Physics Club Problem Sheet - Introduction to Fluids

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1 Introduction

Fluid mechanics is the physics that governs the behaviour of fluids. Any substance that does not adhere to a specific shape, but rather has the ability to **flow** can be classified as a fluid. Some equations you may find useful for fluid mechanics are as follows:

$$A_1 v_1 = A_2 v_2$$

$$P = \rho g h$$

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

$$F = PA$$

2 Questions

Question 1 (Principles of Physics) A garden hose of internal diameter 1.9cm is connected to a stationary lawn sprinkler consisting of a container with 20 holes, each of them being 0.15cm in diameter. If water in the hose has a speed of $0.91\mathrm{m\,s^{-1}}$, at what speed does it leave the sprinkler?

Question 2 (Isaac Physics) CO_2 bubbles form on a thin straw of mass 0.43g placed in a fizzy drink. Given that bubbles have an average radius of 0.60mm and the liquid has a density of $\rho = 1.0\mathrm{g\,cm^{-3}}$, how many spherical bubbles must form on the straw to rise to the surface of the drink?

Question 3 (Isaac Physics) The 'spouting can', as shown in the figure below, is sometimes used to demonstrate the variation of pressure with depth. When the corks are removed from the tubes on the side of the can, the water of density ρ flows out with a speed that depends on the depth. (a) Assuming that the water level in the can remains constant, calculate the work done by hydrostatic pressure when a volume ΔV leaves the tube at height h below the

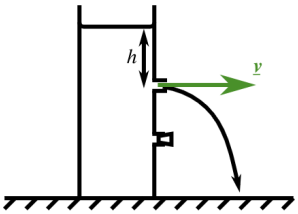

Figure 1: Question 1

top. (b) Assuming that this work provides all of the kinetic energy of the emerging water, find the speed of efflux (outflow).

3 Additional optional problems

Question 4 (Isaac Physics) King Hiero II hired a goldsmith to make him a gold crown. Yet, he has a feeling that the goldsmith had cheated him and alloyed the crown with silver whilst keeping some of the unused gold for himself. He asks the Greek mathematician Archimedes of Syracuse to find out if the crown is in fact pure gold without spoiling the crown. Throughout this question, assume that the density of gold is $19.32\text{g}\,\text{cm}^{-}3$ and the density of silver is $10.49\text{g}\,\text{cm}^{-}3$ (a) How many times more will the water level rise by placing some arbitrary mass of silver into container of water than the same mass of gold? (b) The (small) 'gold' crown, weighing 900g, is placed into a cylindrical container of radius 5cm. By how much would the water level rise if the crown was pure gold? (c) Given that the water level instead rises by 0.772cm, what percentage of the crown by mass is alloyed with silver?

Question 5 (JEE) When a train enters a narrow tunnel, your ears pop because of the pressure change. Find the pressure change, assuming the air has constant density ρ, the atmospheric pressure is P_0, the train speed is v, and the cross-sectional area of the train and tunnel are A_t and A_0 respectively.

4 Further reading for those interested

Physics Olympiad Handouts:
`https://knzhou.github.io/handouts/M7.pdf`

Video about Bernoulli's Principle:
`https://www.youtube.com/watch?v=DW4rItB20h4`

Thank you all for coming!