PHYS 3511, Biological Physics, Assignment 7

Due Thursday March 30. This assignment is to be **handed in**. A part of this assignment will also be part of **quiz 3** on Thursday **March 30**.

QUESTION 1 Bernoulli's law is an expression of (A) the conservation of mass, (B) the conservation of kinetic energy, (C) the conservation of total energy, (D) the conservation of velocity, (E) the conservation of momentum.

QUESTION 2 Do the following experiment as shown in Fig. 12.32: Push a pin through the center of a thin sheet of cardboard. Locate the tip of the pin in the central hole of a thread spool from below. Hold the cardboard from below and start to blow through the hole. The cardboard will not drop to the floor when you release it. Which law explains this effect?
(A) Poiseuille's law, (B) Ohm's law, (C) equation of continuity, (D) Bernoulli's law, (E) Pascal's law.

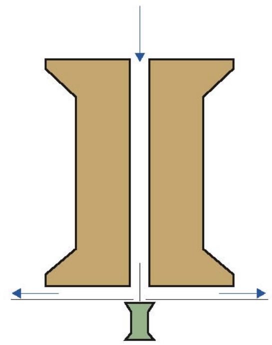

FIGURE 12.32

QUESTION 3
A blood vessel of radius r splits into two smaller vessels, each with radius $r/4$. If the speed of the blood in the large vessel is v_{large}, what is the speed of the blood in each of the smaller vessels (v_{small})? Treat blood as an ideal dynamic fluid.
(A) $v_{\text{small}} = 8 \times v_{\text{large}}$, (B) $v_{\text{small}} = 4 \times v_{\text{large}}$, (C) $v_{\text{small}} = v_{\text{large}}$, (D) $v_{\text{small}} = v_{\text{large}}/4$,
(E) $v_{\text{small}} = v_{\text{large}}/8$.

Start with **continuity equation**, $A_{\text{large}} v_{\text{large}} = 2 \times A_{small} v_{small}$, where the factor of 2 is due two smaller vessels. Now use, $A_{\text{large}} = \pi r^2$ and similar equation for, A_{small}.

QUESTION 4 Figure below shows a horizontal tube with a constriction and two open vertical columns. The inner radius of the larger section of the horizontal tube is 1.25 cm. Water passes through the tube at a rate of $0.18 L/s$. If $h_1 = 10 cm$ and $h_2 = 5 cm$, what is the inner radius of the constriction?

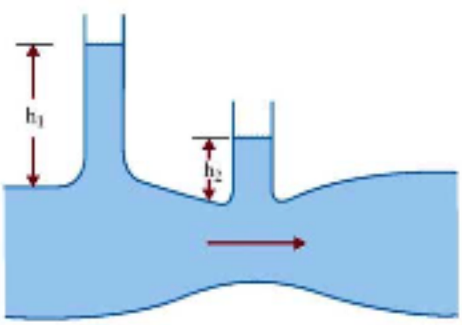

FIGURE 12.37

HINT: Use Bernoulli's Law Equation 13.5 and 13.6. Also look at class notes.
ANSWER: $r = 7.4 \times 10^{-3} m$

Question 5 A patient is to be injected with 0.5 L of an electrolyte solution in 1/2 hour. Assuming that the solution is elevated by 1.0 m above the arm and the needle is 2.5 cm long, what inner radius should the needle have? Use water parameters for the solution, and assume that the pressure in the patient's vein is atmospheric pressure. **ANSWER:** $r = 0.205mm$.

Question 6

A) Read section 13.1 (pp 320-322) and focus on Figure 13.3. Estimate the **total length of all arteries, veins, and capillaries** from the data of Figure 13.3 (page 323). Compare to the 60000 to 100000 km found online.

As an example, I will calculate the length of the arterioles,

Arterioles: one arterioles $A_{arteriole} = \pi(0.001cm)^2 = 3.14\times10^{-6}cm^2$; all area $A_{all} = 500cm^2$; number $n_{arteriole} = A_{all} / A_{arteriole} = 1.6\times10^8$ (matches value on Figure 13.3); 1 arteriole $\ell_{arteriole} = V / A_{all} = 125cm^3 / 500cm^2 = 0.25cm$; total length of arterioles $n_{arteriole}\ell_{Sarteriole} = 4\times10^7 cm$.

Use the same method to do the other lengths.

B) Read example 13.6 on pp. 337-338. Table 13.2 calculates the effective resistance of the arterioles, aorta, and capillaries. Using data from figure 13.3, calculate the resistance of the remaining type of vessels. Calculate the effective resistance of the blood circulation system. Use the Poseuille's law to estimate the pressure drop, ΔP, over the whole circulation system. Compare your result with the pressure drop of 2000 Pa, from when blood left the heart from the aorta to when it returns to the heart through the veins.

Again I will do as an example the arterioles:

Arterioles: $R_{arteriole} = \left(\frac{8\times2.5\times10^{-3}m}{\pi\times(1\times10^{-5}m)^4}\right)\times2.5\times10^{-3}Pa\bullet s = 1.6\times10^{15}\frac{Pa\bullet s}{m^3}$. There are $n_{arterioles} = 1.6\times10^8$, which we will assume are in **parallel**, giving $R^{total}_{arteriole} = \left(\frac{n_{arteriole}}{R_{arteriole}}\right)^{-1} = 1\times10^7 Pa\bullet s\bullet m^{-3}$. **NOTE:** In the textbook the inner radius of $r = 8\times10^{-6}m$ is used, which gives $R_{arteriole} = 3.9\times10^{15}Pa\bullet s\bullet m^{-3}$ and $R^{total}_{arteriole} = 2.4\times10^7 Pa\bullet s\bullet m^{-3}$