

Internal Combustion Engine 1

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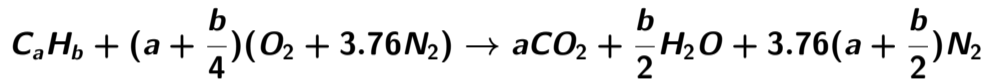
Examples

Example 1

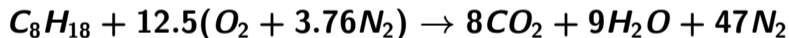
- Isooctane C_8H_{18} is supplied to a four-cylinder spark-ignition engine at a rate of 2 g/s . Calculate the air flow rate required for stoichiometric combustion. If the engine operates at 1500 rev/min , estimate the mass of fuel and air entering each cylinder per cycle. The engine has a displaced volume of 2.4 liters . Determine the **volumetric efficiency** and calculate the **power output**, assuming a fuel **conversion efficiency of 0.3**.
 - Fuel is Isooctane C_8H_{18}
 - $k = 4$ number of cylinder
 - $m_f = 2 \text{ g/sec} = 0.002 \text{ kg/sec}$
 - $V_d = 2.4 \text{ liters} = 2.4 \times 10^{-3} \text{ m}^3$

Example 1 - Solution

- For stoichiometric combustion



- $a = 8$ and $b = 8$



$$(m_f)_{stoic} = n_f \times M_f \quad \text{and} \quad (m_a)_{stoic} = n_a \times M_a$$

- $(m_f)_{stoic} = 1 \times (8(12) + 18(1.008)) = 144.144 \text{ kg}$
- $(m_a)_{stoic} = 12.5 \times (32 + 3.76(28)) = 1716 \text{ kg}$

Example 1 - Solution

$$(A/F)_{stoic} = \frac{(m_a)_{stoic}}{(m_f)_{stoic}} = \frac{1716}{114.144} = 15.03$$

To determine the actual air mass $(m_a)_{act}$ for a stoichiometric Air-Fuel ratio, we can use $(A/F)_{stoic}$.

$$(A/F)_{stoic} = \frac{(m_a)_{act}}{(m_f)_{act}} = \frac{(m_a)_{act}}{0.002} = 15.03$$

$$(m_a)_{act} = 0.03006 \text{ kg/sec}$$

Example 1 - Solution

To find volume efficiency we use the following formula:

$$\eta_v = \frac{V_a \text{ per cycle}}{V_d}$$

$$V_a = \frac{m_a}{\rho_a} \Rightarrow V_a \text{ per cycle} = \frac{V_a}{\text{cycle/sec}}$$

$$\rho_{\text{at } 25^\circ \text{ and } 1 \text{ atm}} = 1.184 \text{ kg/m}^3$$

$$V_a = \frac{0.03006}{1.184} = 0.0254 \text{ m}^3/\text{sec}$$

Example 1 - Solution

To find V_a per cycle we need to convert N from *rpm* to *cycle/sec*, assuming a 4-stroke engine:

$$\text{No. of cycles per min.} = \frac{N}{2} = \frac{1500}{2} = 750 \text{ cycle/min}$$

$$\text{No. of cycles per sec.} = \frac{\text{No. of cycles per min.}}{60} = \frac{750}{60} = 12.5 \text{ cycle/sec}$$

$$V_a \text{ per cycle} = \frac{0.0254}{12.5} = 2.032 \times 10^{-3} \text{ m}^3/\text{cycle}$$

$$\eta_v = \frac{2.032 \times 10^{-3}}{0.0024} = 84.7\%$$

Example 1 - Solution

$$\eta_f = \frac{P_{out}}{m_f \times Q_{HV}}$$

If $\eta_f = 0.3$

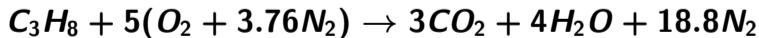
$$0.3 = \frac{P_{out}}{0.002 \times 44300}$$

$$P_{out} = 26.58 \text{ kW}$$

Example 2

The molar composition of dry exhaust gas of a Propane-fueled SI engine (C_3H_8) is given below (water was removed before the measurement). Calculate the equivalence ratio and then perform the exhaust gas analysis.

- $CO_2 = 10.8\%$
- $O_2 = 4.5\%$
- $CO = 0\%$
- $H_2 = 0\%$



Example 2 - Solution

- Mass of fuel

$$12 \times 3 + 8 \times 1 = 44 \text{ kg}$$

- Mass of air

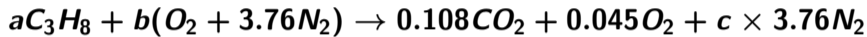
$$5(16 \times 2 + 14 \times 2 \times 3.76) = 686.4 \text{ kg}$$

- Stoichiometric air-fuel ratio

$$(A/F)_{stoic} = \frac{686.4}{44} = 15.6$$

Example 2 - Solution

To determine the actual Air-Fuel mass ratio A/F , consider the following reaction:

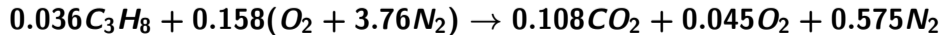


Balancing the elements:

$$\text{Carbon balance: } 3a = 0.108 \qquad a = 0.036$$

$$\text{Oxygen balance: } b = 0.108 + 0.045 \qquad b = 0.153$$

$$\text{Nitrogen balance: } 3.76 \times b = 3.76 \times c \qquad c = 0.153$$



Example 2 - Solution

- Mass of fuel

$$0.036 \times 12 \times 3 + 0.036 \times 8 \times 1 = 1.584 \text{ kg}$$

- Mass of air

$$0.158(16 \times 2 + 14 \times 2 \times 3.76) = 21.69 \text{ kg}$$

- Actual air-fuel ratio

$$(A/F)_{act} = \frac{21.69}{1.584} = 13.7$$

Example 2 - Solution

- Actual air-fuel ratio

$$(A/F)_{act} = \frac{21.69}{1.584} = 13.7$$

- Stoichiometric air-fuel ratio

$$(A/F)_{stoic} = \frac{686.4}{44} = 15.6$$

- Equivalence Ratio

$$\phi = \frac{(A/F)_{stoic}}{(A/F)_{act}} = \frac{15.6}{13.7} = 1.14$$

Example 2 - Solution

- Exhaust Gas Analysis:

$$\text{Total No. of moles of product} = 0.108 + 0.045 + 0.575 = 0.728$$

- Dry Analysis:

$$CO_2\% = \frac{0.108}{0.728} = 14.84\%$$

$$O_2\% = \frac{0.045}{0.728} = 6.18\%$$

$$N_2\% = \frac{0.575}{0.728} = 78.98\%$$

End of Lecture 9

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