Thermodynamics
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Lecture No 26
Tutorial problem - Part 2

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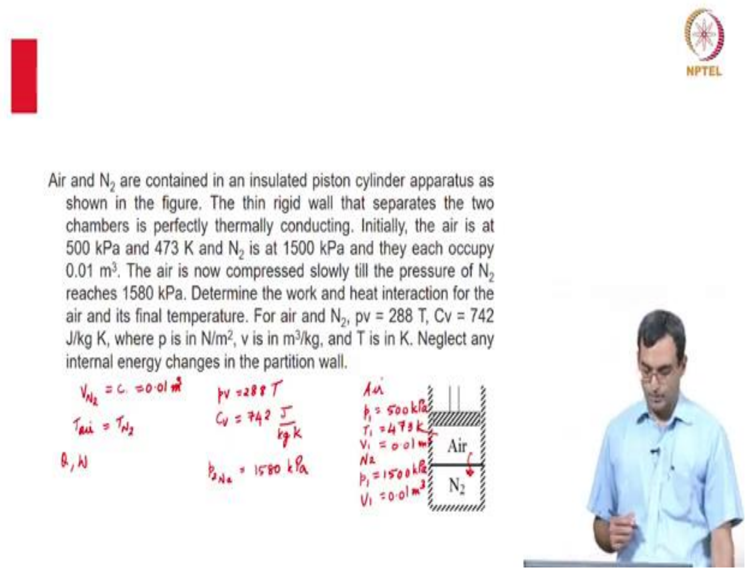

Figure 1.

Solution of the problem in Fig. 1:

$p_{1,air} = 500\ kPa, T_{1,air} = 473\ K, V_{1,air} = 0.01\ m^3$

$p_{1,N_2} = 1500\ kPa, V_{1,N_2} = 0.01\ m^3$

$pv = 288\ T, C_v = 742\,\frac{J}{kgK},$

$p_{2,N_2} = 1580\ kPa, V_{2,N_2} = 0.01\ m^3$(as the separating wall is rigid)

Since the separating wall is perfectly conducting, the temperature of air and nitrogen is equal all the time, $T_{air} = T_{N_2}$. Also, $T_{1,air} = T_{1,N_2} = 473\ K$.

As the air gets compressed, it gets heated and transfers some amount of heat to nitrogen. There is no work interaction for nitrogen as the separating wall is rigid.

Using pv = 288 T, we can calculate T_{2,N_2}.

$\frac{p_{1,N_2}v_{1,N_2}}{T_{1,N_2}} = \frac{p_{2,N_2}v_{2,N_2}}{T_{2,N_2}} \rightarrow \frac{p_{1,N_2}V_{1,N_2}}{T_{1,N_2}} = \frac{p_{2,N_2}V_{2,N_2}}{T_{2,N_2}}$ (since $m_{1,N_2} = m_{2,N_2}$)

Also, $V_{1,N_2} = V_{2,N_2}$.

Therefore, $T_{2,N_2} = 498.2\ K = T_{2,air}$

For nitrogen, the first law is $dU = \delta Q - \delta W$. As the work interaction is zero for nitrogen, $dU = \delta Q$.

After integration, $\Delta U = Q$. $\Delta U = m_{N_2} C_v \Delta T$. Hence, we need the mass of nitrogen.

Now, $\frac{p_{1,N_2}V_{1,N_2}}{m_{1,N_2}} = 288\ T_{1,N_2} \quad \rightarrow \quad m_{N_2} = 0.11\ kg$

For nitrogen, $Q = \Delta U = 0.11 \times 742 \times (498.2 - 473) = 2\ kJ$

Heat interaction for nitrogen is positive as it is receiving heat from air. The heat interaction for the air is negative of the heat interaction for nitrogen (air is losing heat to nitrogen).

The first law for air in the integrated form is $\Delta U = Q - W$. We are asked to find out W.

For air, $\Delta U = m_{air} C_v \Delta T$. We need the mass of air.

Now, $\frac{p_{1,air}V_{1,air}}{m_{1,air}} = 288\ T_{1,air} \quad \rightarrow \quad m_{air} = 0.036\ kg$

Now, $\Delta U = m_{air} C_v \Delta T = 0.036 \times 742 \times (498.2 - 473) = 686\ J$

Therefore, for air, $W = Q - \Delta U = (-2000\ J) - 686\ J = -2686\ J$

Work interaction for air is negative as work is being done on the system (air).

Therefore, for air, $\boldsymbol{Q = -2\ kJ, W = -2.686\ kJ, T_2 = 498.2\ K}$

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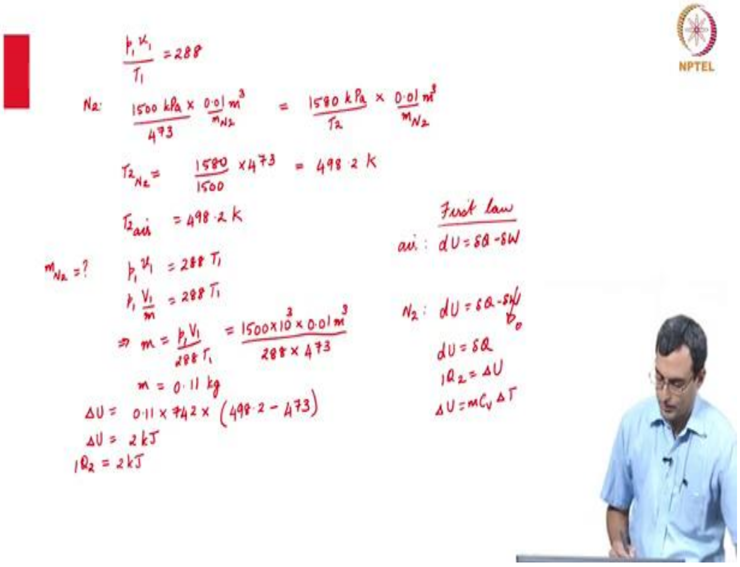

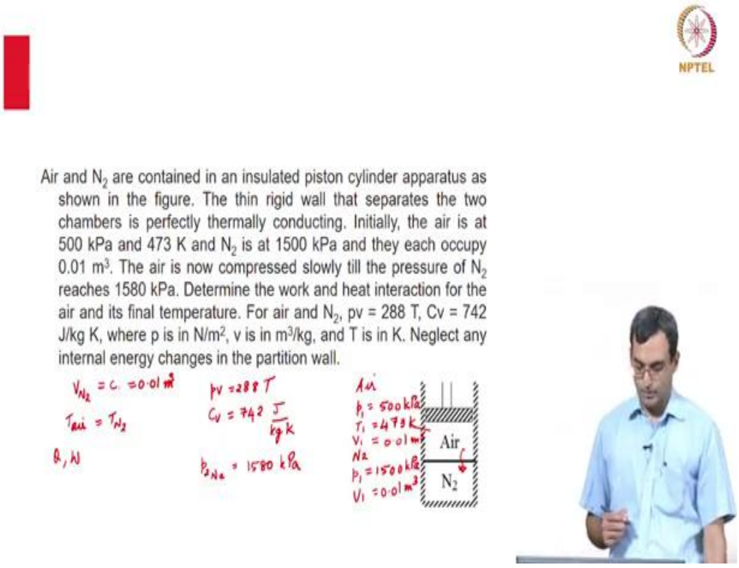

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