Energy and the 1st law Treatment
Summary of mathematical forms

System	Expression
1. closed, general	$d\underline{E} = \delta Q + \delta W$
2. closed, simple	$d\underline{E} = d\underline{U} = \delta Q + \delta W$
3. closed, simple, only PdV work	$d\underline{U} = \delta Q - Pd\underline{V}$
4. open, simple	$d\underline{U} = \delta Q_\sigma + \delta W_\sigma + \sum_{in} H_{in}\delta n_{in} - \sum_{out} H_{out}\delta n_{out}$
5. open, non-simple PE+KE only (use mass basis)	$d\underline{E} = \delta Q_\sigma + \delta W_\sigma + \sum_{in}\left(H_{in} + gz_{in} + \frac{v_{in}^2}{2}\right)\delta m_{in} - \sum_{out}\left(H_{out} + gz_{out} + \frac{v_{out}^2}{2}\right)\delta m_{out}$ $d\underline{E} = d\left(\underline{U} + mg\langle z\rangle + \frac{m\left(\langle v\rangle^2\right)}{2}\right)$
6. steady state, open, non-simple	$d\underline{E} = 0 \quad dm = 0 \quad$ or $\quad dN = 0$ (if no reactions) $\frac{d\underline{E}}{dt} = \frac{dm}{dt} = \frac{dN}{dt} = 0$ $\frac{\delta n_{in}}{\delta t} = \frac{\delta n_{out}}{\delta t} = \dot{n}$ plus expression (5) $\frac{d\underline{E}}{dt} = 0 \qquad \frac{\delta Q_\sigma}{\delta t} + \frac{\delta W_\sigma}{\delta t} = \left(\Delta H_{ss} + \Delta PE_{ss} + \Delta KE_{ss}\right)\dot{n}$ $\Delta H_{ss} = H_{out} - H_{in} \quad \Delta PE_{ss} = g\left(z_{out} - z_{in}\right) \quad \Delta KE_{ss} = \frac{v_{out}^2 - v_{in}^2}{2}$
7. non-simple, open distributed interaction along σ-surface	$\int_{\underline{V}}\left(\frac{\partial(\rho E)}{\partial t}\right)d\underline{V} = -\int_{\underline{a}_\sigma}\mathbf{q}\cdot\underline{\underline{\mathbf{n}}}\,d\underline{a}_\sigma + \sum\dot{W}_{\sigma,i} - \int_{\underline{a}_\sigma}\rho\left(H + gz + \frac{v^2}{2}\right)\mathbf{v}\cdot\mathbf{n}\,d\underline{a}_\sigma$