Physics 112
Exam 1
Winter 1994
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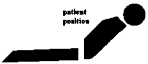
Name: ____________________

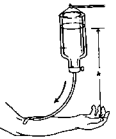
Social Security #: ____________________

15 TA (circle one): Denholm Erickson Freier Inglefield Plautz Stigers

5 A tube is inserted into a vein in the wrist of a patient in a reclined position on a hospital bed. The heart is vertically 25.0 cm above the position of the wrist where the tube is inserted. Take $\rho_{BLOOD} = 1.06 \times 10^3$ kg/m³. The gauge venous blood pressure at the level of the heart is 6.16×10^3 N/m². Assume blood behaves as an ideal nonviscous fluid.



(a)



(b)

A. (*10 pts.*) What is the gauge venous blood pressure at the position of the wrist?

$P_{GAUGE\ AT\ WRIST} = P_{GAUGE\ AT\ HEART} + \rho_{BLOOD}\, g\, h_{HEART\ ABOVE\ WRIST}$

$= 6.16\times10^3\ N/m^2 + (1.06\times10^3\ kg/m^3)(9.8\ m/s^2)(0.25\ m)$

$P_{GAUGE\ AT\ WRIST} = 8.76\ kPa$

B. (*11 pts.*) The tube coming from the wrist is connected to a bottle of whole blood the patient needs in a transfusion. See above figure (b). What is the minimum height above the level of the heart at which the bottle must be held to deliver the blood to the patient? FOR FLUID IN BOTTLE TO BE DELIVERED TO PATIENT $P_{GAUGE\ AT\ WRIST}$ (OF FLUID) > P_{GAUGE} (FROM A)

THUS $h_{MIN} = \dfrac{P_{GAUGE\ FROM\ A}}{\rho_{BLOOD}\, g} = \dfrac{8.76\times10^3\ N/m^2}{(1.06\times10^3\ kg/m^3)(9.8\ m/s^2)}$

$h_{MIN} = 0.843\ m$

C. (*12 pts.*) Suppose the bottle of blood is held 1.00 m above the level of the heart. Assume the tube inserted in the wrist has a diameter of 2.80 mm. What is the velocity, v, and flow rate of blood as it enters the wrist. You may also assume the rate at which the blood level in the bottle drops is very small. The answer you get here is a substantial overstatement. Blood is not really a non-viscous fluid.

USE STREAMLINE FROM TOP SURFACE OF BLOOD IN BOTTLE TO A POINT AT END OF NEEDLE IN ARM. ALSO LET REF. BE AT NEEDLE. ALSO, ASSUME $P_{SURFACE\ OF\ BLOOD} = P_{ATM}$. THEN,

$P_{ATM} + \frac{1}{2}\rho v_{TOP}^2 + \rho g h = P_{AT\ WRIST} + \frac{1}{2}\rho v_W^2 + \rho g(0)$ $\quad v_{TOP} \approx 0$

$P_{AT\ WRIST} = P_{ATM} + P_{GAUGE\ AT\ WRIST}$

NOTE: $h = 1.00\ m + 0.25\ m$

$v_W = \sqrt{\dfrac{2\rho g h - 2P_{GAUGE}}{\rho}}$

$= \sqrt{\dfrac{(2)(1.06\times10^3\ kg/m^3)(9.8\ m/s)(1.25\ m) - (2)(8.76\times10^3\ N/m^2)}{1.06\times10^3\ kg/m^3}}$

$v_W = 2.82\ m/s$

FLOW RATE

$\frac{dV}{dt} = Av = \pi(1.4\times10^{-3}\ m)^2\, 2.82$

$\frac{dV}{dt} = 1.74\times10^{-5}\ \frac{m^3}{s}$