Hydraulics

# Heron’s Fountain

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## Abstract

This paper will focus on a specific hydraulic device, Heron’s fountain, invented by Heron of Alexandria and its corresponding fluid dynamic principles. His creation has largely impacted the world by demonstrating crucial concepts within fluid dynamics, leading to countless technological improvements. This paper will provide an insight into the construction, principles, and history behind Heron’s fountain.

# Introduction

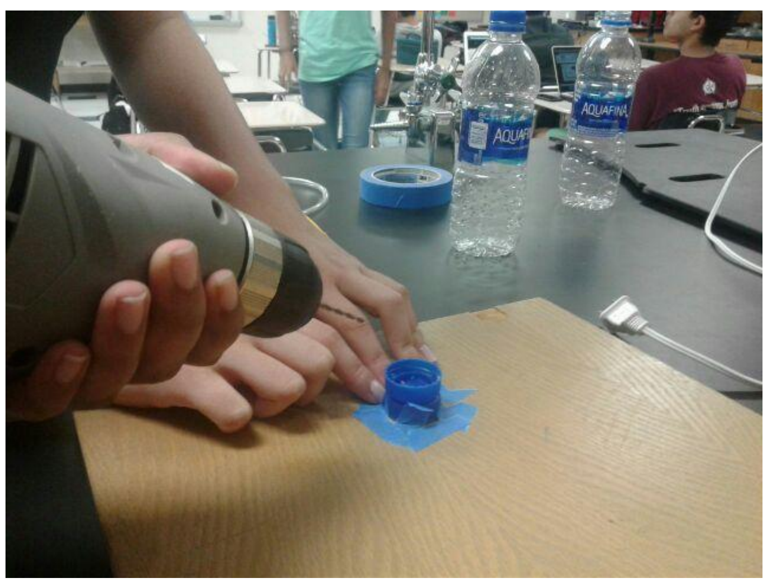
The study of fluid dynamics allows us to achieve a deeper understanding of the relationships between liquids and gases. Heron successfully created a model to portray such properties of fluid dynamics with his invention. Ranging from the creation of this fountain to the principles behind it, this paper will strive to establish a more intricate understanding of Heron's fountain.

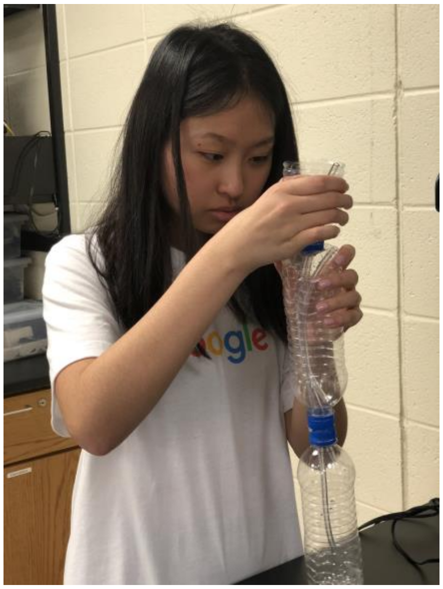
# History

From 10 AD to 70 AD, Greek physicist and mathematician Heron of Alexandria lived and became a well known scientific figure. He was a professor at the University of Alexandria in Eqypt where he taught mathematics and engineering. During his time teaching, he often created various devices to aid in his students' learning process. Among those many inventions was the Heron's fountain which was initially meant to function as a perpetual motion machine. Although he never achieved that goal, the fountain has proven useful to physicists since by providing a model of fundamental hydraulic and pneumatic principles.

# Construction

The creation of this fountain required three sections: a water basin, water supply, and air supply (the latter two being sealed while the former remains open). Our simple model utilized three empty water bottles as these necessary compartments. First, we removed all the caps and drilled two identical holes in all of them. Then, we hot glued two of the caps together and screwed them back onto their respective water bottles to create the two air tight compartments. Once the contraption was secure, we drilled two more identical holes into the base of the second bottle and glued the final cap on top of it. For the open water





basin, we cut the last water bottle in half and secured it to the remaining cap. Finally using a diagram we found online, we threaded the plastic tubing through the bottles at the appropriate lengths and positions before sealing any gaps with more hot glue.

# Explanation

In order for the fountain to function properly it must be initially set up with some water in the middle bottle and only air in the bottom one. By pouring water into the basin, gravity will cause the water to go through the tube and fall into the bottom bottle. The sudden addition of water in the bottom compartment will displace the air that was in it, forcing it up the tube into the middle compartment. The increased air in the middle compartment will then push the water up through the final tube and spray out the top, creating a fountain. This process will repeat until eventually the water level in the middle compartment falls below the level of the water tube, causing the fountain to die down.

# Current Applications

Fountains can be found nearly everywhere in everyday life, from parks and lawns to smaller scale ones like water fountains in buildings. Such fountains serve a multitude of purposes, ranging from providing a source of water to aesthetic designs and entertainment such as the impressive water shows all over the world. Similar hydraulic concepts can be discovered in hydraulic car brakes, certain exercise machines, and more.

# Future Developments

Unfortunately, Heron's original goal will never come to fruition. A perpetual motion machine is impossible to produce as we are not able to create energy. Despite this, it is likely future technologies will strive to improve and overcome the flaws of current designs to create a more efficient near perpetual device. These machines could potentially become the key to an available source of renewable energy that is not currently achievable.

# AP Multiple Choice Questions

1. You are given three blocks composed of different materials. They are completely submerged into water. The blocks are made of silver, gold and platinum. Which of the following statements is the correct regarding the buoyant force on each block given that $\rho_{silver}$ = 10490 kg/m$^3$ , $\rho_{gold}$= 19320 kg/m$^3$ , $\rho_{platinum}$ = 21400 kg/m$^3$?

A. $F_{silver} < F_{gold} < F_{platinum}$

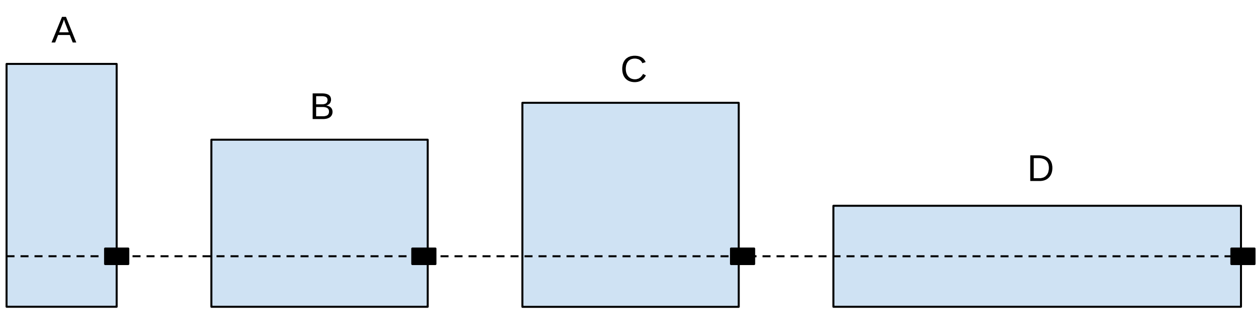
B. $F_{silver} > F_{gold} > F_{platinum}$

C. $F_{silver} = F_{gold} = F_{platinum}$

D. $F_{silver} = F_{gold} > F_{platinum}$

E. $F_{silver} > F_{gold} < F_{platinum}$

2. 4 containers with stoppers placed at the same vertical height are shown below. The figures are drawn to scale. Select the correct ordering of containers from highest to lowest pressure on the stopper.




A. A, B, C, D

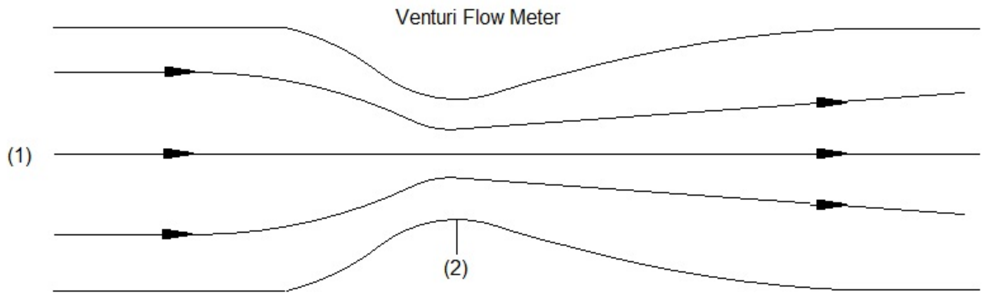
B. A, C, B, D

C. D, B, C, A

D. C, B, A, D

E. C, D, B, A

3. In this venturi meter, all cross sections are circular. The radius of the pump at (1) is 3 m and the radius of the pump at (2) is 2 m. If the speed of the fluid is 12m/s at (1), what is the speed of the fluid when it passes through (2)?




A. 36 m/s

B. 18 m/s

C. 8 m/s

D. 27 m/s

E. 24 m/s

4. A hydraulic lift is made with a small piston of radius 4 cm and a large piston of radius 20 cm. A force of 50 N is applied to the small piston in attempt to raise a large object that is placed on the large piston. What is the maximum possible weight of the large object such that it can still be supported?

A. 1250 N

B. 250 N

C. 10 N

D. 2 N

E. 800 N

5. In a certain set up, a gauge pressure of 150 kPa is measured. At sea level, what is calculated to be the absolute pressure?

A. 101 kPa

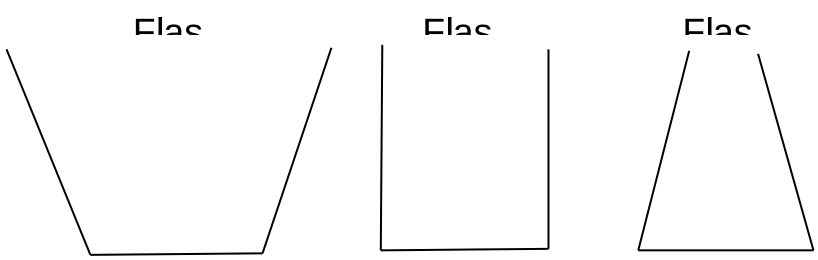
B. 15150 kPa

C. 49 kPa

D. 251 kPa

E. 150 kPa

6. Consider the 3 flasks of different shapes below. All of the bases are identical in shape and size. When equal amounts of water are poured into each of the flasks, which flask has a base that experiences the most force?




A. Flask A

B. Flask B

C. Flask C

D. Flask A and Flask C

E. They are all the same

7. When a block is placed in water ($\rho$ = 1000 kg/$m^3$) , 1/5 of the volume is submerged. The same block is placed in oil that has density $\rho$ = 900 kg/$m^3$. If the block again floats, what fraction of the volume is submerged?

A. 9/50

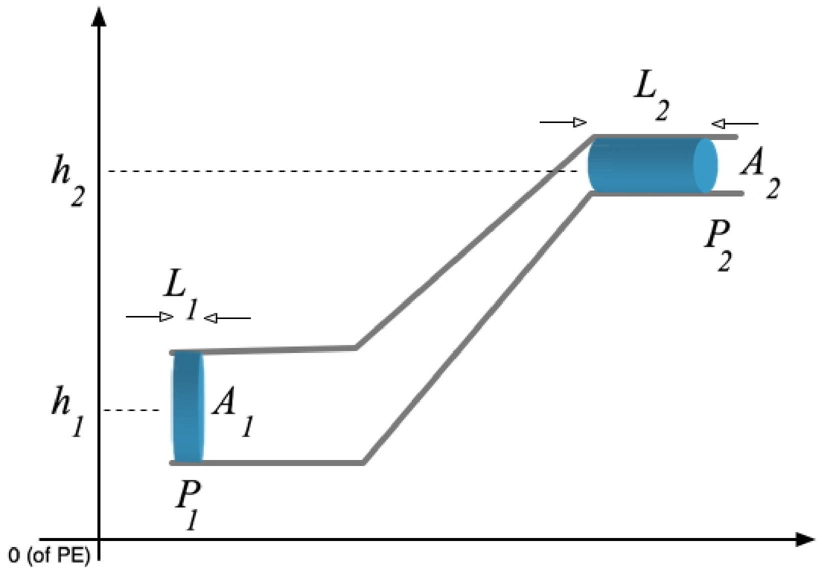
B. 5/9

C. 2/5

D. 1/2

E. 2/9

8. In the diagram below, $h_1$= 3 m, $h_2$= 3.5 m. The cross sectional areas have areas of $A_1$= 4 $m^2$ and $A_2$= 2 $m^2$. If the velocity of the fluid is v = .5 m/s and the pressure is P = 8,000 kPa at the bottom of the pipe, what is the pressure P' at the top portion of the pipe?




A. 3025 kPa

B. 2725 kPa

C. 34800 kPa

D. 37525 kPa

E. 3100 kPa

Answer Key

1. C
2. B
3. D
4. A
5. D
6. C
7. E
8. B