Prelim 1 Review

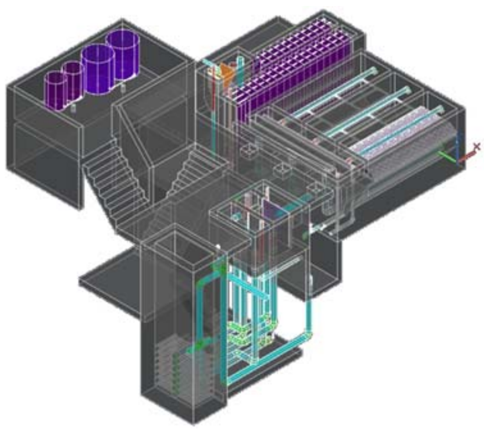
Prelim 1
Tuesday October 17
7:30 pm in 318 Phillips

General Question

- Test format: What types of questions should we expect?
  - 7 multiple choice questions (4 points each)
  - Short problems (includes one graph)
- How far should we be able to extrapolate beyond what is in the notes?
  - You should understand the fundamental concepts and be able to talk about those concepts with your friends
  - Algebra and arithmetic are expected

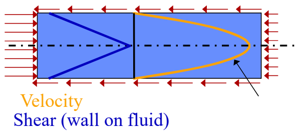
Python based Prelim

- What could fail?
  - No communication with other humans during the exam
  - No posting questions or answers on the web
  - Delete part of the exam by mistake (save a copy with your name in the title as step 1)
- How do you minimize risk of failure?
  - Save versions
  - Also submit a pdf copy. Print the webpage as a pdf (File – print preview, then print as pdf)



What are examples of major and minor losses?

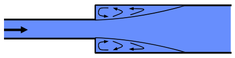
- Major: Caused by shear with the solid surface
  - Pipe walls
  - Flocculator baffle surfaces (insignificant)



- Minor: Flow expansions (analogous to pressure drag)
  - Orifice, elbow, valve, any place where flow is expanding!
  - KE is converted into 2 things!

$$h_e = K\frac{V^2}{2g}$$

Head Loss due to Sudden Expansion



Energy $h_e = \frac{p_{in} - p_{out}}{\rho g} + \frac{V_{in}^2 - V_{out}^2}{2g}$

Mass $\frac{A_{in}}{A_{out}} = \frac{V_{out}}{V_{in}}$

Momentum $\frac{p_{in} - p_{out}}{\rho g} = \frac{V_{out}^2 - V_{in}^2 \frac{A_{in}}{A_{out}}}{g}$

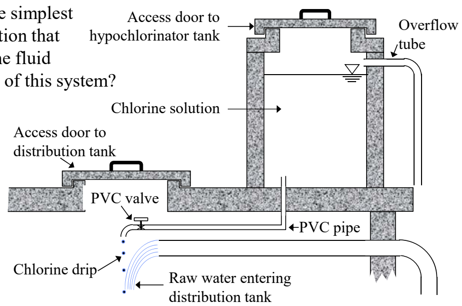
$$h_e = \frac{2V_{out}^2 - 2V_{in}^2 \frac{V_{out}}{V_{in}}}{2g} + \frac{V_{in}^2 - V_{out}^2}{2g} \qquad h_e = \frac{V_{out}^2 - 2V_{in}V_{out} + V_{in}^2}{2g}$$

$$h_e = \frac{(V_{in} - V_{out})^2}{2g} \qquad h_e = \frac{V_{in}^2}{2g}\overbrace{\left(1 - \frac{A_{in}}{A_{out}}\right)^2}^{K_e} \qquad h_e = \frac{V_{out}^2}{2g}\overbrace{\left(\frac{A_{out}}{A_{in}} - 1\right)^2}^{K_e'}$$

Discharge into a reservoir? Loss coefficient = 1

The Challenge of Chemical Metering (Hypochlorinator)

What is the simplest representation that captures the fluid mechanics of this system?



Hole in a bucket (tank drain)

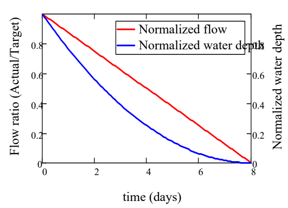
- What type of head loss (major or minor)?
- What is the equation for those loses?
- How would you calculate the initial flow rate given the minor losses?
- How does the flow vary with time?

$$\frac{Q}{Q_0} = 1 - \frac{1}{2}\frac{t}{t_{Design}}\frac{h_{Tank}}{h_0}$$

- What is the average flow rate while the tank is emptying?

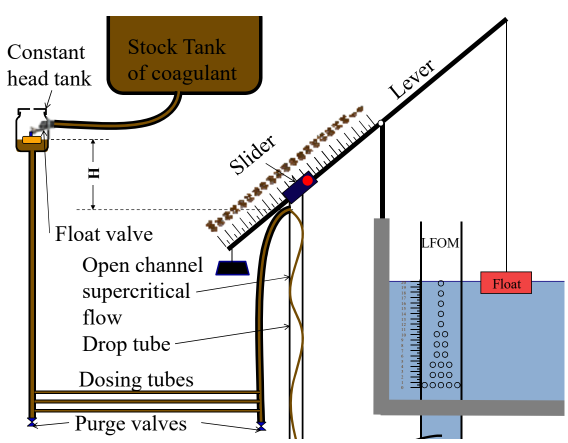
Hole in a bucket (tank drain)

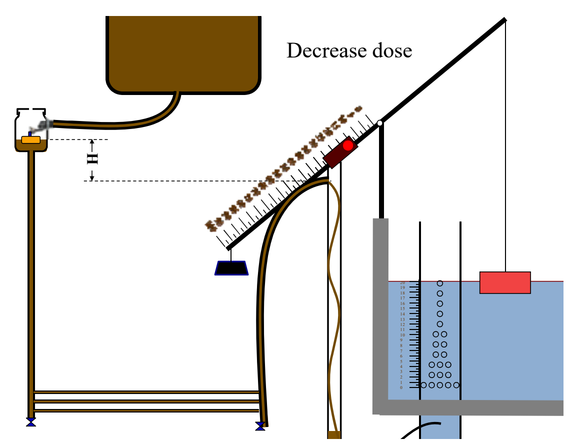
Case 2, h_0=1 m, h_{tank} = 1 m, t_{design}=4 days

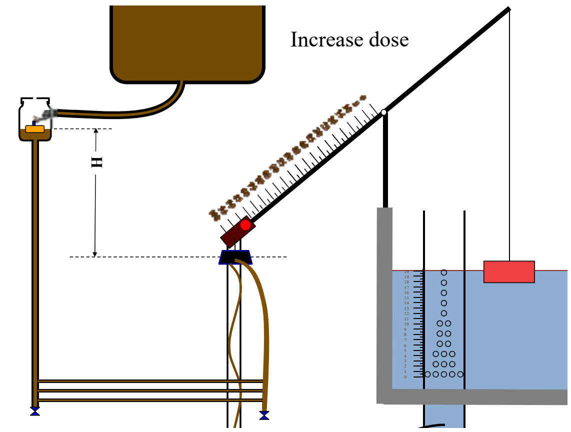


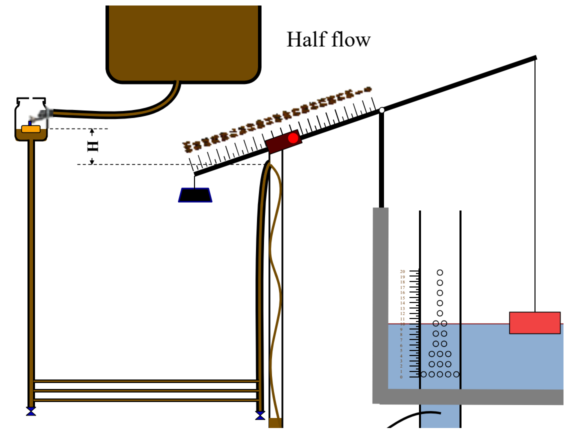
What happens if raw water temperature drops in a WTP?

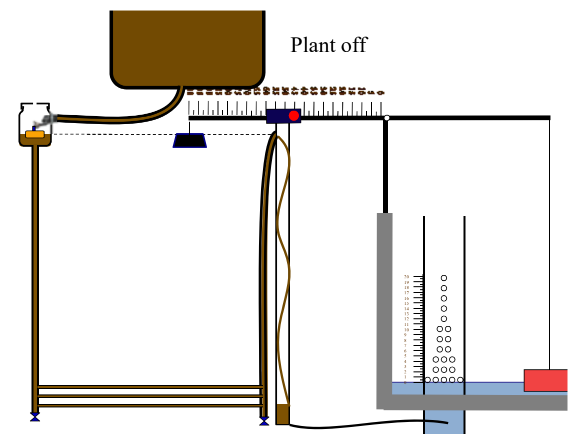
- Flow measurement
- Chemical feed (air temperature?)
- Rapid mix
- Flocculation
  - Head loss through flocculator
  - Fluid deformation (Gθ)
- Sedimentation – prelim 2!











Where is this equipment in the new design?

Chemical Dose Controller

- What is the purpose of CHT?  
- What is the purpose of the dosing tubes?
- What is the design constraint for the maximum flow rate in the dosing tubes? $h_L \Pi_{Error} = \sum K_e \frac{V_{Max}^2}{2g}$ $\quad V_{Max} = \sqrt{\frac{2h_L g \Pi_{Error}}{\sum K_e}}$
- Why does the flow through the dose controller increase if the plant flow rate increases? $h_f = \frac{128\mu LQ}{\rho g \pi D^4}$

$$Q = \frac{h_f \rho g \pi D^4}{128\mu L}$$

Head loss, energy dissipation rate, velocity gradient

$$h_e = K_e \frac{V^2}{2g}$$

$$\bar{\varepsilon} = \frac{gh_e}{\theta_e}$$

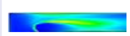
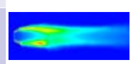
$$\bar{G} = \sqrt{\frac{\bar{\varepsilon}}{\nu}} \qquad \bar{\varepsilon} = \nu \bar{G}^2$$

Use these equations to relate velocity gradient to velocity (and then to flow geometry)

Energy dissipation rate

ε	Equation source	Equation	scale
Ave	Control volume • mass • momentum • energy	$\bar{\varepsilon} = K_e \frac{V^2}{2} \frac{1}{\theta_e}$	time over which energy is dissipated
Max	Dimensional analysis	$\varepsilon_{Max} \cong \frac{(\Pi V)^3}{D}$	Flow dimension

Maximum Energy Dissipation Rate

Type of expansion	Context	Π	Equation	
Round jet	Rapid mix	0.5	$\varepsilon_{Max} \cong \frac{(\Pi_{JetRound} V_{Jet})^3}{D_{Jet}}$	
Plane jet	Hydraulic flocculator	0.225	$\varepsilon_{Max} \cong \frac{(\Pi_{JetPlane} V_{Jet})^3}{S_{Jet}}$	
Plate	Mechanical flocculator	0.34	$\varepsilon_{Max} = \frac{(\Pi_{Plate} V)^3}{W_{Plate}}$	

Π

Power and Energy

- Energy: Joule = Newton*meter
- Power: Watt = Joule/s
- Water elevation change in an AguaClara plant is about 2 m. How much energy are we using per kg of water? 2m*g = 19.6 (m/s)^2 = J/kg
- If the flow rate is 100 L/s, what is the equivalent power?
  0.1m^3/s*1000kg/m^3*19.6J/kg = 1900 W
- Desalination = 1 km, distillation = 250 km

Identify all of the parameters in the Floc Model

$$pC^* = \frac{3}{2}\log\left(\frac{2}{3}\pi k \frac{d_P^2}{\Lambda_0^2} \bar{G}t\alpha + 1\right)$$

$$n_P = \frac{6}{\pi d_P^3} \frac{C_P}{\rho_P}$$

$$\bar{G}t = \frac{3}{2} \frac{\left(\Lambda^2 - \Lambda_0^2\right)}{k\pi d_P^2 \alpha}$$

$$\Lambda = \frac{1}{n_P^{1/3}}$$

$$\bar{G}t \approx \frac{3}{2} \frac{\Lambda^2}{k\pi d_P^2 \alpha}$$