

NYU General Physics 1—Problem set 11

Problem 1: (a) Look up the pressure corresponding to one atmosphere in kPa. At sea level (that is, at $g = 9.8 \text{ m s}^{-2}$), under what depth h of water will the pressure be 2 atmospheres? That is, what depth leads to a pressure increase of one atmosphere?

(b) Same but for mercury. What is the conversion between mm of Hg and kPa?

(c) Imagine that the air was incompressible (that is, constant density). What height of atmosphere corresponds to one atmosphere of pressure? Use the STP density for air.

(d) The air is *not* incompressible, so what really is the meaning of the height computed in part (c) (no, the answer is not “no meaning at all”)? Can you think of any industrial activity on Earth that makes use of the altitude or height computed in part (c)?

Problem 2: A cube of ice 2 cm on a side floats in a glass of water. The water is at 0 deg C and the glass is in a room at STP. Look up or assume what you need in order to solve these problems.

(a) What is the pressure *difference* ΔP between the atmospheric pressure and the pressure at the bottom surface of the ice cube?

(b) If the ice cube melts, does the water level go up or down? Why?

(c) If you submerge the ice cube, and hold it at rest under water, there is a pressure difference ΔP between the top and bottom face of the cube. Is this larger than, smaller than, or the same as the pressure difference you calculated in part (a)?

(d) If you release the submerged cube, it will accelerate upwards. Immediately after release, what is the net force F on the ice cube? Can you think of two different ways of calculating this?

Problem 3: Blood flows through the aorta at a volumetric rate of something like $5 \ell \text{ min}^{-1}$.

(a) If the aorta has a diameter of 3.5 cm, at what speed v does the blood flow? Did you have to make any assumptions to answer that?

(b) Imagine that, because of a pathology, over a 20 cm length, the aorta narrows to 2.5 cm in diameter. What is the velocity change Δv from one end of this to the other?

(c) Consider a little cube of blood in the part of the aorta that is getting narrower. Give the cube a side length Δx and note that it is *accelerating*. What—qualitatively—does this mean about the pressure in the aorta? Ignore gravity for this problem; imagine that all blood flow is driven by blood pressure (this is true if the patient is lying down).

(d) In preparation for part (e), find a combination of speed v and mass density (mass per volume) ρ that has dimensions of pressure. Look up the density of blood and compute the pressure corresponding to the velocity v you found in part (a).

(e) Compute the pressure change from one end of this narrowing aorta to the other end, by thinking about the pressure gradient at each point that produces the necessary local acceleration. *Note: This is not easy!* Compare your result to normal mean human blood pressure. Discuss with your friends and colleagues.