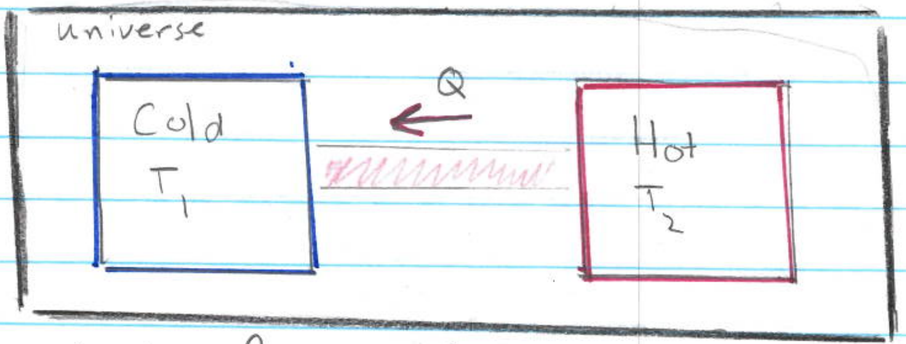
Now We can Distinguish between Reversible and Irreversible



- Then heat flows from right to left increasing probability & entropy of universe:

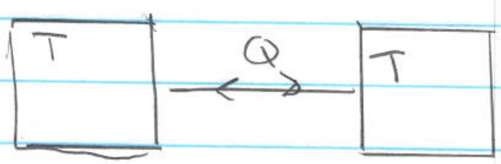
$$\frac{dS_{tot}}{dt} = \left(\frac{1}{T_1} - \frac{1}{T_2}\right)\frac{dE_1}{dt} \qquad \Delta E_1 = Q$$

$$\Delta E_2 = -Q_2$$

$$\boxed{\Delta S_{univ} = \Delta S_{TOT} = \overset{\Delta S_1}{\frac{Q}{T_1}} - \overbrace{\frac{Q}{T_2}}^{\Delta S_2} > 0}$$

this is irreversible and $\Delta S_{universe} \equiv \Delta S_{TOT} > 0$.

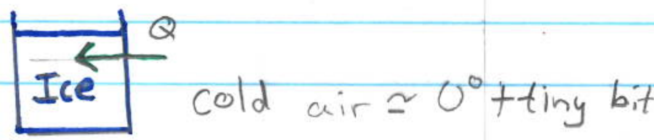
- Now the spotaneous flow of heat will stop when $T_1 = T_2$, then heat can flow both ways reversibly:



$\Delta S = 0$

Example:

Ice and Water



- Ice of mass m (400g) is surrounded by air only slightly above 0°C actring as a "resevoir" meaning it is large enough so that it can absorb heat w/out changing themperature significantly. The ice has a latent heat per kilo of $L_m = 334$ J/kg meaning it takes 334 J to melt one kilo of ice. The temperature doesn't change during the melting process. Find the change in entropy as the ice melts of ice, air, and universe

$$\Delta S_{air} = -\frac{Q}{T_{freeze}} = -\frac{mL_m}{T_{frz}}$$

$$\Delta S_{ice} = +\frac{Q}{T_{frz}} = +\frac{mL_m}{T_{frz}}$$

$$\left.\begin{array}{l} \Delta S_{air} \\ \Delta S_{ice} \end{array}\right\} \Delta S_{universe} = 0$$

- If the air would drop to just below freezing The ice will slowly begin to freeze. The process is reversible, $\Delta S_{universe} = 0$

Blundel: Example 14.2

- Take a large resevoir (e.g. lake) and small ball with specific heat C. (The difference between C_p and C_v is very small for solids). The lake has temperature T_R the ball has initial temperature T_S, "system" is ball.

Now

heat $\text{đ}Q$ flows in to system

- Then in one step:

$$dS_S = +\frac{\text{đ}Q}{T} \qquad dS_R = -\frac{\text{đ}Q}{T_R}$$

ball   lake

- The ball's change in temperature is $+\text{đ}Q = +C\,dT_S$:
So we find

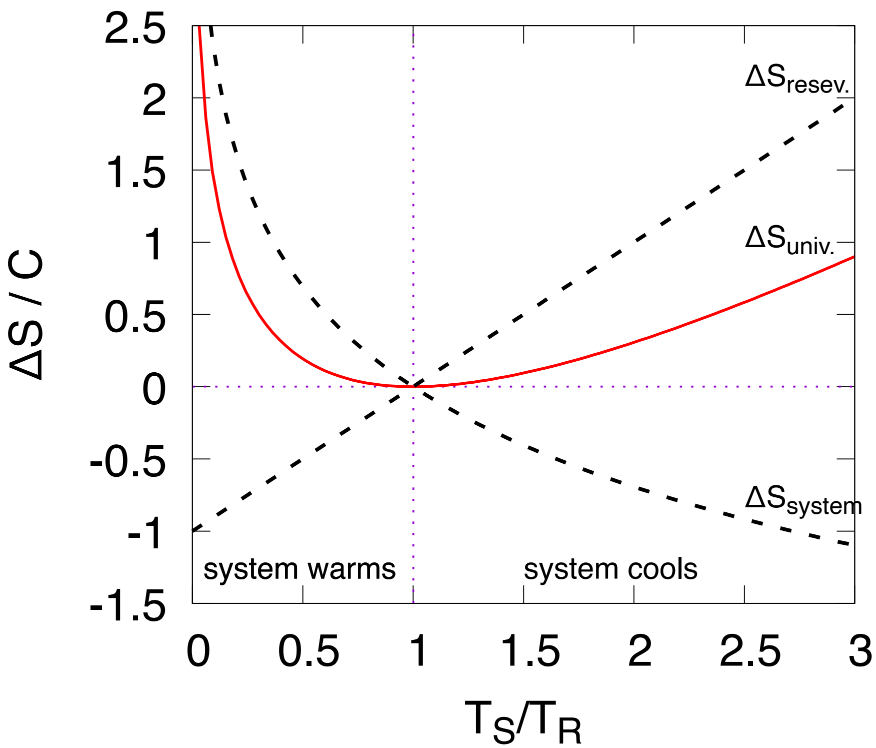
$$dS_s = +\frac{C\,dT}{T} \qquad dS_R = -\frac{C\,dT}{T_R}$$

lake's temperature remains fixed

Integrating from $T = T_S \ldots T_R$

$$\boxed{\Delta S_S = C \ln \frac{T_R}{T_S}} \qquad \boxed{\Delta S_R = -C\,\frac{T_R - T_S}{T_R}}$$

Change in Entropy Ball in Lake: Blundell Example 14.1



System = Ball

The ball has (initial) temperature T_S

Reservoir = Lake

The reservoir has constant temperature T_R

Universe is the ball and lake

And

$$\Delta S_{universe} = \Delta S_S + \Delta S_R$$

$$\boxed{\Delta S = C \ln\left(\frac{T_R}{T_S}\right) + C\left(\frac{T_S}{T_R} - 1\right)}$$

A plot of the ΔS is shown on the next slide.

- As the temperature ratio deviates significantly from one the change in entropy $\Delta S_{universe}$ gets larger and larger. For $T_S/T_R \simeq 1$, ΔS is nearly zero, and the process is (almost) reversible

- In home work you will show that if $T_S = T_R + \delta T$ with δT small then

$$\Delta S_{universe} = \frac{C(\delta T)^2}{2T_R^2}$$