6.8 EXERCISES

Definition of Pressure

Ex 6.8.1. In a zero gravity environment, some gas is kept at a pressure of 50,000 Pa in a rigid cylinder with movable piston. The area of the movable piston is 20 cm^2. What force must be applied on the piston so that it does not move?

Ans: 100 N.

Ex 6.8.2. In a low pressure laboratory, partial vacuum of 10^{-6} Torr is achieved. (a) What is the corresponding reading in millibar? (b) How much is that in psi? (c) How much is that in Pa?

Ans: (a) $1.33 \times 10^{-6}\ mbar$; (b) $1.9 \times 10^{-8}\ psi$; (c) $1.33 \times 10^{-4}\ Pa$.

Ex 6.8.3. Compare the pressures by a 1 N force on a pin and a nail. The tip of the pin has a diameter of 10 μm and the nail 100 μm.

Ans: pin: $1.27 \times 10^{10}\ Pa$; nail: $1.27 \times 10^{8}\ Pa$.

Ex 6.8.4. On a windy day, the air pressure outside a 90 cm $\times$ 200 cm door is 0.8 atm, while the air pressure inside the building is 1.0 atm. How much force must be applied at the handle of the door if the door opens outside and the door is hinged on the other end of the 200-cm side?

Ans: 18,000 N.

Variation of Pressure

Ex 6.8.5. Depth in a pond varies from 1 meter to 5 meters. What is the range of pressure at the bottom across the pool?

Ans: 111,000 to 150,000 Pa.

Ex 6.8.6. Acceleration due to gravity at moon is $\dfrac{1}{6}g$. What is the pressure at a depth of 2 meters in a tank of water at moon?

Ans: 3270 Pa.

Ex 6.8.7. Deduce a formula for the rate of change of pressure in a fish tank in an accelerating elevator when the elevator is (a) going up at acceleration $\vec{a}$ pointed up, (b) going down with acceleration a pointed up, (c) going down at acceleration a pointed down, and (d) going down at acceleration a pointed down. Hint: Direction of motion is not important.

Ans: With the positive y-axis pointed down, (a) $dp/dy = \rho(g+a)$; (b) $dp/dy = \rho(g-a)$.

Ex 6.8.8. Plot $p(y)$ vs y for atmosphere up to a height of 20,000 meters.

Ex 6.8.9. What is the air pressure at 40,000 feet?

Ans: $25,350$ Pa.

Ex 6.8.10. Solve $dp/dy = -3p^2$, given $p(0) \;=\; 1$ atm.

Ans: $p = 1/(1+3y)$.

Ex 6.8.11. Solve $dp/dy = -3\exp(-2y)$, given $p(0) \;=\; 1$ atm.

Ans: $p(y) = \frac{3}{2}\exp(-2y) - \frac{1}{2}$.

U-tube

Ex 6.8.12. An open U-tube has uniform cross-sectional area of 3 cm^2 and same height on both ends. Mercury is poured in it till the height from the top is 50-cm. How much water must be poured on one side so that the level of the mercury rises by 2 cm on the other side? Use $\rho_{\text{Hg}} = 13.6$ g/cm^3.

Ans: 81.6 cm^3.

Ex 6.8.13. Ethyl alcohol is now poured on the other side of the mercury in Ex. 6.8.12. How much ethyl alcohol must be poured so that the water level on the other side rises by 1 cm?

Ans: 47.8 cm^3.

Ex 6.8.14. An open U-tube has different cross-sections on the two sides. On one side the cross-section is 2.5 cm^2 and on the other side it 4.0 cm^2. Water is poured so that the level is 30 cm from the top on both sides. How much oil of density 0.8 g/cm^3 must be poured on the wider end so that water rises by 2 cm on the other end?

Ans: 16.4 cm^3.

Pascal's Principles

Ex 6.8.15. A freely movable piston of mass 100 kg covers water in a rigid cylinder of radius 5 cm touching the surface of the water. (a) What is the pressure at a depth of 50 cm from the top of water? A block of steel of mass 300 kg is placed on the piston. (b) What is the new pressure at a depth of 50 cm from the top?

Ans: (a) $2.31 \times 10^5\ Pa$; (b) $6.06 \times 10^5\ Pa$.

Ex 6.8.16. In a hydraulic jack, a 4,000 kg pickup truck is supported on the side with cross-sectional area 0.3 m^2 by a 100-N force act on the narrower end. (a) Find the area of cross-section of the narrower end. (b) A refrigerator weighing 3,000 kg is loaded on the truck. Now, what force must be used to support the truck?

Ans: (a) 7.65 cm^2; (b) 175 N.

Ex 6.8.17. A cylindrical tank containing oil is under pressure such that at the bottom pressure is 3 atm, while at the top the pressure is 1.5 atm. The cover of the container is removed so that the pressure at the top is now 1 atm. What is the pressure at the bottom now?

Ans: 2.5 atm.

Archimedes's Principle

Ex 6.8.18. A plastic spherical ball of negligible mass filled with air has a radius of 10 cm. A boy pushes the ball in water till quarter of its volume is submerged. How much force the boy must apply to keep the ball so submerged? Assume negligible change in the volume of the ball.

Ans: 10.3 N, down.

Ex 6.8.19. A 1-mm thick steel sheet is made into a cylindrical cup of area of radius 10 cm and height 30 cm with one end sealed and the other end open. It is then placed in water with the closed end first. How much of the cup stays above water? Do the problem first using symbols: Let M = mass of the cup, A = area of the bottom, h = height submerged, H = full height of the cup, ρ_0 = density of water.

Ans: in symbols: $h = M/A\rho_0$; height above water = 25.4 cm.

Ex 6.8.20. A cubic wooden block (density 0.9) of side 5 cm is placed in water. (a) How much of the block is under water? (b) The block is then pushed down by a force which balances the increase in the buoyancy force at each instant. What is the total work needed to fully submerge the block?

Ans: (a) 4.5 cm; (b) 0.31 mJ.

Ex 6.8.21. A closed cubical box of side a made of aluminum sheet floats in water with $\frac{1}{4}$ of it above the surface of water. From the given information and known densities of aluminum and water, determine the thickness t of the sheet as a function of a?

Ans: $t = 0.016\ a$.

Ex 6.8.22. A cubical box of side 10 cm made of steel has an open side. With open side of the box up, 90% of the box floats in mercury. How much of the box will float if 200 gram of load is put inside the box?

Ans: 0.953 cm above mercury.

Ex 6.8.23. A block of brass of mass 800 grams is attached to a string and hung from a support. The block is then placed so that half of the block is submerged in the water. What is the tension in the string? Use density of brass 8.6 g/cm^3.

Ans: 7.4 N.

Surface Tension

Ex 6.8.24. A rectangular film of mercury has a length of 2 cm and width 1 cm. It is stretched by 1.5 mm along its length while keeping the width same. What is the increase in surface energy of the film? Use surface tension of Hg = 0.48 N/m.

Ans: 14.4 μJ.

Ex 6.8.25. A perfectly spherical bubble of diameter 2 cm is blown with Olive oil aboard the International Space Station. How much work was done in going from 1 cm to 2 cm diameter? Surface tension of olive oil = 0.032 N/m.

Ans: 241 μJ..

Ex 6.8.26. An liquid of density 2 g/cc rises by 1.8 cm in a capillary tube of radius 0.075 cm when dipped vertically in the liquid. What is its surface tension?

Ans: 0.132 N/m.