Investigating Effect of Resistance on the Net Force on a Falling Object

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1 Introduction

1.1 Purpose

Understand how density affects a falling object by comparing how a steel ball bearing falls in air and in water.

1.2 Hypothesis

As resistance increases, the net force on the ball bearing will decrease, as more fluid will work against the force of gravity.

1.3 Variables

Independent Variable

- Resistance

Dependent Variable

- Net force (F_{net})
  - Acceleration

Controlled Variables

- Drop height in air (100 cm)
- Drop height in resistance medium (25.0 cm)
- Resistance medium
- Object mass+size

2 Materials

- 1.00 L H_2O
- 1 · 1.00 L graduated cylinder
- 1 · metre-stick

- 1 · scale
- 1 · timer
- 1 · ball bearing

3 Procedure

1. Measure, record mass and diameter of ball bearing
2. Suspend top of ball bearing from 100 cm
3. Drop ball, start timer
4. Stop timer when ball hits "ground"
5. Record time taken to fall
6. Repeat steps 3-6 as necessary for data collection
7. Fill graduated cylinder with 1.00 L water
8. Suspend top of ball bearing at surface of water
9. Drop ball, start timer
10. Stop timer when ball hits "ground"
11. Record time taken to fall
12. Repeat steps 8-12 as necessary for data collection

4 Data

Table 0: Information

Medium	Density $\mathrm{g\,cm^{-1}}$
Air	0.001 23
Water	1.000

Table 1: Raw Data

Medium	Trial 1 s	Trial 2 s	Trial 3 s	Trial 4 s	Trial 5 s	avg s
Air	0.470±0.05	0.440±0.05	0.400±0.05	0.500±0.05	0.450±0.05	0.45±0.05
Water	0.260±0.05	0.230±0.05	0.250±0.05	0.300±0.05	0.220±0.05	0.25±0.05

Table 2: Acceleration and Net Force

Medium	a $\mathrm{m\,s^{-2}}$	F_{net} N
Air	9.87	0.0780
Water	8.00	0.0630

5 Calculations

5.1 Average

Given that s(r) is the function of time taken to drop given resistance:

$$\langle \mathrm{s}(r) \rangle \tag{1}$$

$$\frac{\sum_i \mathrm{s}(r)}{i} \tag{2}$$

$$\frac{\mathrm{s}(r_1) + \mathrm{s}(r_2) + ... + \mathrm{s}(r_{i-1}) + \mathrm{s}(r_i)}{i} \tag{3}$$

5.2 Acceleration and Force

Acceleration can be calculated from the distance traveled and the taken to travel as follows:

$$a = \frac{2d}{t^2} \tag{4}$$

Let a_g equal the acceleration in air and a_l equal the acceleration in the water. Solving for $a_{g,l}$ with their respective parameters yields:

$$a_g = \frac{2 * 100.0}{0.45^2} = 987\,\mathrm{cm\,s^{-2}} = 9.87\,\mathrm{m\,s^{-2}} \tag{5}$$

$$a_l = \frac{2 * 25.0}{0.25^2} = 800\,\mathrm{cm\,s^{-2}} = 8.00\,\mathrm{m\,s^{-2}} \tag{6}$$

From there, calculating F_{net} only requires multiplying the acceleration by the mass of the ball bearing:

$$F_g = a_g * 0.0079 = 0.0780\,\mathrm{N} \tag{7}$$

$$F_l = a_l * 0.0079 = 0.0630\,\mathrm{N} \tag{8}$$

6 Conclusion

My hypothesis, that net force on an object will decrease as the density of a fluid increases, is correct. In air, the net force of gravity on the ball bearing was 0.0780 N, while in water, the net force was 0.0630 N. This is proportional to the acceleration, which was $9.87\,\mathrm{m\,s^{-2}}$ in air, but dropped to $8.00\,\mathrm{m\,s^{-2}}$ in water.
A difficulty with this lab was the fact that, being human, I could not perfectly time how long it took for the ball bearing to drop. There was obvious error; acceleration in air was reported as being around $9.87\,\mathrm{m\,s^{-2}}$, while it should have been $\leq 9.81\,\mathrm{m\,s^{-2}}$. However, given that the collected data was rather consistent—standard deviations of 0.037 and 0.031 for air and water, respectively—it would be safe to assume that my hypothesis holds true, as the other data points adhere to the same result.
In the future, I could conduct experiments with more mediums to get more information before making a conclusion. While I did try to compensate for my lack of variation with an increased trial count, I did not feel comfortable making a conclusion with only two manipulations.