CONCORDIA UNIVERSITY
FACULTY OF ENGINEERING AND COMPUTER SCIENCE
DEPARTMENT OF MECHANICAL INDUSTRIAL AND AEROSPACE ENGINEERING

NAME:

ID:

WRITE YOUR ANSWERS IN THE BOXES. SHOW ALL YOUR WORK, NEATLY, IN THE FOLLOWING SPACE.

PROBLEM I [6 pts]

Energy is added to a piston-cylinder arrangement, and the piston is withdrawn in such a way that the temperature (i.e., the quantity *PV*) remains constant. The initial pressure and volume are 200 kPa and 2 m³, respectively. If the final pressure is 100 kPa,

- ***Calculate the work done by the ideal gas on the piston.***

Work done [kJ]
277 kJ

$$W_{12} = \int_1^2 P\,dV$$

but $PV = c^t$ $\quad W_{12} = c^t \int_1^2 \frac{dV}{V}$

$$W_{12} = P_1 V_1 \ln\left(\frac{V_2}{V_1}\right) \quad 2$$

with $V_2 = \frac{P_1 V_1}{P_2} = \frac{200 \times 2}{100} = 4\ m^3$ $\quad 2$

Then $W_{12} = 200 \times 2 \ln\left(\frac{4}{2}\right)$

$$\boxed{W_{12} = 277\ kJ} \quad 2$$

PROBLEM II [12 pts]

A cylinder device fitted with a piston contains initially argon gas at 100kPa and 27°C occupying a volume of 0.4 m^3. The argon gas is first compressed while **the temperature is held constant** until the volume reaches 0.2 m^3. Then the argon is allowed to expand while **the pressure is held constant** until the volume becomes 0.6 m^3.

- ***Determine the total amount of net heat transferred to the argon in kJ.***

Consider Argon as an ideal gas with: C_v=0.3122 kJ/kg K; C_p = 0.5203 kJ/kg·K; R=0.2081 kJ/kg K

Net heat transferred [kJ]
172.3 kJ

- mass of the Argon:

$$m = \frac{P_1 V_1}{R T_1} = \frac{100 \times 0.4}{0.2081 \times 300} = 0.6407 \text{ kg} \quad 1$$

- Process from 1 → 2 isothermal:

$$W_{12} = P_1 V_1 \ln \frac{V_2}{V_1} = 100 \times 0.4 \ln\left(\frac{0.2}{0.4}\right) = -27.7 \text{ kJ} \quad 2$$

- Process from 2 → 3 isobaric

$$W_{23} = P_2 (V_3 - V_2)$$

with $P_2 = P_1 \frac{V_1}{V_2} = 100 \times \frac{0.4}{0.2} = 200 \text{ kPa}$ 2

$$W_{23} = 200 \times (0.6 - 0.2) = 80 \text{ kJ} \quad 2$$

- Net Heat transferred:

$$m C_v (T_3 - T_1) = Q_{net} - W_{13} \quad 2$$

with $T_3 = T_2 \frac{V_3}{V_1} = 300 \frac{0.6}{0.2} = 900\,K.$ 2

Then: $Q_{net} = (0.6407)(0.3122)(900-300) + (-27.7 + 80)$

$$\boxed{Q_{net} = +172.3\ kJ}$$ 1

PROBLEM II [12 pts]
Argon gas flows steadily with a velocity of 50 m/s into an adiabatic turbine at 1500 kPa and 450°C. The gas leaves the turbine at 140 kPa with a velocity of 140 m/s. The inlet area of the turbine is 55 cm^2. The power output of the turbine is measured to be 180 kW.

- ***Determine the exit temperature of the argon.***

Consider Argon as an ideal gas with: C_v=0.3122 kJ/kg K; C_p = 0.5203 kJ/kg·K; R=0.2081 kJ/kg K

Exit Temperature [°K]
580.4

- computation of $\dot{m}$:

$\dot{m}_1 = \dot{m}_2 = \dot{m}$

$v_1 = \frac{RT_1}{P_1} = \frac{0.2081 \times 723}{1500} = 0.1003\ m^3/kg$ (3)

$\dot{m} = \frac{A_1 V_1}{v_1} = \frac{0.0055 \times 50}{0.1003} = 2.742\ kg/s$ (3)

- 1st law of thermo:

| ΔE_k and ΔE_p are neglected
| steady state

$\dot{W} = -\dot{m}\left(h_2 - h_1 + \frac{V_2^2 - V_1^2}{2}\right)$

$\dot{W} = -\dot{m}\left(c_p(T_2 - T_1) + \frac{V_2^2 - V_1^2}{2 \times 1000}\right)$ (4)

Then: $\boxed{T_2 = 580.4\ K}$ (2)