Physics 2020 Laboratory
Experiment 1: Human Reaction Time

Objective

To measure human reaction time by measuring the distance a freely falling meter stick travels before it can be caught.

Introduction

Human reaction times are typically too short to measure conveniently with an ordinary stopwatch. Instead, we can convert the measurement of a short **time interval** into the measurement of a **distance**.

Suppose a meter stick is released from rest and allowed to fall freely. Neglecting air resistance, its downward displacement x after a time t is

$$x = \frac{1}{2}gt^2,$$

where g is the acceleration due to gravity. We will use

$$g = 9.8 \text{ m/s}^2.$$

Solving for the time gives

$$\boxed{t = \sqrt{\frac{2x}{g}}}.$$

Thus, if we measure how far a meter stick falls before a person catches it, we can calculate that person's reaction time.

Equipment

- Meter stick
- Two students

Procedure

Work with a partner.

1. One student will be the **subject** and the other will release the meter stick.
2. The subject should hold the thumb and forefinger a short distance apart, with the fingers positioned at the 0-cm mark of the meter stick. Do **not** touch the meter stick.
3. The other student should hold the meter stick vertically. Without warning, release it.
4. As soon as the subject sees the meter stick begin to fall, the subject should catch it between the thumb and forefinger.
5. Record the distance x that the meter stick fell.
6. Repeat the measurement **five times**.
7. Convert each measured distance from centimeters to meters.
8. For **each individual measurement**, calculate the reaction time using

$$t = \sqrt{\frac{2x}{g}}.$$

9. Find the mean reaction time,

$$\bar{t} = \frac{t_1 + t_2 + t_3 + t_4 + t_5}{5}.$$

Data and Calculations

Trial	**Distance x (cm)**	**Distance x (m)**	**Reaction time t (s)**
1			
2			
3			
4			
5			

Mean reaction time:

$\boxed{\bar{t} = \_\_\_\_\_ \text{ s}}$

An Important Point About Averaging

It may seem reasonable to average the five measured distances first and then calculate a reaction time from the average distance. **Do not do this.**

The correct procedure is

$$\boxed{\bar{t} = \frac{1}{5}\left[\sqrt{\frac{2x_1}{g}} + \sqrt{\frac{2x_2}{g}} + \sqrt{\frac{2x_3}{g}} + \sqrt{\frac{2x_4}{g}} + \sqrt{\frac{2x_5}{g}}\right].}$$

If instead you first calculate the mean distance,

$$\bar{x} = \frac{x_1 + x_2 + x_3 + x_4 + x_5}{5},$$

and then calculate

$$t' = \sqrt{\frac{2\bar{x}}{g}},$$

you obtain

$$t' = \sqrt{\frac{2}{g}\left(\frac{x_1 + x_2 + x_3 + x_4 + x_5}{5}\right)}.$$

These two expressions are **not equal in general**:

$$\boxed{\frac{1}{5}\sum_{i=1}^{5}\sqrt{x_i} \neq \sqrt{\frac{1}{5}\sum_{i=1}^{5}x_i}.}$$

In words,

the mean of the square roots is not the square root of the mean.

This happens because the relationship between t and x is **nonlinear**. Averaging may be performed before or after a linear transformation without changing the result, but that is not generally true for nonlinear functions such as square roots.

In fact, because the square-root function is concave,

$$\frac{1}{N}\sum_{i=1}^{N}\sqrt{x_i} \leq \sqrt{\frac{1}{N}\sum_{i=1}^{N}x_i}.$$

Therefore, calculating the reaction time from the average distance will generally give a reaction time that is **slightly too large**.

Laboratory Report

Complete the data table and answer the following questions.

1. What was your mean reaction time?

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2. Were all five measurements identical? If not, give one reason why repeated measurements of human reaction time might vary.

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3. Why must the reaction time be calculated for each trial before the reaction times are averaged?

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4. A student obtains falling distances of 12.0**,** 18.0**, and** 24.0 **cm. Which of the following is the correct procedure? Circle one.**

A. Average the three distances, then calculate one reaction time.

B. Calculate three reaction times, then average the reaction times.

Conclusion

Measured mean reaction time:

_____ s