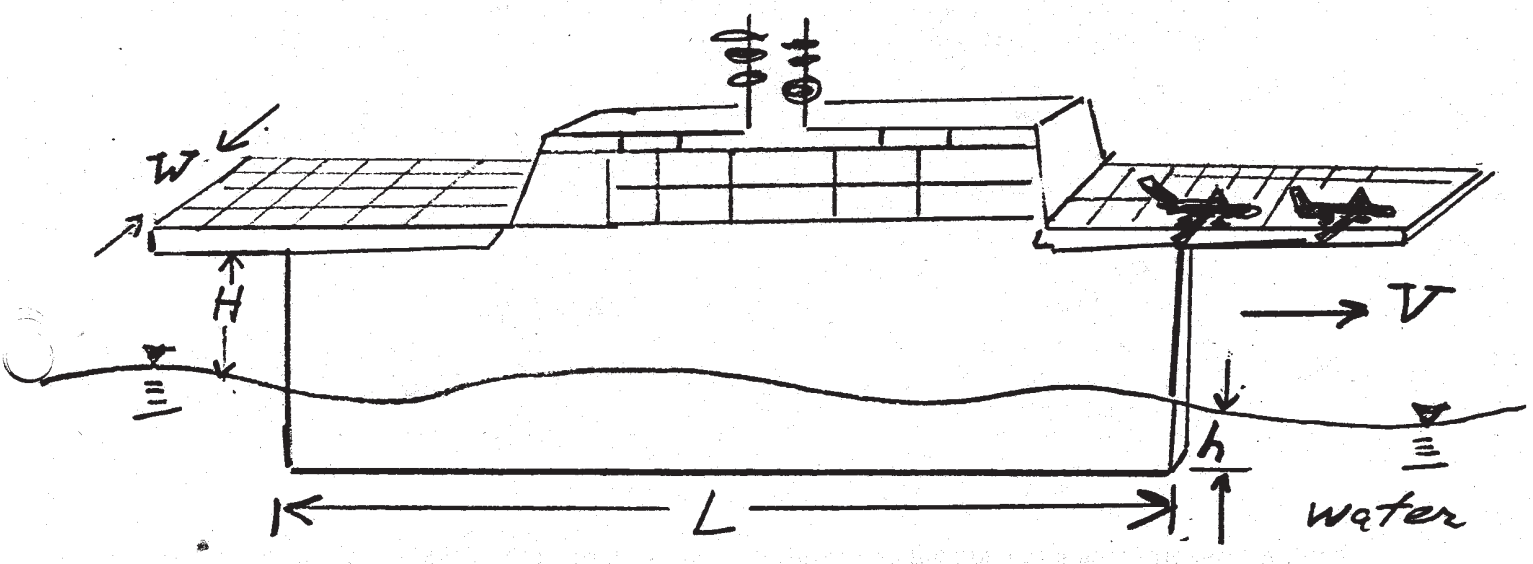
NAME_____ University of California, Berkeley
CEE100 Exam 2, Spring 2004

PROBLEM 1

A CV-61 aircraft carrier ship has the following dimensions:

Maximum speed, V = 30 knots = 15.4m/s
Length at waterline, L = 304m
Width (at flight deck), W = 19.3m
Height above waterline, H = 29.5m
Draft below waterline, h=11m
The viscosity of ocean water is $\nu=10^{-6} m^2/s$.

The Ocean Engineering group at UC Berkeley maintains an experimental facility in Richmond. The facility has a towing tank where model ships can be towed at a maximum speed of 1.8m/s.



1a.) Experiments will be conducted in the towing tank to measure the drag on the ship, D, as a function of the ship geometry (see above for variables), ship speed V, fluid density ρ, fluid kinematic viscosity ν, and gravity g. Perform dimensional analysis on the problem and generate the nondimensional groups describing the flow. Your answer should be in the form $\pi_1 = f(\pi_2, \pi_3, \ldots)$, and you should rearrange the groups into the usual familiar groups. Neglect surface tension effects. (8pts)

1b.) Assume that the testing facility will be run at the maximum possible towing speed. *Ideally*, in order to achieve *full* dynamic similarity between the model and the prototype, what would be the values of
a.) the length of the model ship (5pts)
b.) the preferred viscosity of the fluid used in the model study (5pts)

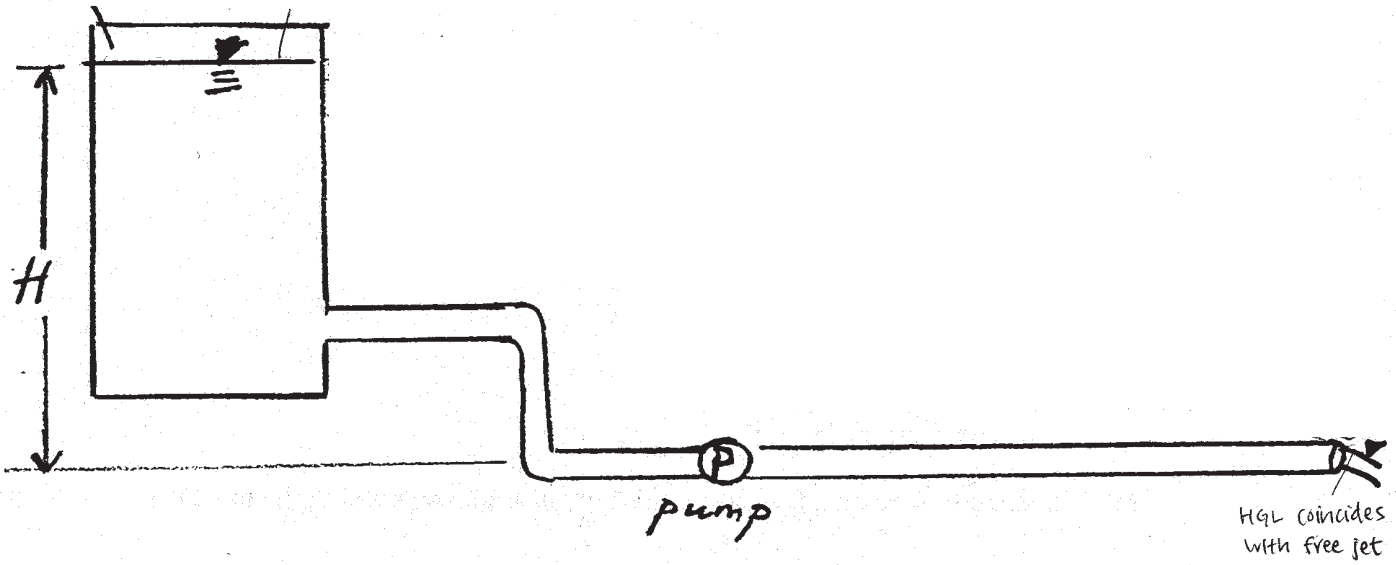
1c.) If fresh water (ρ=1000kg/m^3) is used for the experiments in the hope that approximate similitude can be achieved, and a drag force D = ~~14,000N~~ 10 is measured in the experiment, what will be the drag be on the real ship? Assume that the density of ocean water is ρ=1025kg/m^3. (6pts)

1d.) How much of the measured drag on the **real** ship is due to skin friction? Assume that the flow around the ship's hull can be modeled as two growing boundary layers on each side of the ship that transition from laminar to turbulent (*neglect the friction on the underside of the ship*). The viscosity of ocean water is $\nu=10^{-6} m^2/s$. (8pts)

1e.) At sea, the ship drag is affected by ocean waves. For deep, small amplitude water waves, the additional parameter describing water waves is the wave period, T_0. The towing tank has a wavemaker to generate water waves. If a representative ocean wave period is $T_0=20s$, then what should the period of the waves be in the experiment? (7pts)

PROBLEM 2. Water ($\nu=10^{-6}m^2/s$ $\rho=1000kg/m^3$) is fed from a reservoir into the pipe system as shown below:

- Pipe is cast iron, with constant diameter D = 0.20*m*.
- Pipe entrance is sharp-cornered
- Pipe bends are smooth, with r/D=4: K=0.16
- Total length of pipe is L=20m.
- The pump adds h_p=20m of energy to the flow.



2a.) Sketch the energy grade lines and hydraulic grade lines for the pipe system. Point out the important features, especially if you can't draw very well. (5pts)

2b.) What height H is required in the reservoir to maintain a flow of Q = 0.5m^3/s? (11pts)

2c.) In the fully-developed portion of the pipe, what is the shear stress at the wall of the pipe? (7pts)

2d.) What is the boundary layer thickness in the fully-developed portion of the pipe? (5pts)