Chapter 11: Thermodynamics - NCERT Exercise Solutions

Physics Class 11

11.1 Geyser Fuel Consumption Rate

Given: Water flow = 3.0 L/min, temperature rise: 27°C → 77°C, heat of combustion = 4.0×10^4 J/g

Solution:

Heat required per minute = m × c × ΔT
= (3.0 kg/min) × (4186 J/kg·K) × (50 K)
= 627,900 J/min = 10.465 kJ/s

Fuel consumption rate = Heat required / Heat of combustion
= 10.465×10^3 J/s / 4.0×10^4 J/g
= 0.262 g/s = 15.7 g/min

Answer: Fuel consumption = 0.26 g/s or 15.7 g/min

11.2 Heating Nitrogen at Constant Pressure

Given: m = 2.0×10^{-2} kg nitrogen, ΔT = 45°C, molecular mass = 28, R = 8.3 J/mol·K

Solution:

Number of moles: $\mu = m/M = 0.02/0.028 = 0.714$ mol

For diatomic gas: $C_p = (7/2)R = 3.5 \times 8.3 = 29.05$ J/mol·K

Heat required: $Q = \mu C_p \Delta T = 0.714 \times 29.05 \times 45 = 933$ J

Answer: Heat required = 933 J

11.3 Conceptual Questions

(a) Why don't two bodies settle to mean temperature? Bodies have different heat capacities. Final temperature depends on masses and specific heats: $T_f = (m_1c_1T_1 + m_2c_2T_2)/(m_1c_1 + m_2c_2)$

(b) Why should coolant have high specific heat? High specific heat means more heat absorption per unit temperature rise, providing better cooling efficiency and temperature stability.

(c) Why does tire pressure increase while driving? Friction with road converts kinetic energy to heat, increasing tire temperature. For fixed volume: $P_2/P_1 = T_2/T_1$

(d) Why are harbor towns more temperate? Water has high specific heat capacity, so coastal areas experience smaller temperature variations than inland desert regions.

11.4 Adiabatic Compression Pressure Increase

Given: 3 moles hydrogen at STP, compressed to half volume adiabatically

Solution:

For adiabatic process: $P_1V_1^\gamma = P_2V_2^\gamma$
For diatomic gas (H_2): $\gamma = 7/5 = 1.4$

$P_2/P_1 = (V_1/V_2)^\gamma = (V_1/(V_1/2))^{1.4} = 2^{1.4} = 2.64$

Answer: Pressure increases by factor of 2.64

11.5 Work Done in Different Processes

Given: Adiabatic A→B: Work done on system = 22.3 J Alternative path A→B: Heat absorbed = 9.35 cal = 39.2 J

Solution:

Adiabatic process: $Q = 0$, $W = -22.3$ J, $\Delta U = -W = 22.3$ J

Alternative process: $Q = 39.2$ J, $\Delta U = 22.3$ J (same states)
From First Law: $Q = \Delta U + W$
$39.2 = 22.3 + W$
$W = 16.9$ J

Answer: Work done by system = 16.9 J

11.6 Free Expansion Analysis

Given: Gas expands from container A to evacuated container B

Solution: (a) Final pressure: P_final = P_initial/2 (volume doubles, temperature constant)

(b) Change in internal energy: $\Delta U = 0$ (free expansion, no temperature change for ideal gas)

(c) Change in temperature: $\Delta T = 0$ (no work done against external pressure)

(d) Intermediate states on P-V-T surface: NO (non-equilibrium expansion, no well-defined intermediate states)

11.7 Electric Heater Power Balance

Given: Heat supplied = 100 W, Work done by system = 75 J/s

Solution:

From First Law: $Q = \Delta U + W$
Rate of internal energy increase = $dU/dt = \dot{Q} - \dot{W}$
= 100 W - 75 W = 25 W

Answer: Internal energy increases at 25 W

11.8 Work Done in Combined Process

Given: Linear process D→E, then isobaric process E→F

Solution: From P-V diagram:

Process D→E (linear):
Initial: (2×10^3 Pa, 2×10^{-3} m^3)
Final: (8×10^3 Pa, 5×10^{-3} m^3)
Work = Area under line = $\frac{1}{2}(P_1 + P_2)(V_2 - V_1)$
= $\frac{1}{2}(2\times10^3 + 8\times10^3)(5\times10^{-3} - 2\times10^{-3})$ = 15 J

Process E→F (isobaric at 8×10^3 Pa):
Volume change: $5\times10^{-3} \rightarrow 2\times10^{-3}$ m^3
Work = $P(V_2 - V_1) = 8\times10^3 \times (-3\times10^{-3}) = -24$ J

Total work = 15 + (-24) = -9 J

Answer: Net work done = -9 J (work done on gas)

Key Concepts Summary

First Law Applications

- **$Q = \Delta U + W$** (sign conventions: +Q absorbed, +W done by system)
- **Adiabatic:** $Q = 0$, so $W = -\Delta U$
- **Isothermal:** $\Delta U = 0$ (ideal gas), so $Q = W$
- **Isochoric:** $W = 0$, so $Q = \Delta U$

Specific Heat Relations

- **Molar heat capacities:** $C_p - C_v = R$
- **Diatomic gas:** $C_v = (5/2)R$, $C_p = (7/2)R$, $\gamma = 7/5$
- **Monatomic gas:** $C_v = (3/2)R$, $C_p = (5/2)R$, $\gamma = 5/3$

Process Equations

- **Isothermal:** PV = constant
- **Adiabatic:** PV^γ = constant
- **Isobaric:** V/T = constant
- **Isochoric:** P/T = constant

Work Calculations

- **General:** $W = \int P\, dV$
- **Isobaric:** $W = P(V_2 - V_1)$
- **Isothermal:** $W = \mu RT \ln(V_2/V_1)$
- **Adiabatic:** $W = (P_1V_1 - P_2V_2)/(\gamma-1)$