Physics 11/11H/12/AP

Calculating Percent Error and Percent Difference of Measurements and Experimental Results

(adapted from http://www.studyphysics.ca/newnotes/20/unit01_kinematicsdynamics/chp02_intro/lesson05.htm)

There are three common ways to calculate your error: absolute error, percentage difference, and percentage error.

Absolute Error is when you subtract the accepted value from your measured value...
Absolute Error = Measured Value - Accepted Value
A positive answer means you are over the accepted value.
A negative answer means you are under the accepted value

Percent Error is the most common way of measuring an error, and often the most easy to understand.

Equation:
Percent Error = (Absolute Error / Accepted Value) × 100%
= (Measured Value - Accepted Value / Accepted Value) × 100%

So, if you measured a pencil to be 102mm long, and an independent lab with high tech equipment measured it as 104mm, the percentage error is...
Percent Error = [(102mm - 104mm) / (104mm)]×100% = -2%

Which means you got a -2% error. *The negative sign means that you were under the accepted value.*

Percent Difference is useful if you have two measurements you've taken and you wish to see how different they are as a percentage. This is handy when you do not have an accepted value to compare to.

Equation:
Percent Difference
=[(absolute value of the difference in measurements)/(average of measurements)]×100%

Don't confuse this with percentage error. Here we have two measurements you've made, but no "accepted value." For example, you measure the length of a desk twice and get the numbers 1.15m and 1.13m.

Percentage Difference = (1.15-1.13) / [(1.15+1.13)/2]×100% = 1.75%
A percent difference of 1.75%.

Lab Reports (Physics 11)

When carrying out investigations, it is important that scientists keep records of their plans and results, and share their findings. In order to have their investigations repeated (replicated) and accepted by the scientific community, scientists generally share their work by publishing papers in which details of their design, materials, procedure, evidence, analysis, and evaluation are given.

Lab reports are prepared after an investigation is completed. To ensure that you can accurately describe the investigation, it is important to keep thorough and accurate records of your activities as you carry out the investigation.

Investigators use a similar format in their final reports or lab books, although the headings and order may vary. Your lab book or report should reflect the type of scientific inquiry that you used in the investigation and should be based on the following headings, as appropriate. (See **Figure 1** for a sample lab report.)

Title

At the beginning of your report, write the number and title of your investigation. In this course the title is usually given, but if you are designing your own investigation, create a title that suggests what the investigation is about. Include the date the investigation was conducted and the names of all lab partners (if you worked as a team).

Purpose

State the purpose of the investigation. Why are you doing this investigation?

Question

This is the question that you attempted to answer in the investigation. If it is appropriate to do so, state the question in terms of independent and dependent variables.

Hypothesis/Prediction

Based on your reasoning or on a concept that you have studied, formulate an explanation of what should happen (a hypothesis). From your hypothesis you may make a prediction, a statement of what you expect to observe, before carrying out the investigation. Depending on the nature of your investigation, you may or may not have a hypothesis or a prediction.

Design

This is a brief general overview (one to three sentences) of what was done. If your investigation involved independent, dependent, and controlled variables, list them. Identify any control or control group that was used in the investigation.

Materials

This is a detailed list of all materials used, including sizes and quantities where appropriate. Be sure to include safety equipment such as goggles, lab apron, latex gloves, and tongs, where needed. Draw a diagram to show any complicated setup of apparatus.

Procedure

Describe, in detailed, numbered, step-by-step format, the procedure you followed in carrying out your investigation. Include steps to clean up and dispose of waste.

Observations

This includes all qualitative and quantitative observations that you made. Be as precise as appropriate when describing quantitative observations, include any unexpected observations, and present your information in a form that is easily understood. If you have only a few observations, this could be a list; for controlled experiments and for many observations, a table will be more appropriate.

Analysis

Interpret your observations and present the evidence in the form of tables, graphs, or illustrations, each with a title. Include any calculations, the results of which can be shown in a table. Make statements about any patterns or trends you observed. Conclude the analysis with a statement based only on the evidence you have gathered, answering the question that initiated the investigation.

Evaluation

The evaluation is your judgment about the quality of evidence obtained and about the validity of the prediction and hypothesis (if present). This section can be divided into two parts:

- Did your observations provide reliable and valid evidence to enable you to answer the question? Are you confident enough in the evidence to use it to evaluate any prediction and/or hypothesis you made?
- Was the prediction you made before the investigation supported or falsified by the evidence? Based on your evaluation of the evidence or prediction, is the hypothesis supported or should it be rejected?

Investigation 2.5 – Acceleration of Different Masses

Conducted: February 2, 2001

By: Jenny Wilson and Sharif Khan

Purpose

The purpose of this investigation was to determine whether the mass of a falling object determines its acceleration while falling.

Question

What effect does the mass of a free-falling object have on the value of its acceleration?

Hypothesis/Prediction

It seems logical that an object with a greater mass will fall faster because it is pulled down to Earth at a greater rate. Our prediction was that the greater the mass, the greater the acceleration of the object when it falls.

Design

A ticker-tape timer of known frequency and a measuring tape were used to measure the time and distance for falling balls of similar size but different masses. The size of ball was the controlled variable, the ball's mass was the independent variable, and the acceleration of the ball was the dependent variable.

Materials

3 balls of similar size with different masses
ticker-tape timer
measuring tape

Procedure

1. A safe area to set up the apparatus was selected.
2. An observation table similar to **Table 1** was prepared.
3. The ticker-tape timer was clamped to a stand placed near the edge of a lab bench. The timer was set to 60 dots per second.
4. A piece of ticker tape slightly shorter than the distance the ball would fall was obtained so that the tape passed completely through the timer before the ball hit the floor.
5. The ticker tape was inserted through the timer and the end of the ticker tape was attached to the first ball with a small piece of masking tape.
6. The ball was kept steady, just below the timer, by holding the upper end of the piece of ticker tape. The tape was held directly above the timer so the tape would move freely through the timer.
7. The timer was started and the ball was immediately released.

Figure 1
Sample lab report

8. The timer was turned off when the tape passed completely through the timer.
9. The tape was checked to make sure that the dots were clear and that no dots were missing. If the tape wasn't usable, the procedure was repeated to get a good tape.
10. The number of dots were counted and the distance between the start and the last dot was measured.
11. Steps 4 to 10 were repeated twice more.
12. The observations were recorded in the observation table.
13. Steps 4 to 12 were repeated with two other balls of different masses.
14. All equipment was put away and all waste was recycled or disposed of.

Observations

The measurements we made when we carried out the procedure described above are recorded in **Table 1**.

Table 1 Time and Displacement

Ball	Ball mass (g)	Trial	Number of timer intervals	Total displacement (m [down])
1	37	1	25	0.860
		2	24	0.792
		3	26	0.923
2	55	1	25	0.855
		2	26	0.925
		3	25	0.860
3	89	1	25	0.858
		2	26	0.926
		3	26	0.924

Analysis

Using our observations we calculated the time of each fall, and we could then calculate the acceleration. The calculations below show how we figured out the time and how we calculated the acceleration of each fall and then the average acceleration. The results of all calculations are presented in **Table 2**.

Total Time

The total time for the 37-g ball, Trial 1, is calculated as follows:

$$\Delta t = 25 \text{ intervals} \times \frac{1 \text{ s}}{60 \text{ intervals}}$$

$$\Delta t = 0.417 \text{ s}$$

Acceleration

Assuming an initial velocity of 0 m/s and down to be positive, the acceleration for the 37-g ball (Trial 1) is calculated as follows:

$$\Delta\vec{d} = \frac{1}{2}\vec{g}(\Delta t)^2$$

Since $\vec{v}_i = 0$, then $\Delta\vec{d} = \frac{1}{2}\vec{a}_g(\Delta t)^2$, or $\vec{g} = \frac{2\Delta\vec{d}}{(\Delta t)^2}$

$$\vec{g} = \frac{2\Delta\vec{d}}{(\Delta t)^2}$$

$$= \frac{2(+0.860\text{ m})}{(0.417\text{ s})^2}$$

$$\vec{g} = +9.91\text{ m/s}^2$$

The acceleration for the 37-g ball in Trial 1 was 9.91 m/s^2 [down].

Average Acceleration

The average acceleration for all three trials of the 37-g ball is calculated as follows:

$$\vec{a}_{av} = \frac{(9.91 + 9.90 + 9.83)\text{ m/s}^2\text{ [down]}}{3}$$

$$\vec{a}_{av} = 9.88\text{ m/s}^2\text{ [down]}$$

The average acceleration for the 37-g ball is 9.88 m/s^2 [down].

According to the evidence in **Table 2**, the mass of the ball apparently has no significant effect on the value of the acceleration due to gravity.

Table 2 Calculated Accelerations

Ball mass (g)	Trial	Number of timer intervals	Total time (s)	Total displacement (m [down])	Acceleration (m/s^2 [down])	Average acceleration (m/s^2 [down])
37	1	25	0.417	0.860	9.91	9.88
	2	24	0.400	0.792	9.90	
	3	26	0.433	0.923	9.83	
55	1	25	0.417	0.855	9.85	9.88
	2	26	0.433	0.925	9.87	
	3	25	0.417	0.860	9.91	
89	1	25	0.417	0.858	9.88	9.86
	2	26	0.433	0.926	9.86	
	3	26	0.433	0.924	9.84	

Evaluation

The design of the investigation is adequate because the question was clearly answered and there are no obvious flaws. The materials, skills, and procedure were all satisfactory because they produced sufficient and reliable evidence. We consider the evidence reliable because all of the trials produced results that were very close.

The accepted value for the acceleration of gravity is 9.81 m/s^2. We calculated the percentage error as follows:

$$\%\ \text{error} = \frac{|\text{experimental} - \text{accepted}|}{\text{accepted}} \times 100\%$$

$$= \frac{|(9.88 - 9.81)\ \text{m/s}^2|}{9.81\ \text{m/s}^2} \times 100\%$$

$$\%\ \text{error} = 0.7\%$$

The percentage error between the experimental value of acceleration due to gravity for the 37-g ball and the accepted value is 0.7%. The percentage error for the 55-g ball was also 0.7% and for the 89-g ball, 0.5%. These low percentage errors indicate that the mass of the ball has no significant effect on the value of its acceleration due to gravity.

Some possible sources of error and uncertainty include the dots made by the timer. We assume that the timer frequency (60 dots per second) is constant. The dot marked as dot 1 is not really the precise starting point of the fall, because the tape must move enough to provide a clear dot from which to measure. Measurement uncertainties and some friction are also present.

The prediction is not supported because of the very similar values for the acceleration due to gravity for balls with very different masses. The small differences obtained for different balls can easily be accounted for by the sources of error and uncertainty.

The hypothesis that a greater mass with its greater weight is pulled down to Earth at a greater rate is clearly not supported by the evidence obtained in this investigation.