Fluids

Problem 1
Crew members attempt to escape from a damaged submarine 100.0 m below the surface. What force must be applied to a pop-out hatch, which is 1.25 m by 0.600 m, to push it out at that depth? Assume that the air inside the submarine is at atmospheric pressure and that the density of the ocean water is 1025 kg/m³.

Note: To figure out the force necessary to open the pop-out hatch, we first figure out the difference in pressure inside and outside of the hatch. We then use \( P = \frac{F}{A} \) or \( F = PA \) to get the force.

Pressure at 100.0 m → \( P_a = P_i + \rho gh \)

\( P_i = P_{atm} \) \( \rho = 1025 \text{ kg/m}^3 \)

\( P_{100m} = P_{atm} + \rho gh \) \( h = 100.0 \text{ m} \)

Pressure inside submarine → \( P_{sub} = P_{atm} = 1.103 \times 10^5 \text{ Pa} = 1 \text{ atm} \)

\( \Delta P = P_{100m} - P_{sub} \)

\( = (P_{atm} + \rho gh) - P_{atm} = \rho gh \)

\( \Delta F = \Delta P \frac{A}{A} \rightarrow \Delta F = (\Delta P) A \)

\( \Delta F = (\rho gh) A \rightarrow \Delta F = (1025 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(100.0 \text{ m})(1.25 \text{ m} \times 0.600 \text{ m}) \)

\( F = 7.53 \times 10^5 \text{ N} \)

Note: \( \Delta F \) gives the net force on the hatch. We must apply at least this amount of force to open the hatch.
Problem 2
A paperweight, when weighed in air, has a weight of \( w = 6.90 \text{ N} \). When completely immersed in water, however, it has a weight of \( w_{\text{in water}} = 4.30 \text{ N} \). Find the density of the paperweight.

Note: The difference between the weight of an object in air and the weight of the object when completely submerged in a fluid is the buoyant force on the object.

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F_b = W_{\text{in air}} - W_{\text{in water}}
\]
\[
= 6.90 \text{ N} - 4.30 \text{ N} = 2.60 \text{ N}
\]

\[
F_b = \rho V_{\text{sub}} g
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\[
\rho = \text{density of fluid}
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\[
V_{\text{sub}} = \text{volume of object submerged}
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Note: for a completely submerged object, \( V_{\text{sub}} = V_{\text{object}} \)

\[
F_b = \rho V_{\text{obj}} g \rightarrow V_{\text{obj}} = \frac{F_b}{\rho g} = \frac{2.60 \text{ N}}{(1.0 \times 10^{-3} \text{ kg/m}^3)(9.8 \text{ m/s}^2)}
\]

\[
V_{\text{obj}} = 2.65 \times 10^{-4} \text{ kg/m}^3
\]

Note: this is the volume of the paperweight. To get the density, all we need is the mass.

\[
\omega = mg
\]

\[
m = \frac{w}{g} = \frac{6.90 \text{ N}}{9.8 \text{ m/s}^2} = 0.704 \text{ kg}
\]

\[
\rho = \frac{m}{V} = \frac{0.704 \text{ kg}}{2.65 \times 10^{-4} \text{ m}^3}
\]

\[
\rho = 2.65 \times 10^3 \text{ kg/m}^3
\]