Chapter 1 Fluid Mechanics

1.1. Fluids at Rest

1.2. Ideal Fluids in Motion

1.3. Bernoulli's Equation

Homework:

Chapter 14: 1, 2, 17, 28, 38, 39, 48, 58, 65, 71

1. A fish maintains its depth in fresh water by adjusting the air content of porous bone or air sacs to make its average density the same as that of the water. Suppose that with its air sacs collapsed, a fish has a density of 1.08 g/cm^3. To what fraction of its expanded body volume must the fish inflate the air sacs to reduce its density to that of water?

Let the volume of the expanded air sacs be V_s and that of the fish be V_f:

$$\rho_{fish} = \frac{m_{fish}}{V_f} = 1.08\ (g/cm^3)$$

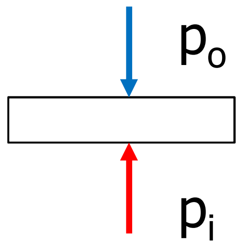
$$\rho_{water} = \frac{m_{fish}}{V_f + V_s} = 1\ (g/cm^3)$$

$$\rightarrow \frac{V_s}{V_f + V_s} = \frac{\rho_{fish} - \rho_{water}}{\rho_{fish}} \approx 7.4\%$$

2. A partially evacuated airtight container has a tight-fitting lid of surface area 77 cm^2 and negligible mass. If the force required to remove the lid is 480 N and the atmospheric pressure is 1.0×10^5 Pa, what is the internal air pressure

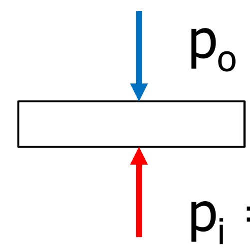
$F = (p_o - p_i)A$

$1 N/m^2 = 1 Pa$



$$p_i = p_o - \frac{F}{A} = 10^5 Pa - \frac{480\ N}{77 \times 10^{-4}\ m^2} = 3.8 \times 10^4\ Pa$$

17. Crew members attempt to escape from a damaged submarine 100 m below the surface. What force must be applied to a pop-out hatch, which is 1.2 m by 0.6 m, to push it out at that depth? Assume that the density of the ocean water is 1024 kg/m^3 and the internal air pressure is at 1.0 atm.



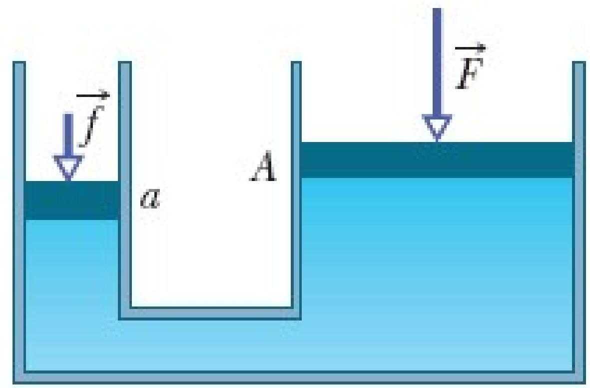
$p_o = p_0 + \rho g d$

$p_i = p_0$

$F = (p_o - p_i)A = \rho g d A$

$F = (1024)(9.8)(100)(1.2 \times 0.6) = 7.2 \times 10^5 \mathrm{N}$

28. A piston of cross-sectional area *a* is used in a hydraulic press to exert a small force of magnitude f on the enclosed liquid. A connecting pipe leads to a larger piston of cross-sectional area *A* (Fig. 14-36). (a) What force magnitude F will the larger piston sustain without moving? (b) If the piston diameters are 3.80 cm and 53.0 cm, what force magnitude on the small piston will balance a 20.0 kN force on the large piston?



(a) According to Pascal's principle,

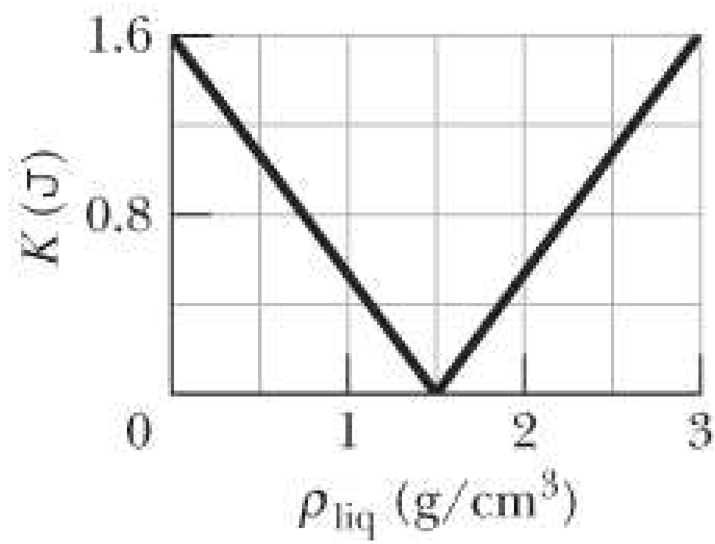
$$F/A = f/a \rightarrow F = (A/a)f.$$

(b) We obtain

$$f = (a/A)F$$

$$f = (3.8)^2/(53.0)^2(20.0\times10^3) = 103\ \text{N}.$$

38. A small solid ball is released from rest while fully submerged in a liquid and then its kinetic energy is measured when it has moved 4.0 cm in the liquid. Figure (below) gives the results after many liquids are used: The kinetic energy K is plotted versus the liquid density ρ_{lid}. What are (a) the density and (b) the volume of the ball?



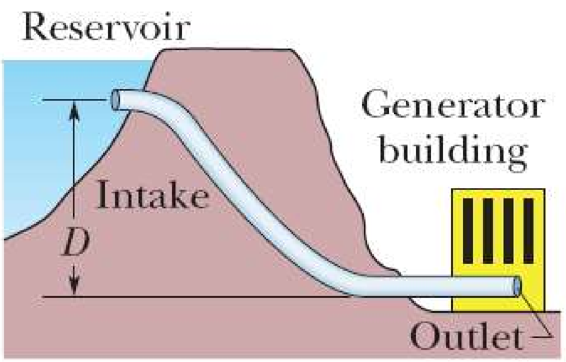
(a) An object, which has the same density as the liquid surrounding, won't gain any kinetic energy ($K = 0$) after releasing from rest: At $K = 0$, $\rho_{lid} = 1.5$ g/cm^3. So, $\rho_{ball} = 1.5$ g/cm^3 or 1500 kg/m^3

(b) At $\rho_{lid} = 0$, $K = 1.6$ J: In this case, the ball is freely falling in vacuum:

$$v^2 = 2gh; \quad K = \frac{1}{2}mv^2 \quad \rightarrow \quad m = \frac{K}{gh} = \frac{1.6}{9.8 \times 4.0 \times 10^{-2}} = 4.08\,(\text{kg})$$

$$\rightarrow \quad V_{ball} = \frac{m}{\rho_{ball}} = 2.72 \times 10^{-3}\,(\text{m}^3)$$

58. The intake in Fig. 14-47 has cross-sectional area of 0.74 m^2 and water flow at 0.40 m/s. At the outlet, distance D = 180 m below the intake, the cross-sectional area is smaller than at the intake and the water flows out at 9.5 m/s into equipment. What is the pressure difference between inlet and outlet?



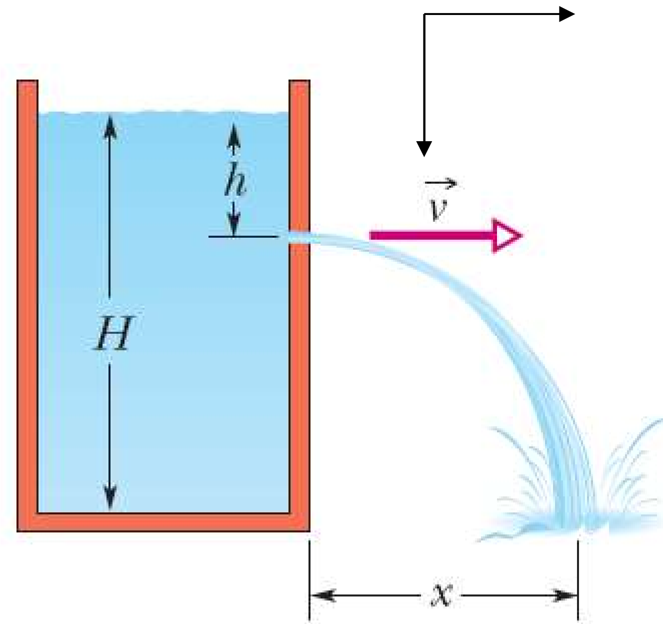
Bernoulli's equation:

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

$$p_2 - p_1 = \rho g D + \frac{1}{2}\rho(v_1^2 - v_2^2)$$

$$\Delta p = 1.7 \times 10^6 \text{ Pa} = 1.7 \text{ MPa}$$

71. Figure below shows a stream of water flowing through a hole at depth *h* = 10 cm in a tank holding water to height *H* = 40 cm. (a) At what distance *x* does the stream strike the floor? (b) At what depth should a second hole be made to give the same value of *x*? (c) At what depth should a hole be made to maximize *x*?



a)

$$x - x_0 = v_{0x}\, t \qquad (1)$$

$$y - y_0 = v_{0y}\, t - \tfrac{1}{2} g\, t^2 \qquad (2)$$

$$mgh = \tfrac{1}{2} m v_{0x}^2 \rightarrow v_{0x} = (2gh)^{1/2} \qquad (3)$$

$$(2) \rightarrow t = [2(y-y_0)/g]^{1/2} = [2(H-h)/g]^{1/2}$$

$$(1) \rightarrow x = v_{0x} t = [2gh*2(H-h)/g]^{1/2}$$

$$= 2[h(H-h)]^{1/2} = 35 \text{ cm}$$

71. Figure below shows a stream of water flowing through a hole at depth h = 10 cm in a tank holding water to height H = 40 cm. (a) At what distance x does the stream strike the floor? (b) At what depth should a second hole be made to give the same value of x? (c) At what depth should a hole be made to maximize x?

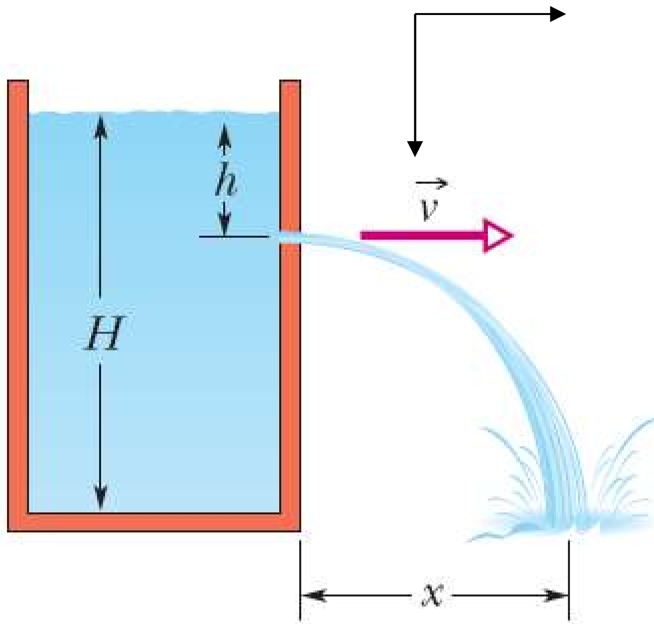
b)

$x^2 = 4h(H-h) \rightarrow h^2 - Hh + x^2/4 = 0$

$\rightarrow h = ½(H \pm (H^2 - x^2))^{1/2}$

$\rightarrow h_1 + h_2 = H$

$\rightarrow h_1 = 10$ cm $\rightarrow h_2 = 30$ cm



c) $f = x^2 = 4h(H - h)$

$df/dh = 8h - 4H = 0 \rightarrow h = ½ H = 20$ cm