

**University of Ottawa**

**Faculty of Engineering**

**Department of Mechanical Engineering**



**uOttawa**

L'Université canadienne  
Canada's university

**Fluid Mechanics 1**

**MCG 3340**

LAB 1 - Jet Impact

By:

**Abstract:**

The goal of this lab is to measure the force generated by a jet of water impacting two different solid surface. We are able to measure the force of the jet by using a weight scale balance. We can measure the force in two different ways. One way is by using a balance of equations of as a balance of moments as well as using the conservation of momentum equation. We were able to prove the that the theoretical force is the same as the experimental force with an error of about 22%.

**Table of Contents:**

Introduction	pg. 3
Methodology	pg. 3
Apparatus	pg. 4
Results	pg. 4
Discussion	pg. 7
Conclusions	pg. 8
References	pg. 12

## Introduction:

The goal of this lab is to measure the force generated by a jet of water impacting two different solid surface. We are able to measure the force of the jet by using a weight scale balance. We can measure the force in two different ways. One way is by using a balance of equations of as a balance of moments. The other way we can get the force of the jet is by using the conservation of momentum equation.

$$\Sigma F = \iiint \rho v dV + \oint \rho v (v \cdot n) dS$$

## Methodology:

- 1) Start by moving the weight on the balance until the balance is level. At this point, the moments generated by the spring, the weight of the balance itself, and the force from the added weight are all in balance. Note the position,  $\theta_0$ , and size of the force,  $F \sim W$  provided by the added weight on top.
- 2) Start the flow of water. Using the tank-balance apparatus, measure the flow rate. This is done by closing the drain from the fill tank, when the balance tilts, quickly add a weight to the other side of the balance and start measuring the time. When the balance tilts a second time, stop your time measurement. The amount of water added to the tank in that interval is written on the weight you added (the number on the weight applies to the water, not the weight itself). You can use these measurements to calculate the mass-flow rate of water.
- 3) Once you are confident that you know the mass-flow rate. Move the small weight on top of the apparatus until the balance returns to its original position (the angle it was at before the jet was activated). Note the new position of the weight and calculate the change,  $\Delta \theta$ , as shown in Figure 2.1b. The increase in the moment generated by moving the weight is balanced by the moment generated by the jet of water. The perpendicular distance of the jet from the pivot,  $\ell$ , is 6 inches
- 4) Repeat the procedure for a second flow rate.

## Apparatus:

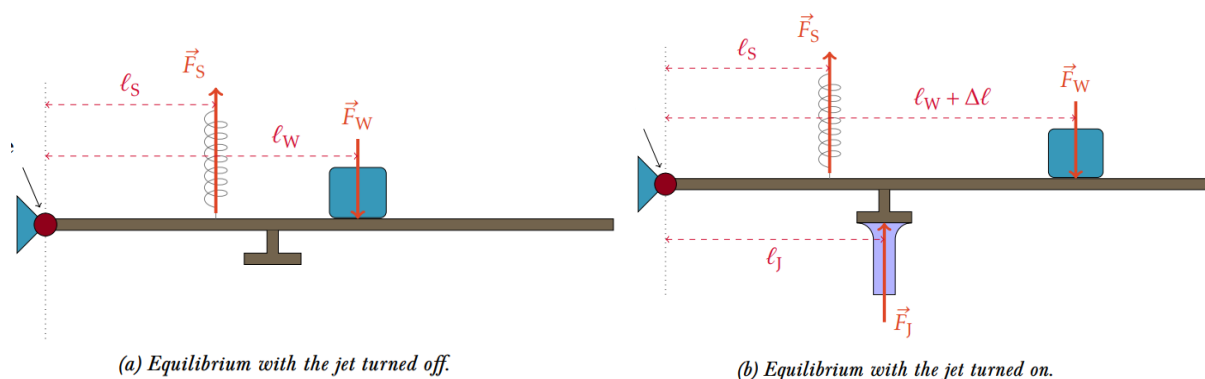
In this experiment, a pump supplies a flow of water that passes upward through a nozzle. The nozzle exit has a diameter of 9.5 mm. The jet of water impacts either a flat plate and is deflected horizontally, or a hemispherical cup and is deflected downwards. The measurement of the force is accomplished using a force balance, as shown in Figure 2.1. Another balance and tank are used to measure the mass flow rate of water.

## Results:

Table 1: Results

Test Case	Flow rate (lbs/s)	Rested weight distance (inch)	Jet equilibrium distance (inch)
Flat #1	1.02	0.2	4.45
Hemisphere #1		1.1"	7.25
Flat #2	1.08	0.2	3.1
Hemisphere #2		1.1"	6.25

Sample Calculations: Flat impact for case 1



Given and measured values:

$$L_s = 6''$$

$$L_w = 6.2''$$

$$L_j = 6''$$

$$L_w + \Delta l = 6 + 4.45 = 10.45''$$

$$F_w = 1.21 \text{ lbs}$$

By summation of moments about the hinge:

$$\Sigma M = 6 * F_s - 6.2 * 1.21$$

$$F_s = 1.25 \text{ lbs}$$

Given that  $Q = \text{reference weight/time} = 30/29.265 = 1.02 \text{ lbs/s} = 0.46 \text{ kg/s}$

$$Q = \rho A V$$

$$0.46 = 1000 * \Pi * (.0095/2)^2 * V$$

$$V = 6.49 \text{ m/s}$$

By conservation of momentum, by flux in the y direction.

$$F_j = \Pi r^2 * \rho * V^2$$

$$F_j = \Pi * (0.0095/2)^2 * 1000 * 6.49^2$$

$$F_j = 2.95 \text{ N} = 0.663 \text{ Lbs, the force of the water by jet properties.}$$

Finding force of water by balance

By summation of moments about the hinge:

$$\Sigma M = L_s * F_s + L_j * F_j - (L_w + \Delta l) * F_w$$

$$\Sigma M = 6 * 1.25 + 6 * F_j - 10.45 * 1.21$$

**F<sub>j</sub> = 0.857lbs = 3.81N by balance**

Percentage error = |balance force - jet force|/balance force \* 100 = 22.5%

### Sample Calculations: Hemispherical impact for case 1:

By summation of moments about the hinge:

$$\Sigma M = 6 * F_s - 7.1 * 1.21$$

F<sub>s</sub> = 1.43lbs

Finding force of water by balance

By summation of moments about the hinge:

$$\Sigma M = L_s * F_s + L_j * F_j - (L_w + \Delta l) * F_w$$

$$\Sigma M = 6 * 1.43 + 6 * F_j - 13.25 * 1.21$$

**F<sub>j</sub> = 1.24lbs = 5.51N by balance**

Test Case	Flow rate (lbs/s)	F <sub>j</sub> by jet analysis (lbs)	F <sub>j</sub> by balance analysis (lbs)	Error (%)
Flat #1	1.02	0.663	0.857	22.5
Hemisphere #1		1.326	1.24	6.9
Flat #2	1.08	0.759	0.575	22.9
Hemisphere #2		1.518	1.04	45

**Discussion:**

In this lab we tested the difference between the jet impact of a water stream on a flat surface as well as on a Hemispherical surface. We found that the hemispherical surface generates a greater upward force on the surfaces. We also saw that as we increase the fluid flow rate the force generated decreases. In the analysis we are assuming there is no friction on the plate or hemisphere.

For the flat plate, after the jet hits the plate, It forms a radial sheet around the plate. The only flux that we in the y-direction is the water entering the system. However for the hemispherical plate, We see that there are 2 fluxes in the y-direction. One for the water entering the system and another exiting the system.

One possible source of experimental error is in the way we measured our finding. Most of the results were done by measuring with very inaccurate tools. For example measuring the flow rates we had to hit the timer to start and stop as well as when the hinge moved. These measurements were very inaccurate and cause a lot of experimental error. Another measuring error is on the balance. There was no exact point to say it was level so we had to make educated guesses as to when it was level. We have also assumed that the radius of the water does not change with height. These points added up to give us a percent error of around 22 - 23%.

**Conclusion:**

This experiment successfully demonstrates how fluid flux can change the force on an object. We saw that adding a hemispherical surface to the balance created almost double the force compared to a flat surface.