CEE 342 Aut 2005 Exam #1 Solutions

1. An upward force is exerted on the dime equal to the product of the perimeter and the surface tension. This force is thus:

$$\pi d\sigma_{\mathrm{Hg}} = \pi(1.8\text{ cm})(0.466\text{ N/m}) = 0.026\text{ N}$$

The weight of the dime is:

$$W = (2.3\text{ g})(9.81\text{ m/s}^2)\left(\frac{1\text{ kg}}{1000\text{ g}}\right)\left(\frac{1\text{ N}}{\text{kg-m/s}^2}\right) = 0.0226\text{ N}$$

The weight of the coin is less than the upward force on it, so it will not break the surface of the liquid.

2. The pressure at the level of the gage is γh, where h is the vertical distance from the top of the liquid. Since this distance is not changed by the replacement of liquid with the solid block, the pressure at the gage will not change.

3. A pressure gage measures the difference in pressure between the location where it is inserted and the ambient atmosphere. In the system shown, gage C is inserted into container 1, whereas the ambient atmosphere to which it is exposed is that in container 2, so the pressure it will measure is $p_1 - p_2$. The ambient pressure to which gages 1 and 2 are exposed is 14.7 psi or 760 mm Hg. Therefore:

$$p_1 - p_{atm} = 207\text{ kPa}; \qquad p_1 = (101.5 + 207)\text{kPa} = 308.5\text{ kPa}$$

$$p_2 - p_{atm} = -254\text{ mm Hg}; \; p_2 = (760 - 254)\text{mm Hg} = 506\text{ mm Hg}$$

p_2 can be converted to kPa by:

$$p_2 = 506\text{ mm Hg}\frac{101.5\text{ kPa}}{760\text{ mm Hg}} = 67.6\text{ kPa}$$

Finally, we find the reading on gage C as:

$$p_1 - p_2 = 308.5\text{ kPa} - 67.6\text{ kPa} = 240.9\text{ kPa}$$

4. The water will boil if the total pressure is less than the vapor pressure of water at the given temperature of 20^{o}C. The vapor pressure of water at this temperature is 2.34 kPa, and the total pressure in the gas phase is 0.1 atm, or 10.15 kPa. Thus, the water will not boil. The water will evaporate if its vapor pressure is larger than the pressure exerted by the water vapor already in the gas phase. The water vapor accounts for 20% of the gas phase, so it exerts a pressure of 0.02 atm, or 2.03 kPa. Since the vapor pressure is larger than the existing pressure exerted by the water vapor, water will evaporate.

5. The forces on the plate must sum to zero, since it is being lifted at a constant velocity. The downward forces include its weight and the frictional force due to viscous drag, and the upward forces include buoyancy and the applied force. The gap between the fixed plates and each side of the moving one is $(25-1.6)$ mm/2, or 11.7 mm. The first three of the forces noted can therefore be quantified as follows:

$$W = 45 \text{ N}$$

$$F_B = \gamma_{\text{oil}} \forall_{\text{plate}} = (0.95)\left(9800\frac{\text{N}}{\text{m}^3}\right)\left(1.5\text{x}1.5\text{x}0.016 \text{ m}^3\right) = 33.5 \text{ N}$$

$$F_D = 2\mu\frac{dv}{dx}A_{\substack{one\\side}} = 2(2.5 \text{ Pa-s})\left(\frac{0.06 \text{ m/s}}{0.0117 \text{ m}}\right)(1.5\text{m x } 1.5\text{m})\frac{1 \text{ N}}{\text{Pa-m}^2} = 57.7 \text{ N}$$

where the factor of 2 in the final equation accounts for the fact that the viscous force applies on both sides of the moving plate. The upward force required to pull the plate is therefore:

$$F_{applied} = W + F_D - F_B = (45.0 + 57.7 - 33.5)\text{ N} = 69.2 \text{ N}$$

6. The manometer on the right indicates that the barometric pressure in the test vessel is 840 mm Hg, so that is the pressure in the open end of the manometer on the left. The pressure at the interface of the seawater and the Hg in the manometer on the left is the barometric pressure inside the vessel plus 400 mm Hg, or 1240 mm Hg. From that location to the top of the seawater, the pressure declines by γh, where $h = y + 200$ mm. The pressure at the seawater surface is 740 mm Hg. Therefore:

$$(840+400)\text{mm Hg} - (y + 0.2\text{m})\left(10{,}000\frac{\text{N}}{\text{m}^3}\right)\left(\frac{760 \text{ mm Hg}}{101.5 \text{ kPa}}\right)\left(\frac{1 \text{ kPa}}{1000 \text{ N/m}^2}\right) = 740 \text{ mm Hg}$$

$$y = 6.48 \text{ m}$$

7. (Choice #1). The total force on the gate can be expressed as the force exerted by the water above the gate and that exerted by the water that is at the same depth as the gate. These forces are:

$$F_{above} = \gamma h_{above} A = \left(62.4\frac{\text{lb}}{\text{ft}^3}\right)h_{above}(10\text{ft x } 6\text{ft}) = (3744 h_{above})\text{lb}$$

$$F_{gate\ level} = \gamma l_c A = \left(62.4\frac{\text{lb}}{\text{ft}^3}\right)(5 \text{ ft})(10\text{ft x } 6\text{ft}) = 18{,}720 \text{ lb}$$

where l_c is the distance from the top of the gate to the centroid. When the gate is just about to open, the moment about the pivot will be zero. The force due to the water above the gate acts at the center of the gate, or 0.5 ft above the pivot, whereas the force due to the water at the same depth as the gate acts 2/3 of the way down the gate (6.67 ft below the top of the gate), or 1.17 ft below the pivot. Therefore, when the moment about the gate is zero, we have:

$$\left[(3744h_{above})\text{lb}\right](0.5\text{ ft})-(18,720\text{ lb})(1.17\text{ ft})=0$$

$$h_{above}=11.7\text{ ft}$$

The total depth d equals the depth above the gate plus 14 ft, so $d = 25.7$ ft.

7. (Choice #2). The horizontal force exerted by the fluids equals the force that would be exerted if the surface were flat with a shape corresponding to the projection of the surface on a vertical plane. Such a projection would have a circular shape, with the top half of the circle in contact with water and the bottom half in contact with CCl_4.

   The force exerted on the top half of the circle is $\gamma h_c A$, where h_c is the depth of the centroid of the area. This depth is a distance $4r/3\pi$ away from the flat part of the semi-circle, which is at the bottom of the semi-circle for the portion in contact with water. Thus, for the upper semi-circle:

$$h_{c,upper}=7\text{ ft}-\frac{4r}{3\pi}=7\text{ ft}-\frac{4(5\text{ ft})}{3\pi}=4.88\text{ ft}$$

$$F_{upper}=\gamma_{water}h_cA=\left(62.4\frac{\text{lb}}{\text{ft}^3}\right)(4.88\text{ ft})\left(\frac{1}{2}\pi[5\text{ ft}]^2\right)=11960\text{ lb}$$

   The force exerted on the lower portion of the tank end also equals the product of the pressure at the centroid and the area. In this case, the flat part of the semi-circle is at the top. Also, the pressure at the top of this section is that exerted by a depth of 7 ft of water. Therefore, the force is:

$$F_{lower}=p_cA=\left[\gamma_{water}(7.0\text{ ft})+\gamma_{\text{CCl}_4}l_c\right]\left(\frac{1}{2}\pi r^2\right)$$

   where l_c is the distance from the top of the semi-circle to the centroid. Thus:

$$F_{lower}=\left[\left(62.4\frac{\text{lb}}{\text{ft}^3}\right)(7.0\text{ ft})+1.59\left(62.4\frac{\text{lb}}{\text{ft}^3}\right)\frac{4(5\text{ ft})}{3\pi}\right]\left(\frac{1}{2}\pi(5\text{ ft})^2\right)$$

$$=25,421\text{ lb}$$

$$F_{tot}=F_{upper}+F_{lower}=11,960\text{ lb}+25,421\text{ lb}=37381\text{ lb}$$