Exploring the pendulum.

Purpose.
In this experiment I want to explore how the pendulum moves and what factors affect the movement.
More precisely, my aim is to determine whether the size of the bob affects the speed of the movement. In here I have to say the question to be tested, but I don't need to use the exact words or magnitudes.

A pendulum is made of three parts: the hinge, the string and the bob. Now I'm DESCRIBING the situation or problem, that is, I give the information needed to understand the experiment. This is what we call THE BACKGROUND, and it is best to give it before you explain your purpose (that is, before you say what makes you think that the two things mentioned above might be related. The string is a piece of wire or thread (truth be told, it can also be a solid bar or a tube) that is tied in one end to the bob and in the other end to the hinge. The hinge is an articulation that links the thread to the ceiling or some other steady non-moving place.
The bob is an object, usually dense, that hangs from the thread and will move backwards and forward when the pendulum is set in motion.

A pendulum has a movement called "oscillatory movement", in which the bob moves inside a circumference but only in the lower part of it (that is, a semicircumference).

The time it takes for the bob to swing forward and backwards once until it reaches the original position and speed is called the period (T). That process of swinging forward and backwards is called an oscillation. The length of the string will be referred to as "the length". If I want to define any terms so that I can use them in the rest of the text, I do it here.
The size of the bob might affect the speed of the movement because now, since I said earlier that the size migh affect the speed, I have to explain what makes me think so the oscillatory movement is actually driven by the weight, that is, when the string is not vertical, a component of the weight is not counteracted by the tension of the string and pushes the bob back to the vertical position. Since the weight is proportional to the mass of the bob, the more mass the more weight and therefore the force driving the movement will be stronger, and the movement will be faster.

Hypothesis.
The key to the Hypothesis is: by the time you write your hypothesis you already must have decided your two main variables.
The first form of the hypothesis is “an attempt to state how things work”. Now I do have to use the exact names of the variables.
The **weight of the bob** affects the **speed of the movement** (just that would be only a 2, but now I have to explain, that is, say the cause and the consequences) because the weight is the force that drives the movement, and if that force is stronger, the movement will be faster.
Now the if-then form of the hypothesis. Remember that if you can only do one form, do this one.
<u>If</u> the **mass of the bob** is increased, <u>then</u> the **period of the oscillation** will decrease, and now the explanation because the more mass the bob has the bigger the weight and since the weight is the force that moves the bob, the bigger the acceleration.
Now you know this is not true, but if you do a valid reasoning and it's wrong, I won't count that it's wrong.

Variables.
The key to the variables is to use a quantitative continuous variable, it will spare you a lot of problems. If your variable is qualitative, try to “change it” into a quantitative one.
Independent: the **mass of the bob** this is just a 2, now I have to say how I will control it and how exactly I will measure it. I will control that by using four different bobs, numbered 1 to 4 with the following masses. Don't forget to say the values it is going to take.
1. 50g
2. 67.6g

3. 100g
4. 200g
The mass will be measured using a scale. If I need to measure in some particular way, I say it in detail here too.

Dependent: the **period** I have already defined what the period is, so that's all. Since the period is time I will measure time using a chronometer. Maybe here I would say something more, like "starting the chronometer when releasing the bob and stopping it when it reaches the highest point after 10 oscillations". The precise way to measure the period will be by measuring how much time it takes for the pendulum to complete 10 swings. That way I minimize the error and increase the accuracy of my reading. In order to get an accurate average, I will repeat every experiment six times. What I did there is I explained exactly how the data will be collected. That is absolutely essential.

Controlled.
Any variable you think may affect the dependent variable and you want them to stay the same every time.
The length. I will control that by measuring it with a ruler or a measuring tape.
The initial angle of the swing. I will control that by measuring the angle with a protractor located at the hinge. I use a table as a reference, therefore I don't measure every time.
The material of the string. It could have different air resistance depending on if it's made of nylon, cotton or wire. I'll use always cotton.
Two or three should be enough. If there is something you think might affect the experiment but you can't control it, say it here if you have time.
To achieve the highest mark you also have to say why you control it, that is, how could that variable affect the result if it was not controlled.
The temperature or the humidity in the air may make the string a bit shorter or longer, but I can't control that for now.

Materials.
The key to the materials list is to leave a space after. You always forget something and it will come back to you when you are writing the method.

Pendulum.
- Bobs
- Hinge (a magnet)
- String (cotton thread)

Hook (used to make the changing of the bobs easier and faster)
Ruler
Scissors
Chronometer
Scale
Protractor

Method
The key to the method is to explain everything like it was for dumb people. If you have to repeat stuff you said earlier in another section, do it.
Remember the guy who was planting beans and forgot so say "put the bean in the soil".
It helps to make a drawing, that way you visualise it and it's less likely to forget something.

1. Cut a piece of string of about two meters long with the scissors.
2. Tie one end to the magnet with a knot.
3. Tie the other end to the hook.
4. Attach the magnet to one of the iron parts of the ceiling or lamp.
5. Put bob #1 in the hook.
6. Pull aside the bob until you reach the reference point and keep it there.

7. Measure the angle using the protractor.
8. Release the pendulum and, using the chronometer measure the time it takes to undergo ten oscillations. Do this 6 times.
9. Repeat steps 5,6 and 8 with the rest of the bobs.
10. Weigh the bobs using the scale.
11. Write down all results.

Keep an eye on the order of the steps, you can't measure the string before the pendulum has been attached to the ceiling/lamp.

I will be checking if the method is logical (good order and makes sense), complete (no steps are missing) and safe (appropriate safety precautions).

Safety

The key to safety: everything is super dangerous.

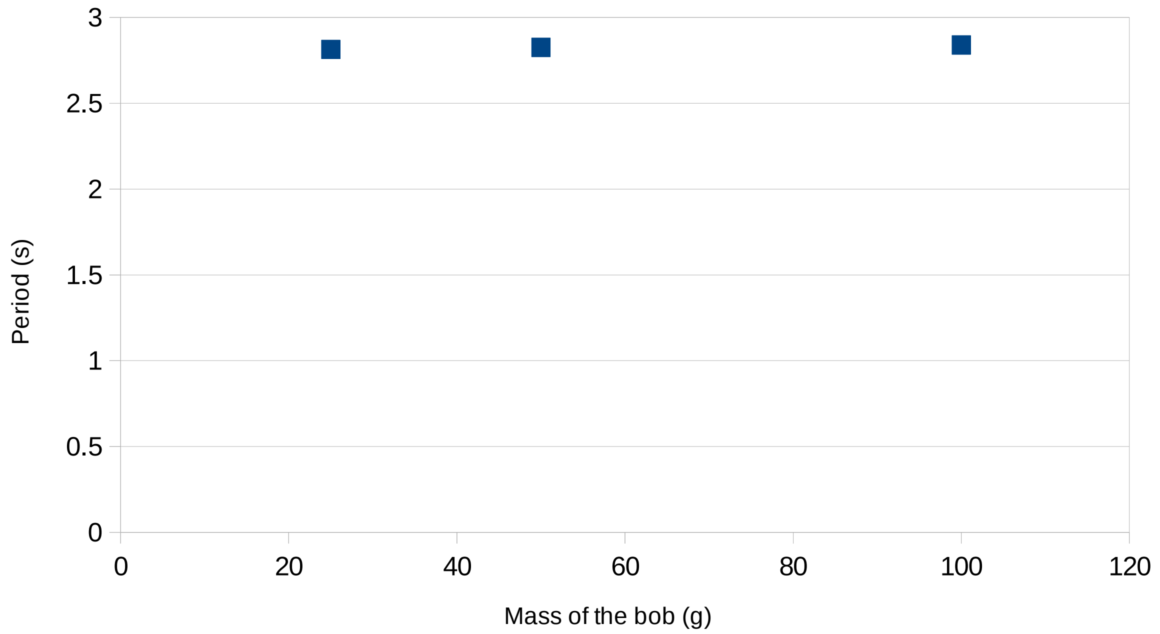
Wear lab coat and safety goggles at all times. Don't try to cut the string with your hands, use the scissors (and handle them with care).

Results

This table is called the main table. As you can see, the mass of the bob (independent variable) is in the left side and progressing down (that is, as I read down the table, the variable increases). All trials are to the right and at the end I do some calculations. The Rsd% is nothing you can do right now, so don't bother.

	Time for ten oscillations (s)								
Mass of the bob	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	average	period(s)	Rsd%
25g	28.13	28.06	28.2	28.06	28.24	28.12	28.135	2.8135	0.26
50g	28.2	28.25	28.26	28.24	28.28	28.24	28.245	2.8245	0.09
100g	28.36	28.43	28.41	28.39	28.33	28.42	28.39	2.839	0.1355

Remember to check that this table is present and has the independent variable progressing down. I will also check that the units are present.



This chart is the main chart. Note that I only use the average for each experiment. I don't represent the result for each trial unless there is something interesting to say about that. I also put the independent variable in the x axis and the dependent one in the y axis. Nothe that both axis start at 0.

If the independent variable is a qualitative variable, the order is not relevant, so you can put them in the order you wish, but the labels must be present.

The initial angle is 13º
The length is 2m

Analysis

The data shows that the period suffers very little or no change when we change the mass of the bob. There is a very slight increasing trend, but the difference between the shortest reading and the longest is smaller than 2% of the average, therefore it is not considered to actually change, especially since the mass of the bob is increased by a factor of 4.

In here I have to say what I observe about the data, not actually explaining why, just noticing.

Now, this part that comes here is a bit odd for you, but I have to say it because I noticed it.
The accuracy is very good, and because of that and even if the values are very close together, the average for the 100g is clearly out of the interval found for the 50g, and the average for the 50g is out of the interval for 25g. This indicates that, although the change is small, it is not due to the inaccuracy of the readings but a consistent difference in the period.

Discussion

The accuracy of the method is very good, as shown by the short intervals of data (0.18s for the 25g bob, 0.08 for the 50g bob and 0.1 for the 100g bob), but it is subjected to the fact that the timer is started and stopped by hand. An improvement to the method would be to use an automated system that would release the bob and start the time exactly at the same time and also stop the time after the tenth oscillation exactly at the point where the bob is at its maximum height. Here I am suggesting solutions for a specific flaw that I found.
The very short intervals and the good precision is partly due to the fact that a pendulum is a very simple physical system and also to the technique of measuring a good number of oscillations.
The consistency of the period for different masses clearly indicates that the period does not change when using a bob with more mass. This is in accordance with the pendulum formulas, which state that the period of a pendulum only depends on its length and on the value of gravity.
The small difference observed between the different bobs was most likely due to the string's elasticity: when using a heavier bob, the string stretched slightly, and therefore the length of the pendulum was increased. As mentioned above, the length of the pendulum does affect the period.
Since I noticed this small thing in the analysis I have to give an explanation here.
An upgrade to the method would be using a string that is more difficult to elongate (that is, that has a higher elasticity constant), that way the elongation due to the increased mass would be minimized.
Finally, there was a change in the swing amplitude as the trials progressed. The angle at the tenth oscillation was significatively smaller than the initial angle. This is due to the air resistance, and in order to solve this problem, the experiment should be done in vacuum.

In this section I talked about the **accuracy of the method and its validity**, that is, if we were actually finding out what we wanted or not. I have to address flaws in the method and also suggest solutions.
One of the rules is the following: if you mentioned it in the analysis then you have to give an explanation here. That is why I adress the fact that there is basically no change in period, but I also mention the fact that there is a small but consistent change and it is due to the elongation.

Remember that in the discussion you do not have to say what things you did wrong by mistake, you have to look for flaws in the method that make the results or the conclusion invalid.

Conclusion

In this section I have to say whether the hypothesis is correct or wrong, but that is a bit of a trick question: there might be some of it that is right and some of it that is wrong. It is better if you think it like this: in what way is the hypothesis right and why, and in what way is the hypothesis wrong and why?

The hypothesis was “If the mass of the bob is increased, then the period of the oscillation will decrease”. The data indicates that this is not true. When the mass of the bob is increased, the period of the oscillation does not seem to be altered or, if it is, then it is due to the elongation of the string caused by the increased weight.
From a theoretical point of view, there should be no change whatsoever in the period, and in case a change is observed, the period will not decrease but slightly increase.
The reasoning behind this is simple: even though the weight is the force that drives the movement, if the bob has more mass then the weight will also have to accelerate a bigger mass.
The acceleration is the ratio between the force and the mass, and in this case, the force is also proportional to the mass, therefore when the latter is increased, both sides of the fraction increase in the same way and the result remains constant.