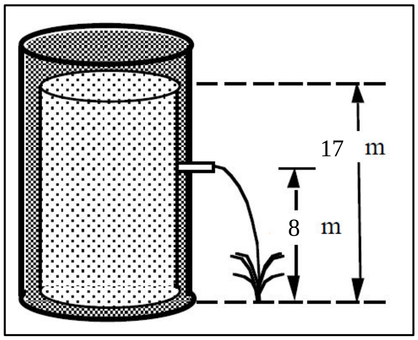
Physics

Unit 5: Fluids

1. Meanings and concepts of terms like fluid, density, barometer, Pascal's principle, Bernoulli's principle, Archimedes' principle, continuity equation, pressure, buoyant force, gauge pressure, absolute pressure, Poiseuille's Law, laminar flow, turbulent flow, viscosity
2. The density of mercury is 1.36×10^4 kg/m^3. What is the mass of a 10-m^3 sample of mercury?
3. The average density of the material in intergalactic space is approximately 2.5×10^{-27} kg/m^3. What is the volume of a gold sample, ρ = 19300 kg/m^3, that has the same mass as 5×10^{24} m^3 of intergalactic space?
4. A barometer is taken from the base to the top of a 10-m tower. Assuming the density of air is 1.29 kg/m^3, what is the measured change in pressure?
5. How much force does the atmosphere exert on one side of a vertical wall 10-m high and 20-m long?
6. A force of 500 N is applied to a hydraulic jack piston that is 0.01 m in diameter. If the piston which supports the load has a diameter of 2 m, approximately how much mass can be lifted by the jack? Ignore any difference in height between the pistons.
7. A balloon inflated with helium gas (density = 0.2 kg/m^3) has a volume of 5 m^3. If the density of air is 1.3 kg/m^3, what is the buoyant force exerted on the balloon?
8. Water enters a pipe of diameter 10 cm with a velocity of 5 m/s. The water encounters a constriction where its velocity is 20 m/s. What is the diameter of the constricted portion of the pipe?
9. A large tank is filled with water to a depth of 17 m. A spout located 8 m above the bottom of the tank is then opened as shown in the drawing. With what speed will water emerge from the spout?



10. A small crack occurs at the base of a 10 .0-m-high dam. The effective crack area through which water leaves is 1.30×10^{-3} m^2. Ignoring viscous losses, what is the speed of the water flowing through the crack?
11. Water flows through a pipe with radius 2 m and speed of 10 m/s. The density of water is 1000 kg/m^3 and its viscosity is 1.002×10^{-3} Pa•s. Calculate the Reynold's number for this situation.
12. The density of ice is 800 kg/m^3; and the density of seawater is 900 kg/m^3. A large iceberg floats in Arctic waters. What fraction of the volume of the iceberg is exposed?
13. A small artery has a length of 3×10^{-4} m and a radius of 1×10^{-6} m . If the pressure drop across the artery is 2000 Pa, what is the flow rate through the artery? (Assume that the viscosity of blood is 1.257 mPa/s.)

2. $\rho = 1.36 \times 10^4 \frac{kg}{m^3}, V = 10\ m^3$

$\rho = \frac{m}{V}$

$1.36 \times 10^4 \frac{kg}{m^3} = \frac{m}{10\ m^3}$

$m = \mathbf{1.36 \times 10^5\ kg}$

3. $\rho_{space} = 2.5 \times 10^{-27} \frac{kg}{m^3}, \rho_{gold} = 19300 \frac{kg}{m^3}, V_{space} = 5 \times 10^{24}\ m^3$

$\rho = \frac{m}{V}$

$2.5 \times 10^{-27} \frac{kg}{m^3} = \frac{m}{5 \times 10^{24}\ m^3}$

$m = 0.0125\ kg$

$19300 \frac{kg}{m^3} = \frac{0.0125\ kg}{V}$

$V = \mathbf{6.48 \times 10^{-7}\ m^3}$

4. $h = 10\ m, \rho_{air} = 1.29 \frac{kg}{m^3}$

$P = h\rho g$

$P = (10\ m)\left(1.29 \frac{kg}{m^3}\right)\left(9.8 \frac{m}{s^2}\right) = \mathbf{126\ Pa}$

5. $h = 10\ m, \ell = 20\ m$

$P = \frac{F}{A}$

$1.01 \times 10^5\ Pa = \frac{F}{(10\ m)(20\ m)}$

$F = \mathbf{2.02 \times 10^7\ N}$

6. $F_1 = 500\ N, d_1 = 0.01\ m, d_2 = 2\ m$

$\frac{F_1}{A_1} = \frac{F_2}{A_2}$

$\frac{500\ N}{\pi(0.005\ m)^2} = \frac{F_2}{\pi(1\ m)^2}$

$F_2 = 2.0 \times 10^7\ N$

$W = mg$

$m = \frac{W}{g} = \frac{2.0 \times 10^7\ N}{9.8\ m/s^2} = \mathbf{2.04 \times 10^6\ kg}$

7. $\rho_{He} = 0.2 \frac{kg}{m^3}, V = 5\ m^3, \rho_{air} = 1.3 \frac{kg}{m^3}$

$F_B = w_{fl}$

$F_B = m_{air} g$

$\rho = \frac{m}{V}$

$1.3 \frac{kg}{m^3} = \frac{m_{air}}{5\ m^3}$

$m_{air} = 6.5\ kg$

$F_B = (6.5\ kg)\left(9.8 \frac{m}{s^2}\right) = \mathbf{63.7\ N}$

8. $d_1 = 10\ cm, v_1 = 5 \frac{m}{s}, v_2 = 20 \frac{m}{s}$

$A_1 \overline{v}_1 = A_2 \overline{v}_2$

$(\pi(0.05\ m)^2)\left(5 \frac{m}{s}\right) = (\pi r_2^2)\left(20 \frac{m}{s}\right)$

$r_2 = 0.025\ m$

$d_2 = \mathbf{0.05\ m}$

9. $h_1 = 17\ m, h_2 = 8\ m, \rho = 1000 \frac{kg}{m^3}$

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$

$$1\ atm + 0 + \left(1000 \frac{kg}{m^3}\right)\left(9.8 \frac{m}{s^2}\right)(17\ m) = 1\ atm + \frac{1}{2}\left(1000 \frac{kg}{m^3}\right) v_2^2 + \left(1000 \frac{kg}{m^3}\right)\left(9.8 \frac{m}{s^2}\right)(8\ m)$$

$166600 \frac{N}{m^2} = \left(500 \frac{kg}{m^3}\right) v_2^2 + 78400 \frac{N}{m^2}$

$88200 \frac{N}{m^2} = \left(500 \frac{kg}{m^2}\right) v_2^2$

$v_2 = \mathbf{13.3 \frac{m}{s}}$

10. $P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$

$$1\ atm + 0 + \left(1000 \frac{kg}{m^3}\right)\left(9.8 \frac{m}{s^2}\right)(10\ m) = 1atm + \frac{1}{2}\left(1000 \frac{kg}{m^3}\right) v_2^2 + 0$$

$98000 \frac{J}{m^2} = 500 \frac{kg}{m^3}\ v_2^2$

$v_2 = 14 \frac{m}{s}$

11. $r = 2\ m, v = 10 \frac{m}{s}, \rho = 1000 \frac{kg}{m^3}, \eta = 1.002 \times 10^{-3} Pa \cdot s$

$N_R = \frac{2\rho v\ r}{\eta}$

$N_R = \frac{2\left(1000 \frac{kg}{m^3}\right)\left(10 \frac{m}{s}\right)(2\ m)}{1.002 \times 10^{-3} Pa \cdot s}$

$N_R = \mathbf{3.99 \times 10^7}$

12. $\rho_{ice} = 800 \frac{kg}{m^3}, \rho = 900 \frac{kg}{m^3}$

$Fraction\ submerged = \frac{\rho_{obj}}{\rho_{fl}}$

$Fraction\ submerged = \frac{800 \frac{kg}{m^3}}{900 \frac{kg}{m^3}}$

$Fraction\ submerged = \frac{8}{9} = 88.9\ \%$

$Fraction\ exposed = 1 - Fraction\ submerged$

$Fraction\ exposed = 1 - \frac{8}{9}$

$Fraction\ exposed = \mathbf{\frac{1}{9}} = \mathbf{11.1}\ \%$

13. Start by finding Q. $R = \frac{8\eta\ell}{\pi r^4}$

$$R = \frac{8(1.257 \times 10^{-3}\ Pa \cdot s)(3 \times 10^{-4}\ m)}{\pi(1 \times 10^{-6}\ m)^4} = 9.60 \times 10^{17} \frac{Pa \cdot s}{m^3}$$

Now find Q. $Q = \frac{P_2 - P_1}{R}$

$$Q = \frac{2000\ Pa}{9.60 \times 10^{17} \frac{Pa \cdot s}{m^3}} = \mathbf{2.08 \times 10^{-15} \frac{m^3}{s}}$$