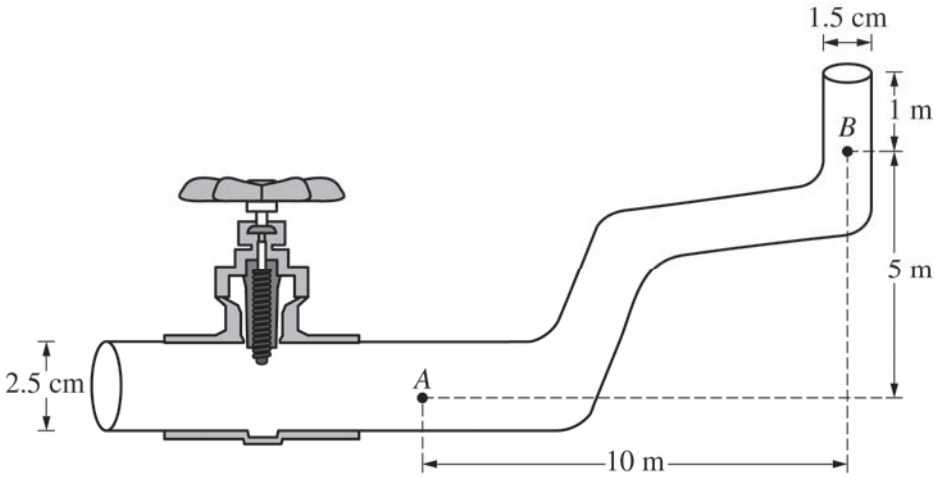
PHYSICS 2
Section II
4 Questions
Time—90 minutes

Directions: Questions 1 and 4 are short free-response questions that require about 20 minutes each to answer and are worth 10 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



Note: Figure not drawn to scale.

1. (10 points, suggested time 20 minutes)

Two students observe water flowing from left to right through the section of pipe shown above, which decreases in diameter and increases in elevation. The pipe ends on the right, where the water exits vertically. At point *A* the water is known to have a speed of $0.50\ \text{m/s}$ and a pressure of $2.0 \times 10^5\ \text{Pa}$. The density of water is $1000\ \text{kg/m}^3$.

(a) The students disagree about the water pressure and speed at point *B*. They make the following claims.
Student *Y* claims that the pressure at point *B* is greater than that at point *A* because the water is moving faster at point *B*.
Student *Z* claims the speed of the water is less at point *B* than that at point *A* because by conservation of energy, some of the water's kinetic energy has been converted to potential energy of the Earth-water system.

i. Indicate any aspects of student *Y*'s claim that are correct.

ii. Indicate any aspects of student *Y*'s claim that are incorrect. Support your answer using appropriate physics principles.

iii. Indicate any aspects of student *Z*'s claim that are correct.

iv. Indicate any aspects of student *Z*'s claim that are incorrect. Support your answer using appropriate physics principles.

(b) Calculate the following at point *B*.

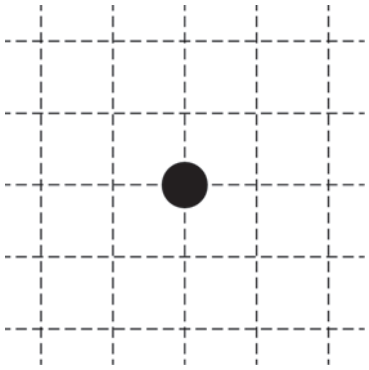
i. The speed of the water

ii. The pressure in the pipe

(c) A valve to the left of point *A* now closes off that end of the pipe. The section of pipe shown is still full of water, but the water is no longer flowing.

i. Calculate the absolute pressure at point *A* (the pressure that includes the effect of the atmosphere).

ii. An air bubble forms at point *A*. On the figure below, where the dot represents the air bubble, draw a free-body diagram showing and labeling the forces (not components) exerted on the bubble. Draw the relative lengths of all vectors to reflect the relative magnitudes of the forces.



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Question 1

10 points total | **Distribution of points**

(a)

i. 1 point

For indicating that student Y is correct in stating that the water moves faster at point *B*, and not indicating any other aspect — 1 point

ii. 2 points

Student Y's statement that P_B is greater than P_A is not correct.

For a correct indication of how height affects pressure using the Bernoulli equation (i.e., conservation of energy principles) — 1 point

For correct indication of how the speed affects pressure using the Bernoulli equation (i.e., conservation of energy principles) — 1 point

Example: The pressure at point *B* is not greater. Because the water at *B* is moving faster and is higher than at point *A*, the kinetic energy and the gravitational potential energy terms in Bernoulli's equation are both greater. Because the sum of pressure and these energy terms is a constant, the pressure must be less.

iii. 1 point

For indicating one of the following: — 1 point

- Student Z is correct in stating that the potential energy of the water-Earth system has increased.
- Student Z is correct in stating that conservation of energy applies.
- Stating that nothing is correct or giving no response, with a justification in (iv).

iv. 1 point

For indicating that student Z is incorrect in stating that the speed is less at point *B*, not indicating any other aspect, and using continuity or the Bernoulli equation (i.e., conservation of energy principles) to show that it is greater — 1 point

OR

if third bullet for (iii) applies, indicating that work is done on the water due to the pressure difference, so the energy is not constant

Question 1 (continued)

Distribution of points

(b)

i. 2 points

For a correct application of the continuity equation including substitutions 1 point

$A_A v_A = A_B v_B$

$v_B = A_A v_A / A_B = r_A^2 v_A / r_B^2 = (2.5 \text{ cm})^2 (0.5 \text{ m/s}) / (1.5 \text{ cm})^2$

For a correct answer with units 1 point

$v_B = 1.4 \text{ m/s}$

ii. 1 point

For an application of Bernoulli's equation to this situation and substitutions consistent with (b)(i) 1 point

$$P_A + \rho g y_A + \frac{1}{2}\rho v_A^2 = P_B + \rho g y_B + \frac{1}{2}\rho v_B^2$$

$$P_B = P_A + \rho g (y_A - y_B) + \frac{1}{2}\rho \left(v_A^2 - v_B^2\right)$$

$$P_B = 2 \times 10^5 + (1000)(10)(-5) + \frac{1}{2}(1000)\left(0.5^2 - 1.4^2\right) = 2 \times 10^5 - 50000 - 855$$

$$P_B = 1.5 \times 10^5 \text{ Pa}$$

(c)

i. 1 point

For substituting correctly in an appropriate equation for determining the pressure 1 point

$P = P_0 + \rho g h_A = 1 \times 10^5 \text{ Pa} + \left(1000 \text{ kg/m}^3\right)\left(10 \text{ m/s}^2\right)(6 \text{ m})$

$P = 1.6 \times 10^5 \text{ Pa}$

ii. 1 point

For indicating that the buoyant force is toward the top of the page and gravity is toward the bottom of the page, with the buoyant force longer 1 point

Student can draw lots of pressure forces around the dot instead of one buoyant force, as long as there is no buoyant force labeled and they add up to a net buoyant force that is longer than the gravitational force.