

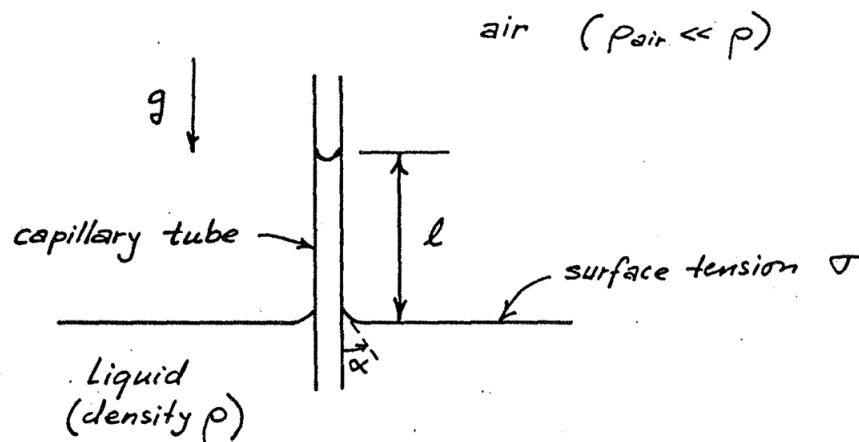
### Midterm Exam 1

2:10 - 3:00 PM – October 8, 2018

#### Problem 1 (15 Points)

A capillary tube with a small radius is held vertically in air with its bottom immersed in a large body of liquid. The surface tension of the air-liquid combination is  $\sigma$ , and the contact angle of the air-liquid-tube wall combination is  $\alpha$ .

- Find an expression for the capillary rise.
- How would this expression change if the system were comprised of two plates separated by  $2a$ , instead of being a tube with radius  $a$ ?



#### Problem 2 (20 Points)

Consider the following given velocity field:

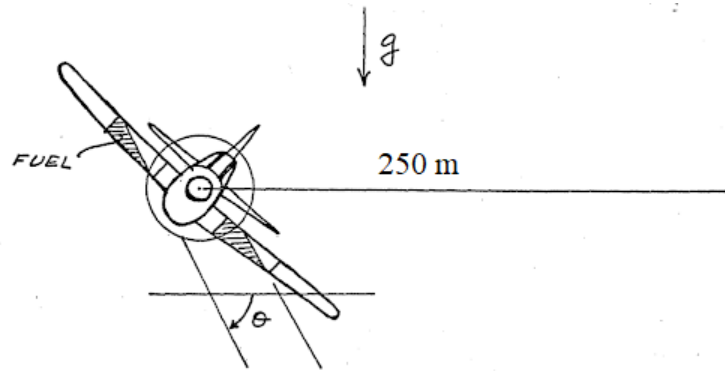
$$u = \frac{x}{1 + 2t}$$

$$v = \frac{y}{2t}$$

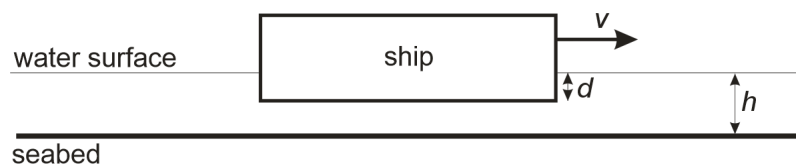
- Is it a 1D, 2D, or 3D flow field? Is it steady or unsteady?
- Find the streamline passing through the point  $x_o, y_o$ .
- Find the pathline of the particle that passes through the point  $x_o, y_o$  at  $t=t_o$ .

**Problem 3 (15 Points)**

The sketch shows a small airplane making a steady turn of 250 meter radius while banking in a horizontal plane at 180 km/hr. The fuel tanks are in the wings. Estimate the angle  $\theta$  between the free surface of the fuel and the horizontal.

**Problem 4 (20 Points)**

The squat effect is the hydrodynamic phenomenon by which a vessel moving quickly through shallow water creates an area of lowered pressure that causes the ship to be closer to the seabed than would otherwise be expected. It is believed to have been one of the causes of the 7 August 1992 grounding of the Queen Elizabeth 2 (QE2) off Cuttyhunk Island, near Martha's Vineyard.



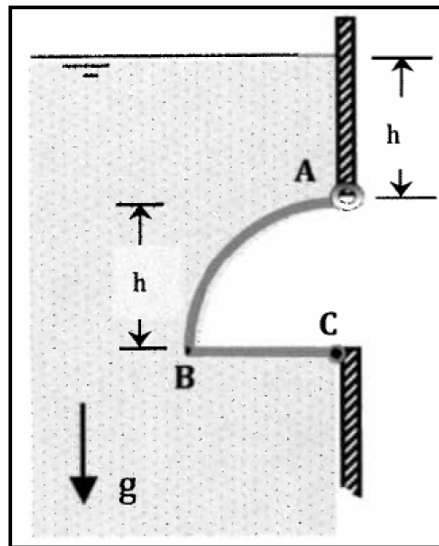
Consider a simplified model in which a wide ship with an initial draft <sup>1</sup> of  $d$ , starts to move in a water of depth  $h$ . What is the new draft when ship is at its cruising speed  $v$ ? Assume that ship is wide enough that a two-dimensional approximation can be made.  
(Hint: write your equation in a frame of reference moving with the ship.)

<sup>1</sup>The draft of a ship's hull is the vertical distance between the waterline and the bottom of the hull.

**Problem 5 (30 Points)**

A gate having the cross section shown in the figure below, closes an opening of width  $b$  (normal to the page) and height  $h$  in a water reservoir. The cross-section consists of a quarter-circle section and a horizontal baffle (See ABC in the figure below). It hinges at point A and touches the opening at point C. It is desired to evaluate the contact force at C, as it would affect the sealing property. The fluid is of specific weight  $\gamma$  and you can neglect the weight of the gate.

- (a) Find the horizontal force  $F_x$  acting on the curved section AB.
- (b) Find the non-dimensional reaction force  $F_c/(h^2b\gamma)$  at point C (which is horizontal) using a balance of linear momentum.



GOOD LUCK!