MIDTERM ENGR251/2 Fall 16

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

NAME:

ID:

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

PROBLEM I [12 pts]

A volume of 0.1 m^3 containing an ideal gas is compressed from a pressure of 120 kPa and a temperature of 25°C to a pressure of 1.2 MPa according to the law $PV^{1.2} = \text{constant}$. Determine:

1- The work transferred during the compression.

Note: for a polytropic process the work can be written as: $W = \frac{P_2V_2 - P_1V_1}{1-n}$ for $n \neq 1$

2- The change in internal energy (in kJ).
3- The heat transferred during the compression.

Assume: $C_v = 0.72$ kJ/kg.K and $R = 0.285$ kJ/kg.K

Work	Change in internal energy
-28.2 kJ	14.2 kJ
Heat transferred	
-14 kJ	

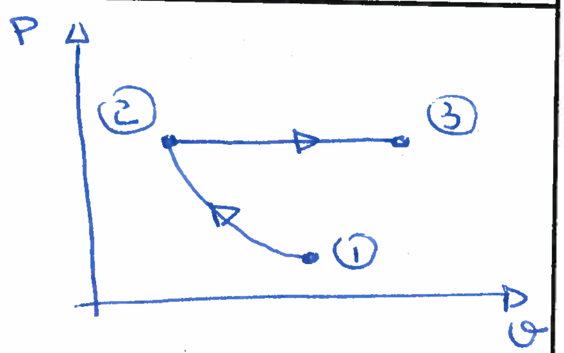
PROBLEM II [12 pts]

A cylinder device fitted with a piston contains initially argon gas at 100 kPa 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 net amount of heat transferred to the argon in kJ and sketch the system's thermodynamic path on a $P-v$ diagram.

Assume: $C_v = 0.3122$ kJ/kg.K and $R = 0.2081$ kJ/kg.K.

Note: isothermal process for an ideal gas: PV=C^t

Heat transferred
+172.3 kJ
$P-v$ diagram



1 pt

PROBLEM III [6 pts] : Multiple Choice or Short Answer.

1- The state postulate is completely satisfied by:

- [ ] One intensive property
- [x] Two independent intensive properties 1
- [ ] Two independent extensive properties
- [ ] One extensive and one intensive property

2- Which thermodynamic property is introduced using the zeroth law of thermodynamics?

Temperature 1

3 - Consider a saturated liquid-vapor mixture of pure water. Select each of the following combinations of properties that fulfill the state postulate:

- [ ] Temperature and pressure
- [x] Pressure and specific volume 1
- [x] Temperature and quality
- [x] Temperature and specific volume

4- Is C_p higher than C_v? Explain why from a physical point-of-view.

$C = \frac{Q}{\Delta T}$ at $Q = ct$ the variation in T° is higher then if $P = ct$ $\Delta T|_{Q=ct} > \Delta T|_{P=ct}$. then $C_p > C_v$. 1

~~6~~5- For a substance to be at **thermodynamic** equilibrium, it must be at:

Thermal equilibrium, Mechanical equilibrium, 1

Phase equilibrium, and chemical equilibrium.

~~5~~6- At which thermodynamic state can the liquid, solid, and gaseous phases coexist?

- [ ] At the critical point.
- [x] At the triple point. 1
- [ ] At thermodynamic equilibrium.
- [ ] Two phases can never coexist.
- [ ] All three phases cannot coexist at the same time.

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Problem I 12 pts

1) we have $W = \frac{P_2V_2 - P_1V_1}{1-n}$ $n \neq 1$

V_1 ✓ P_1 ✓ T_1 ✓ P_2 ✗ V_2 ✗

computation of V_2.

$PV^n = c^t \Rightarrow P_1V_1^n = P_2V_2^n$

1 $V_2 = V_1\left(\frac{P_1}{P_2}\right)^{1/n}$

$= 0.1\left(\frac{120}{1200}\right)^{1/1.2}$

1 $\boxed{V_2 = 0.0147\ m^3}$

Then $\boxed{W = -28.2\ kJ}$ 2

2) The change in internal energy for an ideal gas: $\Delta U = m\,c_v(T_2 - T_1)$

we have to determine T_2 and m

$m = \frac{P_1V_1}{RT_1} = \frac{120 \times 0.1}{0.285 \times 298} = 0.141\ kg$

1 1

and : $m_1 = m_2 \Rightarrow \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$.

1

So $\boxed{T_2 = T_1 \left(\frac{P_2 V_2}{P_1 V_1} \right) = 438\,K}$ 1

Then $\Delta U = m\, c_v\, (T_2 - T_1)$ 1

$\boxed{\Delta U = 14.2\ kJ}$ 1

3) Heat transferred

Hyp: ΔE_p and ΔE_k are neglected

1st law for a closed system

$\Delta U = Q - W \Leftrightarrow Q = \Delta U + W$ 1

$= 14.2 - 28.2$

$\boxed{Q = -14\ kJ}$ 1

Problem II 12 pts

Hyp : ΔE_K and ΔE_p are neglected

$$\Delta U = Q_{net} - W_{net}$$

$$Q_{net} = Q_{13}$$

$$W_{net} = \underbrace{W_{12}}_{\text{isothermal}} + \underbrace{W_{23}}_{\text{isobaric}}$$

Then $m c_v (T_3 - T_1) = Q_{net} - W_{net}$ 2

1

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

$$\boxed{m = 0.6407 \text{ kg}}$$ 1

computation of W_{12}

$$W_{12} = P_1 V_1 \ln \frac{V_2}{V_1} = 100 (0.4) \ln \left(\frac{0.2}{0.4}\right)$$

1

$$\boxed{W_{12} = -27.7 \text{ kJ}}$$ 1

computation of W_{23}

$$W_{23} = \cancel{P_2 (V_3 - T_2)} \quad P_2 (V_3 - V_2) \quad 1$$

with $P_2 = P_1 \dfrac{V_1}{V_2} = 200\ kPa$ (isotherm process) 1

Then $\boxed{W_{23} = 80\ kJ}$ 1

finally:

$$Q_{net} = \Delta U + W_{net}$$

$$= m\, c_v (T_3 - T_1) + W_{net}$$

with $T_3 = T_2 \dfrac{V_3}{V_2} = 900\ K$ (isobaric process) 1

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

$\boxed{Q = +172.3\ kJ}$ 1

P-v diagram 1