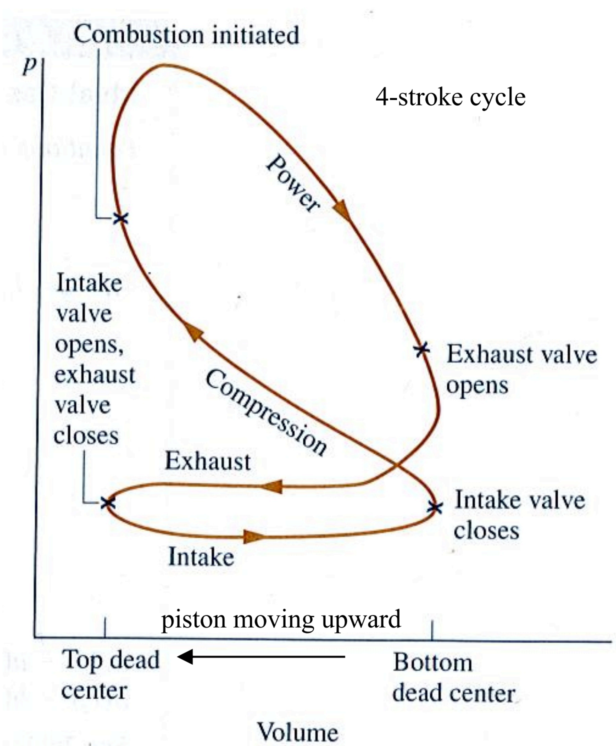
Two revolutions of the crankshaft to complete four strokes.

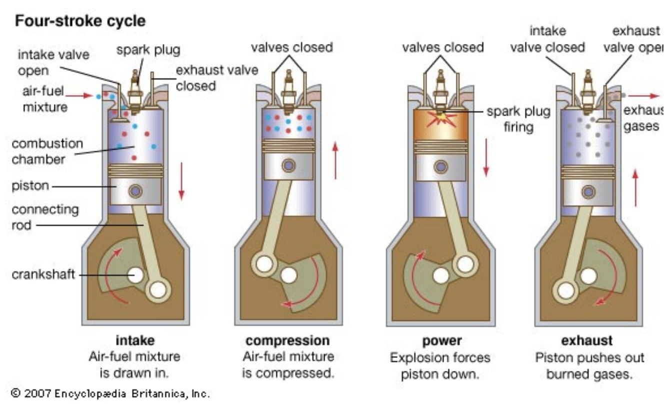
Air Standard Analysis

- Highly simplified to provide qualitative understanding
- Fixed mass of air modeled as an ideal gas.
- Combustion modeled as a heat addition process.
- No intake or exhaust processes.
- Exhaust modeled as a constant volume heat removal process.
- All processes are internally reversible.

Cold air standard analysis

- An air standard analysis that assumes constant specific heats (perfect gas assumption).





(Image from Moran et al., 7th ed.)

Mean Effective Pressure (MEP):

$$MEP \equiv \frac{W_{out,net}}{V_{bdc} - V_{tdc}}$$

Compression ratio, $r \equiv \frac{V_{bdc}}{V_{tdc}} = \frac{v_{bdc}}{v_{tdc}} > 1$

Two and a half cycles to be considered: Otto cycle, Diesel cycle, dual cycle

- Define the cycle paths – draw on *p-v* and *T-s* plots
- Apply the 1st Law to determine
  - Net work out
  - Heat transfer
  - Thermal efficiency
- Make use of compression ratio and MEP
- Examine trends

TABLE 9.1

Ideal Gas Model Review

Equations of state:

$$pv = RT \quad (3.32)$$
$$pV = mRT \quad (3.33)$$

Changes in u and h:

$$u(T_2) - u(T_1) = \int_{T_1}^{T_2} c_v(T)\, dT \quad (3.40)$$
$$h(T_2) - h(T_1) = \int_{T_1}^{T_2} c_p(T)\, dT \quad (3.43)$$

Constant Specific Heats	Variable Specific Heats
$u(T_2) - u(T_1) = c_v(T_2 - T_1)$ (3.50) $h(T_2) - h(T_1) = c_p(T_2 - T_1)$ (3.51) See Tables A-20, 21 for data.	$u(T)$ and $h(T)$ are evaluated from appropriate tables: Tables A-22 for air (mass basis) and A-23 for other gases (molar basis).

Changes in s:

$$s(T_2, v_2) - s(T_1, v_1) = \int_{T_1}^{T_2} c_v(T)\frac{dT}{T} + R\ln\frac{v_2}{v_1} \quad (6.17)$$

$$s(T_2, p_2) - s(T_1, p_1) = \int_{T_1}^{T_2} c_p(T)\frac{dT}{T} - R\ln\frac{p_2}{p_1} \quad (6.18)$$

Constant Specific Heats	Variable Specific Heats
$s(T_2, v_2) - s(T_1, v_1) = c_v \ln\frac{T_2}{T_1} + R\ln\frac{v_2}{v_1}$ (6.21) $s(T_2, p_2) - s(T_1, p_1) = c_p \ln\frac{T_2}{T_1} - R\ln\frac{p_2}{p_1}$ (6.22) See Tables A-20, 21 for data.	$s(T_2, p_2) - s(T_1, p_1) = s^\circ(T_2) - s^\circ(T_1) - R\ln\frac{p_2}{p_1}$ (6.20a) where $s^\circ(T)$ is evaluated from appropriate tables: Tables A-22 for air (mass basis) and A-23 for other gases (molar basis).

Relating states of equal specific entropy: $\Delta s = 0$:

Constant Specific Heats	Variable Specific Heats — Air Only
$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{(k-1)/k}$ (6.43) $\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{k-1}$ (6.44) $\frac{p_2}{p_1} = \left(\frac{v_1}{v_2}\right)^{k}$ (6.45) where $k = c_p/c_v$ is given in Tables A-20 for several gases.	$\frac{p_2}{p_1} = \frac{p_{r2}}{p_{r1}}$ (air only) (6.41) $\frac{v_2}{v_1} = \frac{v_{r2}}{v_{r1}}$ (air only) (6.42) where p_r and v_r are provided for air in Tables A-22.

Table 9.1 from Moran et al.