

Subject Name & Code:**BASIC MECHANICAL ENGINEERING- BE01R00081**

Assignment – 1**Topic: Properties of Gas.**

(Disclaimer: The purpose of these AI-generated responses is just education and reference. Utilise them to grasp topics and structure, but always rewrite in your own words and double-check the content before submitting.)

Q-1: One kg of ideal gas is heated from 18°C to 98°C. Assuming $R = 0.264 \text{ kJ/kg}\cdot\text{K}$ and $\gamma = 1.2$ for the gas and Work done 200 kJ, find:

- (1) Specific heats**
 - (2) The change in internal energy**
 - (3) The change in enthalpy**
 - (4) The heat supplied**
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Answer:

Given:

- Mass, $m = 1 \text{ kg}$
 - $T_1 = 18 + 273 = 291 \text{ K}$
 - $T_2 = 98 + 273 = 371 \text{ K}$
 -
 - $\gamma = 1.2$
 - Work done, $W = 200 \text{ kJ}$
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Step 1: Find Specific Heats (c_v, c_p)

We know:

$$\gamma = \frac{c_p}{c_v} \text{ and } c_p - c_v = R$$

Substitute $c_p = \gamma c_v$:

$$\begin{aligned} \gamma c_v - c_v &= R \\ c_v(\gamma - 1) &= R \end{aligned}$$

Now,

∴ (1) Specific Heats:

Step 2: Find Change in Internal Energy (ΔU)

$$\begin{aligned}\Delta U &= mc_v(T_2 - T_1) \\ \Delta U &= 1 \times 1.32 \times (371 - 291) \\ \Delta U &= 1.32 \times 80 = 105.6 \text{ kJ}\end{aligned}$$

∴ (2) Change in Internal Energy = 105.6 kJ

Step 3: Find Change in Enthalpy (ΔH)

$$\begin{aligned}\Delta H &= mc_p(T_2 - T_1) \\ \Delta H &= 1 \times 1.584 \times 80 = 126.72 \text{ kJ}\end{aligned}$$

∴ (3) Change in Enthalpy = 126.72 kJ

Step 4: Find Heat Supplied (Q)

Using the First Law of Thermodynamics:

$$\begin{aligned}Q &= \Delta U + W \\ Q &= 105.6 + 200 = 305.6 \text{ kJ}\end{aligned}$$

∴ (4) Heat Supplied = 305.6 kJ

Final Answers for Q-1:

- (1)
- (2) $\Delta U = 105.6 \text{ kJ}$
- (3) $\Delta H = 126.72 \text{ kJ}$
- (4) $Q = 305.6 \text{ kJ}$

Q-2: The characteristic constant for a gas is 0.29 kJ/kg·K. 0.9 kg of this gas receives heat at constant pressure of 8 bar. The increase in temperature is from 25°C to 300°C as a result of heat supplied. If $C = 0.72 \text{ kJ/kg·K}$, calculate:

- (1) Increase in internal energy
 - (2) Increase in work done (External energy)
 - (3) Increase in total energy
 - (4) Specific heat at constant pressure
-

Answer:

Given:

- - Mass, $m = 0.9$ kg
 - Constant Pressure process, $p = 8$ bar
 - $T_1 = 25 + 273 = 298$ K
 - $T_2 = 300 + 273 = 573$ K
 - (Given as 'C')
-

Step 1: Find Specific Heat at Constant Pressure (c_p)

∴ (4) Specific heat at constant pressure,

Step 2: Find Increase in Internal Energy (ΔU)

$$\Delta U = mc_v(T_2 - T_1)$$

$$\Delta U = 0.9 \times 0.72 \times (573 - 298)$$

$$\Delta U = 0.9 \times 0.72 \times 275 = 0.9 \times 198 = 178.2 \text{ kJ}$$

∴ (1) Increase in Internal Energy = 178.2 kJ

Step 3: Find Increase in Work Done (W)

For a constant pressure process:

$$W = p(V_2 - V_1)$$

Using ideal gas law: $pV = mRT$

$$W = mR(T_2 - T_1)$$

$$W = 0.9 \times 0.29 \times 275 = 0.9 \times 79.75 = 71.775 \text{ kJ}$$

∴ (2) Increase in Work Done = 71.78 kJ

Step 4: Find Increase in Total Energy (ΔH)

The "increase in total energy" for a constant pressure process is the change in enthalpy (ΔH).

$$\Delta H = mc_p(T_2 - T_1)$$

$$\Delta H = 0.9 \times 1.01 \times 275 = 0.9 \times 277.75 = 249.975 \text{ kJ}$$

∴ (3) Increase in Total Energy = 250.0 kJ

Final Answers for Q-2:

- (1) Increase in Internal Energy = **178.2 kJ**
- (2) Increase in Work Done = **71.78 kJ**
- (3) Increase in Total Energy = **250.0 kJ**
- (4) Specific heat at constant pressure = **1.01 kJ/kg·K**

Q-3: One kg of an ideal gas is heated from 18°C to 98°C. Assuming $R = 0.27 \text{ kJ/kg}\cdot\text{K}$ and $\gamma = 1.18$ for the gas, calculate:

- (1) Specific heats
- (2) Change in internal energy
- (3) Change in enthalpy

Answer:

Given:

- $m = 1 \text{ kg}$
- $T_1 = 291 \text{ K}$
- $T_2 = 371 \text{ K}$
-
- $\gamma = 1.18$

Step 1: Find Specific Heats (c_v, c_p)

∴ (1) Specific Heats:

Step 2: Find Change in Internal Energy (ΔU)

$$\Delta U = mc_v(T_2 - T_1) = 1 \times 1.5 \times 80 = 120 \text{ kJ}$$

∴ (2) Change in Internal Energy = 120 kJ

Step 3: Find Change in Enthalpy (ΔH)

$$\Delta H = mc_p(T_2 - T_1) = 1 \times 1.77 \times 80 = 141.6 \text{ kJ}$$

∴ (3) Change in Enthalpy = 141.6 kJ

Final Answers for Q-3:

- (1)
- (2) $\Delta U = 120 \text{ kJ}$
- (3) $\Delta H = 141.6 \text{ kJ}$

Q-4: A cylinder contains 0.6 m^3 of a gas at a pressure of 1 bar, and 90°C . The gas is compressed to a volume of 0.18 m^3 according to law $PV^n = C$. The final pressure is 5 bar. Calculate:

- (1) The mass of gas
 - (2) The value of index 'n' for compression
 - (3) The increase in internal energy of the gas
 - (4) The heat received or rejected by the gas during compression. Take $\gamma = 1.4$ and $R = 294.2 \text{ J/kg}\cdot\text{K}$.
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Answer:

Given:

- $V_1 = 0.6 \text{ m}^3$
 - $p_1 = 1 \text{ bar} = 100 \text{ kPa}$
 - $T_1 = 90 + 273 = 363 \text{ K}$
 - $V_2 = 0.18 \text{ m}^3$
 - $p_2 = 5 \text{ bar} = 500 \text{ kPa}$
 - $\gamma = 1.4$
 -
 - Process: $PV^n = C$
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Step 1: Find Mass of Gas (m)

$$m = \frac{p_1 V_1}{RT_1} = \frac{100 \times 0.6}{0.2942 \times 363}$$

$$m = \frac{60}{106.7946} = 0.5618 \text{ kg}$$

∴ (1) Mass of gas = 0.5618 kg

Step 2: Find Polytropic Index (n)

For a polytropic process: $p_1V_1^n = p_2V_2^n$

$$\frac{p_2}{p_1} = \left(\frac{V_1}{V_2}\right)^n$$

$$\frac{5}{1} = \left(\frac{0.6}{0.18}\right)^n$$

$$5 = (3.333)^n$$

Taking log on both sides:

$$\ln(5) = n \cdot \ln(3.333)$$

$$1.6094 = n \times 1.20397$$

$$n = \frac{1.6094}{1.20397} = 1.337$$

∴ (2) Polytropic index, n = 1.337

Step 3: Find Final Temperature (T₂)

Using the ideal gas law:

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

$$T_2 = T_1 \times \frac{p_2V_2}{p_1V_1} = 363 \times \frac{500 \times 0.18}{100 \times 0.6}$$

$$T_2 = 363 \times \frac{90}{60} = 363 \times 1.5 = 544.5 \text{ K}$$

Step 4: Find Increase in Internal Energy (ΔU)

First, find c_v :

$$\Delta U = mc_v(T_2 - T_1)$$

$$\Delta U = 0.5618 \times 0.7355 \times (544.5 - 363)$$

$$\Delta U = 0.5618 \times 0.7355 \times 181.5$$

$$\Delta U = 0.5618 \times 133.49 = 74.99 \text{ kJ}$$

∴ (3) Increase in Internal Energy = 75.0 kJ

Step 5: Find Heat Transfer (Q)

Work done for polytropic process:

$$W = \frac{p_1V_1 - p_2V_2}{n - 1}$$

$$W = \frac{(100 \times 0.6) - (500 \times 0.18)}{1.337 - 1}$$

$$W = \frac{60 - 90}{0.337} = \frac{-30}{0.337} = -89.02 \text{ kJ}$$

Using First Law:

$$Q = \Delta U + W$$

$$Q = 74.99 + (-89.02) = -14.03 \text{ kJ}$$

The negative sign indicates heat is rejected.

∴ (4) Heat Rejected = 14.03 kJ

Final Answers for Q-4:

- (1) Mass of gas = **0.562 kg**
- (2) Polytropic index, $n = 1.337$
- (3) Increase in Internal Energy = **75.0 kJ**
- (4) Heat Rejected = **14.03 kJ**

Q-5: 0.3 kg of air at a pressure of 1.5 bar occupies 0.2 m³ and is compressed to 15 bar according to the law $PV^{1.25} = C$. Calculate:

- (1) **The change in internal energy of the air**
 - (2) **The work done on or by the air**
 - (3) **The heat received or rejected by the air**
- Take $C_p = 1.005 \text{ kJ/kg}\cdot\text{K}$ and $C_v = 0.718 \text{ kJ/kg}\cdot\text{K}$.**

Answer:

Given:

- $m = 0.3 \text{ kg}$
- $p_1 = 1.5 \text{ bar} = 150 \text{ kPa}$
- $V_1 = 0.2 \text{ m}^3$
- $p_2 = 15 \text{ bar} = 1500 \text{ kPa}$
- Polytropic index, $n = 1.25$
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Step 1: Find Initial and Final State Properties**Initial Temperature (T_1):**

$$T_1 = \frac{p_1 V_1}{mR} = \frac{150 \times 0.2}{0.3 \times 0.287} = \frac{30}{0.0861} = 348.4 \text{ K}$$

Final Volume (V_2):

For polytropic process: $p_1 V_1^n = p_2 V_2^n$

$$V_2 = V_1 \left(\frac{p_1}{p_2} \right)^{1/n} = 0.2 \times \left(\frac{1.5}{15} \right)^{1/1.25} = 0.2 \times (0.1)^{0.8}$$

$$(0.1)^{0.8} \approx 0.1585$$

$$V_2 = 0.2 \times 0.1585 = 0.0317 \text{ m}^3$$

Final Temperature (T_2):

$$T_2 = \frac{p_2 V_2}{mR} = \frac{1500 \times 0.0317}{0.3 \times 0.287} = \frac{47.55}{0.0861} = 552.3 \text{ K}$$

Step 2: Find Change in Internal Energy (ΔU)

$$\Delta U = m c_v (T_2 - T_1)$$

$$\Delta U = 0.3 \times 0.718 \times (552.3 - 348.4)$$

$$\Delta U = 0.3 \times 0.718 \times 203.9 = 0.3 \times 146.4 = 43.92 \text{ kJ}$$

\therefore (1) Change in Internal Energy = 43.92 kJ (Increase)

Step 3: Find Work Done (W)

For polytropic process:

$$W = \frac{p_1 V_1 - p_2 V_2}{n - 1}$$

$$W = \frac{(150 \times 0.2) - (1500 \times 0.0317)}{1.25 - 1}$$

$$W = \frac{30 - 47.55}{0.25} = \frac{-17.55}{0.25} = -70.2 \text{ kJ}$$

\therefore (2) Work Done = -70.2 kJ (Work is done on the air)

Step 4: Find Heat Transfer (Q)

Using First Law of Thermodynamics:

$$Q = \Delta U + W$$

$$Q = 43.92 + (-70.2) = -26.28 \text{ kJ}$$

\therefore (3) Heat Transfer = -26.28 kJ (Heat is rejected)

Final Answers for Q-5:

- (1) Change in Internal Energy = **43.92 kJ**
- (2) Work Done = **-70.2 kJ** (Work done on the air)
- (3) Heat Transfer = **-26.28 kJ** (Heat rejected)

Q-6: 2 kg of air at a pressure of 7 bar occupies a volume of 0.3 m³. This air is then expanded to a volume of 1.5 m³ isothermally. Assuming $C_p = 0.9965 \text{ kJ/kg}\cdot\text{K}$, $C_v = 0.708 \text{ kJ/kg}\cdot\text{K}$ and $R = 287.2 \text{ J/kg}\cdot\text{K}$, calculate:

- (1) The final temperature**
- (2) The work done**
- (3) Heat abstracted or rejected in the process.**

Answer:**Given:**

- $m = 2 \text{ kg}$
- $p_1 = 7 \text{ bar} = 700 \text{ kPa}$
- $V_1 = 0.3 \text{ m}^3$
- $V_2 = 1.5 \text{ m}^3$
- Process: Isothermal (Constant Temperature)
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Step 1: Find Initial and Final Temperature**Initial Temperature (T_1):**

$$T_1 = \frac{p_1 V_1}{mR} = \frac{700 \times 0.3}{2 \times 0.2872} = \frac{210}{0.5744} = 365.6 \text{ K}$$

For isothermal process: $T_2 = T_1$ **∴ (1) Final Temperature = 365.6 K**

Step 2: Find Work Done (W)

For isothermal process:

$$W = p_1 V_1 \ln \left(\frac{V_2}{V_1} \right)$$

$$W = 700 \times 0.3 \times \ln \left(\frac{1.5}{0.3} \right)$$

$$W = 210 \times \ln(5) = 210 \times 1.6094 = 337.97 \text{ kJ}$$

∴ (2) Work Done = 337.97 kJ (Work done by the air)

Step 3: Find Heat Transfer (Q)

For an ideal gas in an isothermal process: $\Delta U = 0$

Using First Law of Thermodynamics:

$$Q = \Delta U + W = 0 + 337.97 = 337.97 \text{ kJ}$$

∴ (3) Heat Transfer = 337.97 kJ (Heat absorbed)

Final Answers for Q-6:

(1) Final Temperature = **365.6 K**

(2) Work Done = **337.97 kJ** (Work done by the air)

(3) Heat Transfer = **337.97 kJ** (Heat absorbed)