for run 1:

mass flow rate:

$$\Rightarrow \frac{(\text{mass water + beaker}) - (\text{beaker})}{\text{time collected}} = \frac{0.6785 - 0.185\ [kg]}{10.16\ [s]} = 0.0486 \left[\frac{kg}{s}\right]$$

cross sec Area of tube:

$$A_1 = \underbrace{N_1}_{1 \text{ tube}} \pi \cdot \frac{D_{in}^2}{4} = (1)\pi \cdot \frac{(0.603)^2}{4}\ [in^2] = 0.285\ in^2.$$

Cylindrical area of tube:

$$A_{1-L} = \pi D_{in} L = \pi \cdot 0.603[in] \cdot 24[in] = 45.5\ in^2$$

counter-current log mean ΔT:

$$dT = \frac{(T_{2,in} - T_{1,out}) - (-T_{1,in} + T_{2,out})}{\ln\left(\frac{T_{2,in} - T_{1,out}}{T_{2,out} - T_{1,in}}\right)}$$

$$= \frac{(50.4 - 18.4) - (50.1 - 18.3)}{\ln\left[\frac{50.4 - 18.4}{50.1 - 18.3}\right]}$$

$$= 31.98\ ^\circ C./K$$

Heat rate of tube 1:

$$Q = \dot{m} \cdot c_p \cdot (T_{1,out} - T_{1,in})$$

$$= 0.0486 \frac{kg}{s} \cdot 4200 \frac{J}{kg\,K} \cdot (18.4 - 18.3)\,K$$

$$= 20.4 \frac{J}{s}$$

Mass velocities $G_{i,1}$:

$$G_{i,1} = \frac{\dot{m}_1}{A_{cross}} = \frac{0.0486}{0.286} = 0.17 \left[\frac{kg}{in^2 s}\right]$$

$$\left[\frac{kg}{s}\right] \rightarrow \left[in^2\right]$$

Heat transfer coefficient $U_{1,in}$:

$$U_{1,in} = \frac{Q_1}{A_{1,L} \cdot \Delta T_1} = \frac{20.4\,J}{45.5\,in^2 \cdot 31.9\,K} = 0.0141 \left[\frac{J}{s\,in^2\,K}\right]$$

(can be done same step to find $U_{2,in}$)

but $$\Delta T_2 = \frac{(T_{3,out}^{in} - T_{2,in}^{out}) - (T_{3,out} - T_{2,in})}{\ln\left(\frac{T_{3,in} - T_{2,out}}{T_{3,out} - T_{2,in}}\right)}$$

$$= 9.234\,K$$

and $Q_2 = \dot{m}_2 C_p (T_{2,out} - T_{2,in})$

$= 0.0239 \frac{kg}{s} \cdot 4200 \frac{J}{kg\,K} (50.1 - 50.4)\,K$

$= -30.2 \frac{J}{s}$

b we make $|Q_2| = 30.2 \frac{J}{s}$

$V_{2-in} = \frac{Q_2}{A_{2,L} \cdot \Delta T_2} = \frac{30.2 \frac{J}{s}}{57.34\,in^2 \cdot 9.23\,K} = \frac{0.057\,J}{in^2\,s\,K}$