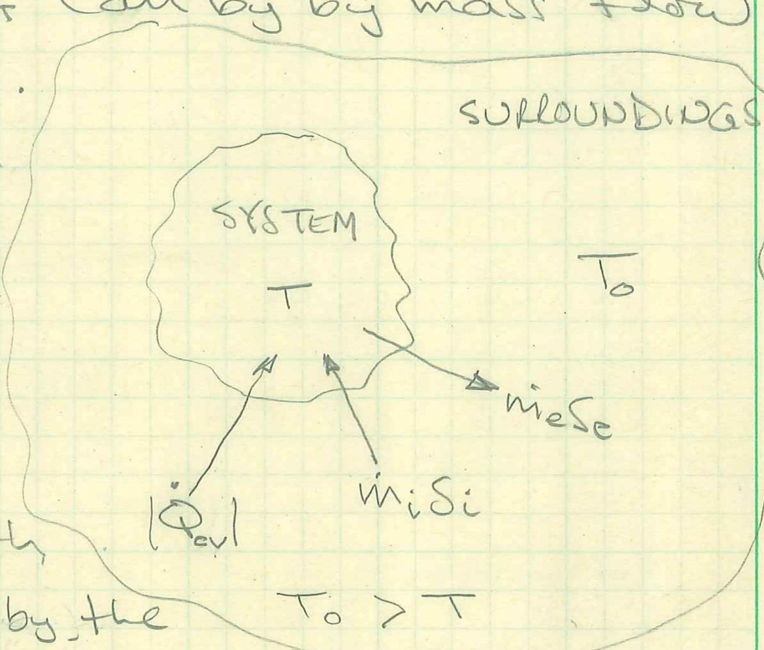
# RATE OF ENTROPY GENERATION

Consider any open or closed system at temp. T undergoing any process while interacting with the surroundings at temp. $T_o$.

$$\boxed{S_{IN} - S_{OUT} + S_{GEN} = \Delta S_{syst.}} \quad (1)$$

where $S_{IN}$ and $S_{OUT}$ can by by mass flow or heat transfer.




$\dot{m}_i$ = mass flow rate in with entropy $s_i$.
$\dot{m}_e$ = mass flow rate out with entropy $s_e$.
$|\dot{Q}_{cv}|$ is a rate of heat transfer, with direction shown by the arrow. Writing the above equation as a rate equation for the control volume (CV)

$$\boxed{\dot{S}_{cv} = \frac{dS_{cv}}{dt} = \Sigma \dot{m}_i s_i - \Sigma \dot{m}_e s_e + \frac{|\dot{Q}_{cv}|}{T} + \dot{S}_{GEN_{cv}}} \quad (2)$$

$\dot{S}_{GEN_{cv}}$ is entropy generation due to irreversibilities within the CV and is always positive. $S_{cv}$ is the extensive entropy within the CV. For the surroundings

$$\boxed{\dot{S}_{SURR} = \frac{dS_{SURR}}{dt} = \Sigma \dot{m}_e s_e - \Sigma \dot{m}_i s_i - \frac{|\dot{Q}_{cv}|}{T_o} + \dot{S}_{GEN_{SURR}}} \quad (3)$$

with $\dot{S}_{GEN_{SURR}}$ always positive.

Adding equations (2) and (3) gives

$$\frac{dS_{UNIVERSE}}{dt} = \frac{dS_{CV}}{dt} + \frac{dS_{SURR}}{dt}$$

$$= |\dot{Q}_{CV}| \left( \frac{1}{T} - \frac{1}{T_0} \right) + \dot{S}_{GEN_{CV}} + \dot{S}_{GEN_{SURR}} \quad (4)$$

Since $T_0 > T$, this is positive.

If $T > T_0$, the signs in equations (2) and (3) in front of the $\left|\frac{\dot{Q}_{CV}}{T}\right|$ terms both switch giving

$$\frac{dS_{UNIVERSE}}{dt} = |\dot{Q}_{CV}| \left( \frac{1}{T_0} - \frac{1}{T} \right) + \dot{S}_{GEN_{CV}} + \dot{S}_{GEN_{SURR}}$$

which still gives a positive number.

Therefore, the rate of change of entropy in the universe is always positive!

Entropy of the universe must increase!

Since the time rate of change for any extensive property within a CV must be zero for steady flow, $\dot{S}_{CV} = 0$.

Therefore, from equation (2), the rate of entropy generated by the CV for steady flow is

$$\boxed{\dot{S}_{GEN_{CV}} = \sum \dot{m}_e s_e - \sum \dot{m}_i s_i - \sum \frac{\dot{Q}_{CV}}{T}}$$

The summation signs allow for mass flow rates in or out at multiple places and heat transfer in or out (with the proper sign) at multiple places.