# CONSERVATION of MASS

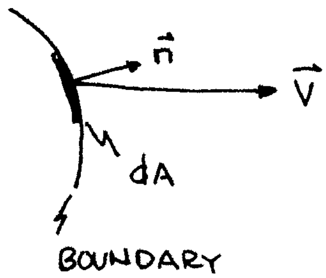
GENERAL RATE EQN:

$$\boxed{\frac{dm_{sys}}{dt} = \sum_{in} \dot{m} - \sum_{out} \dot{m}}$$

WHERE

$$m_{sys} = \int_{\forall_{sys}} \rho \, d\forall$$

## MASS FLOW CALCULATIONS




$$\dot{m} = \int_A \rho \vec{V} \cdot \vec{n} \, dA = \int_A \rho V_n dA$$

- IF $\rho$ = CONST (INCOMPESS. APPROX. → *MOST* LIQUIDS & SOLIDS)

$$\dot{m} = \rho \int_A V_n dA = \rho \dot{\forall}$$

$\dot{\forall}$ ↑ VOLUMETRIC FLOW RATE

- IF $\rho$ IS CONST & V IS UNIFORM

$$\dot{m} = \rho V_n A$$

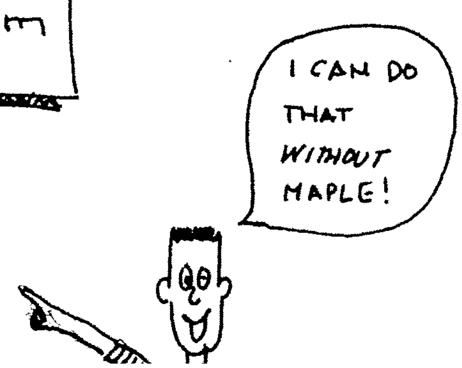
- IF $\rho$ IS CONST & V IS *NOT* UNIFORM

$$\dot{m} = \rho V_{n,AVG} A$$ DEFINES $V_{AVG}$

FINITE TIME FORM of MASS CONS.:

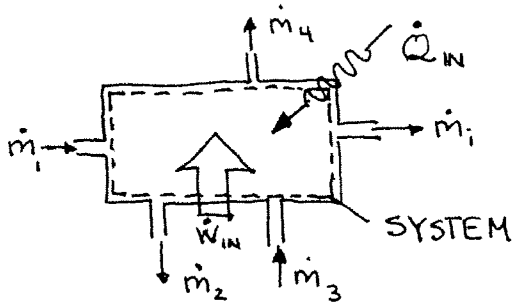
$$\boxed{m_{sys}(t_2) - m_{sys}(t_1) = \sum_{IN} m - \sum_{OUT} m}$$

⇧ BY INTEGRATING RATE FORM



# CONSERVATION of ENERGY

(SUMMARY)




## The "Big, Nasty Equation":

$$\boxed{\frac{dE_{sys}}{dt} = \dot{Q}_{IN} + \dot{W}_{IN} + \sum_{IN} \dot{m}\left(h + \frac{V^2}{2} + gz\right) - \sum_{OUT} \dot{m}\left(h + \frac{V^2}{2} + gz\right)}$$

$\underbrace{\dot{Q}_{IN} + \dot{W}_{IN}}_{\text{NON-FLOW BOUNDARIES}}$ $\underbrace{\sum \dot{m}(\ldots)}_{\text{FLOW BOUNDARIES}}$

- $E_{sys} = E_{KE} + E_{PE} + U + \ldots E_{sp}$ (MAYBE) ...

  $E_{KE} = \frac{1}{2} m_{sys} V_{sys}^2$

  $E_{PE} = m_{sys}\, g\, z_{sys}$

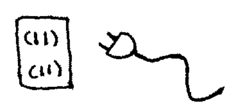
  $U =$ *Internal Energy* $= m_{sys}\, u_{sys}$

  *specific internal energy*

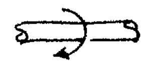
- $\dot{Q}_{IN}$ = RATE of HEAT TRANSFER IN. (DUE TO A TEMPERATURE DIFFERENCE.)

- $\dot{W}_{IN}$ = POWER IN @ *Non-flow boundaries.*

  CAN BE ELECTRICAL $\dot{W}_{ELEC} = i(V_A - V_B)$

  " " SHAFT PWR $\dot{W}_{SHFT} = \vec{\tau} \cdot \vec{\omega}$

  " " SHEAR/FRICTION $\dot{W}_F = \vec{F}_F \cdot \vec{V}$

  $= (\mu N)\hat{e}_F \cdot \vec{V}$

- $h \equiv u + Pv$

  $\equiv u + P/\rho$

  = SPECIFIC ENTHALPY

**SPECIAL FORMS** (DON'T MEMORIZE - DERIVE!)

| CLOSED SYS | CLOSED SYS, FINITE TIME |
|---|---|
| $\frac{dE_{sys}}{dt} = \dot{Q}_{IN} + \dot{W}_{IN}$ | $E_{sys,2} - E_{sys,1} = Q_{IN} + W_{IN}$ |

(  LUNCH SPECIAL )

## COMMON MISTAKES AND HOW TO AVOID THEM

DOES $\dot{W} = -\int p\,d\forall$?

NO! $W = -\int p\,d\forall$, & THAT'S JUST COMP/EXP WORK. DON'T BE SLOPPY W/ YOUR DOTS. YES DOT → POWER; NO DOT → WORK.

I DON'T KNOW WHEN TO USE $h$ & WHEN TO USE $u$.

CLEARLY DEFINE YOUR SYSTEM & TIME FRAME. *Usually* (NOT ALWAYS) $u$ POPS UP IN CLOSED SYSTEMS & $h$ IN OPEN SYSTEMS.

I DON'T KNOW WHEN TO IGNORE K.E. & P.E.

EXPERIENCE WILL GUIDE YOU (SO DO MORE PROBLEMS!) IF YOU HAVE K.E. & P.E. INFO, INCLUDE IT & SEE IF IT'S SIGNIFICANT.

I KEEP MESSING UP THE SIGN ON $Q$ AND $W$.

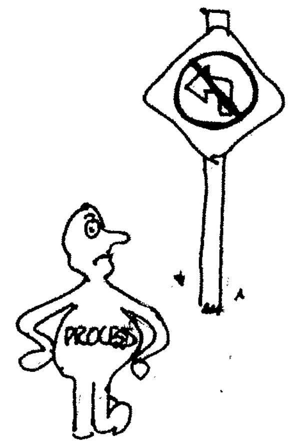
WRITE $Q$, $\dot{W}$, ETC. W/ IN/OUT SUBSCRIPTS; E.G., $W_{in}$, $\dot{Q}_{out}$.

ASK DR. THOM!

TMA

# ENTROPY & THE 2ND LAW of THERMO


ALL REAL PROCESSES HAVE PREFERED DIRECTIONS. THIS IS ONE STATEMENT OF THE SECOND LAW OF THERMO...




ANOTHER STATEMENT IS THAT **ENTROPY** (AN EXTENSIVE PROPERTY) *CAN ONLY BE PRODUCED.* IN THE LIMIT of AN INTERNALLY REVERSIBLE PROCESS, ENTROPY IS CONSERVED.

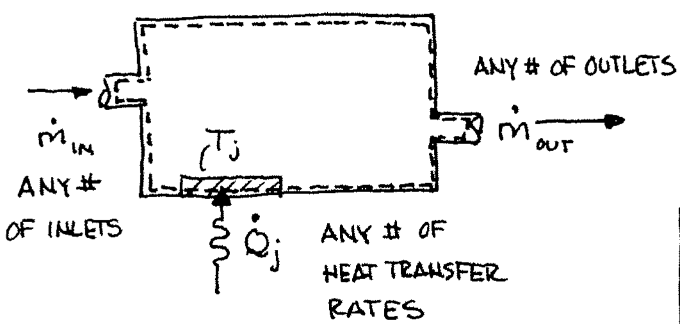
IN EQN FORM ⇨ (ENTROPY *ACCOUNTING*)

$$\boxed{\frac{dS_{sys}}{dt} = \sum \frac{\dot{Q}_j}{T_j} + \sum_{IN} \dot{m}s - \sum_{OUT} \dot{m}s + \dot{S}_{GEN}}$$

- Rate of change of entropy of system
- Rate of entropy transport in due to $\dot{Q}$
- Net rate of transport of entropy due to mass flow
- Entropy generation

$\dot{S}_{GEN} > 0$ IF INTERNALLY IRREVERSIBLE

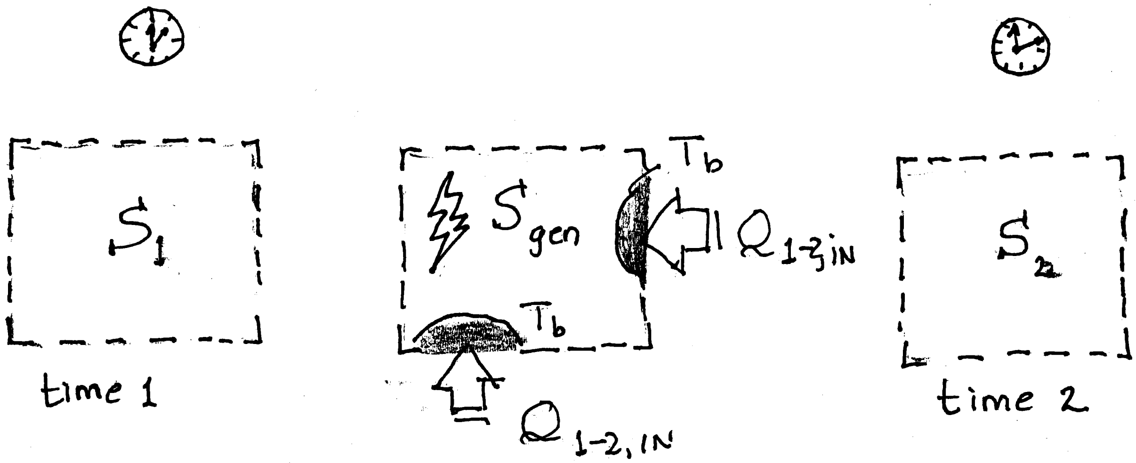
$\dot{S}_{GEN} = 0$ IF INTERNALLY REVERSIBLE




$T_j$ IS ABSOLUTE TEMPERATURE OF SYSTEM BOUNDARY WHERE $\dot{Q}$ CROSSES.

- DIMENSIONS of $S$: $\frac{[ENERGY]}{[TEMP.]}$
- $s$: ENTROPY PER UNIT MASS

# CLOSED SYSTEM, FINITE TIME




$$\boxed{\underbrace{\left(S_2 - S_1\right)_{SYSTEM}}_{\text{Increase in system } S \text{ from time 1 to time 2}} = \underbrace{\sum_i \frac{Q_{IN, 1\to2}}{T_{b,i}}}_{\text{Transport of } S \text{ into system with } Q} + \underbrace{S_{gen}}_{S \text{ generated inside system during time 1 to time 2}}}$$