Chapter 10: Fluids

Lecture 5
The University of Jordan/Physics Department
Prof. Mahmoud Jaghoub
أ.د. محمود الجاغوب

Applications

Torricelli's theorem

Find the speed v_1 of the water out of the small shown opening.

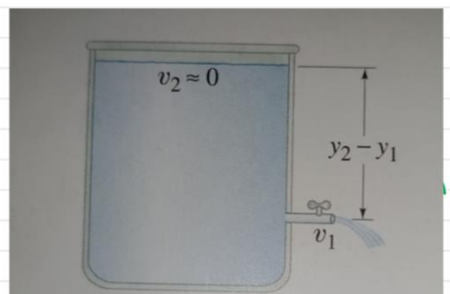


FIGURE 10–23 Torricelli's theorem: $v_1 = \sqrt{2g(y_2 - y_1)}$.

$$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2} m v_2^2$$

Note: $A_2 \gg A_1 \Rightarrow v_2 \sim 0$

$(A_1 v_1 = A_2 v_2)$.

$P_1 = P_2 = P_{atm}$

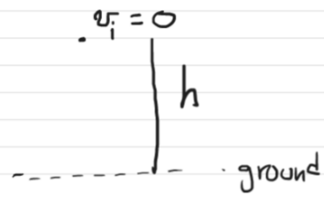
$$\therefore\ \cancel{P_{atm}} + \rho g y_1 + \tfrac{1}{2}\rho v_1^2 = \cancel{P_{atm}} + \rho g y_2 + \tfrac{1}{2}\rho \underbrace{v_2^2}_{=0}$$

$$A_1 v_1 = A_2 v_2$$
$$v_2 = \frac{A_1}{A_2} v_1 \sim 0$$

$$\therefore\ \tfrac{1}{2}\rho v_1^2 = \rho g (y_2 - y_1) = \rho g h$$

$$\therefore\ v_1^2 = 2gh \Rightarrow v_1 = \sqrt{2gh}\ ,\ h = y_2 - y_1 .$$

Compare: A stone is released from rest from a heigh h above the surface of the ground. Find its speed just before it hits the ground.



$\overset{\downarrow}{+}\ a = g$

$$v_f^2 - v_i^2 = 2g(y_f - y_i)$$
$$v_f^2 - 0 = 2gh$$
$$\therefore\ v_f = \sqrt{2gh}$$

So, the water in the tank acts <u>as if</u> it is in free fall.

62%

Transient Ischemic Attack (TIA)

small A → large v → small Pressure

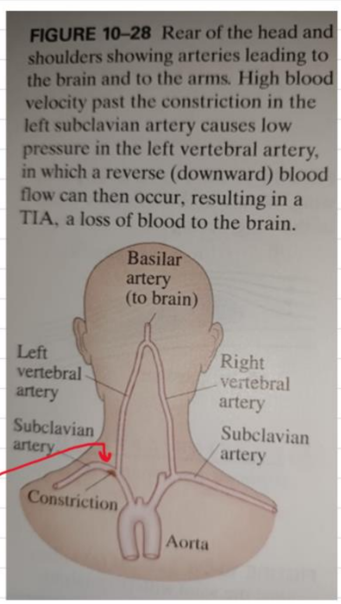


FIGURE 10–28 Rear of the head and shoulders showing arteries leading to the brain and to the arms. High blood velocity past the constriction in the left subclavian artery causes low pressure in the left vertebral artery, in which a reverse (downward) blood flow can then occur, resulting in a TIA, a loss of blood to the brain.

This means temporary lack of blood supply to the brain. It causes symptoms such as double vision, headache, weakness of limbs.

blood Pressure in right subcalvian artery is higher than left subcalvian artery ⇒ instead of blood going to the brain it is diverted to the left subcalvian artery as it has lower pressure.

Lift force on airplane wing : Lift force causes plaine to fly.

It is due to the difference in pressure.

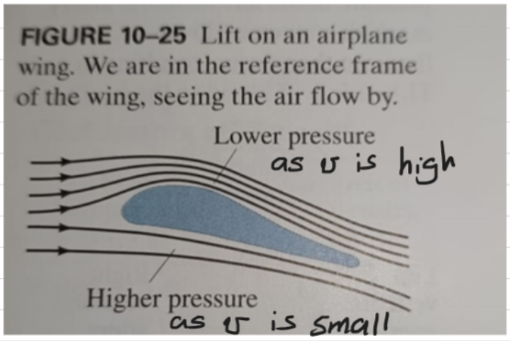


FIGURE 10–25 Lift on an airplane wing. We are in the reference frame of the wing, seeing the air flow by.

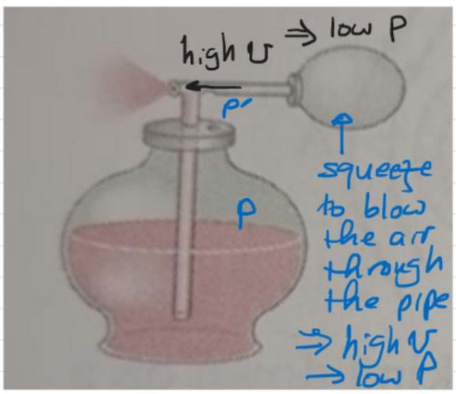
below wing : low $v \rightarrow$ high P.

above wing : high $v \rightarrow$ low P.

$\Rightarrow$ resultant lift force acts on the wing upwards.

Remember : $F = PA$.

Perfume Atomizer



Air is blown at high speed in the horizontal tube $\Rightarrow$ high v $\Rightarrow$ P' is low.

P' is lower than the pressure inside the perfume container $\Rightarrow$ perfume is pushed upwards through the vertical tube and then outside.

10-12] Flow in tubes: Poiseuill's Equation, Blood Flow

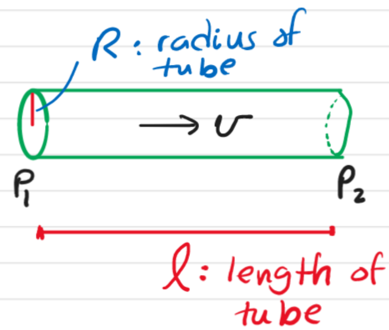
A non-viscous fluid can flow in a horizontal tube without applying a force.

When the fluid is viscous, the viscosity plays the role of friction and impedes the flow of the fluid layers.

For a viscous fluid to flow in the tube a pressure difference between the two ends of a level tube is necessary for the steady flow of any real (viscous) fluid.

Poiseuilli studied the factors that affect the flow rate of an incompressible fluid undergoing laminar flow in a cylindrical tube. His equation known as Poiseuilli's equation is given by:

$$Q = \frac{\pi R^4 (P_1 - P_2)}{8 \eta l}$$



$P_1 - P_2$: pressure difference between the two ends of the tube.

R : Inside radius of the tube

l : length of the tube.

η : coefficient of viscosity, which has units of $\frac{N.s}{m^2} \equiv Pa.s$ (Pascal)

Q : volume flow rate which has units of volume/unit time which is m^3/s in the SI system

Note that $Q \propto R^4 \Rightarrow$ when $R \rightarrow \frac{R}{2}$

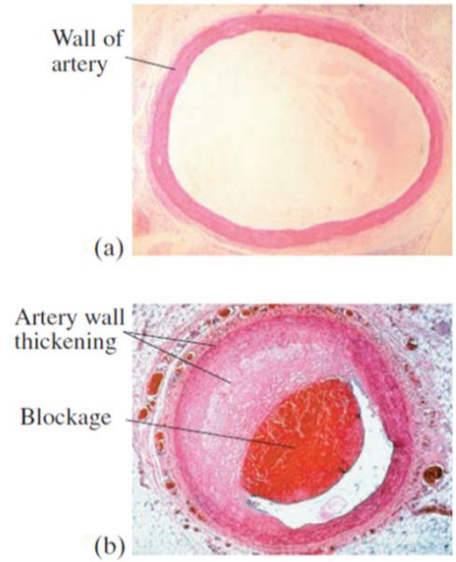
$\therefore Q \rightarrow Q/16$

Blood flow in the arteries is not 100% streamline flow, it can also be turbulant flow $\Rightarrow$ Poiseuilli's equation applies approximately to blood flow in the arteries, veins, capillaries.

Arteriosclerosis (thickening of the artery walls) case a reduction in the radius R.

So, to maintain the same flow rate Q unchange an increase in blood pressure gradient

$\frac{P_1 - P_2}{l}$ is required.



Therefore, the heart must work harder to maintan the same flow rate. Therefore, an increase in blood pressure is an indication that the heart is working harder and the blood flow rate is reduced.