The quantitative relationship between force, mass and acceleration

Introduction

Newton's Second Law of Motion is concerned with the effect that unbalanced forces have on motion.

An unbalanced force acting on an object causes it to accelerate. There are two points to note about the acceleration of an object when an unbalanced force acts on it:

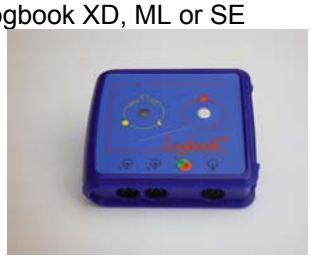
- The bigger the unbalanced force acting on the object the bigger the acceleration of the object.
- The more mass the object has the more inclined it is to resist any change in its motion. For example, if you apply the same unbalanced force to a mass of 1000 kg and a mass of 1 kg, the acceleration (change in motion) of the 1000 kg mass will be much less than that of the 1 kg mass.

Newton's Second Law provides a relationship between the unbalanced force on the object, the mass of the object and the acceleration that is produced: unbalanced force = mass x acceleration or F = ma.

The unbalanced force F is measured in newtons (N), the mass m is measured in kilograms (kg) and acceleration a is measured in metres per second per second (m/s^2).

Apparatus

Datadisc Au
Force sensor
Distance sensor
Logbook XD, ML or SE



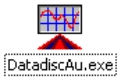
A serial lead or USB-serial lead

Two hooks
Some masses (450g)
A sheet of paper (210*297mm and $160g/m^2$)
A spring
A retort stand

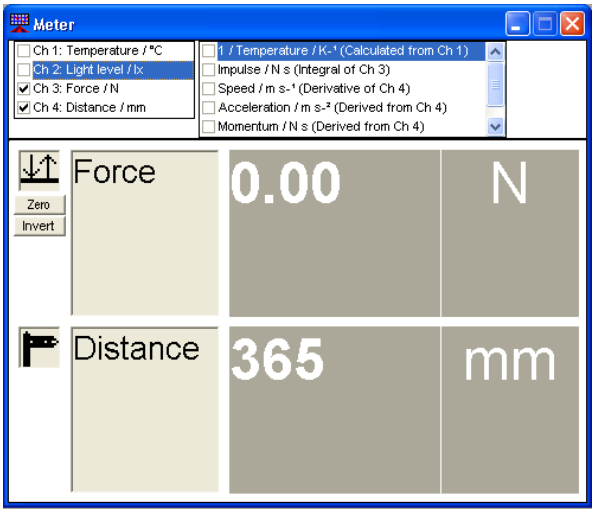
Duration

1 hour

Method

1. Plug the Logbook into the PC using a serial lead or USB-serial lead.
2. Plug the Force sensor into port 1 or 3 according to the Logbook you are using. 1/3
3. Plug the Distance sensor into port 2 or 4. 2/4
4. Place the sheet of paper under the masses for the Distance sensor to detect it.
5. Screw a hook on to each ends of the Force sensor.
6. Start Datadisc Au. 

7. To set up the Force sensor:
    a. Click on “Measure” and then click on “Meter”. A menu will appear asking you to choose channels to meter.
    b. Click on “OK”. You will see the force and distance readings. Remove the readings you don’t need (Temperature, Light level) if you are using Logbook SE or ML.
    c. Point the Force sensor towards the floor and screw or unscrew it as far as about 4.5N. Click on “Invert”.
    d. Attach it to the retort stand. Trim the sheet of paper if it touches the retort stand.
    e. Attach the spring to the hook and the masses to the spring.
    f. Place the Distance sensor standing up on the table, under the masses.
    g. When the masses are stationary, the force reading must be zero. The distance reading must be about 350mm because the Distance sensor is more accurate between 200 and 500mm.



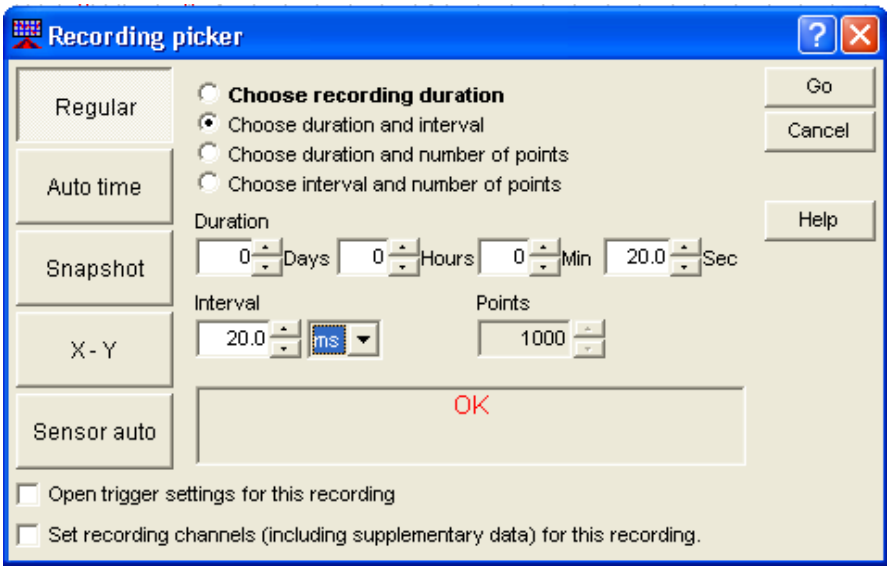

h. Close the Meter window.

8. Click on “Measure”.

9. Click on “Record…”. Then the “Recording picker” dialogue will open.

10. Select “Regular” and then “Choose duration and interval”.

11. Choose Duration (20s) and Interval (20ms). This is the smallest interval you can choose with the distance sensor.



12. Click on “Go”. The Recording window will open.

13. Choose the channels you want to measure on the toolbar if you are using Logbook ML or SE.

14. To make the recording:

a. Click on the green recording icon on the toolbar: this starts the recording.

b. Start the experiment: pull on the masses until they are 250mm far from the distance sensor. Do not pull them lower because they will swing. Release them. Prevent the Force sensor from swinging.

c. The recording will stop automatically after 20s.

d. The graph should show two sinusoids.

15. Click on “Keep this data”.

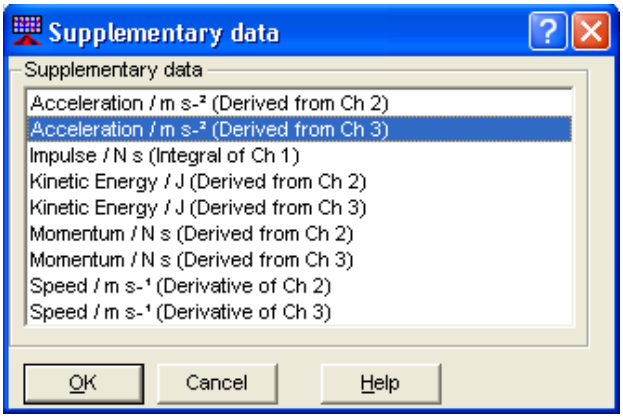
How to save your recording

1. Click on “File”.

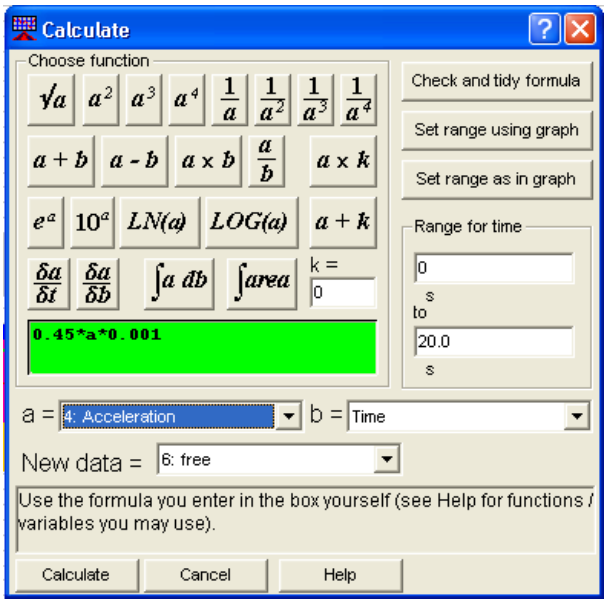
2. Click on “Save as…”.
3. Choose the directory you want to save in and type the name of your file.
4. Click on “Save”.

How to find the relationship between force, mass and acceleration

1. Click on “Data”.
2. Click on “Calculate”.
3. Click on “Smooth”. The Smooth window will open.
4. Choose the Distance.
5. Click on “OK”.
6. You will have a message from Datadisc Au. Read it and click on “OK”.



7. Click on “Data”.
8. Click on “Supplementary data”.
9. Select “Acceleration”, choose the acceleration derived from the channel of the smoothed function.
10. Click on “OK”.
11. The new displayed function represents the acceleration.
12. Click on “Data”.
13. Click on “Calculate”.
14. Click on “Function”. The Calculate window will open.
15. Click on the box to type this formula: “0.45*a*0.001”. 0.45 represents the mass of the masses in kilograms. “a” will be the acceleration. As the acceleration is in mm/s^2, you multiply by 0.001 to have it in m/s^{-2}.
16. Choose a=Acceleration.

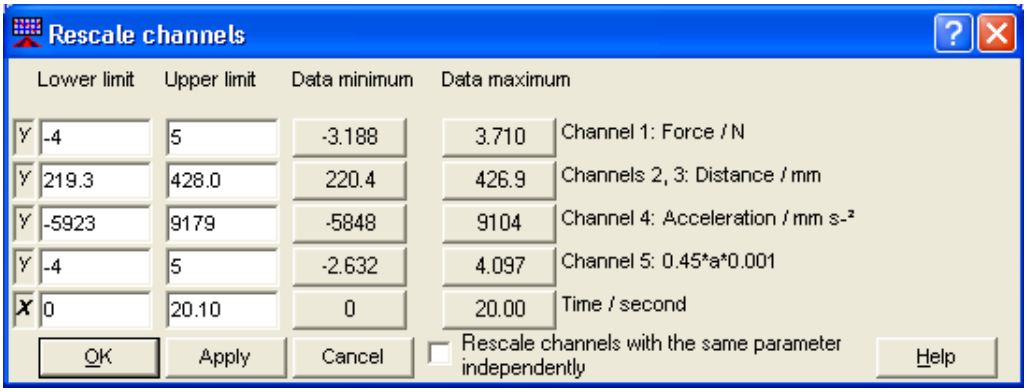


17. Click on “Calculate”.
18. The new calculated function represents “ma”. So it must be the same as the force.

How to amend the scale of a graph

To see if the force graph and the calculated function are the same, you have to choose the same scale for both these readings.

1. Click on “Graph”.
2. Click on “Scale”.
3. Click on “Direct entry”.
4. According to the data minimum and maximum, choose the same lower and upper limit for both the readings.



5. Click on “OK”.

How to change the colour of a graph

1. Double click on the graph you want to modify. A “graph symbols and lines” dialogue will open.
2. Choose all the options you want.
3. Click on “OK”.

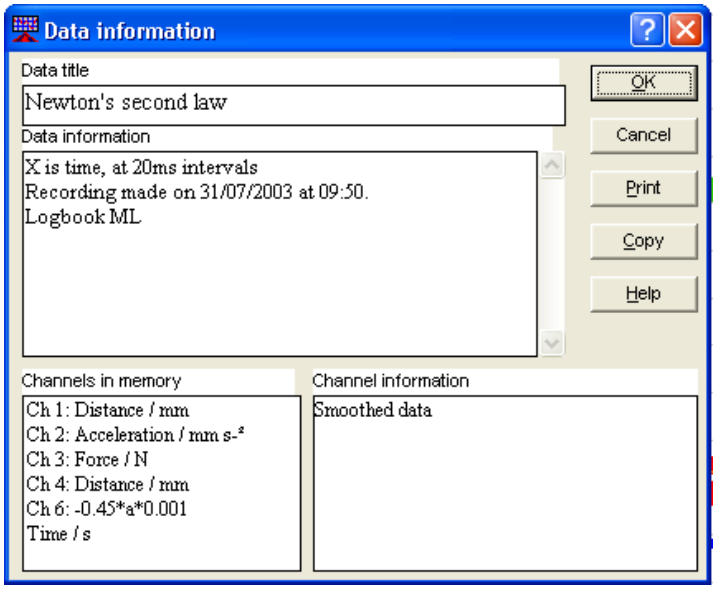
How to select a part of the graph

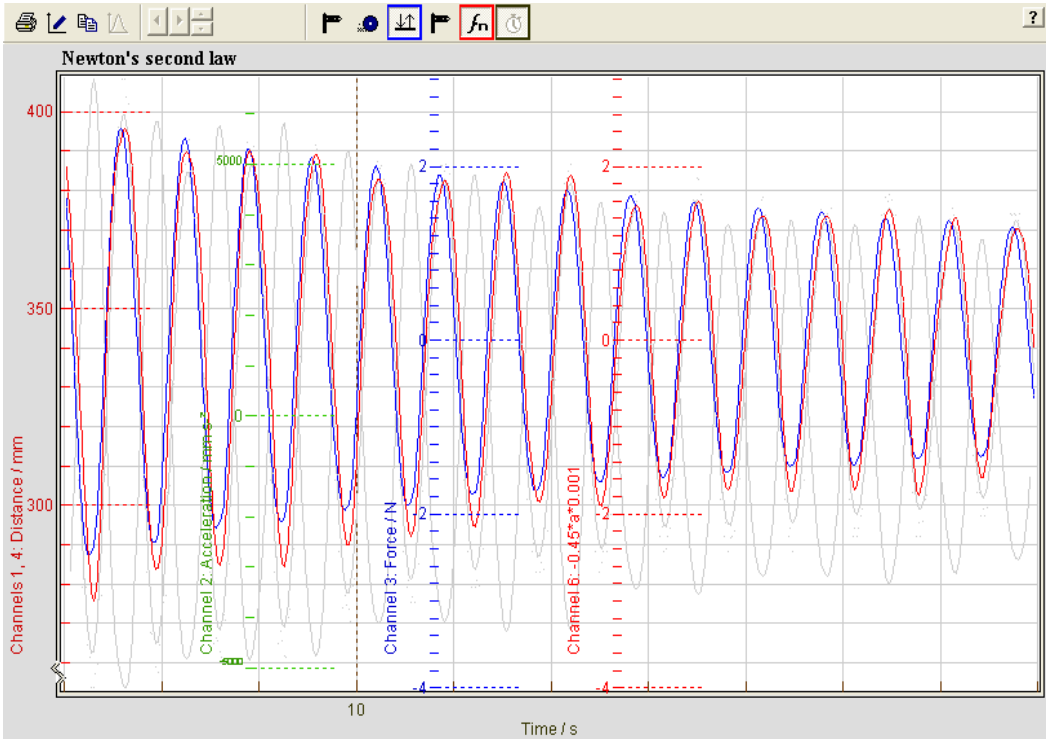
1. Click on “Data”.
2. Click on ”Select part”. You will have a message from Datadisc Au.
3. Read it and click on “OK”.
4. Select with the mouse the part of the graph you want to keep.
5. You will have to rescale the graphs.

How to store information about your recording

1. Click on “Data”.
2. Click on “Data information”.
3. Type all the information you want in “Data title” and “Data information”.

4. Click on “OK”.





How to save your file and exit

1. Click on “File”.
2. Click on “Save”.
3. Click on “File”.
4. Click on “Exit”.