Determination of the acceleration due to gravity (g) by free fall

In this experiment we will determine the acceleration of gravity *g* by measuring the time of fight for balls dropped from a known height. I also verify that the acceleration due to gravity does not depend on the mass of the ball.

The falling body in this experiment will be a metal ball, which falls freely from the catch at the top of the apparatus to the pad below it. The apparatus is designed to record the time of flight for the ball. When the ball is in the catch, it forms part of an electrical circuit. When the ball is released, the circuit breaks and the timer start. The pad acts as a switch, such that when the ball hits it the timer is stopped.

Knowledge:

Any object, which is moving, and being acted upon only be the force of gravity is said to be "in a state of free fall." This definition of free fall leads to two important characteristics about a free-falling object:

- Free-falling objects do not encounter air resistance.
- In the absence of air resistance, all objects in free-fall near the surface of the Earth will experience the same uniform acceleration

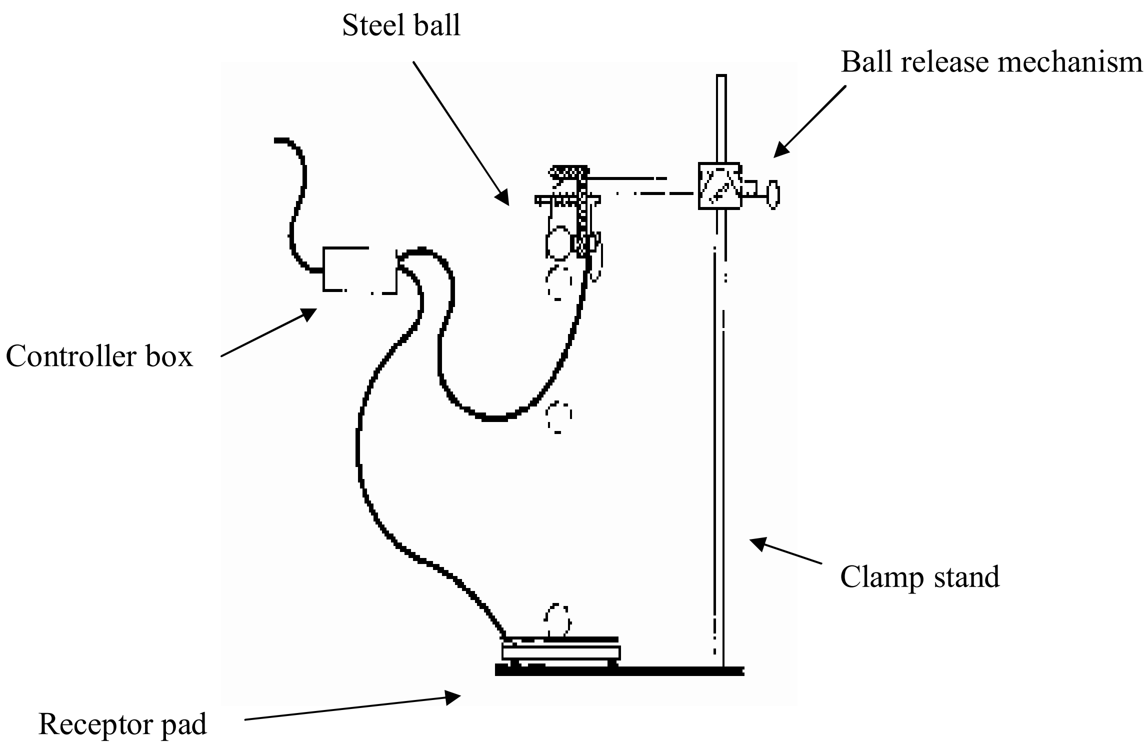
Gravity:

The force of gravity is the force at which the earth, moon, or other massively large object attracts another object towards itself. By definition, this is the weight of the object. All objects upon earth experience a force of gravity, which is, directed "downward" towards the centre of the earth.

Acceleration:

Acceleration is the rate of change of velocity. On Earth, one force we can always count on is the ever present force of gravity pulling down on any object that has mass. If gravity is the only force acting on an object, then we find the object will accelerate at a rate of $9.81 m/s^2$ down toward the centre of the Earth (this is often rounded to $10 m/s^2$).

Diagram:



Equipment:

- A free fall adaptor (ball release mechanism)
- Receptor pad
- Clamp stand
- Electronic timing device
- Metric stick
- A steel ball

Method:

1. Clamp the Ball Release Mechanism in the vertical position as illustrated in my diagram, at the desired height.

2. Put the Ball Receptor plate on the table, positioning it beneath the Ball Release Mechanism.

3. Make several test drops to insure that the ball will strike the Ball Receptor Plate. To make a test drop, insert a steel ball into the Release Mechanism so that it is positioned on the contact screw and aligned with the hole in the release plate. Close the Release Mechanism by pushing on the dowel pin, which clamps the release plate on the ball, and then lightly tighten the thumbscrew to lock the release plate in place. Release the ball by unscrewing the thumbscrew.

4. The height h is measured from the bottom of the ball (held in the Release mechanism) to the top surface of the target pad when the pad is pressed against the metal base of the Receptor Plate.

5. Read the time on the digital display of the timer. This is the time it took for the ball to fall the distance.

6. Measure the time of fall from 8 different heights. Measure the distance as accurately as possible and record the distance and time in a Table. Repeat the measurement least three times and record these values. Calculate the average of your measured times.

Results:

The table below shows the obtained results, with the time period squared.

Height / m	t_1 (s)	t_2 (s)	t_3 (s)	t_a (s) Average	Time Period t^2 / s^2
0.3	0.2273	0.2221	0.2226	0.2226	0.0495
0.4	0.2614	0.2615	0.2615	0.2614	0.0683
0.5	0.2979	0.2979	0.2972	0.2975	0.0885
0.6	0.3307	0.3311	0.3316	0.3311	0.1096
0.7	0.3601	0.3602	0.3617	0.3605	0.1299
0.8	0.3867	0.3976	0.3895	0.3897	0.1518
0.9	0.4144	0.4149	0.4147	0.4146	0.1718
1.0	0.4375	0.4384	0.4374	0.4377	0.9195

I acquired the results for 8 different heights of the free fall experiment. I took three readings of each value and took an average for each the times. I then divided by 3 to get the average reading for the time. This should influence the accuracy of my results.

g is the acceleration due to gravity so the calculation of g is be acquired by measuring an object in free-fall and then measure its time and height through the following equation of Motion:

$$S = ut + ½ at^2$$

Where:

s = height / displacement m (meters)

u = initial velocity ms^{-1}

v = final velocity ms^{-1}

a = acceleration due to gravity ms^{-2}

t = time s (seconds)

Initial velocity of the steel ball is 0 (ms^{-1}) so,

$S = 0 + ½ gt^2$

$S = ½ gt^2$

Therefore

$$g = \frac{2h}{t^2}$$

Where

g = acceleration due to gravity (ms^{-2})

h = distance the ball falls through (m)

t = time taken to fall (seconds)

This equation shows that *g* can be easily determined by measuring free fall time's *t* as a function of height *h*. Therefore, we can determine the acceleration of gravity by simply dropping the steel ball from a known height and measuring the time it takes to hit the ground.

I rearranged this formula for the value of g, after plotting a graph to calculate the gradient, with t^2 vs. h as the axis.

To find "g" I had to find the gradient of the line on the graph.

Using the graphs gradient

GRADIENT = $\frac{1}{2} gt^2$

$$\frac{2 \times 0.7}{0.14} = 10.00 \text{ ms}^{-2}$$

Therefore **g = 10.00 $\mathbf{ms^{-2}}$**

Interpretations of results:

My graph shows that height is directly proportional to t^2, i.e. if the height was doubled, the period would be doubled. As they are directly proportional to each other, the graph should show a straight line through the origin.

I had to find the gradient of the line on the graph. I drew a line of best fit, which goes through all the points on the graph, which means there are no odd results that may affect the value of g. There is a positive correlation, which shows that the experiment was carried out fairly accurately each time the experiment was done and a reading was taken.

Conclusion:

The obtained value of the acceleration due to gravity has been calculated to $10.00ms^{-2}$. This is not very accurate compared to the accepted value of $9.81ms^{-2}$ as it was off by $0.19ms^{-2}$. I think that If I were to rectify the recognised causes of error I would easily get $g = 9.81ms^{-2}$. If I were to use more accurate equipment I would probably be able to show that the gravitational field strength of the earth is 9.81 ms^{-2}.

Evaluation:

The following factors were considered when providing an accurate experiment:

- The mass of the steel ball will be a constant throughout the experiment
- The value of gravitational field strength will certainly remain constant, helping me to provide a fair test.
- The intervals between the heights will increase by 100 mm each time. This will help me to identify a clear pattern in my results.
- If any anomalous results are identified, readings will be repeated. This will ensure that all readings are sufficiently accurate.
- There will bee no obstructions to the fall of the steel ball and therefore the velocity is not affected.

As my results came to g = 10.00 ms^{-2}, which is only off 0.19 ms^{-2}, I am sure that If I were to correct the recognised causes of error I would easily get g = 9.81 N/kg.

Errors / Limitations:

The results in our experiment certainly contained errors. Some errors arise because of mistakes. Examples of this kind of error are recording the wrong number, reading an instrument incorrectly. Errors also occurred because of the limit of precision of equipment involved.

Since there are only two variables (h and t) measured in this experiment, all of the error in the determination of g comes from the error in the measurements of h and t. The errors in the measurements of h and t depend on the equipment used. A meter rule was used for measuring h. Similarly; the error in the measurement of t depends on the Receptor pad used. A Receptor pad is accurate to 0.1 sec was used in the experiment, and to minimize the error in the measurement of t the average time period was calculated, thus error in the measurement of t will be about 0.02 sec. Also, the error in the measurement of t was doubled because of square of t in the formula so it was It twice as more important to reduce the fractional error in the measurement of t (time) than to reduce the fractional error in the measurement of h (height), especially as this information was put into the graph to calculate the gradient. Also human error can be a major factor in distorting my results in this experiment. Carelessness in the experiment, for example if I had misread the scale on the meter rule it can cause a major error. Repeating my own work and measuring and comparing the results with others students is an effective way to detect human errors.

The calculation of the percentage error is calculated as follows:

Δt^2 = 0.14 ± 0.02s Δh =0.7 ± 0.001m

%g = [0.001 / 0.7 x 100] + [0.02 / 0.14 x 100] = 0.1% + 14.00% = 14.1%

g = 10.00 ± 14.1% ms^{-2}

The percentage error value of 14.1%percent is unsatisfactory. This high percentage error indicates experimental errors.

The percentage difference for the experiment can be calculated as:

$$\% \text{ Difference} = \frac{\text{The accepted value - The value measured}}{\text{The accepted value}} \times 100$$

$$\% \text{ Difference} = \frac{9.81-10.00}{9.81} \times 100 = \pm \mathbf{1.93\%}$$

Improvements:

In order to improve on the experimental procedures, I could use an apparatus with a higher degree of accuracy such as a meter rule with the marks of millimetres standing out more so that the measurements will be more accurate. In addition, because of the fact that the error in the measurement of t (time) was doubled because it was squared in the formula and it would make severe errors in the value of g. For example, if t were too big it would make t^2 much bigger than it really is, and hence would decrease the value of g. I can improve on this by implementing better techniques and equipment, however in turn these are very difficult to eliminate and the experiment would need to be repeated. Given more time I would have repeated the whole experiment and maybe taken 5 or more readings of each height to make my results more reliable. I also could have used a pendulum experiment to measure g (gravity) although this experiment is more difficult to carry out and therefore more likely to cause experimental errors. Measuring the time taken for oscillations to occur from the pendulum will do this.

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