Solution to Quiz

Problem 1

Mass \( M = 1500 \text{ kg} \)

Vehicle frontal area \( A = 1.8 \times 1.5 = 2.7 \text{ m}^2 \)

Gear ratio @ 5th gear: \( 3.89 \times 0.69 = 2.69 \)

Level road cruising at velocity \( U = 35 \text{ mph} = 15.7 \text{ m/s} \)

Rolling resistance \( F_R = C_R M g = 0.015 \times 1500 \times 9.81 = 236.7 \text{ N} \)

Drag resistance \( F_D = \frac{1}{2} ho A C_D U^2 = \frac{1}{2} \times 1.2 \times (15.7)^2 \times 0.3 = 119.8 \text{ N} \)

Brake Power \( P_b = \frac{1}{6} \left[ F_R + F_D \right] U = \frac{1}{6} \left[ 236.7 + 119.8 \right] \times 15.7 \times 0.29 = 2.59 \text{ kW} \)

1) Engine speed \( n = \frac{N \times \pi}{60} \text{ or } \frac{N}{\pi} = \frac{15.7 \times 2.99}{60 \times 0.632} = 19.69 \text{ rpm} \)

\( P_b = \text{BMEP} \times V_p \times \eta \) \( \Rightarrow \text{BMEP} = \frac{P_b}{V_p \times \eta} = \frac{0.29 \times 10^3}{2.5 \times 10^{-3} \times 0.619} = 182.7 \text{ bar} \)

2) The operating point is at (B) on the engine map.

The sfc is 275 g/kWh

To travel 1 mile, time \( \Delta t = \frac{35}{35} \text{ s} \)

Energy required \( = \frac{1}{35} = 0.29 \)

Fuel required \( = 0.180 \times 49.4 = 8.91 \text{ g} \)

Vol @ fuel: \( 61.8 \text{ cc} = \frac{11.8}{3.755} \text{ gallon} \)

\( = 1.60 \text{ gallon} \)

\( \text{Time @ mpg} = \frac{1}{14.1\text{mpg}} = 0.072 \text{ h} \)

3) \( P_b = \frac{1}{n} \left[ F_R + F_D + M a \frac{dv}{dt} \right] \)

WOT at 1180 rpm \( \Rightarrow \text{BMEP} = 8 \text{ bar} \)

\( P_b = 8 \times 10^5 \times 2.5 \times 10^{-3} \times (0.64) = 10.7 \text{ kW} \)

\( \frac{dv}{dt} = \left[ \frac{8 P_b}{n} - F_R - F_D \right] \frac{M \omega}{1800} \)

\( = 0.48 \text{ m/s}^2 \)
4) 3rd gear: see ratio Gr: 3.89 x 1.19 = 4.63

\[ N = \frac{k (60)}{\pi d} = \frac{157 \times 4.6}{0.85} = 90.7 \text{ rev/min} = 200 \times \text{rpm} \]

\[ \text{BMEP} = \frac{(F_m + F_o) \cdot L}{\pi (N^2 - N_0^2)} = \frac{(119 + 2207) \times 15.7}{0.85 \times 15.7 \times 0.85} = 1.37 \text{ bar} \]

The operating point before homing the gas is at point (c).

At WOT @ 2207 rpm, BMEP = 13.5 bar (point (b) in the figure)

\[ P_b = \frac{\text{BMEP} \times L}{R} = \frac{13.5 \times 10^5 \times 2.5 \times 10^{-3}}{15.7} = 62 \text{ kN} \]

\[ \frac{du}{dx} = \frac{1}{M} \left( \frac{d_v \cdot P_b - F_o - F_v}{u} \right) = \frac{0.05 \times 10^5 \times 2.5 \times 10^{-3}}{15.7} = 0.7 - 0.88 \]

Note the much higher force comes from (a) the engine speed is higher and (b) that the BMEP at WOT is the higher N is larger.
Problem 2

Heat release at 298K, \( \Delta H_m \) = \((\Sigma H_\text{f}^0)_{\text{f}} - (\Sigma H_\text{f}^0)_{\text{g}}\)

(a) \( C + \frac{1}{2} O_2 \rightarrow CO \)

\( \Delta H_{\text{release}} = (0) - (-110.5) = 110.5 \text{kJ/mol & exothermic} \)

(b) \( \text{H}_2(\text{g}) + \text{CO} \rightarrow \text{H}_2\text{O} + \text{CO}_2 \)

\( \Delta H_{\text{release}} = \left[(-285.8)+(-110.5)\right] - [-293.5] = -2.81 \text{kJ/mol & exothermic} \)

(c) Reactions

<table>
<thead>
<tr>
<th>Reactants</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mol of H(_2)</td>
<td>a mol of H(_2)</td>
</tr>
<tr>
<td>1 mol of CO</td>
<td>b mol of CO</td>
</tr>
<tr>
<td>c mol of H(_2)</td>
<td>d mol of CO ( = \frac{10.41}{4.27} )</td>
</tr>
</tbody>
</table>

Equilibrium: \( H_2 + CO = H_2O + CO_2 \)

Thus, \( \frac{c}{d} = k = 4.27 \)

Carbon balance \( b + a = 1 \) \( (i) \)

Hydrogen balance \( a + b = 2 \) \( (ii) \)

Oxygen balance \( a + b = 2 \) \( (iii) \)

Thus, \( \frac{c}{d} = k \) ; Substitute into \((ii) \) and substitute from \((iii) \) \( \Rightarrow a = b \)

Thus, \( \Delta H_{\text{reaction}} = \frac{1}{a^2} \times k \)

Therefore, \( a = \frac{1}{1 + \sqrt{k}} = 0.326 \); \( b = 0.326 \); \( c = 0.674 \); \( d = 0.674 \)

(d) \( \text{H}_2(\text{g}) + \text{CO} \rightarrow 0.5 \text{H}_2 \text{(H}_2\text{O) + 0.674 (H}_2\text{O}) \)

\( \Delta H_{\text{release}} = \left[(-285.8)+(-110.5)\right] - \left[0.5 \times (-241.8)+(-110.5)\right] + 0.674 \times (-293.5) \)

\( = (-396.3) - \left\{(-121.4)+(-293.5)\right\} \)

\( = -16.9 \text{kJ/mol} \)

\( \text{in fuel stream; slightly endothermic} \)

(a) \( \text{C}_3\text{H}_6 + 3 \text{H}_2 \rightarrow 

\( \Delta H_{\text{release}} = 3 \times \left[(-110.5) - [(-184.1) + (-293.5)] \right] \)

\( = -331.5 - (-577.6) = 246.1 \text{kJ/mol & exothermic} \)
(f) The reactions are:

\[ \text{A: } C + \frac{1}{2} O_2 \rightarrow CO \]

\[ \text{B: } \text{H}_2(\text{g}) + \text{CO}_2 \rightarrow 0.376(\text{H}_2\text{O} + \text{CO}) + 0.674(\text{H}_2 + \text{CO}_2) \]

\[ \text{C: } 3\text{CO} + 3\text{H}_2 \rightarrow \text{C}_2\text{H}_6\text{O} + \text{CO}_2 \]

To make 1 mole of DME takes:

- 1 cycle of C
- \(\frac{3}{0.674}\) cycles of B to make the \(\text{H}_2\)
- The above step would generate \(\left(\frac{3}{0.674} \times 0.376\right)\) mole of \(\text{CO}\), so to make up for the \(\text{CO}\) required in B, needs \(3 - \left(\frac{3}{0.674} \times 0.376\right)\) cycles of B
- Need \(\frac{3}{0.674}\) cycles of B to produce CO for B

**Summary:**

\[ \text{1 cycle of C} = 1 \]

\[ \frac{3}{0.674} \text{cycles of B} = 4.45 \]

\[ 2\left(\frac{3}{0.674} \times 0.376\right) + \frac{3}{0.674} \text{cycles of B} = 6 \]

**Energy released**

\[ \text{Q}_{\text{B}} = (246.1) + 4.45(-16.23) + 6(110.5) = 876.9 \text{kJ/Kmol B} \]

\[ \frac{3}{0.674} \text{(Kmol C)} = 5 \]

Compared to burning directly, the 6 mole of C used in the 6 cycles of A:

\[ 6\text{C} + 6\text{O}_2 \rightarrow 6\text{CO}_2 \]

Energy released = \(6(-393.5) = 2361\text{kJ}\)

The heating value of DME (1Kmol):

\[ \text{C}_2\text{H}_6\text{O} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O} \]

Energy released = 1328.3 kJ/Kmol DME

The difference is in the heat release in the production (876.9 kJ)

and the energy used to vaporize the lea water

\[ \frac{3}{0.674} \times (285.8 \times 341.8) = 195.85 \]

\[ 1328.3 + 876.9 + 195.85 = 2361 \text{ - Check} \]