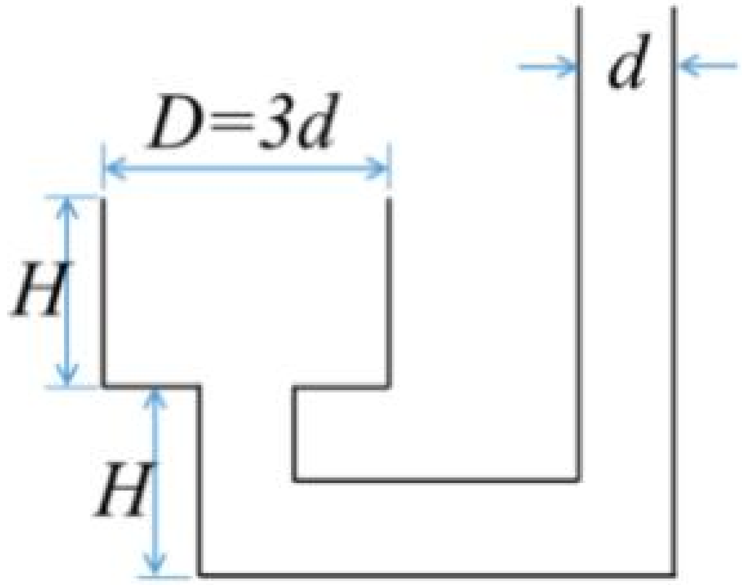
The hydraulic system below is filled with water up to the midline of the wider reservoir on the left so that the water head measured from the bottom of the horizontal pipe is $1.5H$. Oil of volume $\pi H d^2/4$ m^3 (and with $\rho_{water} = 1.10\rho_{oil}$) is then introduced to the system from the right side via the pipe of diameter d. The relationship between the diameter of the wide reservoir and the pipe is $D = 3d$, and the height of the pipe on the right side is $10H$ (not shown fully).



Your text is automatically saved every 2 minutes. You can manually save your text any time. After saving you can continue to write your text (until the assignment is closed). All access is logged!

Question 1; maximum score: 5 points

Question 1; maximum score: 5 points

Save

Given that water and oil are immiscible, sketch the system at static equilibrium.

For the toolbar, press ALT+F10 (PC) or ALT+FN+F10 (Mac).

Question 2; maximum score: 15 points

Saved: 8:32:28

Calculate the height difference between the left and right vessels as a function of H.

Question 3; maximum score: 20 points

Saved: 8:32:28

Now a piston of mass m and diameter D (equal to that of the left reservoir) is introduced and brought into contact with the waterline (on the left side).

What should be the piston mass to eject fully the water from the wider reservoir (i.e., when the piston has moved all the way to the bottom of the wider reservoir)? Assume that no leakage occurs between the piston and the walls of the reservoir. Hint: mass (and volume) is conserved in this system.

Question 4; maximum score: 5 points

Saved: 8:32:28

Using conservation of mass, we can derive an equation that describes the change of pressure over time (dp/dt) as a function of specific weight ($\gamma = \rho g$) and the volumetric flowrate over the cross-sectional area into which the water flows. This is defined as the capacitance.

Starting from the definition of capacitance, write the equation for the change of pressure over time (dp/dt) at the base of the wider reservoir as a function of the average flow velocity.

Question 5; maximum score: 10 points

Saved: 8:32:28

The piston oscillates with displacement $z_p = (H/2)\sin\omega t$ measured relative to the midline of the left (wider) reservoir (i.e., $z_p = 0$ at a distance of $1.5H$ from the bottom of the horizontal pipe). Sketch, in one plot, the kinematics (displacement and velocity) of the piston and, in another plot, the behavior of the change of pressure over time (dp/dt) corresponding to the piston kinematics (i.e., for the instantaneous velocity instead of the average).

Question 6; maximum score: 5 points

Saved: 8:32:28

Write down the initial condition describing the pressure (*p* and not *dp/dt*) at the base of the wider reservoir at time zero.

Question 7; maximum score: 20 points

Saved: 8:32:28

Derive the equation of the time-varying pressure at the base of the wider reservoir (p and not dp/dt) as a function of the instantaneous piston velocity described in Question 5, by applying the initial condition of Question 6. Neglect the weight of the piston.

Question 8; maximum score: 20 points

Saved: 10:00:40

We want to know how the pressure at the center of the horizontal pipe connecting the two reservoirs evolves as a function of time under the effect of a piston that oscillates as described in the previous questions.

Derive an expression for the time-varying pressure at the center of the horizontal pipe. (10 points)

EXTRA CREDIT 1 (5 points):

Replace water and oil with two solutions of compounds A and B, respectively, that react to form product C as follows: $2A + B \rightarrow C$. What is the reaction rate if the reaction is 1^{st} order in A and 2^{nd} order in B? (5 pts)

EXTRA CREDIT 2 (5 points):

For the extra credit 1 problem above: if the reaction were diffusion-controlled, would it occur faster if solution B was introduced to solution A in the wider reservoir? Explain your reasoning. (5 pts)