

1. [2pt] An irregularly shaped chunk of concrete ( $\rho = 2200 \text{ kg/m}^3$ ) has a hollow spherical cavity inside. The mass of the chunk is  $30.3 \text{ kg}$ , and the volume enclosed by the outside surface of the chunk is  $0.0279 \text{ m}^3$ . What is the radius of the spherical cavity?

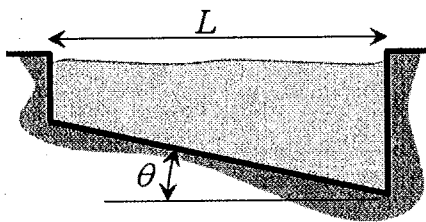
2. [2pt] At a given instant, the blood pressure in the heart is  $1.50 \times 10^4 \text{ Pa}$ . If an artery in the brain is  $0.483 \text{ m}$  above the heart, what is the pressure in the artery? Ignore any pressure changes due to blood flow.

3. [2pt] A hollow sphere of inner radius  $5.0 \text{ cm}$  and outer radius  $7.2 \text{ cm}$  floats half submerged in a liquid of density  $640 \text{ kg/m}^3$ . What is the mass of the sphere?

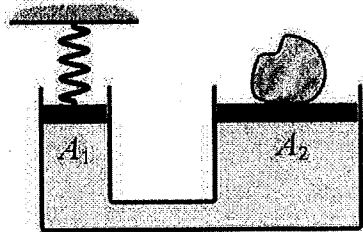
4. [2pt] Calculate the density of the material of which the sphere is made.

5. [2pt] An airtight box of negligible weight has a removable lid of area  $1.32 \times 10^{-2} \text{ m}^2$ . The lid is placed on the box in the mountains, where the air pressure is  $8.51 \times 10^4 \text{ Pa}$ , and then driven to the coast where the pressure is  $1.051 \times 10^5 \text{ Pa}$ . At the coast, what is the magnitude of the force required to pull the lid off the box?

6. [2pt] Measured along the surface of the water, a rectangular swimming pool has a length of  $16.7 \text{ m}$ . Along this length, the flat bottom of the pool slopes downward at an angle of  $10.9^\circ$  below the horizontal, from one end to the other. By how much does the pressure at the bottom of the deep end exceed the pressure at the bottom of the shallow end?



7. [2pt] The figure below shows a hydraulic chamber in which a spring (spring constant =  $1590 \text{ N/m}$ ) is attached to the input piston ( $A_1 = 14.7 \text{ cm}^2$ ), and a rock of mass  $35.9 \text{ kg}$  rests on the output plunger ( $A_2 = 65.4 \text{ cm}^2$ ).



The piston and plunger are at the same height, and each has a negligible mass. By how much is the spring compressed from its unstrained position?

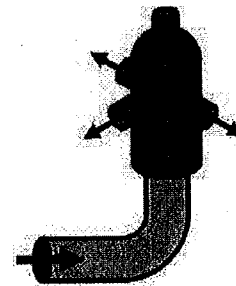
8. [2pt] A room has a volume of  $127 \text{ m}^3$ . An air-conditioning system replaces the air in this room every thirty minutes, using an inlet duct with a square cross section (there is also a similar outlet duct). Assuming air is incompressible, find the length of a side of the square duct if the air speed within the ducts is  $2.94 \text{ m/s}$ .

9. [2pt] A paperweight, when weighed in air, has a weight of  $W = 7.33 \text{ N}$ . When completely immersed in water, however, its net downwards force is  $4.10 \text{ N}$ . Find the volume of the paperweight.

10. [3pt] A recreational (open) hot air balloon (i.e.,  $p_{\text{inside}} \approx p_{\text{outside}}$ ) has a volume of  $2275 \text{ m}^3$  when fully inflated. The total weight of the balloon, basket, ballast and pilot is  $1813.0 \text{ N}$  ( $408 \text{ lb}$ ). How much less dense must the air in the balloon be than the surrounding atmosphere in order to keep the balloon floating level near the ground? (That is, give the difference of the densities.)

11. [2pt] The volume flow rate in an artery supplying the brain is  $2.16 \times 10^{-6} \text{ m}^3/\text{s}$ . If the radius of the artery is  $5.34 \text{ mm}$ , determine the average blood speed.

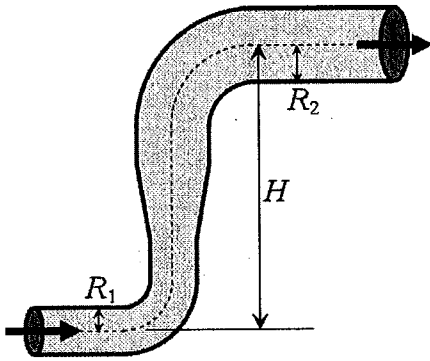
12. [2pt] Three fire hoses are connected to a fire hydrant. Each hose has a radius of  $0.0187 \text{ m}$ . Water enters the hydrant through an underground pipe of radius  $0.0780 \text{ m}$ . In this pipe the water has a speed of  $2.89 \text{ m/s}$ . Find the speed in each hose.



13. [2pt] A small crack occurs at the base of a  $14.4 \text{ m}$  high dam. The effective crack area through which water leaves is  $1.25 \times 10^{-3} \text{ m}^2$ . Ignoring viscous losses, what is the speed of water flowing through the crack?

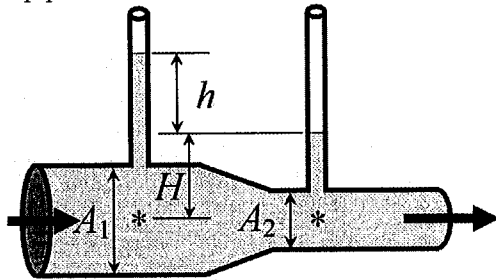
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14. [2pt] A liquid is flowing through a horizontal pipe whose radius is  $0.0214m$ . The pipe bends straight upward through a height of  $11.8m$  and joins another horizontal pipe whose radius is  $0.0402m$ . What volume flow rate in the lower pipe will keep the pressures in the two horizontal pipes the same?

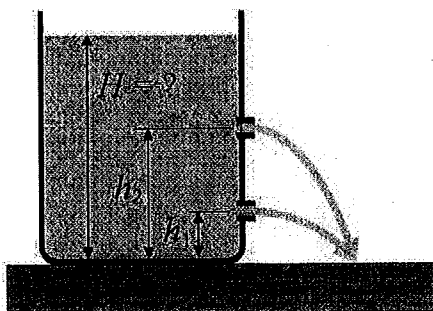


15. [2pt] An airplane has an effective wing surface area of  $17.8m^2$  that is generating the lift force. In level flight the air speed over the top of the wings is  $62.9m/s$ , while the air speed beneath the wings is  $55.8m/s$ . What is the weight of the plane?

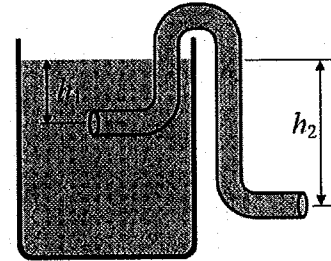
16. [3pt] The inlet of the pipe shown has a cross sectional area of  $184.0cm^2$ , and the outlet has a cross sectional area of  $83.0cm^2$ . The flow-meter in the figure below shows a difference in height  $h$  of  $5.0cm$ . What is the volumetric flow rate in the horizontal pipeline?



17. [3pt] A cardboard milk container has two holes, one above the other, punched in its side. At a given moment, the two escaping streams of milk strike the table the container is standing on, at the same point. If the heights of the upper and lower holes are  $14.4$  and  $10.8$  cm respectively, find the level of the milk at that instant.



18. [3pt] A siphon tube is filled with gasoline and closed at each end. One end is inserted into a gasoline tank  $0.15m$  below the surface. The outlet is placed outside the tank at a distance  $0.50m$  below the surface. The tube has an inner cross-sectional area of  $3.1 \times 10^{-4}m^2$ . The density of gasoline is  $680kg/m^3$ . Ignoring viscous effects, what is the velocity of the gasoline in the tube shortly after the tube is opened? Assume that the diameter of the gas tank is much larger than the diameter of the hose.



# General Physics I Set 13

① Given

$$\rho_{\text{concrete}} = 2200 \text{ kg/m}^3$$

$$M_c = 30.3 \text{ kg} \quad V_{\text{TOT}} = 0.0279 \text{ m}^3$$

$$V_{\text{concrete}} = V_{\text{TOT}} - V_{\text{cavity}}$$

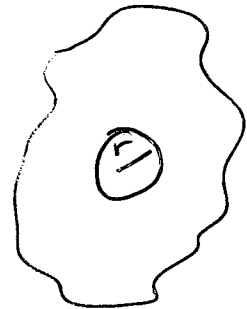
$$V_{\text{cavity}} = \frac{4}{3} \pi r^3$$

$$\rho_c = \frac{M_c}{V_c}$$

$$V_c = \frac{M_c}{\rho_c} = V_{\text{TOT}} - \frac{4}{3} \pi r^3$$

$$V_{\text{TOT}} - \frac{M_c}{\rho_c} = \frac{4}{3} \pi r^3$$

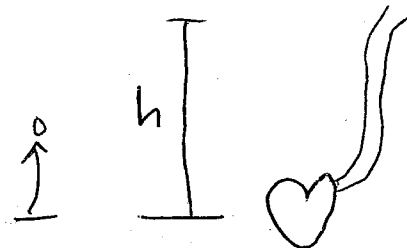
$$r = \sqrt[3]{\frac{3}{4\pi} \left( V_{\text{TOT}} - \frac{M_c}{\rho_c} \right)}$$



② Given

$$P_H = 1.5 \times 10^4 \text{ Pa}$$

$$h_A = 0.483 \text{ m}$$



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

assume  $v_1 = v_2$  (since we ignore pressure change due to flow)

$$P_H + \rho g(0) = P_A + \rho g h_A$$

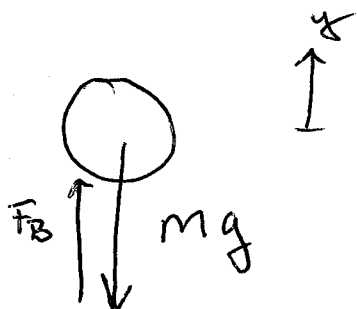
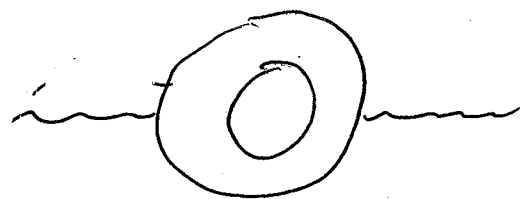
$$P_A = P_H - \rho g h_A$$

③ Given

④  $r_i = 5 \text{ cm}$

$$r_o = 7.2 \text{ cm}$$

$$\rho_e = 640 \text{ kg/m}^3$$



$$\sum F_y = ma_y = 0$$

$$F_B = mg$$

$$F_B = \rho_e V_{\text{disp}} g$$

$$V_{\text{disp}} = \frac{1}{2} V_{\text{sphere}} = \frac{1}{2} \left( \frac{4}{3} \pi r_o^3 \right)$$

$$\rho_e \frac{2\pi}{3} r_o^3 g = mg$$

$$m = \frac{2\pi \rho_e r_o^3}{3}$$

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

$$V = V_{\text{outside}} - V_{\text{cavity}} = \frac{4}{3} \pi r_o^3 - \frac{4}{3} \pi r_i^3$$

$$\rho = \frac{m}{\frac{4}{3} \pi (r_o^3 - r_i^3)} = \frac{\frac{2}{3} \pi \rho_e r_o^3}{\frac{4}{3} \pi (r_o^3 - r_i^3)} = \frac{r_o^3 \rho_e}{2 (r_o^3 - r_i^3)}$$

⑤ Given

$$A = 1.32 \times 10^{-2} \text{ m}^2$$

$$P_{in} = 8.51 \times 10^4 \text{ Pa}$$

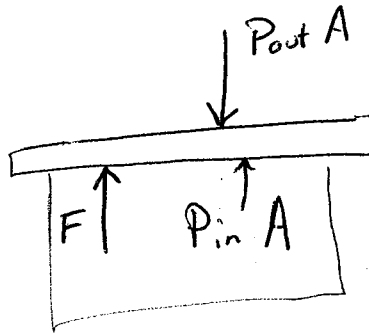
$$P_{out} = 1.051 \times 10^5 \text{ Pa}$$

to lift lid

$$\Sigma F = ma_y = 0$$

$$F + P_{in}A = P_{out}A$$

$$F = (P_{out} - P_{in})A$$



⑥ Given

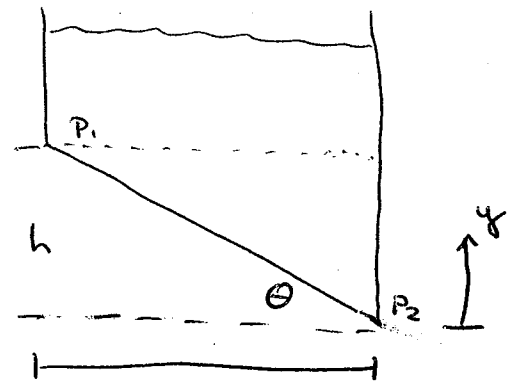
$$L = 16.7 \text{ m}$$

$$\theta = 10.9^\circ$$

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

$$P_1 + \rho g h = P_2$$

$$P_2 - P_1 = \rho g (L \tan \theta)$$



$$\frac{h}{L} = \tan \theta$$

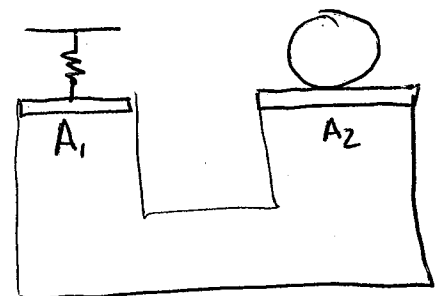
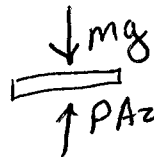
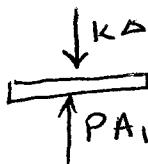
⑦ Given

$$k = 1590 \text{ N}$$

$$A_1 = 14.7 \text{ cm}^2$$

$$m = 35.9 \text{ kg}$$

$$A_2 = 65.4 \text{ cm}^2$$



$$P A_1 = k \Delta L$$

$$P A_2 = mg$$

$$P = \frac{mg}{A_2}$$

$$\Delta L = \frac{mg A_1}{k A_2}$$

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$$V = 127 \text{ m}^3$$

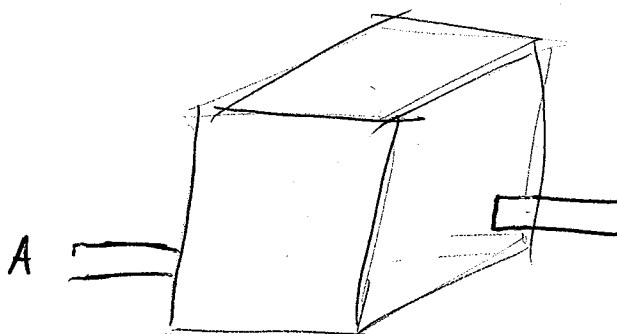
$$\Delta t = 30 \text{ min} = 1800 \text{ s}$$

Volume flow rate

$$\frac{V}{\Delta t} = v, A, = v, L^2$$

$$L^2 = \frac{V}{v, \Delta t}$$

$$L = \sqrt{\frac{V}{v, \Delta t}}$$



$$L \quad L \quad A = L^2$$

9

Given

$$W = 7.33 \text{ N}$$

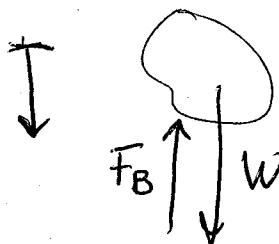
$$F_{\text{down}} = 4.10 \text{ N}$$

$$F_B = \rho_{\text{water}} V g$$

$$W - F_{\text{down}} = F_B = \rho_{\text{water}} V g$$

$$V = \frac{W - F_{\text{down}}}{\rho_{\text{water}} g}$$

underwater



$$\Sigma F_y = F_{\text{down}}$$

$$F_{\text{down}} = W - F_B$$

(10) Given

$$V = 2275 \text{ m}^3$$

$$W_{\text{rest}} = 1813 \text{ N}$$

$$W_{\text{TOT}} = W_{\text{rest}} + W_{\text{hotair}}$$

$$F_B = \rho_{\text{outside}} V g$$

$$W_{\text{hotair}} = \rho_{\text{inside}} V g$$

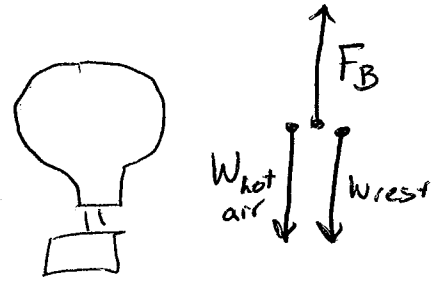
$$F_B = W_{\text{hotair}} - W_{\text{rest}}$$

$$\rho_{\text{out}} V g = \rho_{\text{in}} V g - W_{\text{rest}}$$

$$\rho_{\text{in}} V g - \rho_{\text{out}} V g = W_{\text{rest}}$$

$$(\rho_{\text{in}} - \rho_{\text{out}}) V g = W_{\text{rest}}$$

$$\boxed{(\rho_{\text{in}} - \rho_{\text{out}}) = \frac{W_{\text{rest}}}{V g}}$$



$$\sum F = m a_y = 0$$

$$F_B - W_{\text{hotair}} - W_{\text{rest}} = 0$$

(11) Given  
Volume flow rate:  $2.16 \times 10^{-6} \text{ m}^3/\text{s} = Q$

$$r = 5.34 \text{ m}$$

$$\text{flow rate} = v_1 A_1$$

$$A_1 = \pi r^2$$

$$Q = v_1 \pi r^2$$

$$\boxed{v_1 = \frac{Q}{\pi r^2}}$$

(12)

Given

$$r_{out} = 0.0187 \text{ m}$$

$$r_{in} = 0.0780 \text{ m}$$

$$v_{in} = 2.89 \text{ m/s}$$

$$A_{in} = \pi r_{in}^2$$

$$A_{out} = (\pi r_o^2) \times 3 \quad \leftarrow 3 \text{ outlet hoses}$$

$$v_1 A_1 = v_2 A_2$$

$$v_2 = \frac{v_1 A_1}{A_2} = \frac{v_1 \pi r_i^2}{3 \pi r_o^2}$$

$$v_2 = \frac{v_1 r_i^2}{3 r_o^2}$$

(13)

Given:

$$h = 14.4 \text{ m}$$

$$A = 1.25 \times 10^{-3} \text{ m}^2$$

Since  $A$  is small relative to surface area of water

$$v_{\text{surface}} \approx 0$$

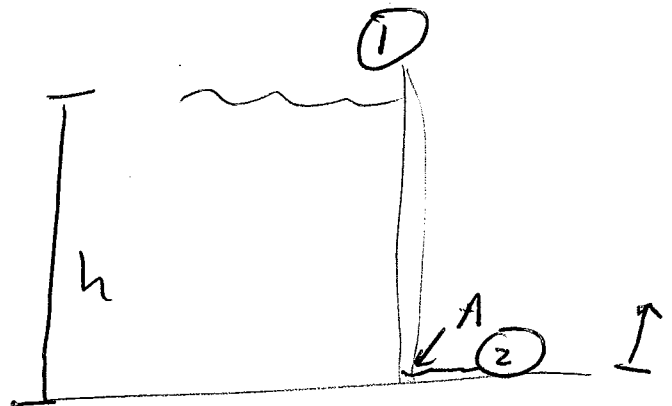
$$P_1 + \rho g h_1 + \frac{1}{2} \rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2} \rho v_2^2$$

$$P_1 = 1 \text{ atm} \quad h_1 = h \quad v_1 = 0$$

$$P_2 = 1 \text{ atm} \quad h_2 = 0 \quad v_2 = ?$$

$$\rho g h = \frac{1}{2} \rho v_2^2$$

$$v_2 = \sqrt{2gh}$$



⑭  $R_1 = 0.0187 \text{ m}$

$h = 10.6 \text{ m}$

$R_2 = 0.0398$

$P_1 = P_2$

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

$\frac{1}{2} V_1^2 = g h + V_2^2$

from Continuity

$V_1 A_1 = V_2 A_2$

$V_1 \pi r_1^2 = V_2 \pi r_2^2$

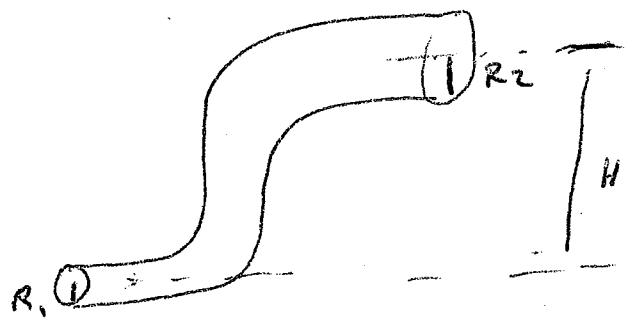
$V_2 = V_1 \frac{r_1^2}{r_2^2}$

$V_1^2 = 2gh + V_2^2 = 2gh + V_1^2 \frac{r_1^4}{r_2^4}$

$V_1^2 \left(1 - \frac{r_1^4}{r_2^4}\right) = 2gh$

$$V_1 = \sqrt{\frac{2gh}{\left(1 - \frac{r_1^4}{r_2^4}\right)}}$$

$Q = V_1 A_1 = \pi r_1^2 \sqrt{\frac{2gh}{\left(1 - \frac{r_1^4}{r_2^4}\right)}}$



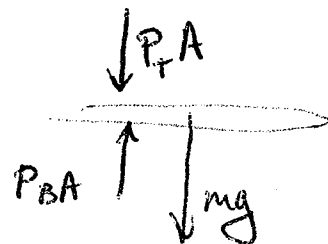
⑮  $A = 18 \text{ m}^2$   $V_{\text{top}} = 61.8 \text{ m/s}$   $V_{\text{bottom}} = 52.7 \text{ m/s}$

$\sum F_y = 0$

$P_B A - P_T A - mg = 0$

$(P_B - P_T) A = mg$

$m = \frac{(P_B - P_T) A}{g}$



$$P_T + \cancel{Pgh} + \frac{1}{2}Pv_T^2 = P_B + \cancel{Pgh} + \frac{1}{2}Pv_B^2$$

$$h=0$$

$$P_B - P_T = \frac{1}{2}(v_T^2 - v_B^2)$$

$$m = \frac{(v_T^2 - v_B^2) A}{2 \rho}$$

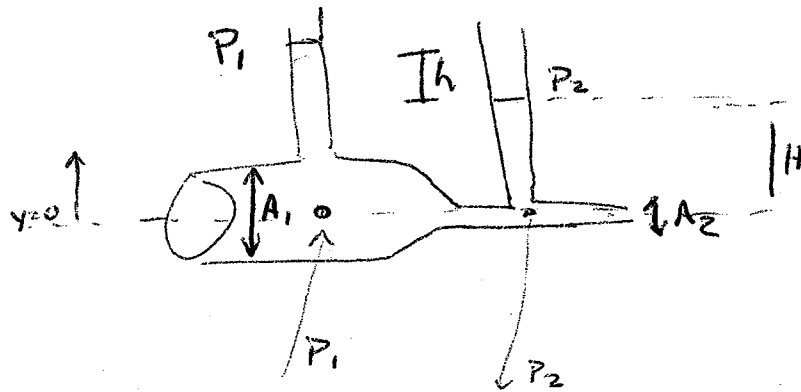
16

$$A_1 = 204 \text{ cm}^2$$

$$A_2 = 97 \text{ cm}^2$$

$$h = 5.4 \text{ cm}$$

$$P_1 = \rho g(H+h) \quad P_2 = \rho gH$$



Bernoulli

$$P_1 + \cancel{Pgh} + \frac{1}{2}Pv_1^2 = P_2 + \cancel{Pgh} + \frac{1}{2}Pv_2^2$$

$$\rho g(H+h) + \frac{1}{2}\rho v_1^2 = \rho gH + \frac{1}{2}\rho v_2^2$$

$$2gh = v_2^2 - v_1^2$$

Continuity

$$v_1 A_1 = v_2 A_2$$

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

$$2gh = v_2^2 - v_2^2 \frac{A_2^2}{A_1^2}$$

$$v_2 = \sqrt{\frac{2gh}{1 - \frac{A_2^2}{A_1^2}}}$$

$$Q = A_2 v_2 = A_2 \sqrt{\frac{2gh}{\left(1 - \frac{A_2^2}{A_1^2}\right)}}$$

①7  $h_1 = 9.2 \text{ cm}$   
 $h_2 = 14.4 \text{ m}$

Look at the freefall problem...

$$y_f = y_0 + v_{y0} \Delta t + \frac{1}{2} a (\Delta t)^2$$

$$\frac{-2y_0}{-g} = \Delta t^2$$

$$\Delta t = \sqrt{\frac{2y_0}{g}}$$

so  $t_1 = \sqrt{\frac{2h_1}{g}}$        $t_2 = \sqrt{\frac{2h_2}{g}}$

in x-direction

$$x_f = x_0 + v_{x0} \Delta t + \frac{1}{2} a_x (\Delta t)^2$$

$$L = v_{x0} \Delta t$$

$$v = \frac{L}{\Delta t}$$

so  $v_1 = \frac{L}{\sqrt{\frac{2h_1}{g}}} = L \sqrt{\frac{g}{2h_1}}$

$$v_2 = L \sqrt{\frac{g}{2h_2}}$$

Bernoulli's Law

$$P_1 + \rho g h_1 + \frac{1}{2} \rho v_1^2 = P_3 + \rho g H + \frac{1}{2} \rho v_3^2$$

$$P_1 = P_3 = 1 \text{ atm}$$

$$\rho h_1 + \frac{1}{2} L^2 \frac{\rho}{2h_1} = \rho H$$

$$H = h_1 + \frac{L^2}{4h_1}$$

or  $L^2 = (H - h_1) 4h_1$

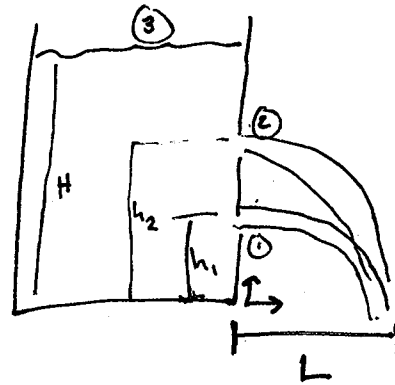
$$P_2 + \rho g h_2 + \frac{1}{2} \rho v_2^2 = P_3 + \rho g H + \frac{1}{2} \rho v_3^2$$

$$P_2 = P_3 = 1 \text{ atm}$$

$$H = h_2 + \frac{L^2}{4h_2}$$

$$L^2 = (H - h_2) 4h_2$$

plug into eqn above



$$(H-h_1)/h_1 = (H-h_2)/h_2$$

$$Hh_1 - h_1^2 = Hh_2 - h_2^2$$

$$H(h_1 - h_2) = h_1^2 - h_2^2$$

$$H = \frac{h_1^2 - h_2^2}{h_1 - h_2} = \frac{(h_1 - h_2)(h_1 + h_2)}{(h_1 - h_2)}$$

$$H = h_1 + h_2$$

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$$h_1 = 0.25 \text{ m}$$

$$h_2 = 0.4 \text{ m}$$

$$A = 4.5 \times 10^{-4} \text{ m}^2$$

$$\rho_{\text{gas}} = 680 \text{ kg/m}^3$$

$$P_0 + \cancel{\rho g_0} + \frac{1}{2} \cancel{\rho V_0^2} = P_2 + \rho g_2 + \frac{1}{2} \rho V_2^2$$

$$\rho g h_2 = \cancel{\rho g^{(0)}} + \frac{1}{2} \rho V_2^2$$

$$P_0 = P_2 = 1 \text{ atm}$$

$$V_2 = \sqrt{2gh_2}$$

