جامعــة محمــد بوضياف بالمسيلة
كليــة التكنولوجيا
القسم: هندسة ميكانيكية

لجمهورية الجزائرية الديمقراطية الشعبية
زارة التعليم العالي والبحث العلمي

FINAL EXAM SOLUTION (2025-2026)

SOLUTION: EXERCISE 1(13 pts)

Preliminary constants:

- $Cv = Cp/\gamma = 1.005/1.4 = 0.7178$ kJ/kg·K
- $R = Cp - Cv = 0.2872$ kJ/kg·K

1. State 2 (Isentropic Compression)

- **Volume (v_1):** $v_1 = RT_1/P_1 = 0.2872 \times 310/95 = 0.9372$ m^3/kg
- **Volume (v_2):** $v_2 = v_1/r = 0.9372/16 \Longrightarrow \mathbf{v_2 = 0.05858}$ m^3/kg $\boxed{1}$
- **Temperature (T_2):** $T_2 = T_1 \times r^{\gamma-1} = 310 \times 16^{0.4} \Longrightarrow \mathbf{T_2 = 939.75}$ K $\boxed{1}$
- **Pressure (P_2):** $P_2 = P_1 \times r^{\gamma} = 0.95 \times 16^{1.4} \Longrightarrow \mathbf{P_2 = 46.08}$ bar $\boxed{1}$
- **2. Intermediate Pressure (Isochoric Heat Addition)**

Heat added at constant volume (Qv): 25% of 1600=400 kJ/kg.

- $Qv = Cv(T_3 - T_2) \Longrightarrow 400 = 0.7178(T_3 - 939.75) \Longrightarrow \mathbf{T_3 = 1497\ K}$ $\boxed{1}$
- **Pressure (P_3):** Since $v_3 = v_2$, $P_3/T_3 = P_2/T_2 \Longrightarrow P_3 = 46.08 \times 1497/939.75 \Longrightarrow \mathbf{P_3 = 73.41}$ bar $\boxed{1}$

3. Max Temperature ($T4$ - Isobaric Heat Addition)

Heat added at constant pressure (Qp): 75% of 1600=1200 kJ/kg.

- $Qp = Cp(T_4 - T_3) \Longrightarrow 1200 = 1.005(T_4 - 1497) \Longrightarrow \mathbf{T_4 = 2691\ K}$ $\boxed{1}$

4. Cut-off Ratio (ρ)

- Since $P_3 = P_4$, $\rho = v_4/v_3 = T_4/T_3 = 2691/1497 \Longrightarrow \boldsymbol{\rho = 1.798}$ $\boxed{1}$

5. Temperature at end of expansion (T_5)

- Expansion ratio $r_e = v_5/v_4 = v_1/v_4 = v_1/v_2 * v_3/v_4 = r/\rho = 16/1.798 = 8.898$
- $T_5 = T_4 \times (1/re)^{\gamma-1} = 2691 \times (1/8.898)^{0.4} \Longrightarrow \mathbf{T_5 = 1122.3}$ K $\boxed{1}$

6. Work calculation

- **Compression (w_{1-2})**
- $\Delta U_{1\text{-}2}=Q_{1\text{-}2}- w_{1-2}=0+w_{1-2} = Cv(T_2-T_1) \Longrightarrow w_{1-2}=\mathbf{-452.1}$ kJ/kg
- **Expansion (w_{3-5}):** This is w_{3-4} (isobaric)+w_{4-5} (isentropic). **1**
- $w_{3-4}= =P_3(v_4-v_3)=R(T_4-T_3)=0.2872(2691-1497)=342.9$ kJ/kg
- $w_{4-5}= -Cv(T_5-T_4)=0.718(1122.3-2691)=1126.1$ kJ/kg
- **Total: 1469** kJ/kg **1**

7. Net Work (w_{net})

- $w_{net}=w_{expansion}+w_{compression}=1469-452.1=\mathbf{1016.9}$ kJ/kg **1**

8. Thermal Efficiency (ηth)

- $\eta_{th}= w_{net}/Q_{in}=1016.9/1600=\mathbf{63.56\%}$ **1**

9. Comparison (r=16)

- **Otto:** $\eta=1-(1/16)^{0.4}=67.2\%$
- **Diesel:** **1**

$$\eta_{diesel} = 1 - \frac{1}{\gamma r^{\gamma-1}}\left[\frac{\rho^{\gamma}-1}{\rho-1}\right] = 58{,}22\%$$

SOLUTION: EXERCISE 2 (07 pts)

1. Combustion Equation (Hexane)

$C_6H_{14}+9.5(O_2+3.76N_2)\rightarrow 6CO_2+7H_2O+35.72N_2$ **1**

2. Stoichiometric Air-Fuel Ratio (*AFRst*)

- Mass Fuel =(6×12)+(14×1)=86 g/mol
- Mass Air = 9.5×(32+3.76×28)≈9.5×137.28=1304.16 g
- ***AFRst*:** 1304.16/86=**15.16** kg_{air}/kg_{fuel} **1**

3. Mass flow rate of fuel ($\dot{m}_{fuel}$)

- Speed = 120 km/h=33.33 m/s.
- Consumption = 7.91 L/100km=0.0791 L/km.
- Volume flow rate =0.0791 L/km×120 km/h=9.492 L/h=**0.009492 m³/h.**
- $\dot{m}_{fuel}$=0.009492×750/3600=**0.0019775** kg/s

1

4. Actual Air Mass Flow ($\dot{m}_{air}$)

- $AFRact=\lambda\times AFRst$=1.05×15.16=15.918
- $\dot{m}_{air}=\dot{m}_{fuel}\times$15.918=**0.03148** kg/s

1

5. Chemical Power ($\dot{Q}_{in}$)

- $\dot{Q}_{in}=\dot{m}_{fuel}\times LHV$=0.0019775×44400=**87.8** kW

1

6. Brake Power (P_{brake})

- $P_{brake}=\dot{Q}_{in}\times$0.32=**28.1** kW

0.5

7. Brake Specific Fuel Consumption ($BSFC$)

- $BSFC$= $\dot{m}_{fuel}$ (in g/h)/ P_{brake} (in kW)= 0.0019775×1000×3600/28.1=**253.3** g/kW·h

0.5

8. CO_2 Emissions (g/km)

- Mass of fuel per km = 0.0791 L/km×0.750 kg/L=0.059325 kg/km=59.325 g/km.
- From equation: 86g fuel produces 6×44=264g CO_2.
- CO_2 per km=59.325×(264/86)=**182.1** g/km

0.5

9. Mass fraction of H_2O in exhaust (y_{H2O})

- Total mass of exhaust per kg of fuel = 1+AFR_{act}=1+15.918=16.918 kg.
- Mass of H_2O per kg of fuel = (7×18)/86=1.465 kg.
- y_{H2O}=1.465/16.918=**0.0866** (or 8.66%)

0.5