Application of Closed System Energy Balance

- Carefully read the problem statement
- Evaluate which terms in the energy balance are zero

$$\Delta U + \Delta E_k + \Delta E_p = Q - W$$

- Write simplified equation
- Plug in known values and solve for desired unknown

Example 1

A gas cylinder contains N_2 at 200 atm and 80°C. As a result of cooling at night, the pressure in the cylinder drops to 190 atm and the temperature to 30°C.

Which of the terms in the energy equation are zero?

(ΔE_k, ΔE_p, W)

For the non-zero terms, are their values positive or negative?

Q = negative

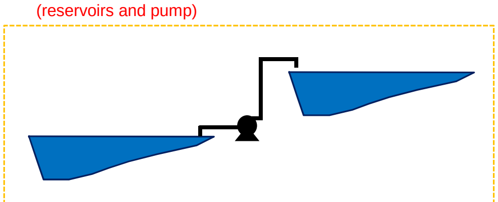
ΔU = negative

Example 2

Water is pumped from one reservoir to another 300 ft away. The water level in the second reservoir is 40 ft above the water level of the first reservoir. How much work per mass of water was performed?

What is the system?

(reservoirs and pump)



As defined here, is this an open or closed system?

Example 2 (cont)

Water is pumped from one reservoir to another 300 ft away. The water level in the second reservoir is 40 ft above the water level of the first reservoir. How much work per mass of water was performed?

$$\Delta U + \Delta E_k + \Delta E_p = Q - W$$

Which terms are zero? Why? (ΔU, ΔE_k, Q)

What is the simplified form of the energy balance?

$\Delta E_P = -W = mgh$

How was the work performed? Pump

What is the answer in Btu/lb_m? $-W/m = g\Delta h$

$$-\frac{W}{m} = \frac{\left(32.2\frac{ft}{s^2}\right)(40\ ft)}{\left(32.2\frac{lb_m\,ft}{lb_f\,s^2}\right)}\left(\frac{9.486\times10^{-4}\,Btu}{0.7376\,ft\cdot lb_f}\right) = 0.33\ Btu/lb_m$$

$$= 9.66\times10^{-5}\,\frac{kW\cdot hr}{lb_m}$$

Example 2 (cont)

How much energy is needed to raise the level in the upper reservoir by 1 ft if the surface area is 8 square miles?

$$m = \left(62.4\frac{lb_m}{ft^3}\right)(8sq\,miles)\left(\frac{5280\ ft}{mile}\right)^2 = 1.392\times10^{10}\,lb_m$$

$$-W = \left(1.392\times10^{10}\,lb_m\right)\cdot\left(9.66\times10^{-5}\,\frac{kW\cdot hr}{lb_m}\right) = 1.34\times10^{6}\,kW\cdot hr$$

$$\$\$ = \left(1.34\times10^{6}\,kW\cdot hr\right)\cdot 8.5\,\frac{cents}{kW\cdot hr} = \$114{,}271$$

Assumes 100% pump efficiency!

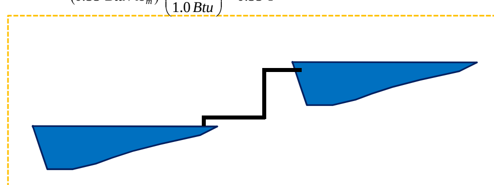
Example 2

What about just letting water flow downhill?

Where does the energy go?

Friction causes slight increase in water temperature (ΔU)

$$\left(0.33\ Btu/lb_m\right)\cdot\left(\frac{lb_m\ {}^\circ R}{1.0\,Btu}\right) = 0.33^\circ F$$



Terms

- **Isothermal** – constant temperature
  - Q may not be zero
  - Example: exothermic reaction, but keep T = constant
- **Adiabatic** – Q = 0
  (no heat transferred through boundary)

Problems 7.5 & 7.6