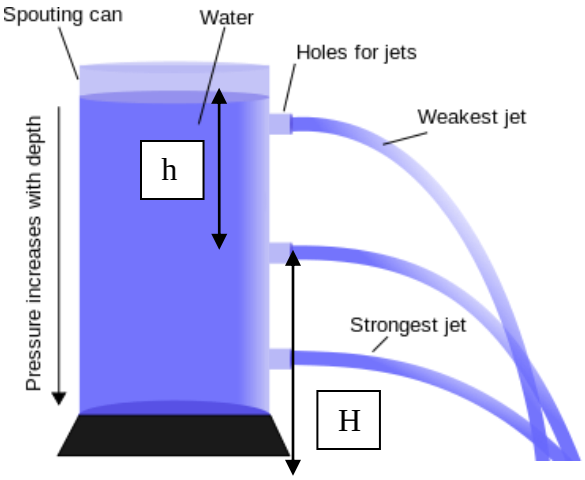
Torricelli's Law

You may work with a team during this activity. The diagram shows h and H for the middle hole. Your bottle may have more than three holes, but note that h and H will change for each hole, but h + H will remain the same: h will be at its minimum value for the top hole and its maximum value for the bottom hole: H will be its maximum value for the top hole, and its minimum value for the bottom hole.



Bernoulli's equation: $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

distance from the hole to the water surface: $y_1 = h$

define the level of the hole : $y_2 = 0\ m$

initial water velocity: $v_1 = 0\ m/s$

pressure at the water surface: $P_1 = P_{at}$

hole exposed the water to the atmosphere: $P_2 = P_{at}$

substitution: $P_{atm} + \frac{1}{2}\rho v_1^2 + \rho g h = P_{atm} + \frac{1}{2}\rho v_2^2 + \rho g y_2$

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

$2gh = v_2^2$

water velocity assumed to be constant: $v_2 = \sqrt{2gh}$

vertical distance traveled by the water: $H = \frac{1}{2} g t^2$

solve for t: $t^2 = \frac{2H}{g}$

time required for water to land: $t = \sqrt{\frac{2H}{g}}$

horizontal distance traveled by the water: $D = x = v_2 t = \sqrt{2gh}\sqrt{\frac{2H}{g}} = \sqrt{\frac{4ghH}{g}} = 2\sqrt{hH}$

1. You and your team require a water container (plastic beaker, small plastic bucket, plastic graduated cylinder, etc.), a plastic funnel, a piece of colored tape, one of the supplied plastic bottles, a few pieces of duct tape to seal the holes in the bottle, a ruler, a meter stick, and a paper towel.

2. Be sure that each of the holes in your team's bottle is taped and sealed securely. Take these materials outside.

3. Using the funnel, fill the bottle until the water level is above all of the holes and mark the top of the water level on the outside of the bottle with a piece of tape so that the bottom of the tape is even with the water but above the top hole.

4. Before you proceed, from which holes do you think the water will travel the farthest and least horizontal distances? Why?

5. Place the bottle on the edge of a structure, no more than a meter in height to where the water will land, that will enable you to measure the **horizontal** distance *D* in meters traveled by the water as it leaves each hole. This won't work if you simply set the bottle directly on the ground.

6. Measure the **vertical** height *H* in meters **from the surface where the water will land up to the uncovered hole in the bottle**.

7. Measure the **vertical** height *h* in meters from the **water level in the bottle down to the uncovered hole** and record the data.

8. Remove the piece of tape covering the bottom hole, record the **horizontal distance *D*** traveled by the water and record the data.

9. Cover the hole, and repeat this process with the remaining holes, working upward. **You will need to remeasure both *H* and *h*, however, note that *H* + *h* will be the same**. If you need to refill the bottle, refill to the colored tape mark.

10. Complete the following table:

Torricelli Bottle Data

A	B	C	E	F	G	I
Trial	*H* in m	*h* in m	*H* + *h* in m	*D* in m	Calculated *v* in m/s	Calculated *t* in s
hole 1 (bottom)						
hole 2						
hole 3 (top)						

11. For which trial did the water travel the farthest horizontal distance? For which trial did the water travel the least horizontal distance?

12. Did the results agree with your assumptions? Explain.

13. If you were able to do this same activity on the Moon or on Mars, for example, would the results be the same or different? Explain. If you aren't sure, review the algebra on the first page of this activity.