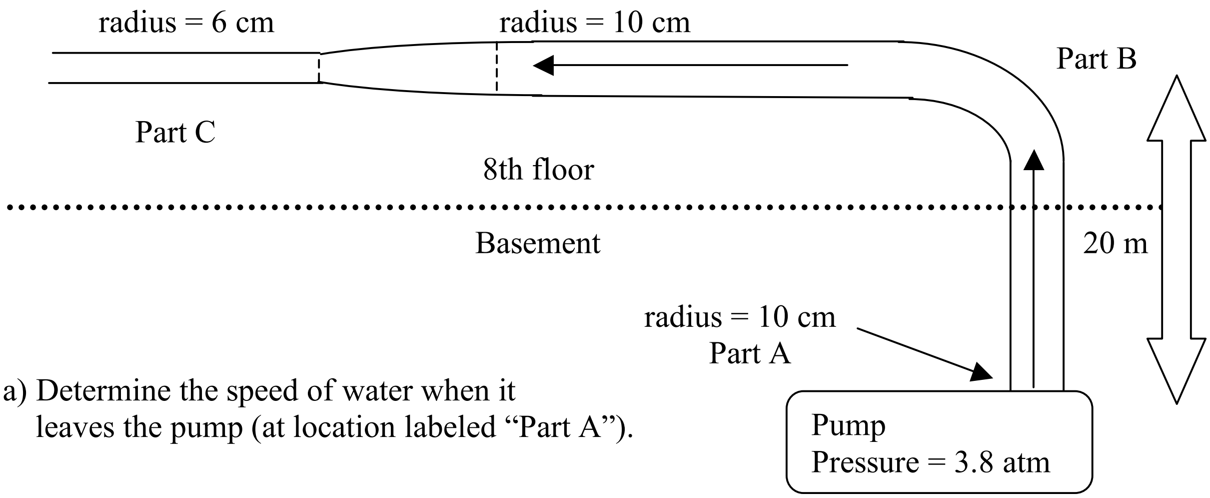
Problem 1 **10 points**

Below is the side view of a pipe (not to scale) that provides water to the 8th floor of a building. The horizontal region is 20 meters above a pump that is in the basement. The arrows represent the direction of water flow. The pump is at the basement and pumps water up to the 8th floor at a volume rate of 0.2 m^3/s. The radius of the pipe remains a constant 10 cm until it reaches the region labeled Part C where the radius decreases to 6 cm.

Drawing is NOT to scale – 8th floor is 20m above pump



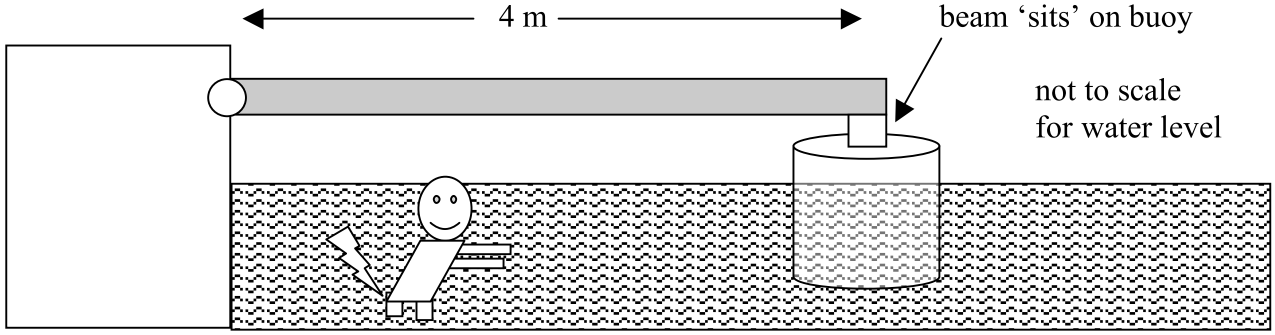
a) Determine the speed of water when it leaves the pump (at location labeled "Part A").

b) Determine the water pressure at the curved point of the pipe, 20 meters above the pump (see "Part B" on diagram).

c) Fully explain why the speed of the water must be the same for parts (a) and (b).

d) Determine the speed of the water after it reaches the narrower piping (r = 6 cm, Part C)

Problem 2 **20 pts**



The system above starts in equilibrium. There is a horizontal walkway that extends over the water so tourists can view sea monkeys that swim below. It rests on a large hollow cylinder (that is at the end of the walkway) that floats and prevents the walkway from rotating. The walkway is 4 meters long and has a mass of 40 kg. The cylinder is exactly under the right end of the beam and has a mass of 10 kg and a radius of 0.3 meters and a height of 0.4 meters.
Sea monkeys like fresh water, which has a density of 1000 kg/m^3. Volume of cylinder = $\pi r^2 h$

a) Draw a free-body diagram for all forces acting ONLY on the beam below. Use the line below, which represents the beam. Label all forces and make sure vectors are to scale.

b) Determine the magnitude and direction of the force exerted by the cylinder on the beam. Make sure to show all work in how you got your answer.

c) Draw a free-body diagram (at the space to the right) for the cylinder.
Make sure to label all forces

d) Determine the buoyant force exerted on the cylinder by the water.

e) Determine the percentage of the sphere that is submerged under water when attached to the walkway as originally shown.

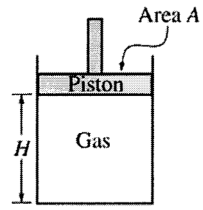
f) If the Sea Monkeys disconnected the cylinder placed it 20 meters out in the middle of the lake, what percentage would be under water?

g) Explain what would happen to the height above the water level at the end of the walkway relative to the initial conditions if the following two scenarios took place (part i and ii are independent of each other). Make sure to use physics ideas, concepts, and terms.

i) The sea monkeys started to swim very fast under the cylinder and created a constant water current directly under the area of the cylinder.

ii) The mass of the cylinder was reduced by 5 kg at the same time the beam's mass was increased by 5 kg.

Problem 3 (10 points)

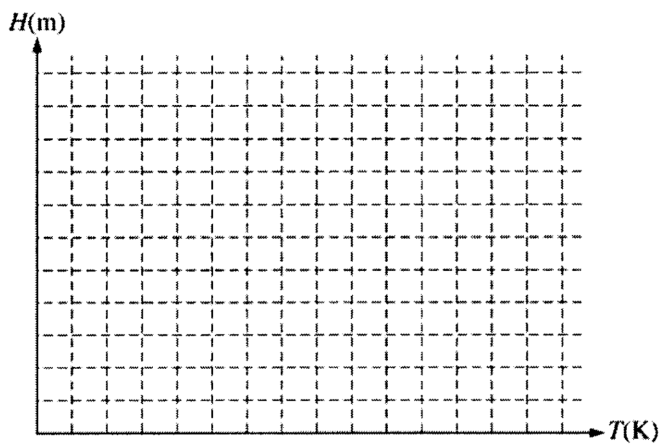


An experiment is performed to determine the number n of moles of an ideal gas in the cylinder shown above. The cylinder is fitted with a movable, frictionless piston of area A. The piston is in equilibrium and is supported by the pressure of the gas. The gas is heated while its pressure P remains constant. Measurements are made of the temperature T of the gas and the height H of the bottom of the piston above the base of the cylinder and are recorded in the table below. Assume that the thermal expansion of the apparatus can be ignored.

T (K)	H (m)
300	1.11
325	1.19
355	1.29
375	1.37
405	1.47

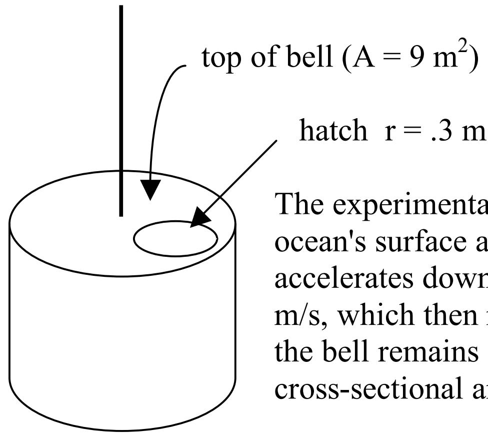
a. Write a relationship between the quantities T and H, in terms of the given quantities and fundamental constants, that will allow you to determine n.

b. Plot the data on the axes below so that you will be able to determine n from the relationship in part (a). Label the axes with appropriate numbers to show the scale.



c. Using your graph and the values A = 0.035 m^2 and P = 1.0 atmosphere, determine the experimental value of n.

Problem 4 (15 points)



The experimental diving bell shown at left is lowered from rest at the ocean's surface and reaches a maximum depth of 150 m. Initially it accelerates downward at a rate of 0.2 m/s^2 until it reaches a speed of 6.0 m/s, which then remains constant. During the descent, the pressure inside the bell remains constant at 1 atmosphere. The top of the bell has a cross-sectional area $A = 9.0\ m^2$. The density of seawater is 1025 kg/m^3 .

a) Calculate the *total time* it takes the bell to reach the maximum depth of 150 m.

b) Calculate the weight of the water on the top of the bell when it is at the maximum depth.

c) Calculate the absolute pressure on the top of the bell at the maximum depth.

On the top of the bell there is a circular hatch of radius $r = 0.3$ m.

(d) Calculate the minimum force necessary to lift open the hatch of the bell at the maximum depth.

(e) What could you do to reduce the force necessary to open the hatch at this depth? Justify your answer.

Most (if not all) of the free response questions are unique to each class (Period 3 and 5). However, some of the problems and ideas are similar. With that in mind, it is imperative that you do not discuss this test with anyone who has not take it until all students have taken it.

Please sign below acknowledging that you will keep the contents of this exam in confidence.

____________________________________ (name)   __________________ (date)

Hints –

Read each part of a problem (a, b, c etc.)before you start part a.

Free body diagrams give us equations to solve for unknowns. They are cool.

Some problems appear difficult but you'll see they end up being rather straightforward.