Investigating Newton's second law

Activity W20E: Experiment

Newton's second law of motion is the key to understanding how and why objects move in the way they do. Although you will have come across the equation F=ma when studying for GCSE you may not have seen it experimentally verified.

What you need

- ✓ Dynamics trolley
- ✓ Trolley card with two 5cm segments
- ✓ Dynamics track with plumb line to measure angles
- ✓ Lab jacks
- ✓ Lightgate and interface able to calculate accelerations
- ✓ Pulley, ten 100g masses and string
- ✓ Computer running the spreadsheet *'Investigating acceleration.xls'*

How it works

Using a lightgate and a piece of card it is possible to measure the speed of a trolley: the card breaks the beam of the lightgate and a timer measures how long it takes the card to pass through. Knowing the length of the card we can calculate the average speed. If the card has two segments that pass through the light beam then we can measure two speeds and if the timer can also measure how much time passed between the two readings then we can calculate the trolley's acceleration.

Open the spreadsheet *'Investigating Newton's second law.xls'* and select sheet *'exp 1'*. In these spreadsheets values are suggested but you can choose your own. Values wildly different from these may cause problems with the lightgates and/ or safety!

Experiment 1

For the first two experiments you will accelerate the trolley down a slope. Use the lab jacks to produce a slope of a few degrees. Measure the angle and type it into the spreadsheet.

Place the lightgate near the bottom of the ramp but ensure that the trolley will have enough room to clear the lightgate before reaching the bottom. Connect the lightgate to the interface and set it to measure acceleration using 1 lightgate. Input the length of the segments. Ensure that both the segments will break the light beam as the trolley passes through the lightgate.

Release the trolley from a point near the top of the ramp. Remember this point. Once the interface has calculated the acceleration, add it to the spreadsheet.

Move the lightgate up the ramp. Before you release the trolley from the same point as before, predict what will happen to the value of the acceleration.

Release the trolley, measure the acceleration and input the values into the spreadsheet. Repeat until you have measured the acceleration for at least 5 different lightgate positions.

Now select the sheet *'graph 1'*. Your results are plotted alongside the theoretical values calculated from the angle of the slope.

Can you explain how your results vary? Which were closest to the theoretical values and why?

Experiment 2

Place the lightgate in the position that gave the most accurate reading in experiment 1. Vary the angle of the slope, always releasing the trolley from the same position. Use *'exp 2'* and *'graph 2'* to analyse your results.

The formula for calculating the theoretical results is on the right side of the spreadsheet in column Q. Before having a look, what formula do you think is used? If you got it wrong can you see why? Have you chosen angles that allow you to see the difference?

Changing the set up

In the next two experiments you will accelerate the trolley along a horizontal track by hanging weights connected to the trolley by string over a pulley at the end of the track. You may need to vary the position of the lightgate and the height of the track to ensure that the trolley is still being accelerated while it passes through the lightgate.

The mass hanging over the edge causes the trolley to accelerate. The weight of these masses is the accelerating force. **The mass being accelerated is the mass of the trolley plus the masses hanging over the edge.**

Experiment 3

Hang about ten 100g masses over the edge. Release the trolley and measure the acceleration. Remove one of the masses and transfer it to the trolley so that the total mass being accelerated remains constant. Release the trolley again. Repeat until only 100g remains on the hanger. Use *'exp 3'* and *'graph 3'* to think about your results.

Experiment 4

Hang about 400g over the edge. Starting with no extra mass on the trolley release it and measure the acceleration. Add 100g to the trolley but keep the acceleration mass the same. Repeat the experiment until about 1kg has been added to the trolley. Type your results into *'exp 4'*.

Two graphs are provided to help you think about your results.

You have seen that

When an object experiences a constant resultant force it moves with a constant acceleration
The magnitude of the acceleration is proportional to the applied force
The magnitude of the acceleration is inversely proportional to the mass of the object.

Files provided

Excel file *Investigating Newton's second law.xls*

Getting it to work

This experiment was developed using the Pasco tracks and trolleys and the djb microtech lightgate interface.

Alternative approaches

nil

Social and Human context

Newton's second law is the key to our understanding of motion yet was put forward well before precision measurements like these were available

Safety

Tracks need to be secured at all angles and trolleys rescued from crashing into the end of the track. Leads for lightgates need to be routed carefully to allow the track elevation and angle to change and to allow the lightgate to be moved along the track.