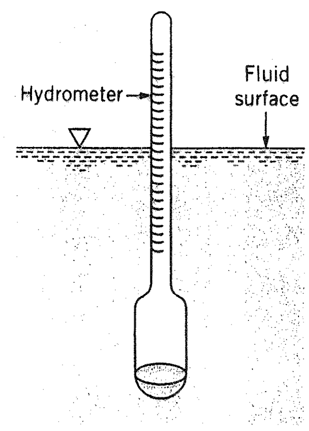
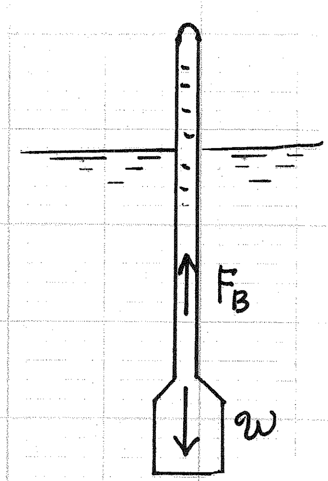
2.89

2.89 When a hydrometer (see Fig. P2.89 and **Video V2.6**) having a stem diameter of 0.30 in. is placed in water, the stem protrudes 3.15 in. above the water surface. If the water is replaced with a liquid having a specific gravity of 1.10, how much of the stem would protrude above the liquid surface? The hydrometer weighs 0.042 lb.



■ FIGURE P2.89

When the hydrometer is floating its weight, $\mathcal{W}$, is balanced by the buoyant force, F_B. For equilibrium,



$$\sum F_{vertical} = 0$$

Thus, for water

$$F_B = \mathcal{W}$$

$$(\gamma_{H_2O})\,\forall_1 = \mathcal{W} \qquad (1)$$

where $\forall_1$ is the submerged volume. With the new liquid

$$(SG)(\gamma_{H_2O})\,\forall_2 = \mathcal{W} \qquad (2)$$

Combining Eqs. (1) and (2) with $\mathcal{W}$ constant

$$(\gamma_{H_2O})\,\forall_1 = (SG)(\gamma_{H_2O})\,\forall_2$$

and

$$\forall_2 = \frac{\forall_1}{SG} \qquad (3)$$

(con't)

2.89 (Con't)

From Eq. (1)

$$\forall_1 = \frac{\mathcal{W}}{\gamma_{H_2O}} = \frac{0.042\ lb}{62.4\ \frac{lb}{ft^3}} = 6.73 \times 10^{-4}\ ft^3$$

so that from Eq. (3)

$$\forall_2 = \frac{6.73 \times 10^{-4}\ ft^3}{1.10} = 6.12 \times 10^{-4}\ ft^3$$

Thus, $\forall_1 - \forall_2 = (6.73 - 6.12) \times 10^{-4}\ ft^3 = 0.61 \times 10^{-4}\ ft^3$

To obtain this difference the change in length, $\Delta \ell$, is

$$\left(\frac{\pi}{4}\right)(0.30\ in.)^2 \Delta \ell = (0.61 \times 10^{-4}\ ft^3)\left(1728\ \frac{in.^3}{ft^3}\right)$$

$$\Delta \ell = 1.49\ in.$$

With the new liquid the stem would protrude

3.15 in. + 1.49 in. = <u>4.64 in.</u> above the surface