Thermodynamics
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Lecture 71
Tutorial Problem (1 number)

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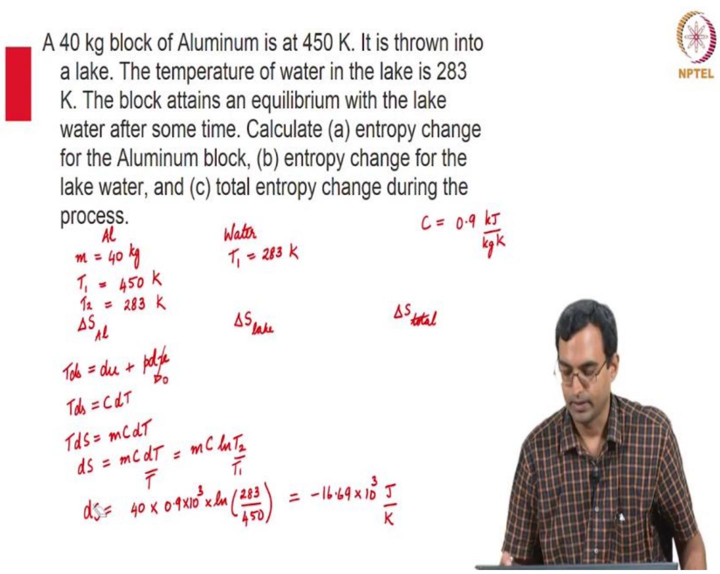

Figure 1.

Solution of the problem in Fig. 1:

$m = 40\ kg, T_{1,Al} = 450\ K, T_{2,Al} = 283\ K, T_{1,water} = 283\ K, C_{Al} = 0.9\ \frac{kJ}{kg \cdot K}$

Lake is very big. Hence, the lake water's mass and temperature do not change because of the Aluminium block. The block attains equilibrium with the lake water and attains lake water's temperature.

We have, Tds = du + pdv

For solids and liquids, $dv \approx 0$. Hence, Tds_{Al} = du = CdT → $TdS_{Al} = mCdT$ → $dS_{Al} = mC\frac{dT}{T}$.

Integrating, $\Delta S_{Al} = mC \ln \frac{T_{2,Al}}{T_{1,Al}} = -16.69 \times 10^3 \frac{J}{K}$ = change in entropy of the Aluminium block.

ΔS_{Al} is negative as the Aluminium block is losing heat. The block's entropy is decreasing.

The process is isothermal for the lake water. Hence, it is reversible.

For the lake water, $dS = \frac{\delta Q}{T}$. Integrating, $\Delta S_{water} = \frac{Q}{T}$.

Now, heat gained by the lake water = heat lost by the aluminium block = $mC\left(T_{2,Al} - T_{1,Al}\right) = -6\ MJ$.

Heat gained by the water is + 6 MJ. Hence, $\Delta S_{water} = \frac{Q}{T} = \frac{6\times10^6}{283} = 21.2\frac{kJ}{K}$.

Total entropy change during the process = entropy change of the universe = entropy change for the aluminium block + entropy change for the lake water = $4.5 \times 10^3\frac{J}{K}$.

The entropy changes for the lake water and the aluminium block are not equal. The entropy is not conserved. We will soon see the principle of increase of entropy in this context. The only way to reduce the entropy of a system is to transfer heat out of the system. For an isolated system, the entropy cannot reduce. Hence, the entropy of the universe cannot decrease as it is the isolated system. If all the processes are reversible, then the change in entropy of the system is 0.

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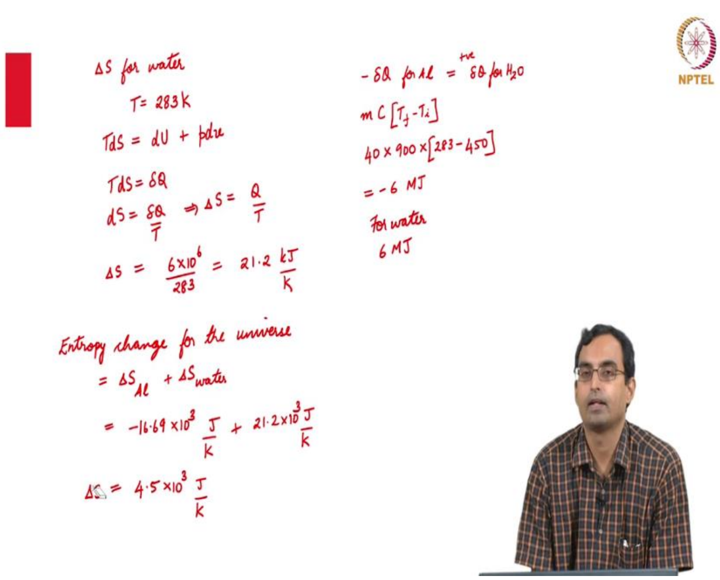

A 40 kg block of Aluminum is at 450 K. It is thrown into a lake. The temperature of water in the lake is 283 K. The block attains an equilibrium with the lake water after some time. Calculate (a) entropy change for the Aluminum block, (b) entropy change for the lake water, and (c) total entropy change during the process.

$C = 0.9 \frac{kJ}{kg\,K}$

Al

$m = 40\ kg$

$T_1 = 450\ K$

$T_2 = 283\ K$

ΔS_{Al}

Water

$T_1 = 283\ K$

ΔS_{lake}

ΔS_{total}

$T ds = du + \cancel{p\,dv}_{\to 0}$

$T ds = C dT$

$T dS = mC dT$

$dS = mC \frac{dT}{T} = mC \ln \frac{T_2}{T_1}$

$dS = 40 \times 0.9 \times 10^3 \times \ln\left(\frac{283}{450}\right) = -16.69 \times 10^3 \frac{J}{K}$