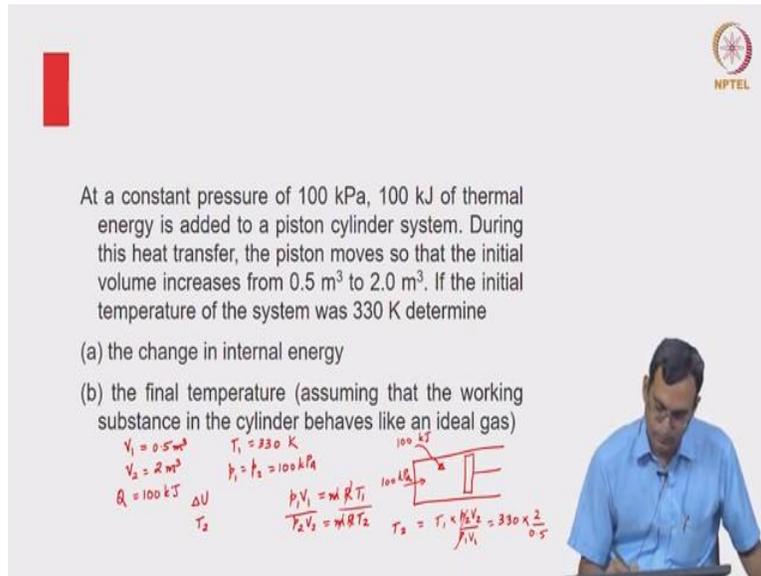


**Thermodynamics**  
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**Lecture - 31**  
**Tutorial Problem - Part 5**

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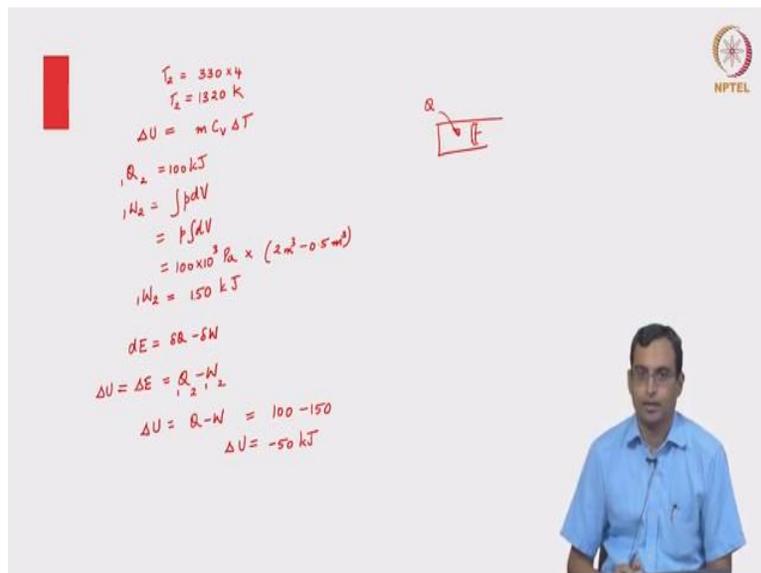
At a constant pressure of 100 kPa, 100 kJ of thermal energy is added to a piston cylinder system. During this heat transfer, the piston moves so that the initial volume increases from 0.5 m<sup>3</sup> to 2.0 m<sup>3</sup>. If the initial temperature of the system was 330 K determine

(a) the change in internal energy  
 (b) the final temperature (assuming that the working substance in the cylinder behaves like an ideal gas)

$V_1 = 0.5 \text{ m}^3$      $T_1 = 330 \text{ K}$   
 $V_2 = 2 \text{ m}^3$      $p_1 = p_2 = 100 \text{ kPa}$   
 $Q = 100 \text{ kJ}$      $\Delta U$

$p_1 V_1 = n R T_1$      $\frac{100 \text{ kJ}}{100 \times 10^3 \text{ Pa}} = n R T_1$   
 $\frac{p_2 V_2 = n R T_2}{p_1 V_1 = n R T_1}$      $T_2 = T_1 \times \frac{V_2}{V_1} = 330 \times \frac{2}{0.5}$

Figure 1.



$T_1 = 330 \text{ K}$   
 $T_2 = 1320 \text{ K}$   
 $\Delta U = m C_v \Delta T$

$Q_2 = 100 \text{ kJ}$   
 $W_2 = \int p dV$   
 $= p \int dV$   
 $= 100 \times 10^3 \text{ Pa} \times (2 \text{ m}^3 - 0.5 \text{ m}^3)$   
 $W_2 = 150 \text{ kJ}$

$dE = \delta Q - \delta W$   
 $\Delta U = \Delta E = Q_2 - W_2$   
 $\Delta U = 100 - 150$   
 $\Delta U = -50 \text{ kJ}$

**Solution of the problem given in Fig. 1:**

$$V_1 = 0.5 \text{ m}^3, V_2 = 2 \text{ m}^3, Q = 100 \text{ kJ}, T_1 = 330 \text{ K}, p_1 = p_2 = 100 \text{ kPa}$$

Assumption: working substance in the cylinder is an ideal gas.

We write the ideal gas equation for two states of the system and take their ratio to calculate  $T_2$ , the final temperature.

$$\frac{p_1 V_1}{p_2 V_2} = \frac{mRT_1}{mRT_2}$$

$$\text{Hence, } T_2 = T_1 \frac{V_2}{V_1} = 330 \times \frac{2}{0.5} = 1320 \text{ K}$$

Heat is transferred into the system. The volume of the system is increasing. Hence, work is done by the system. It is a constant pressure process.

$$W = \int p dV = p \int dV = 100 \times 10^3 \times (2 - 0.5) = 150 \text{ kJ}$$

The first law in the integrated form is,

$$\Delta U = Q - W \quad (\text{There are no changes in kinetic and potential energy. Hence, } \Delta E = \Delta U.)$$

$$\Delta U = 100 - 150 = -50 \text{ kJ}$$

Hence, the final internal energy of the system is lower than its initial internal energy. The system is losing energy during the process.