Free Fall

**Equipment**
- A paper or small bunder clip
- A ball (tennis or golf, or baseball, or fetching ball, or gum ball)
- Stopwatch (use phone or [https://www.online-stopwatch.com/full-screen-stopwatch/](https://www.online-stopwatch.com/full-screen-stopwatch/))
- Soft Pad for landing if necessary

**Objectives**
- To measure the time of a fall for different objects

**Introduction**

Galileo was the first to describe gravity on Earth’s surface correctly. Through experiments, he found that, neglecting air resistance, any object falls with a constant acceleration, \( g = 9.8 \text{ m/s}^2 \) downward. That means that if the object is dropped from rest, it will travel distance

\[
h = \frac{1}{2} g t^2
\]  

The value of 9.8 m/s² implies that any object would travel 4.9 meters in the first second of drop. Such rapid motion makes even a small uncertainty of 0.1 second relatively large unless the object travels a very long distance. For example, in a common laboratory setting where height does not exceed 2 meters, the time of travel won’t exceed 0.64 second. Taking in consideration that typical absolute uncertainty due to human reaction ranges between 0.1s and 0.2 s, an experiment in a common laboratory setting yields at least 17% uncertainty. The same absolute uncertainty will produce much smaller relative uncertainty at larger distance of travel. Increasing a height of drop to 5 meters will increase the time of travel to 1 second and reduce the relative uncertainty to 10%. However, if such increase in distance is not possible, a decrease in absolute uncertainty could solve the problem. Due to high sensitivity, electronic sensors produce much smaller absolute uncertainty that aids in avoiding large relative uncertainty in experiments that incorporate small heights.

**Part #1: Humans vs. Robots**

In this part you will determine your reaction time in two different ways: by using a software and by directly reacting to a fall of a ruler.

1. Open Reaction Time test from Human benchmark site: [https://humanbenchmark.com/tests/reactiontime](https://humanbenchmark.com/tests/reactiontime)
2. Complete the test and record your reaction time converting it from milliseconds to seconds.
3. In one hand, hold a ruler down vertically by 30cm mark. Place fingers of another hand around 0cm mark of the ruler. It is recommended to use a dominant hand to hold the ruler.
4. Drop the ruler from one hand to catch it with another.
5. Note how far from “0” the ruler was caught and record this distance.
6. During the time \( t \) it took you to react, the ruler was in the air and fall down the distance \( h \) at which
you caught it. Use the relationship \( h = 4.9t^2 \) to solve for the time. \( \text{The value of } h \text{ used in calculation must be in meters.} \ (\text{Hint: } t = \sqrt{\frac{h}{4.9}}) \)

6. Calculate % Difference between values obtain by two different ways.

<table>
<thead>
<tr>
<th>Obtained from reaction to a drop</th>
<th>Obtained from the software, seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance ruler traveled, ( \text{cm} )</td>
<td>Distance ruler traveled, ( \text{m} )</td>
</tr>
</tbody>
</table>

**Table 1.** Data recorded for the determining a reaction time.

**Part #2: Timing a Drop**

In this part, the time it takes for a ball and a clip to fall from a set of height will be measured by a stopwatch.

1. Place a soft pad on the floor for landing if necessary.
2. It turns, hold a ball and clip so that it is the desired height from the floor.
3. Use a stopwatch to record the time of the fall.
4. Repeat the experiment for heights of your knee, tabletop, your shoulders, as far as you can reach.
5. Repeat the drop for at least 5 trials at each height and average the values of drop time.
6. Plot the data as a bar diagram Average time vs. Height for each object. Discuss the difference between two plots if any or absence of the difference if none.

<table>
<thead>
<tr>
<th>Height</th>
<th>Knee</th>
<th>Tabletop</th>
<th>Shoulders</th>
<th>Max of reach</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clip</td>
<td>Ball</td>
<td>Clip</td>
<td>Ball</td>
</tr>
<tr>
<td>Trial 1</td>
<td></td>
<td></td>
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<td>Trial 2</td>
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<td>Trial 5</td>
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<tr>
<td>Average</td>
<td></td>
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</tbody>
</table>

**Table 2.** Data recorded for object drops from various heights.
Requirements for the Report:

1) **Only one report needs to be submitted per lab group from the Blackboard “Report Submissions” page.** The names of the lab partners collaborating on the report must be listed in the header on each page of the report; a lab partner whose name is not listed will not receive the credit unless separate report is submitted individually (such report will have 5 points deduction for the team work).

2) The data presented in the report must consolidate the individual data from each lab partners. To achieve that, lab partners must collaborate on re-design of Tables 1 and 2. The collaboration can be done through WebEx (https://iol.tamucc.edu/webex.html), the Blackboard discussion board, or any other collaborative platforms such as Google Docs.

3) The report must include an abstract **of about one page** summarizing the experience of all collaborating lab partners.

- The **abstract section** must contain the following explanations in paragraph form:
  - How the data was collected in each part including an explanation of the used tools
  - How the data was analyzed including the calculation of reaction time in Part 1 and plotting of the collected data in Part 2
  - A statement based on Table 1 about % difference between two values
  - A statement based on bar diagram about the trend in time of drop.

- The **data section** must include
  - 2 Tables (labeled and captioned)
  - 1 bar diagram