Verification of Descartes' Force-Flux Analogy

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Abstract

A simple experiment can be set up to demonstrate the force-flux law. Descartes hydraulic analogy derived from his metaphysics of geo-kinematics was tested, and verified or not.

1 Introduction

In 1637 the philosopher and mathematician Rene Descartes published his book on *Geometry* Descartes (1925). In this work Descartes defined analytical geometry with respects to motion.
In analytical geometry curves are represented by means of equations. However, for Descartes the equations did not define the curve. Descartes argued that curves are only acceptable, provided they can be conceived of as described by a continuous motion or by several successive motions, each motion being completely determined by those which precede; for in this way an exact knowledge of the magnitude of each is always obtainable. In Descartes research program the kinematical generation of curves was essential. This kinematical generation does not take place in empirical space.
In 1645 the wrote to Mersenne about his interest in the motion of water (Descartes, 1991, p. 138,sec. 571). Prior to this letter Descartes had already written to Huygens (18 February 1643 (Descartes, 2001, III)) documenting a set of experiments and apparatus concerned with calculating the conversion of water head to a stream of water through a tiny hole at the bottom of a pipe (point B in Figure 8). Timbs (John Timbs, 1868, p. 41) suggested that in these experiments Descartes may have observed an analogy between the motion of falling body already established by Galileo and fluid discharge (or *flux*). Odum has described this relationship as the the force-flux law given in Equation 1. This general statement of the force-flux relationship appears to have some use with application to specialised domains of science—the familiar equation of Ohm's Law ($V = IR$) is, for example, sometimes given as a special case of the more general relationship.

$$J = CX \tag{1}$$

The experiment was significant in the history of experimental philosophy for the verification of Descartes' emerging metaphysics and fluid mechanics, but also because his interests may have predated, or been contemporaneous to the work of Evangelista Torricelli (1608-1647), the inventor of the barometer. Mach described the experiment thus, "...neglecting all resistances, the velocity of efflux, v, of a liquid discharged through an orifice in the bottom of a vessel is connected with the height h of the surface of the liquid" (Mach, 1919, p. 402). Mach's formula is given in Equation 2. Descartes used the surface area of the outlet as a unit of measure (unity = 1), hence rearranging to Equation 3:

2 Pedagogic Goals

2.1 Geometric Kinematics

The main aim is to attempt to introduce several concepts mentioned in the introduction along with Descartes' geometric kinematics, and geometric method of calculating the ideal hydraulic machine, and predicting the height to which the water will rise in the measurement pipes for each different system configuration.

2.2 Open-Closed Systems

Various configurations of experiment also might be useful for demonstrating the concepts of 0, 1 and 2-port systems, along with the concepts of open and closed systems. The experimenter might firstly test their intuition with Figures 1-4, which present different types of systems, with different numbers of ports. For example, Figure 1 is an example of a closed system. Figure 3 is a 1-port system open to flow, but closed to forcing function.

2.3 *Vis viva*

The experiments should also enable the subsequent development of a second set of experiments by introducing mass placed on top of the tank, to provide an additional source of pressure on the water in the tank. In this instance the experimenter is now coming to a consideration of Leibniz's concept of *vis viva*, defined by the equation, mv^2, and kinetic energy defined as half the *vis viva*, $\frac{1}{2}mv^2$.

3 Predictions

To verify Descartes' force-flux analogy via simple tank and flow apparatus (as defined in 4):

3.1 Equations

$$v = \sqrt{2gh} \tag{2}$$

$$gh = \frac{1}{2}v^2 \tag{3}$$

$$gh = v^2 \tag{4}$$

3.2 Definitions

Velocity ...

Gravity ...

Distance ...

4 Equipment

Item	Quantity
Tank	1 x 1L Water bottle
Clear piping	3 m x 4mm
T-intersection	1 Packet x 4mm (x 10 in pack)
Tape	1 x Roll Masking tape (or equiv.)

5 Experimental Data

Mass of 1 litre	____________	(kilogram)
Height of tank	____________	(mm)
Increments	____________	(mm)
Height of Vertical Measure Pipes	____________	(mm)
Total Length of Horizontal Pipe	____________	(mm)

6 Method

6.1 Step 1

Connect

6.2 Step 2

Take some baseline measurements of the amount of time the tank takes to empty when connected and not connected.
* Remember to catch the water for recycling.

Parameter	Apparatus State	Measurement
Time of emptying	tank disconnected	______________ (sec)
Time of emptying	tank connected	______________ (sec)

7 Sample Calculation

8 Results and Conclusions

9 Discussion of Experimental Uncertainty

10 Answers to Definitions

References

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Mach, E. (1919). *The Science of Mechanics: A Critical and Historical Account of Its Development.* Open Court Publishing Company, LaSalle, Ill., 6 edition edition.

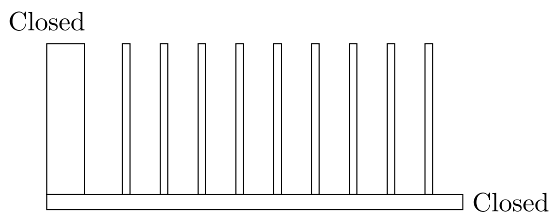

Figure 1: Prediction 1 - Tank Closed, Valve Closed

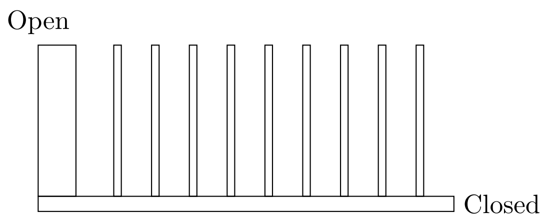

Figure 2: Prediction 2 - Tank Open, Valve Closed

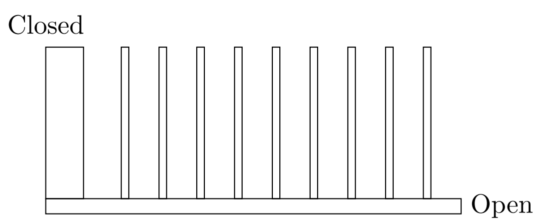

Figure 3: Prediction 3 - Tank Closed, Valve Open

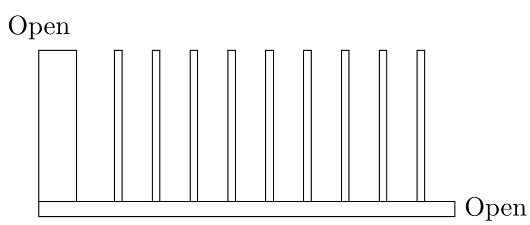

Figure 4: Prediction 4 - Tank Open, Valve Open

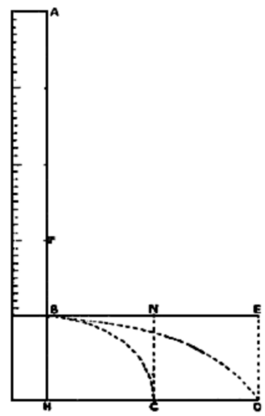

Figure 5: Descartes force-flux

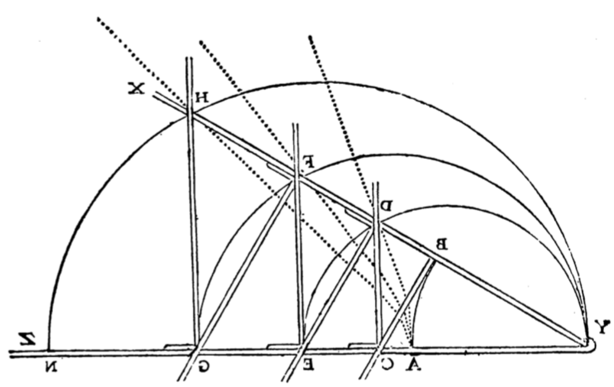

Figure 6: Descartes' "Ideal machine"

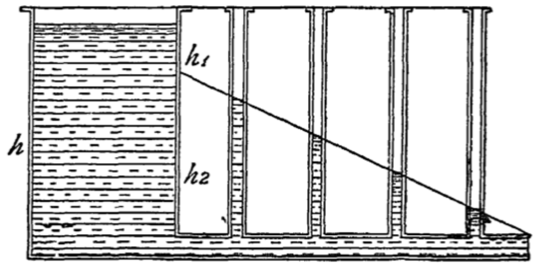

Fig. 220.

Figure 7: Mach's Representation

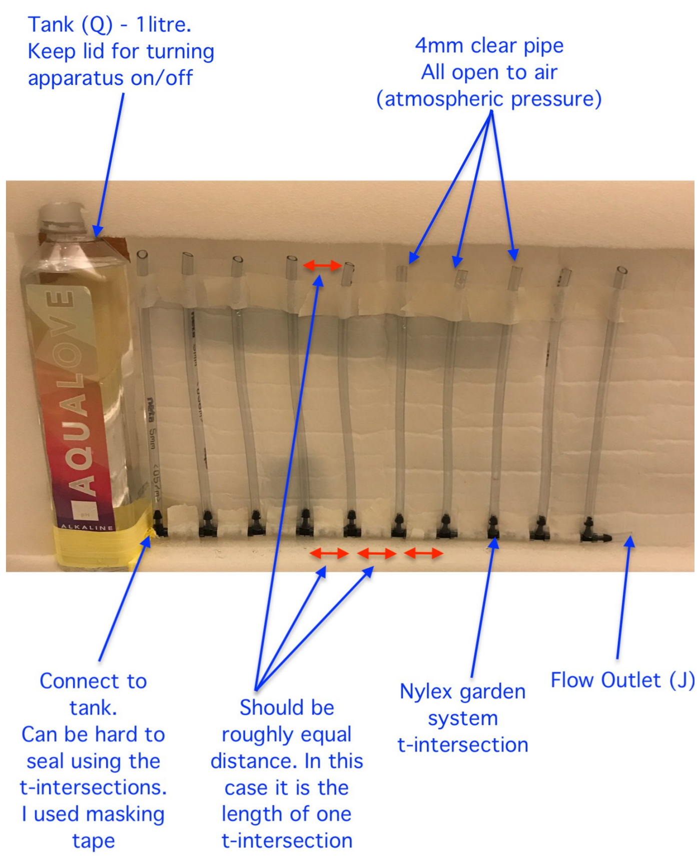

Figure 8: Full picture of apparatus