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PHYSICS FOR THE LIFE SCIENCES

Solution Manual

Created by WebStraw

Physics for the Life Sciences – Fluids Solutions

Introduction:

Dear student,

Thank you for opening this solution manual for the Fluids chapter of the Physics for the Life Sciences Question Manual. This resource has been created by members of the Education Team at WebStraw who have previously taken an introductory university physics course.

Purpose:

This resource is meant to supplement the Physics for the Life Sciences Question Manual, by providing solutions to select questions. To access the full question manual, please click here.

Instructions

We recommend first trying to complete the problems in the question manual on your own. If you get stuck, you can use this resource to view the solution provided by one of our Education Team members. Once you are confident you understand how to solve that question, we recommend solving additional related problems in order to successfully master the topic.

Disclaimer

This resource assumes that you have a basic understanding of key concepts related to the Fluids unit in physics. If you are looking to improve your understanding of specific physics content, check out the additional resources provided at the end of the question manual.

Note: There may be more than one correct method to solve some of the problems outlined in the question manual. Thus, the solutions provided may not represent the only acceptable solution.

If you have any comments or feedback regarding this resource or the solutions contained in it, please do not hesitate to contact us at team@webstraw.ca

We wish you the best of luck on your learning journey!

- The WebStraw Education Team

F1)

air pressure $\propto \frac{1}{\text{altitude}} \propto$ density

↑ air pressure ↓ altitude ↑ density

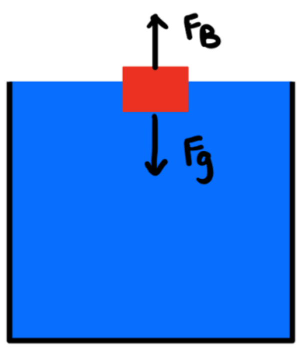
↓ air pressure ↑ altitude ↓ density

bc @ higher altitude, lower gravity

=> air molecule spread more => low density

F3) water help reduce apparent weight so reduce pressure on vessel. Circulation of blood in leg also increase in water.

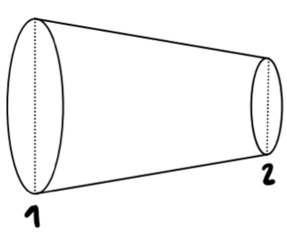
F5)



The downward force change by the addition of gravitational force by object

F7) Priciple of continuity

$A_1V_1 = A_2V_2$



as water go vertical, velocity decrease

bc AV stay constant. ∴ Area has to increase

F9) $F_{Buoyancy} = \rho V_{in} g$

ρ = density of H_2O

g = gravitational acceleration

bc mass same for both object => same $F_{Buoyancy}$

∴ both displace same volume of water

F11) bernoulli theorem

$P_1 + \frac{1}{2}\rho v^2 + \cancel{\rho g h} = \text{constant}$

if velocity decrease, ρ stay constant

∴ Pressure is forced to increase to balance

F13) $\rho_{fresh} < \rho_{salt}$

∴ boat in freshwater float less => less above water

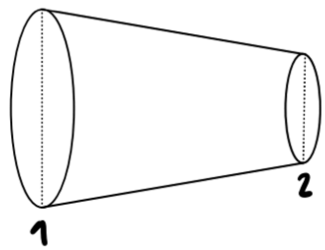
F15) By bernoulli principle,

↑ Pressure ↓ velocity

outside hv higher pressure, try to balance pressure

∴ pull out object to balance

F17)



flow rate = $A \cdot v$

Principle of continuity

$A_1 V_1 = A_2 V_2$

if reduce A_2 $\quad V_2 = \frac{A_1 V_1}{A_2} \Rightarrow \uparrow V_2$

$\therefore$ causing water to exit faster

F19)

$$\% \text{ submerge} = \frac{\rho \text{ of object}}{\rho \text{ of salt } H_2O} \times 100$$

$\hookrightarrow = 1.024 \text{ g/mL}$

$m = 5000 g$

$V = 4300 \text{ mL}$

$\rho_{obj} = \frac{m}{V} = 1.02 \text{ g/mL}$

% submerge = 98.1 %

$\Downarrow$

float = 1 − % submerge = 1.90 %

F21) 1 kpa = 7.5 torr = 0.01 bar = 0.001 atm

$760 \text{ torr} \times \frac{\text{kpa}}{\text{torr}} = 101.3 \text{ kpa}$

$$760 \text{ torr} \times \frac{\text{bar}}{\text{torr}} = 1.01 \text{ bar}$$

$$760 \text{ torr} \times \frac{\text{atm}}{\text{torr}} = 1.0 \text{ atm}$$

F23) $P = \rho g \underbrace{h}_{=y}$

$P_1 = 40 \text{ kpa} \Rightarrow 40 \times 10^3 \text{ Pa}$

$$y = \frac{P_1}{\rho g} = \frac{40 \times 10^3}{\rho g}$$

$P_2 = 80 \text{ kpa} \Rightarrow 80 \times 10^3 \text{ Pa}$

$$h_2 = \frac{80 \times 10^3}{\rho g} = 2y$$

$P_3 = 120 \text{ kpa} \Rightarrow 120 \times 10^3 \text{ Pa}$

$$h_3 = \frac{120 \times 10^3}{\rho g} = 3y$$

$P_4 = 160 \text{ kpa} \Rightarrow 160 \times 10^3 \text{ kpa}$

$$h_3 = \frac{160 \times 10^3}{\rho g} = 4y$$

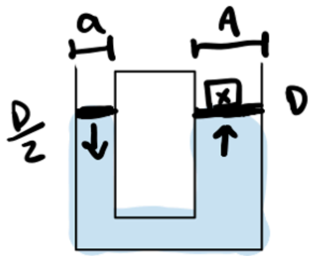
F25) $\rho_{mercury} = 13600 \text{ kg/m}^3$

$P = 3 \text{ atm} = 303975 \text{ Pa}$

$P = \rho g h$

$$h = \frac{P}{gh} = 2.28 \text{m}$$

F27)



$F = Pa \Rightarrow P = \frac{F}{a}$

$F' = PA \Rightarrow F' = F\left(\frac{A}{a}\right) = mg$

$m = x$

$a = \pi\left(\frac{D}{2}\right)^2$

$A = \pi(D)^2$

$F = \frac{a}{A} mg$

$= \frac{\cancel{\pi}\left(\cancel{D}/2\right)^2}{\cancel{\pi}\,\cancel{D^2}} xg$

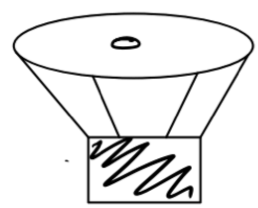
$F = \frac{1}{4} xg$ N

$\therefore$ require $\frac{xg}{4}$ amnt of force

F29)

$r = 0.33\text{mm} = 3.3 \times 10^{-4}\text{m}$

$m = 1.44\text{g} = 1.44 \times 10^{-3}$ kg



$P = \frac{F}{a}$ $\quad F = mg$

$a = \pi r^2$

$\Downarrow$

$P = \frac{mg}{\pi r^2} = 4.13 \times 10^4$ Pa

$\therefore$ pressure exerted is 4.13×10^4 Pa

F31)

$F = PA$

$P = 400\text{atm} = 4.05 \times 10^7$ Pa

$r = 40\text{cm} = 0.40\text{m}$

$F = P \cdot \pi \cdot r^2$

$F = 5.06 \times 10^6\ N$

F33) $P = \frac{F}{A}$ $m = 58kg$ $A_1 = 1.5\ cm^2 = 1.5 \times 10^{-4}\ m^2$

$F = mg = 568.4\ N$ $A_2 = 2.25\ cm^2 = 2.25 \times 10^{-4}\ m^2$

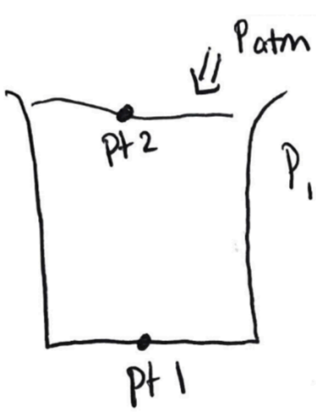
$\Delta P = P_2 - P_1 = \frac{F}{A_2} - \frac{F}{A_1}$

$= F\left(\frac{1}{A_2} - \frac{1}{A_1}\right)$

$\Delta P = 126.3 \times 10^4\ Pa$

$\therefore$ pressure difference is 126.3×10^4 Pa

F35.



Bernoulli's principle:

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

$P_1 = P_{atm} + \rho g h_2$

$= 101\ kPa + (1000\frac{kg}{m^3})(9.8\frac{m}{s^2})(9780\ m)$

$= 101\ kPa + 95844000\ Pa$

$= 101\ kPa + 95844\ kPa$

$= 95945\ kPa$

$\therefore$ the pressure at point 1 (bottom of the trench) is $9.59 \times 10^4\ kPa$.

F37.

$d = 0.5\,m$

$r = 0.25\,m$

$Q = 12\,L/s$

$Q = 0.012\,m^3/s$

$Q = AV$

$V = \dfrac{Q}{A}$

$= \dfrac{Q}{\pi r^2}$

$= \dfrac{0.012\,m^3/s}{\pi(0.25\,m)^2}$

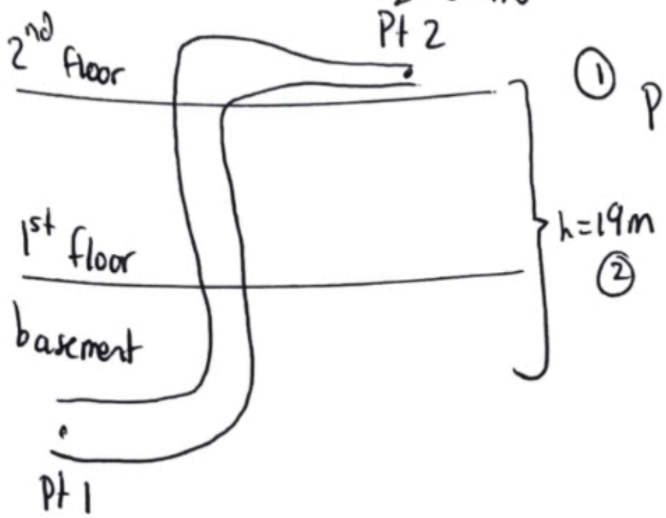
$= 0.0611\,m/s$

$\therefore$ the speed of the fluid moving through the pipe is $0.06\,m/s$.

F39

$d_2 = 8\,cm \quad r_2 = 0.04\,m$

$V_2 = 8\,m/s$



Bernoulli's Principle/Equation

① $P_1 + \frac{1}{2}\rho V_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho V_2^2 + \rho g h$

Equation of continuity:

② $A_1 V_1 = A_2 V_2$

$\cancel{\pi} r_1^2 \cancel{*} V_1 = \cancel{\pi} r_2^2 V_2$

$V_1 = \dfrac{r_2^2}{r_1^2} V_2$

$d_1 = 14\,cm \quad r_1 = 0.07\,m$

$V_1 = ?$

$V_1 = \dfrac{(0.04\,m)^2}{(0.07\,m)^2}(8\,m/s)$

$V_1 = 2.61\,m/s$

① $P_1 + \frac{1}{2}\rho v_1^2 + \cancel{\rho g h_1}^{0} = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$

$$P_1 - P_2 = \frac{1}{2}\rho\left(v_2^2 - v_1^2\right) + \rho g h_2$$

* $P_1 - P_2 = P_{gauge}$

$$= \frac{1}{2}(1000\,kg/m^3)\left((8\,m/s)^2 - (2.61\,\frac{m}{s})^2\right) + (1000\,kg/m^3)(9.8\,m/s^2)(19\,m)$$

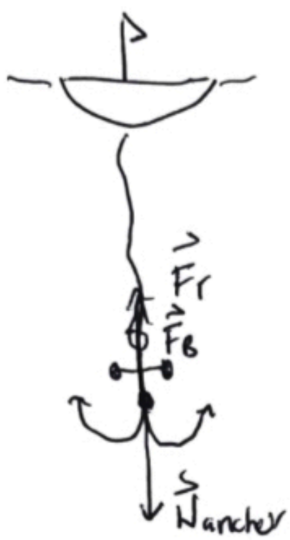
$$= 28593.95\,kg/m\cdot s^2 + 186200\,\frac{kg}{m\cdot s^2}$$

$$= 214793.95\ Pa$$

$$= 215\ kPa$$

∴ the gauge pressure at Point 1 (in the basement) is 215 kPa.

F41.



$m_{anchor} = 110\,kg$

$\rho_{anchor} = 19300\,kg/m^3$

$$\rho = \frac{m}{V}$$

$$V = \frac{m}{\rho}$$

$$= \frac{110\,kg}{19300\,kg/m^3}$$

$$= 0.00569948\,m^3$$

$V_{anchor} = V_{df}$ (when anchor is fully submerged)

$$\Sigma F = \vec{F}_T + \vec{F}_B - \vec{W}_{anchor}$$

$$\cancel{ma} = \vec{F}_T + \vec{F}_B - \vec{W}_{anchor}$$

Archimedes' Principle

$$\vec{F}_B = \vec{W}_{displaced\ fluid}$$

$$\vec{F}_T = \vec{W}_{anchor} - \vec{F}_B$$

$$= M_{anchor}\, g - \vec{W}_{df}$$

$$= (110kg)(9.8\tfrac{m}{s^2}) - M_{df}(9.8\tfrac{m}{s^2})$$

$$= 1078 \tfrac{kg \cdot m}{s^2} - \rho_{df} V_{df} (9.8 m/s^2)$$

$$= 1078 \tfrac{kg \cdot m}{s^2} - (1000 \tfrac{kg}{m^3})(0.0056994898 m^3)(9.8 \tfrac{m}{s^2})$$

$$= 1078 \tfrac{kg \cdot m}{s^2} - 55.8549 \tfrac{kg \cdot m}{s^2}$$

$$= 1022.145 \tfrac{kg \cdot m}{s^2} \text{ or } N$$

∴ the force of tension in the rope is 1022 N.

F43. Given:

$$\rho_{ring} = 3.51\ g/cm^3 = 3510\ kg/m^3$$

$$\rho_{water} = 1000\ kg/m^3$$

Asked For:

% of rings ~~W~~volume above water

Formula/Theory:

Archimedes' Principle

$$\vec{F}_B = \vec{W}_{displaced\ fluid}$$

$$\Sigma F = \vec{F}_B - \vec{W}_{ring}$$

$$\cancel{ma}^{\,0} = \vec{F}_B - \vec{W}_{ring}$$

$$\vec{F}_B = \vec{W}_{ring}$$

$$\vec{W}_{df} = \vec{W}_{ring}$$

$$m_{df} g = m_{ring} g$$

$$\rho_{df} V_{df} = \rho_{ring} V_{ring}$$

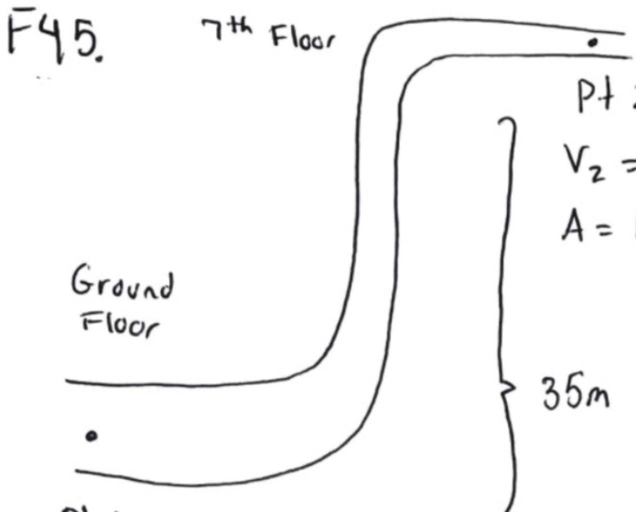
$$\frac{\rho_{df}}{\rho_{ring}} = \frac{V_{ring}}{V_{df}}$$

$$\frac{1000\,kg/m^3}{3510\,kg/m^3} = \frac{V_{ring}}{V_{df}}$$

$$\frac{V_{ring}}{V_{df}} = 0.2849 \times 100\% = 28.5\%$$

$\therefore$ the % volume of the ring above water is 28.5 %.

F45.



Pt 2

$V_2 = ?$

$A = 10\,cm^2 = 0.001\,m^2$

$\rho_{water} = 1000\,kg/m^3$

$g = 9.8\,m/s^2$

$P_1 = ?$

$P_2 = 4.20 \times 10^5\,Pa$

Pt 1

$V_1 = 4\,m/s$

$d_1 = 0.06\,m \quad r_1 = 0.03\,m$

a) Equation of continuity: $Q_1 = Q_2$

$$A_1 V_1 = A_2 V_2$$

$$V_2 = \frac{A_1 V_1}{A_2}$$

$$= \frac{\pi(0.03m)^2(4m/s)}{0.001m^2}$$

$$= 11.31 m/s$$

b) Bernoulli's Principle/Equation:

$$P_1 + \frac{1}{2}\rho v_1^2 + \cancel{\rho g h_1} = P_2 + \frac{1}{2}\rho V_2^2 + \rho g h_2$$

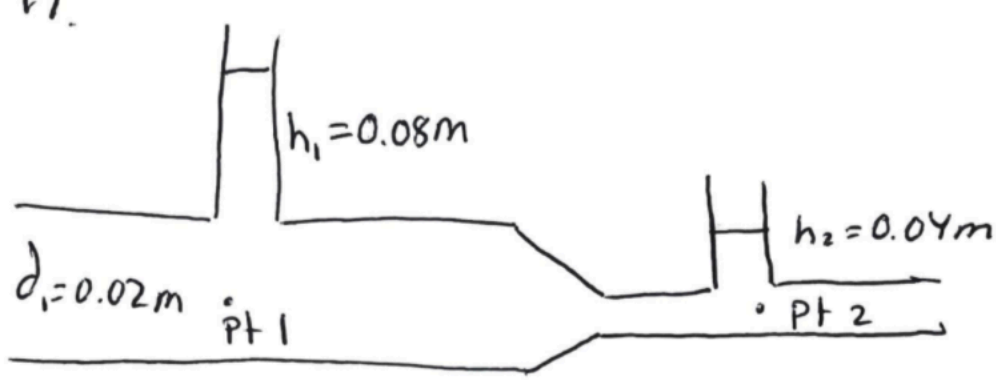
$$P_1 + \frac{1}{2}(1000)(4)^2 = 4.20\times10^5 Pa + \frac{1}{2}(1000\frac{kg}{m^3})(11.31\frac{m}{s}) + (1000)(9.8)(35)$$

$$P_1 = 7.68655\times10^5 Pa - 8000 Pa$$

$$P_1 = 760655 \text{ Pa} = 761 \text{ kPa}$$

$\therefore$ the velocity on the 7th floor is 11 m/s and the pressure on the ground floor is 760 KPa;

F47.



* horizontal

Bernoulli's principle:

$$P_1 + \frac{1}{2}\rho V_1^2 + \cancel{\rho g h_1} = P_2 + \frac{1}{2}\rho V_2^2 + \cancel{\rho g h_2}$$

$$\rho g h_1 + \tfrac{1}{2}\rho V_1^2 = \rho g h_2 + \tfrac{1}{2}\rho V_2^2$$

$$(9.8\,m/s^2)(0.08m) + \tfrac{1}{2}(V_1^2) = (9.8\,m/s^2)(0.04m) + \tfrac{1}{2}(V_2^2)$$

$$0.392\,m^2/s^2 + \tfrac{1}{2}(1.098\tfrac{m}{s})^2 = \tfrac{1}{2}V_2^2$$

$$0.9948\,m^2/s^2 = \tfrac{1}{2}V_2^2$$

$$\sqrt{1.9896\,m^2/s^2} = V_2 \longrightarrow V_2 = 1.41\,m/s$$

Equation of continuity/Q equation:

$$Q_1 = 0.000345\,m^3/s$$

$$d_1 = 0.02\,m \qquad r_1 = 0.01\,m$$

$$Q_1 = A_1 V_1$$

$$V_1 = \frac{(0.000345\,m^3/s)}{\pi(0.01m)^2}$$

$$V_1 = 1.098\,m/s$$

$$0.000345\,\tfrac{m^3}{s} = (1.41\tfrac{m}{s})\pi r_2^2$$

$$\sqrt{7.7884\times10^{-5}} = r_2$$

$$r_2 = 0.0088\,m$$

$$d_2 = 0.0176\,m$$

$$d_2 = 1.76\,cm$$

∴ the diameter of the smaller pipe is 1.76 cm or 1.8 cm.

F49.

$$V = 50.0\,m/s$$

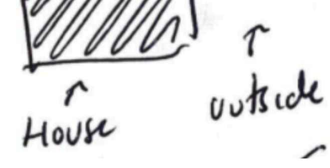
$$A = 250\,m^2$$

$$\rho_{air} = 1.11\,kg/m^3$$

$$P_{atm} = 9.00\times10^4\,N/m^3$$

Assume V inside house is zero

height is not relevant



Bernoulli's Equation:

$$P_1 + \frac{1}{2}\rho V_1^2 + \cancel{\rho g h_1} = P_2 + \frac{1}{2}\rho V_2^2 + \cancel{\rho g h_2}$$

$$P_1 + \cancel{\frac{1}{2}\rho V_1^2}^{\,0} = P_{atm} + \frac{1}{2}\rho V_2^2$$

$$\frac{F_\perp}{A} = P_{atm} + \frac{1}{2}\rho V_2^2$$

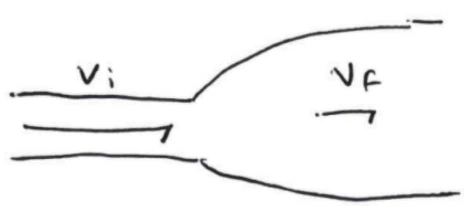
$$\frac{F_\perp}{250\,m^2} = 9.00\times10^4 \frac{N}{m^3} + \frac{1}{2}(1.11\,kg/m^3)(50.0\,m/s)^2$$

$$F_\perp = 22846875\,N$$

$$F_\perp = 2.3\times10^7\,N$$

∴ the force according to Bernoulli's equation is $2.3\times10^7\,N$.

F51.



* Assuming constant flow => Equation of continuity: $Q_i = Q_f$

$$\frac{d}{2} = r$$

$$V_i A_i = V_f A_f$$

$$V_i \pi r_i^2 = V_f \pi r_f^2$$

$$V_i \left(\frac{d_i}{2}\right)^2 = V_f \left(\frac{d_f}{2}\right)^2$$

$$\frac{d_f}{d_i} = \frac{7}{4} \quad \text{or} \quad \frac{4}{7} = \frac{d_i}{d_f}$$

$$V_i \frac{d_i^2}{\cancel{A}} = V_f \frac{d_f^2}{\cancel{A}}$$

$$V_i\, d_i^2 = V_f\, d_f^2$$

$$V_i\, d^2 = V_f\left(\frac{7}{4} d_f\right)^2$$

$$V_1 \cancel{d^2} = V_f \frac{49 \cancel{d^2}}{16}$$

$$16 V_i = 49 V_f$$

$$\frac{V_i}{V_f} = \frac{49}{16}$$

∴ the ratio of initial velocity to final velocity assuming the diameter is $\frac{7}{4}$ times greater is $\frac{49}{16}$

F53. Bernoulli's principle:

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

$$(3.0\times10^6 Pa) + \tfrac{1}{2}\rho v_1^2 + (1000\tfrac{kg}{m^3})(9.8\tfrac{m}{s^2})(60m) = 8.0\times10^5 Pa + \tfrac{1}{2}\rho V_2^2 + (1000\tfrac{kg}{m^3})(9.8\tfrac{m}{s^2})(140m)$$

$$3.0\times10^6 Pa\ \tfrac{1}{2}\rho v_1^2 + 588000 kg/_{m\cdot s^2} = 8.0\times10^5 Pa + \tfrac{1}{2}\rho V_2^2 + 1372000 \tfrac{kg}{m\cdot s^2}$$

$$3.0\times10^6 Pa + 5.88\times10^5 Pa + \tfrac{1}{2}\rho V_1^2 = 8.0\times10^5 Pa + 1.372\times10^6 Pa + \tfrac{1}{2}\rho V_2^2$$

$$3.588\times10^6 Pa + \tfrac{1}{2}\rho V_1^2 = 2.172\times10^6 Pa + \tfrac{1}{2}\rho V_2^2$$

∴ considering the end of the pipe that is at height 60m has a higher pressure aside from the pressure involving velocity and density is consistent for both, the velocity at the other end (height 14m) will be exiting the pipe faster.

P55. Given

$Q_1 = 560 L/min = 0.00933\bar{3} m^3/s$

Equation of Continuity:

$$Q_1 = 4Q_2$$

$$Q_2 = \frac{0.00933 m^3/s}{4}$$

$$= 0.0023325 m^3/s \text{ or } 140 L/min$$

∴ the flow rate in each seperate stream is 140 L/min

F57.

Given:

$V_1 = 10\ m/s$ $\quad V_2 = ?$ $\quad P_1 = P_2$

$h_1 = 3m$ $\quad h_2 = 0$ $\quad \rho = 1000\ kg/m^3$

$d_1 = 0.6m$ $\quad d_2 = ?$ $\quad g = 9.8\ m/s^2$

$r_1 = 0.3m$ $\quad r_2 = ?$

Equations:

① $$\cancel{P_1} + \frac{1}{2}\rho V_1^2 + \rho g h_1 = \cancel{P_2} + \frac{1}{2}\rho V_2^2 + \cancel{\rho g h_2}^{\,0}$$

$$\frac{1}{2}(1000\,kg/m^3)(10\,\tfrac{m}{s})^2 + (1000\,\tfrac{kg}{m^3})(9.8\,\tfrac{m}{s^2})(3m) = \frac{1}{2}(1000\,\tfrac{kg}{m^3})V_2^2$$

$$\frac{79400\ kg/m\cdot s^2}{500\ \frac{kg}{m^3}} = \frac{\cancel{500\,\frac{kg}{m^3}}\ V_2^2}{\cancel{500\,\frac{kg}{m^3}}}$$

$$\sqrt{158.8\ m^2/s^2} = V_2$$

$$V_2 = 12.6\ m/s$$

② $$A_1 V_1 = A_2 V_2$$

$$\cancel{\pi} r_1^2 V_1 = \cancel{\pi} r_2^2 V_2$$

$$\frac{(0.3m)^2(10m/s)}{} = r_2^2 (12.6m/s)$$

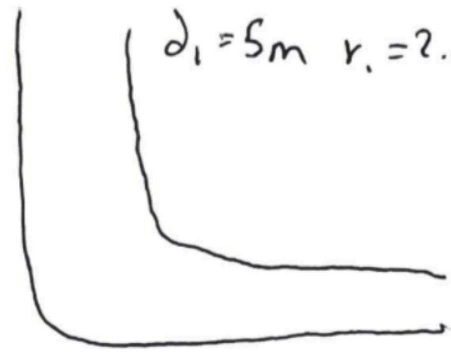
$$\sqrt{0.07142857m^2} = r_2$$

$$r_2 = 0.267m \times 2 = d_2$$

$$d_2 = 0.53\ m$$

$\therefore V_2 = 13\ m$
and $d_2 = 0.53$

F59.



$d_1 = 5m \quad r_1 = 2.5m$

$d_2 = 2m \quad r_2 = 1.0m$

a) Equation of continuty: $A_1 V_1 = A_2 V_2$

$$\pi r_1^2 V_1 = \pi r_2^2 V_2$$
$$(2.5m)^2 V_1 = (1m)^2 V_2$$
$$(6.25m^2)(15m/s) = 1m^2 \, V_2$$
$$V_2 = 93.75 \, m/s$$
$$V_2 = 94 \, m/s$$

∴ the velocity after the turn is 94m/s.

b) Bernoulli's principle:

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

$\uparrow P \quad \downarrow V_1 \qquad \downarrow P \quad \uparrow V$

Based on Bernoulli's Principle a increase in velocity will mean a decrease in pressure. so Yes the pressure will change.

1-61. Given:

$D = 1.23\,cm = 0.0123\,m \quad r = 0.00615\,m$

$\rho_{water} = 1000\,kg/m^3$

$Q = 0.408\,L/s = 0.000408\,m^3/s$

μ_{water} @ 20°c (room temp) $= 1.002\,mPa.s = 0.001002\,kg/m.s$

Asked For:

$R_e = ?$

* $Re < 2000$ laminar flow

$Re > 2000$ turbulent flow

Formula:

$$R_e = \frac{\rho V_{av} D}{\mu}$$

$$Q = A V$$

$$V = \frac{Q}{A}$$

$$= \frac{(1000\,\frac{kg}{m^3})(3.43\,\frac{m}{s})(0.0123\,m)}{0.001002\,kg/m.s}$$

$$V = \frac{0.000408\,m^3/s}{\pi(0.00615\,m)^2}$$

$$V = 3.43\,m/s$$

$$= 42104.8 > 2000$$

$\therefore$ the Reynolds number for flow in the hose is 42100 which suggests turbulent flow.

F63. Given:

$T = 20°c$

$\mu_{water} = 1.002\ mPa.s = 0.001002\ kg/m.s$ @ 20°c

$Q = 2.6 \times 10^{-2}\ L/s = 2.6 \times 10^{-5}\ m^3/s$

$Re = 2000$ (transition) * $Re < 2000$ laminar
$Re > 2000$ turbulent

$\rho_{water} = 1000\ kg/m^3$

Asked For:

$r = ?$

$D = 2r$

Formula:

$$Re = \frac{\rho V_{av} D}{\mu}$$

$$Q = VA$$

$$V = \frac{Q}{A} = \frac{Q}{\pi r^2}$$

$$Re\,\mu = \rho \frac{Q}{\pi r^2} 2r$$

$$Re\,\mu = \frac{\rho Q 2}{\pi r}$$

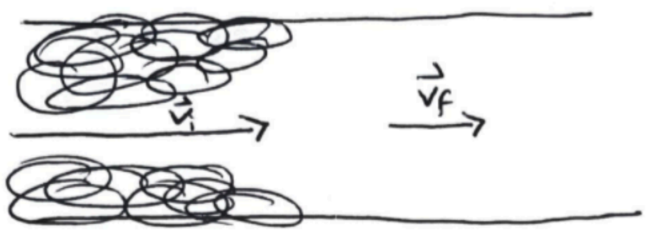
$$r\,Re\,\mu\,\pi = \rho Q 2$$

$$r = \frac{2\rho Q}{Re\,\mu\,\pi} = \frac{2(1000\ kg/m^3)(2.6 \times 10^{-5}\ m^3/s)}{(2000)(0.001002\ \frac{kg}{m.s})\pi}$$

$$= 0.008259\ m$$

$\therefore$ the radius is approximately $8.3 \times 10^{-3}\ m$.

F65.



Equation of continuity: $Q_i = Q_f$

$$A_i V_i = A_f V_f$$

$$\cancel{\pi} r_i^2 V_i = \cancel{\pi} r_f^2 V_f$$

$$r^2 V_i = (3r)^2 V_f$$

$$\cancel{r^2} V_i = 9 \cancel{r^2} V_f$$

$$\frac{V_i}{V_f} = \frac{9 \cancel{V_f}}{\cancel{V_f}}$$

$$\frac{V_i}{V_f} = 9$$

∴ When the radius of the pipe becomes 3 times its initial value, the velocity decreases by a factor of 9. as seen by the ratio of the initial velocity to the final velocity.

F 67.

$$Q = AV = \pi r^2 V$$

if Q becomes $\frac{1}{3}Q$ and V cannot change r needs to be modified to cancel w̄ $\frac{1}{3}$

$$\frac{1}{3}Q = \pi r^2 V$$

$$\frac{1}{3}Q = \pi \left(\frac{1}{\sqrt{3}} r\right)^2 V$$

$$\cancel{\tfrac{1}{3}}Q = \pi \frac{r^2}{\cancel{3}} V$$

$\therefore$ r has to become $\frac{1}{\sqrt{3}} r$ in order to cancel w̄ $\frac{1}{3}Q$. in other words the radius would change by a factor of $\frac{1}{\sqrt{3}}$.