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# STUDENT VERSION
# CONE TO CUBE FLOW

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**Abstract:** We consider a configuration of two containers. An inverted right circular cone with a hole in point at the bottom is suspended above an open-topped cube which also has a hole in the center of the bottom. The cone is filled with water and we wish to model the water flow from cone to cube and out the bottom of the cube. This uses two applications of Torricelli's Law.

## STATEMENT

Consider the following configuration as seen in Figure 1. We have an inverted (point down) right circular conical tank, with a top (base) radius $R$ meters and a total height of $H$ meters, filled with water to a height of $h$ meters. There is a circular hole of radius $r_C$ meters at the very bottom of the cone from where water flows out of the cone. This water falls into an open-topped cubicle tank sitting directly below the cone. Finally, this cubicle tank also has a circular hole at the center of its base with radius $r_B$ meters and water flows out of the bottom cubicle tank.

Can we create a mathematical model to describe this situation?

1. How long does it take the conical container to empty?
2. How long does it take both containers to empty?
3. Further, what if the circular holes in the containers offer friction or resistance?
4. Offer comments on the reality of your solutions.

Here are a reasonable set of working dimensions, parameters, and constants:

- top (base) radius of the cone, $R = 0.3$ m;
- height of the cone, $H = 0.8$ m;
- radius of hole at bottom tip of the cone, $r_C = 0.02$ m;

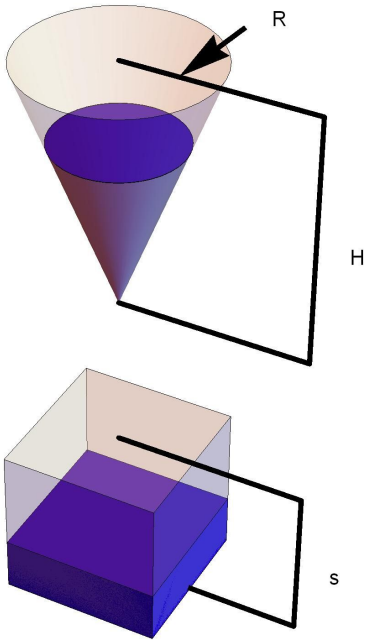


**Figure 1.** Shown is a cone of base radius $R$ and height $H$ sitting above a cube of side $s$ with the water running out of the cone into the cube, whereupon the water runs out of the cube.

- length of side of the cube, $s = 0.5$ m;
- radius of hole at bottom of the cube, $r_B = 0.03$ m;
- acceleration due to gravity, $g = 9.8$ m$^2$/s;
- (for the cone) the empirically determined resistance percentage, $\alpha$, of the flow rate of the liquid which actually goes through the hole in the bottom of the cone is the *contraction coefficient*, here $\alpha = 0.70$;
- (for the cube) the empirically determined resistance percentage, $\beta$, or the percent of the flow rate of the liquid which actually goes through the hole in the bottom of the cube is the *contraction coefficient*, here $\beta = 0.60$.