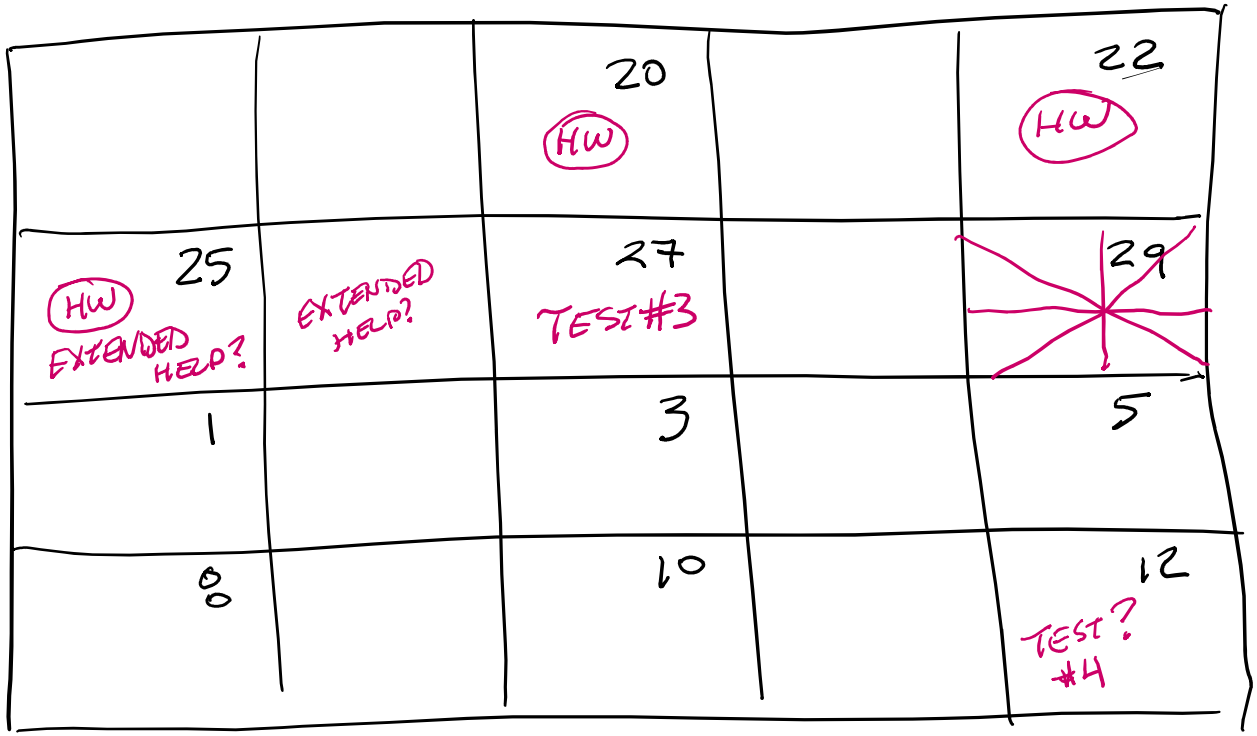
CALENDAR


20
HW
22
HW
25
HW
EXTENDED HELP?
EXTENDED HELP?
27
TEST #3
29
1
3
5
8
10
12
TEST? #4

OVERALL BALANCE

$$\text{ACC} = \text{IN} - \text{OUT}$$

ρ = DENSITY

$$\frac{d(V\rho)}{dt} = Q^{IN}\rho^{IN} - Q^{OUT}\rho^{OUT}$$

BOTH V & ρ ARE FUNCTIONS OF TIME!

SIMPLIFICATIONS

A) TANK IS WELL-MIXED $\quad \rho = \rho^{OUT}$

B) $Q^{OUT} = A_{ORIFICE}\, v$

$$Q^{OUT} = \left(\frac{\pi}{4}d^2\right) C\sqrt{2gh}$$

h IS A VARIABLE!

C) LIQUID VOLUME $\quad V = \frac{\pi D^2 h}{4}$

D IS DIAMETER OF TANK

d IS DIAMETER OF ORIFICE

$$\frac{\pi D^2}{4}\frac{d(\rho h)}{dt} = Q^{IN}\rho^{IN} - \frac{\pi d^2 C_f}{4}\sqrt{2gh}$$

EQN. #1

DEPENDENT VARIABLES: ρ, h

ETHANOL BALANCE

ρ_E = MASS CONC OF ETHANOL

ACC = IN − OUT + ~~GEN~~

$$\frac{d}{dt}(\rho_E V) = Q^{IN}\rho_E{}^{IN} - Q^{OUT}\rho_E{}^{OUT}$$

$$\frac{d}{dt}(\rho_E V) = Q^{IN}\rho_E{}^{IN} - Q^{OUT}\rho^{OUT}w_E{}^{OUT}$$

$$\frac{d}{dt}(\rho_E V) = Q^{IN}\rho_E{}^{IN} - Q^{OUT}\rho w_E$$

$$\frac{\pi D^2}{4}\frac{d}{dt}(\rho_E h) = Q^{IN}\rho_E{}^{IN} - \frac{\pi d^2 C \rho w_E}{4}\sqrt{2gh}$$

EQN #2

NEED 2 MORE EQUATIONS:

DEPENDENT VARIABLES ρ_E, h, w_E, ρ

EQN #3 $\rho = f(w_E)$ EMPIRICAL 4th ORDER EQN.

EQN #4 $\rho_E = w_E \rho$

FOUR EQUATIONS, FOUR DEPENDENT VARIABLES (ρ_E, h, w_E, ρ)

CANNOT BE SOLVED ANALYTICALLY

NON-LINEAR TERM $\sqrt{h}$

DIFFERENTIATION OF 2 DEPENDENT VARIABLE

COMPUTER SOLUTION:

$$\frac{d}{dt}(\rho h) \cong \frac{\Delta(\rho h)}{\Delta t} \qquad \frac{d}{dt}(\rho_E h) \cong \frac{\Delta(\rho_E h)}{\Delta t}$$

Δt --- JUST SELECT A SMALL VALUE

SO, DIFF. EQUATIONS BECOME:

$$\rho_{i+1} h_{i+1} = \left[\frac{4 Q^{IN} \rho^{IN}}{\pi D^2} - \frac{d^2}{D^2} C \rho_i \sqrt{2 g h_i}\right] \Delta t + \rho_i h_i \qquad \#1$$

$$\rho_{E\,i+1} h_{i+1} = \left[\frac{4 Q^{IN} \rho_E{}^{IN}}{\pi D^2} - \frac{d^2}{D^2} C w_{Ei} \rho_i \sqrt{2 g h_i}\right] \Delta t + \rho_{Ei} h_i \qquad \#2$$

$$\rho_i = f(\omega_{Ei}) \qquad \#3$$

$$\rho_{Ei} = \omega_{Ei}\,\rho_i \qquad \#4$$

PROCEDURE

VARIABLES: $\rho, h, \rho_E, \omega_E$

NEED INITIAL VALUES: $\rho_0, h_0, \rho_{E0}, \omega_{E0}$

$\rho_0 = 0.9982$ g/mL — DENSITY OF PURE WATER

$h_0 = 113.18$ cm — CALCULATED PREVIOUSLY

$\rho_{E0} = 0$

$\omega_{E0} = 0$

GIVEN Δt, FIND ρ_{i+1}, h_{i+1}, $\rho_{E\,i+1}$, $W_{E\,i+1}$

STEPS

(A) CALCULATE $\rho_{i+1}\, h_{i+1}$ BY EQN 1

(B) CALCULATE $\rho_{E\,i+1}\, h_{i+1}$ BY EQN 2

(C) CALCULATE $\dfrac{\rho_{E\,i+1}\, h_{i+1}}{\rho_{i+1}\, h_{i+1}} = \dfrac{\rho_{E\,i+1}}{\rho_{i+1}} = W_{E\,i+1}$

(D) CALCULATE ρ_{i+1} BY EQN 3

(E) CALCULATE $\rho_{E\,i+1}$ BY EQN 4

(F) CALCULATE h_{i+1} BY EITHER (A) OR (B) ABOVE

(G) VOLUME $= V_{i+1} = \dfrac{\pi D^2 h_{i+1}}{4}$

REPEAT ALL STEPS UNTIL $W_E > 0.50$

OR $V > V_{TANK}$

COMMENTS:

1) BE CAREFUL ABOUT DIFFERENTIAL EQNS THAT ARE UNSTABLE. USE OTHER METHODS.

2) CALCULATION IMPROVED BY USING SMALLER Δt

SMALLER Δt INCREASES RUN-TIME.

3) PROGRAMS SHOULD HAVE CHECKS ON PHYSICAL CONDITIONS (e.g.; HAS TANK VOLUME BEEN EXCEEDED).