"Physics Lab at Home" Challenge

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We want to emphasize that we expect student collaboration to happen virtually; students should NOT meet in-person for the purpose of any 2021 UBC Physics Olympics activities.

The deadline for submission is 11:59pm on Tuesday, March 2nd. Instructions for submitting materials online will be announced with the final rulebook.

I. Objective

Your team's objective is to carry out collaborative research in experimental physics while remaining at home and communicating with teammates online.

You probably already know that a smartphone is a powerful computer that we carry with us wherever we go. But did you know that a standard smartphone is also a very capable measuring device? It has a number of sensors, such as an accelerometer, a light sensor and a microphone, which can be used for performing a variety of exciting science experiments.

To carry out an experiment using a measuring device, that device must be (a) configured, (b) triggered to start recording data, and (c) queried to retrieve the recorded data. Quite a few apps exist for accessing the sensors in your smartphone and enabling those operations. One of them, aimed specifically at performing physics experiments, is called ***phyphox***. In this challenge, we ask you to download this **free app** to your iOS or Android phone and use it as your main scientific instrument. To learn about phyphox and the ways it can be used, go to https://phyphox.org/ .

The objective of this challenge is to complete two research projects by using a smartphone as the primary scientific instrument (and in Project 2, the only instrument).

In using your smartphone with phyphox, the following is permitted:

I. Establish a communication channel between your smartphone and your computer (of any type, including tablets).

II. Use multiple smartphones with phyphox.

III. Create your own custom-designed phyphox experiments using any method described on the phyphox website.

IV. Process the collected data on either the smartphone itself (e.g., using the built-in capabilities of phyphox) or any external computer of your choice.

In contrast, it is **NOT** permitted to

V. Communicate with other *measuring devices or sensors* (e.g., Arduino circuitry or an external GPS, etc.).

VI. Use any other App, even if it is installed on the same smartphone, for taking measurements.

Failing to comply with the above restrictions will lead to disqualification of the team.

II. Experimental projects

1. Project 1: Gravitational acceleration

In this project your task is to determine experimentally the value of the gravitational acceleration, g, while adhering to the following rules:

a) Instrumentation. You may use your smartphone(s) with phyphox and any other external instrument (e.g., ruler, thermometer, scale, etc.) provided the additional instruments are **NOT** communicating with any of the smartphones.

b) Physical constants. You are **NOT** allowed to use any known physical constants, such as the density of materials, the mass of the Earth, etc., unless you determine it experimentally yourself using instrumentation outlined in a). If you determine such a constant experimentally, then you must explain how you made the measurement.

2. Project 2: Speed of sound at 0°C

In this project your task is to determine experimentally the value of the speed of sound in ambient air at a temperature of 0 degrees C. You must adhere to the following rules:

a) Instrumentation. You may use a smartphone ONLY! Any other common measuring devices, such as a ruler or a thermometer are NOT allowed! For example, if you say that you carried out an experiment outdoors and the temperature was 0 degrees, you are required to explain how you determined the outside air temperature (and using a weather forecast is not allowed either).

b) Physical constants. You can use the values of any fundamental physical constants and material properties, such as the gravitational acceleration, g, thermal expansion of water, density of air, etc. However, you are **NOT** allowed to use well known facts not related to science, such as knowing that the length of a standard Letter page is 11" or that a gallon of milk weighs 8.6 pounds.

c) Physical laws. You **ARE** allowed to use the known dependence of the speed of sound on temperature, and other laws describing how a material property depends on various physical parameters.

III. Scoring scheme

In both projects (and as is often the case in true research), you can reach the final goal by using multiple scientific methods. We encourage you to explore as many approaches to completing a project as you can think of. The final score of your team will be determined according to the following components (listed in order of weight, from highest to lowest):

1. **Number of methods used**. You will receive points for every **distinct method** you used in each project. Two methods are considered distinct if they are using different physical principles. For instance, repeating the same experiment with two different objects (e.g., measuring the time of their free fall) will be considered as a single experimental method. A method that is not explained in the video, or explained poorly (see below), is NOT going to be counted.

2. **Quality of video reports**. For each project, you are required to submit a single video file by uploading it online (*Instructions will be announced soon*). The video must demonstrate and explain every method you used in completing the project. You should dedicate a separate segment to each method used. Segments could be of different length, but the total length of the video MUST NOT EXCEED the following limit: **total length ≤ (3 minutes) x (number of methods).** That is, 6 minutes or less if you used two distinct methods, 9 minutes for three, etc.

   The report must follow the format of phyphox video instructions by Sebastian Staacks (the creator of phyphox) available at https://phyphox.org/experiment/?video=1 .

   The quality of each video segment will be assessed according to the following rubric:

   a) The main physics principles and concepts used to implement the method you are describing;
   b) The details of the experimental setup built for taking data;
   c) The details of what data were recorded and how;
   d) The details of how the recorded data were processed;
   e) The details of how the target value (i.e., g or the speed of sound) was calculated from the processed data;
   f) The method of estimating the uncertainty;
   g) The main result, i.e., the value of g or the speed of sound at 0°C temperature, and the corresponding uncertainty.

   The scientific content of the video, i.e., **the clarity of explaining the points above, serves as the primary scoring factor**. The overall quality of the presentation is secondary. Any method that is shown in the video, but not explained, will not be counted as a distinct method towards the final score of the team.

   NOTE: If two or more methods are using the same tool, e.g., a ruler that you had to make yourself, do not repeat its description in each segment of the video. Describing it once is enough.

3. Each video report must be accompanied by a file with raw data in a format described in Section IV below. The files will also be uploaded online (*Instructions will be announced soon*). Judges must be able to reproduce your derivations of the target value (of g or of the speed of sound) from your data. The easier it is **to understand, follow and reproduce** your derivations from the acquired data, the higher your score.

4. The lower the uncertainty, the higher the score. Note that this does not mean that your results must be as close to the known values as possible, or that the results from different methods must be the same! As long as a scientific hypothesis is offered to explain the disagreement, the magnitude of such disagreement will only be used for breaking ties. For instance, a creative experimental method resulting in $g = (10.123 \pm 0.002)$ m/s^2 may score higher than a poorly explained technique in which $g = (9.8 \pm 0.5)$ m/s^2. We are looking for your **understanding of the scientific method**, rather than your ability to deliver the expected results.

IV. Data submission format

Each team must submit two Excel files, one per project. The files must be named according to the following template 'SCHOOL_NAME_PROJECT_NAME.xls' (e.g., 'University_Hill_Gravitational_acceleration.xls' or 'Lord_Byng_Speed_of_sound.xls ').

Each Excel file will consist of a single sheet if only one method was used for completing the project. In case of multiple methods, the team will create multiple sheets, one per experimental method, and label them 'Method 1', 'Method 2', 'Method 3', etc.

Each individual sheet must contain a single table of numerical values with multiple columns and a clear description of what each column corresponds to, described in the header of that column, including the units used to measure the values. **The only place where non-numerical text is allowed is in the first header row!** For example, use the header to outline the units used (e.g. m/s^2), but do not include these units together with the numerical values representing your data points. Take a look at the screenshot on the next page, in which an example of such table is depicted.

Each spreadsheet must include two mandatory columns, called 'Gravitational Acceleration' and 'Uncertainty' (for Project 1) and 'Speed of sound' and 'Uncertainty' (for Project 2), containing a single number as a final result of your study in that project.

V. Student collaboration

Despite the remote nature of this challenge, we expect a collaborative team effort! All team members are encouraged to conduct phyphox experiments by themselves, share and compare data, discuss and interpret the results. At the same time, we also expect minimum involvement of parents and teachers, limited to the typical guidance they would offer in helping with a "Pre-built" event during a normal year.

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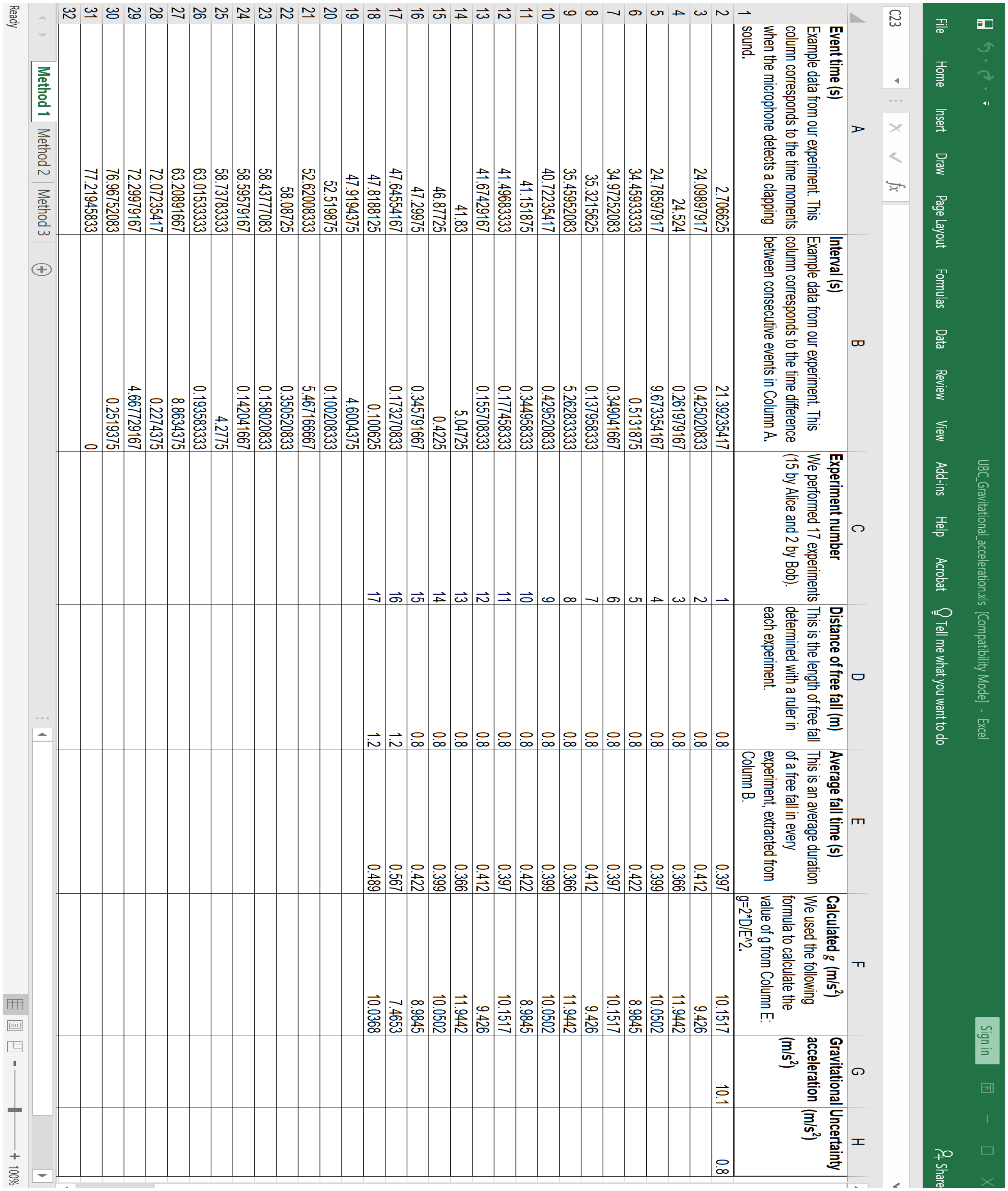

	A	B	C	D	E	F	G	H
1	**Event time (s)** Example data from our experiment. This column corresponds to the time moments when the microphone detects a clapping sound.	**Interval (s)** Example data from our experiment. This column corresponds to the time difference between consecutive events in Column A.	**Experiment number** We performed 17 experiments (15 by Alice and 2 by Bob).	**Distance of free fall (m)** This is the length of free fall determined with a ruler in each experiment.	**Average fall time (s)** This is an average duration of a free fall in every experiment, extracted from Column B.	**Calculated g (m/s^2)** We used the following formula to calculate the value of g from Column E: g=2*D/E^2.	**Gravitational acceleration (m/s^2)**	**Uncertainty (m/s^2)**
2	2.706625	21.39235417	1	0.8	0.397	10.1517	10.1	0.8
3	24.09897917	0.425020833	2	0.8	0.412	9.426		
4	24.524	0.261979167	3	0.8	0.366	11.9442		
5	24.78597917	9.673354167	4	0.8	0.399	10.0502		
6	34.45933333	0.5131875	5	0.8	0.422	8.9845		
7	34.97252083	0.349041667	6	0.8	0.397	10.1517		
8	35.3215625	0.137958333	7	0.8	0.412	9.426		
9	35.45952083	5.262833333	8	0.8	0.366	11.9442		
10	40.72235417	0.429520833	9	0.8	0.399	10.0502		
11	41.151875	0.344958333	10	0.8	0.422	8.9845		
12	41.49683333	0.177458333	11	0.8	0.397	10.1517		
13	41.67429167	0.155708333	12	0.8	0.412	9.426		
14	41.83	5.04725	13	0.8	0.366	11.9442		
15	46.87725	0.4225	14	0.8	0.399	10.0502		
16	47.29975	0.345791667	15	0.8	0.422	8.9845		
17	47.64554167	0.173270833	16	1.2	0.567	7.4653		
18	47.8188125	0.100625	17	1.2	0.489	10.0368		
19	47.9194375	4.6004375						
20	52.519875	0.100208333						
21	52.62008333	5.467166667						
22	58.08725	0.350520833						
23	58.43777083	0.158020833						
24	58.59579167	0.142041667						
25	58.73783333	4.2775						
26	63.01533333	0.193583333						
27	63.20891667	8.8634375						
28	72.07235417	0.2274375						
29	72.29979167	4.667729167						
30	76.96752083	0.2519375						
31	77.21945833	0						
32								

Figure 1 Example of an Excel spreadsheet, submitted by Team 'UBC' for their investigation of the gravitational acceleration g. Note: (1) File name 'UBC_Gravitational_acceleration.xls'; (2) Three separate sheets called 'Method 1', 'Method 2', 'Method 3'; (3) Clear description in the header of each column; (4) Mandatory columns G and H with a final value of g and uncertainty.