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Measuring the acceleration of gravity

Aim:

The aim of this experiment is to calculate the acceleration of gravity via repeated measurements, using statistics.

Background information:

Gravity is the force that attracts a body towards the centre of the earth, or towards any other physical body having mass. The acceleration of gravity, also referred to as free fall, is denoted by $g = 9.81Nkg^{-1}$ and is a type of uniformly accelerated motion, which means that the relationship between velocity versus time creates a non-horizontal straight line when graphed. One of the formulas relating displacement, acceleration and time is $s = ut * \frac{1}{2}at^2$. Air resistance, which is the force directed opposite to the body's velocity, will not be considered in this investigation as the distance travelled and the velocities reached are minimal and so its influence is negligible.

Instruments and materials:

Instruments:

- Meter —> sensitivity ± 0.1 cm; range 3 m
- Timer —> sensitivity ± 0.01 seconds; range 100 hours

Materials:

- Electromagnet (release mechanism)
- Foam
- 2 laser sensors
- Metal sphere

Safety issues:

- Avoid placing any part of the body near or along the trajectory the metal sphere will follow in order to not hurt yourself in any way

Procedure:

- Firstly, vertically align the laser sensors at a distance of approximately 1 meter. You can help yourself with a chord to check, at least for the moment, if the sensors are more or less in line with the electromagnet on top.
- Connect the GDC calculator to the two sensors and check if they are both recording correctly when they are obstructed or not.
- Position the electromagnet as near and precisely as possible to the uppermost sensor in order to obtain an initial velocity equal to zero. To quicken this action, it is easier to magnetise the metal sphere below the electromagnet, approach it to the sensor and fix it in place just before it signs that the sensor is obstructed.
- Place a piece of foam in the landing zone of the sphere to cushion the impact.
- Test if both sensors and the electromagnet are alined by letting the metal sphere fall. If both sensors registered the time in which the object passed through correctly, the system is correctly set up.

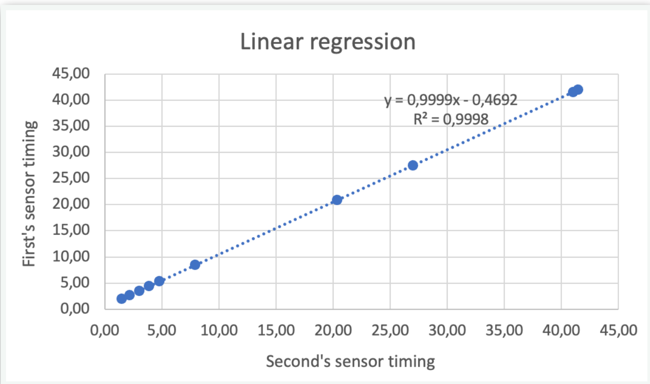
- Measure the vertical distance between the two laser sensors with a meter at the nearest mm. It will function in the formula as the distance travelled by the sphere, ***s***.
- Reattach the sphere to the electromagnet and start recording the activity of the sensors on the GDC calculator. Let the ball fall down and record the data reported. Pay attention to the bounce that can occur due to the foam's elasticity, which may reach a sensor again and be registered by the calculator.
- Repeat the previous step at least 10 times in order to have an appropriate amount of data recorded.
- Calculate *g* for all the values recorded by rearranging the formula $s = ut * \frac{1}{2}at^2$ for *g*, which will give $g = \frac{2h}{t^2}$, as the initial velocity is zero.

Results:

First measurement	Second measurement	Second meas. - First meas.	Height measured
(s ; ± 0.01)	(s ; ± 0.01)	(s ; ± 0.01)	(m ; ± 0.001)
3,04	3,51	0,47	1.118
41,49	41,96	0,47	1.118
1,51	1,98	0,47	1.118
41,05	41,53	0,48	1.118
4,80	5,27	0,47	1.118
27,00	27,47	0,47	1.118
7,96	8,43	0,47	1.118
3,91	4,38	0,47	1.118
2,20	2,67	0,47	1.118
20,36	20,83	0,47	1.118

Analysis:

Calculation ($2h / t^2$)	Value calculated for *g*
(NKg^{-1} ; ± 0.4)	(NKg^{-1} ; ± 0.4)
(2*1,118) / 0,47	10,12
(2*1,118) / 0,47	10,12
(2*1,118) / 0,47	10,12
(2*1,118) / 0,48	9,70
(2*1,118) / 0,47	10,12
(2*1,118) / 0,47	10,12
(2*1,118) / 0,47	10,12
(2*1,118) / 0,47	10,12
(2*1,118) / 0,47	10,12
(2*1,118) / 0,47	10,12



- The R^2 value is of 0.9998, and it represents the degree to which the different measurements are related, so it is almost exactly directly proportional. This means that the measurements where symmetric between each other.
- The value given for *g* according to the calculations is on average 10,08 $NKg^{-1} \pm 0.4$

Conclusion:

In conclusion, the value calculated for g = 10,08 $NKg^{-1} \pm 0.4$ is very close to the real value of g = 9,81 NKg^{-1}, and is in the range given by the uncertainty of the measurement. In addition from the R^2 value of 0,9998 reported on regards of the time taken for the metal ball to fall the exact same distance for 10 times, it can be confirmed that the acceleration of free fall was constant in all cases. Air resistance was neglected in this particular case, but it could explain why the results for *g* were slightly higher than the real value. Even though, with more accurate instruments and a bigger height it is possible to obtain a more precise value for the acceleration of gravity.

Bibliography:

- Physics for the IB diploma, sixth edition
- https://languages.oup.com/google-dictionary-en/