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AE 209 THERMODYNAMICS

QUIZ 5

A piston–cylinder device contains 0.8 kg of nitrogen initially at 100 kPa and 27 °C. The nitrogen is now compressed slowly in a polytropic process during which $PV^{1.3}$ constant until the volume is reduced by one-half. Determine the work done and the heat transfer for this process. (Take values for N_2 as R = 0.2968 kPa.m³/kg.K and c_v = 0.744 kJ/kg.K)

Answer:

$P_1 = 100\ kPa \quad T_1 = 300\ K$

$\forall_1 = \forall \quad \forall_2 = \frac{\forall}{2}$

$E_{in} - E_{out} = \Delta E_{system}$

$W_{b,in} - Q_{out} = \Delta U = m(u_2 - u_1)$

Need to find P_2 and T_2 of Nitrogen. Thus;

$$P_2 \cdot \forall_2^{1,3} = P_1 \cdot \forall_1^{1,3} \longrightarrow P_2 = \left(\frac{\forall_1}{\forall_2}\right)^{1,3} \cdot P_1 = \left(\frac{\forall}{\frac{\forall}{2}}\right)^{1,3} \cdot (100\ kPa) = 246,2\ kPa$$

$$\underbrace{P_1 \cdot \forall_1 = m \cdot R \cdot T_1}_{\text{constant}} \longrightarrow \frac{P_1 \cdot \forall_1}{T_1} = \frac{P_2 \cdot \forall_2}{T_2} \rightarrow T_2 = \frac{P_2}{P_1} \cdot \frac{\forall_2}{\forall_1} \cdot T_1$$

$$= \frac{246,2}{100} \cdot 0,5 \cdot 300\ K = 369,3\ K$$

Now, boundary work can be calculated;

$$W_{b,in} = \int_1^2 P\, d\forall = -\frac{P_2 \cdot \forall_2 - P_1 \cdot \forall_1}{1 - n} = -\frac{m \cdot R \cdot (T_2 - T_1)}{1 - n}$$

$$= -\frac{(0,8\ kg) \cdot (0,2968\ kJ/kg \cdot K) \cdot (369,3 - 300\ K)}{1 - 1,3} = 54,8\ kJ$$

Finally, from the energy balance equation, heat transfer can be found;

$$Q_{out} = W_{b,in} - m \cdot c_v (T_2 - T_1)$$

$$= 54,8\ kJ - (0,8\ kg) \cdot (0,744\ kJ/kg\ K) \cdot (369,3 - 360\ K)$$

$$= 13,6\ kJ$$