Force Sensor
Worksheets

A Curriculum Resource for the Force Sensor

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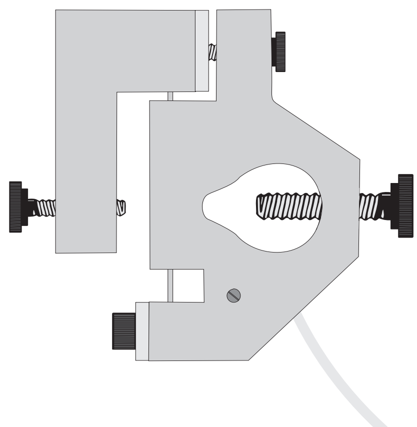

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Acknowledgement

"We would like to thank the GNVQ and A level students at the Cornwallis School for testing these experiments, and, in particular Kirsty Batchelor, Kirsty Sutton and Kim Chegwin for providing the results for FS2."

Document No: **D0113**

Force Sensor Worksheet

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Introduction

The *Smart Q* Force Sensor has made it possible to carry out a whole new range of measurements that were previously impossible in the school science laboratory. Student motivation will be enhanced with these exciting new experiments, which are all linked to real situations. In the majority of these experiments data needs to be collected in fast mode which makes them suitable for loggers with this facility i.e. *EasySense* Advanced and Fast.

The pack comprises five applications of the Force Sensor with Students' worksheets and Teachers' Guides with sample data.

- **FS1 Bungee** - Impulse, momentum, conservation of energy and resultant forces.
- **FS2 Simple harmonic motion** in a spring.
- **FS3 Centripetal force** in a pendulum.
- **FS4 Collisions.**
- **FS5 Buoyant force** - flotation, and resultant forces.

The applications described can be used at a variety of levels. For instance the Bungee Investigation can be used in both KS4 and KS5.

FS1 Bungee
KS4 - Impulse, momentum, conservation of energy, resultant forces.
A Level Physics, AVCE - as above with more advanced analysis.

FS2 Simple harmonic motion of a spring
A level Physics, AVCE

FS3 Centripetal Force
A level Physics, AVCE

FS4 Collisions
KS4 - Impulse, momentum and kinetic energy.
A level Physics, AVCE

FS5 Buoyant Force
KS3 - Resultant forces, flotation as an example.
KS4 - Resultant forces, flotation and density.

The Students' Notes accompanying this guide are examples of investigations and are not meant to cover all of the possibilities presented by a particular application.

General Notes on using the Force Sensor

- Ensure that the *Smart Q* Force Sensor is clamped firmly using rigid supports to reduce flexing as it measures a force.
- The Force Sensor measures **Extension Forces** as **positive.**

Errors

- It is important to be aware of the errors involved when taking measurements.
- The *Smart Q* Force Sensor resolution is 0.01N but with a suspended mass it is not likely to be better than ±0.05N due to vibration noise.
- When measuring velocity using Light Gates.

  a. The width of the light beam is 3 - 4 mm.
  b. The length of an interrupt card will have an error of ±1 - 1.5mm.

These combined will give an error of the order of ±4 - 6%.

- Kinetic Energy values which are calculated from velocity measurements will therefore have errors in the order of ± 8 - 12%.

Viewing sample data files

The sample data files (.sid) included in the teachers' notes are for viewing in the Graph application. The sample files were produced during the testing of the experiments in the Force Sensor collection. In most cases the only change that has been made is the scale of the axis.

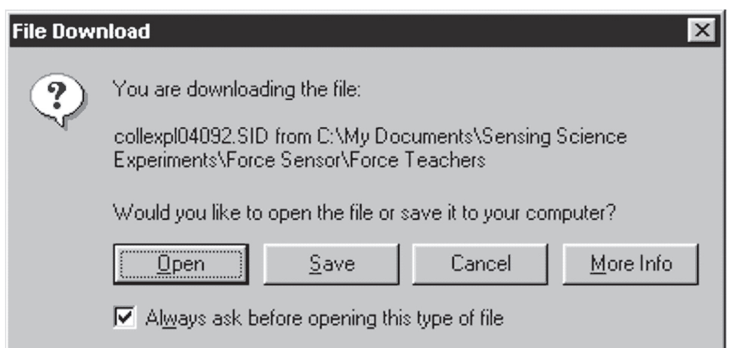
The files have all been made read only through the properties tab of the file in explorer. If the files need to changed and the changes saved then they should be copied to another folder and the read only attribute removed. Renaming the file is advisable to prevent confusion with the original file.

The files are located in the folder that contains the teachers notes and are all in .sid format.

Accessing the files

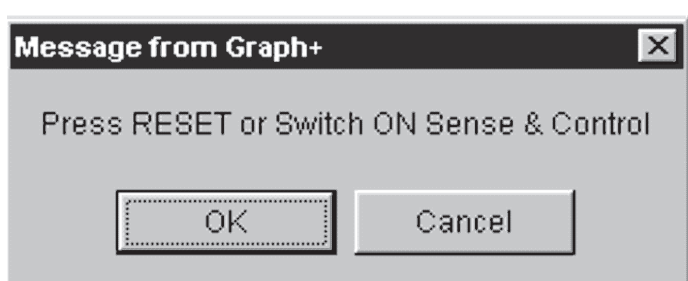
The files can be viewed by clicking on the screen shot of the graph. The file will open Graph and the data will be displayed. All the functions of graph can then be used. Depending on how your system is set up you may see several information panels before the data is loaded into Graph.

Screen message 1



File download message, click on the OPEN button for the file to be loaded into graph. If the "always ask before opening this type of file" tick box is unselected then in future this panel will not reappear.

Screen message 2



Message from graph. This type of communication message will appear if a datalogging interface is not attached to the computer. If an interface is attached follow the instructions and continue loading the file. If there is no datalogging interface attached click on "cancel" to continue loading the file.

Force Sensor
Teachers' notes
FS1 The Bungee Jump
An investigation

The model Bungee can be used to investigate impulse, change of momentum, conservation of energy, and resultant forces.

The experiments provided are:

FS1-A Resultant forces.

FS1-B Impulse and change in momentum.

FS1-C Extension and work done.

FS1-C (Extension)-Bungee challenge.

Learning Objectives:

Measuring the forces operating during the Bungee jump, will enable students to enhance their understanding of:

- Resultant forces, action and reaction, force and acceleration.
- Impulse = change in momentum.
- Work done in stretching a material. Elastic does not give a straight line force extension graph.
- Conservation of energy in the change: gravitational potential energy to kinetic energy to elastic potential energy.

The Investigations can be used at a variety of levels:

- KS3 Resultant forces.
- KS4 Resultant forces, impulse = change in momentum, conservation of energy.
- KS5 Resultant forces and acceleration; impulse = change in momentum, work done in stretching a material, conservation of energy quantitatively.

Apparatus (per group)

1. An *EasySense* Fast or Advanced unit.
2. A *Smart Q* Force Sensor.
3. Approximately 0.75 m. of model elastic (as used for motors in model aircraft or bait catapults).
4. G clamp.
5. Retort stand, bosshead and clamp.

Additional items for FS1 - A

1. 3 x 100g masses taped together or another suitable mass e.g. a weighted "Action man".

Additional items for FS1 - B

1. *A Smart Q* Light Gate.
2. 3 x 100g masses.
3. Strong card - used to make an "interrupt card" for measuring the velocity of the bungee.

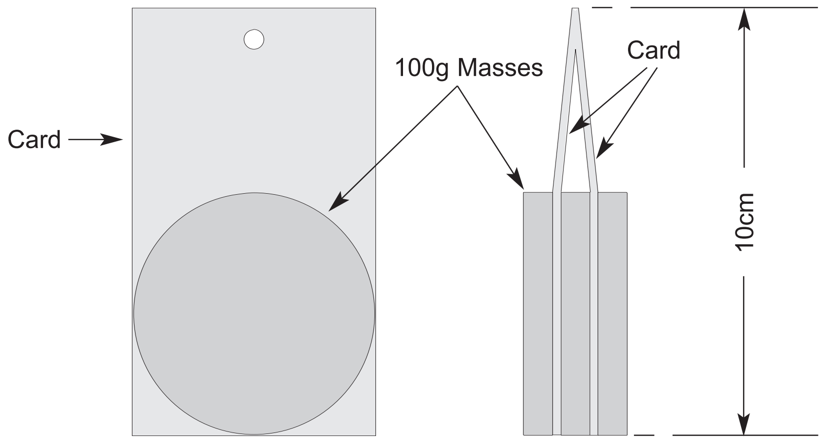
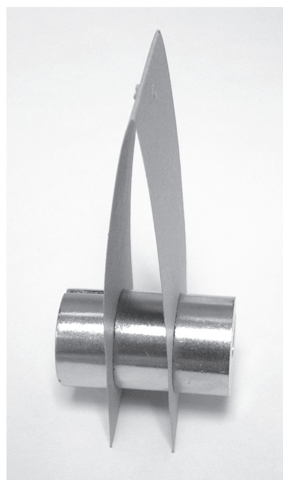


Diagram of the interrupt card with masses attached for FS1-B.



Additional items for FS1-C

1. Metre rule.
2. 10 x 100g masses.
3. Mass hanger.

Experimental procedure

Logger setup for experiments FS1-A and FS1-B

Recording method	Time	Record Sensors	Samples per Sensor	Intersample time	Start Condition	Trigger	Units	Pre -Trigger
Fast	-	1,2	4000	1 millisecond	When Sensor 1	Rises above	1.0N	25%

Note: *At a rate of 1000 samples per second the recording will take 4 seconds to complete.*

Logger setup experiment FS1-C

Recording method	Time	Record Sensors	Samples per Sensor	Intersample time	Start Condition	Trigger	Units	Pre -Trigger
Snapshot	-	1	-	-	-	-	-	-

Advice for all experiments in this series

- The apparatus needs to be setup with the retort clamp rod at least 1.4m from the ground. If a longer drop is available a larger mass can be used.
- It is important to check that the retort stand is firmly clamped to the workbench and that there is the minimum of movement in the boss and clamp rod.
- For the sample data 0.50m of elastic 3.5mm wide was used folded double, 0.40m of 6.5 mm wide elastic will also work well. This type of elastic is used for driving model aircraft and as replacement rubber for fishing catapults.
- Attach the elastic to the Force Sensor hook by tying loops into the end of the elastic.
- A "crash box" should be placed beneath the mass in case it becomes detached from the elastic.
- It is easier to use a small screwdriver to zero the sensor.

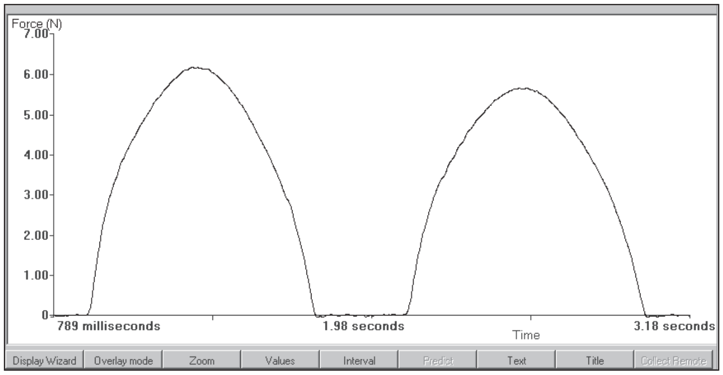
Advice specifically for FS1-B

- Position the Light Gate so that the masses are centred in the Gate when hanging stationary from the elastic.
- It is important that the masses hang vertically; otherwise they will not bounce vertically back through the Gate.

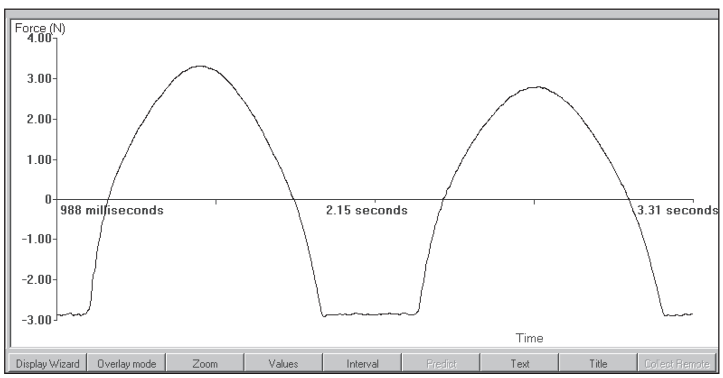
Force Sensor

Teachers' notes
Results and analysis: FS1-A
Resultant forces

Graph 1 The following graph shows the results when the Force Sensor has been zeroed with the mass supported on a bench.



Graph 2 The following graph shows the results when the Force Sensor was zeroed with the mass supported by the elastic.



Take care if using the **Smooth** function to avoid reducing the value of the maximum significantly.

Note: *The Force Sensor gives positive readings when being extended.*

Mass of 'body' = 300g
Weight = 0.300 x 9.81 = 2.94N

Graph 1 Gives the values of the total tension in the elastic.

- Use the Values function to measure the maximum value of the force.
- F_{max} = 6.15N
- Therefore accelerating force = 6.15 – 2.94 = 3.21N

Graph 2 Gives the values of the resultant upward force on the 'body'.

- Read off the maximum value of the resultant force, F_{max}
- F_{max} = 3.30N
- This is an acceptable error compared with 3.21N above. It is impossible to set the zero exactly to 0
- $a = \frac{F}{m} = \frac{3.30}{0.300} = 11.0\ ms^{-2}$

Force Sensor Investigation FS1-A: Bungee

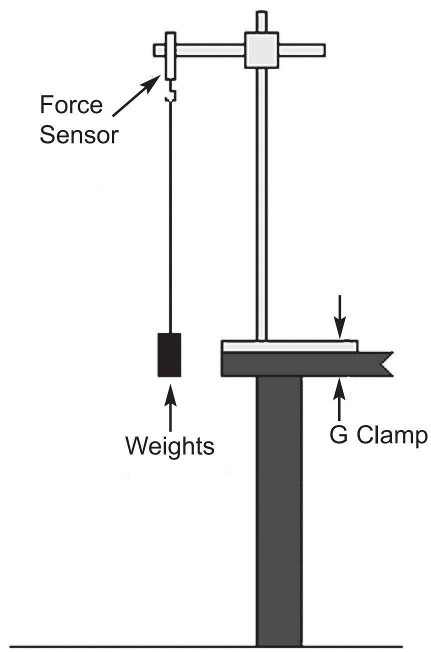
Resultant forces

Read

One of the highest, commercially run bungee jumps (approximately 111 metres high) is from the bridge above the Zambezi River downstream from the Victoria Falls in Zimbabwe. What is the effect of a bungee jump to the person hanging by their ankles from an elastic band, hundreds of metres above a crocodile infested river?
You are to investigate the forces acting on the bungee jumper, and consider the possible dangers to their body. To model the bungee jump use a 300g mass as the ‘jumper’ attached to a length of model elastic. The datalogger will be set to measure the force in the ‘bungee’ at a 1000 times a second, to give you an accurate idea of how the forces are changing during the jump.

What you need to do

1. Set up the apparatus with the retort clamp rod at least 1.4 m. from the ground. A longer drop will make it possible to use a larger mass.
2. Secure the Force Sensor to the rod of the clamp.
3. Attach the elastic to the Force Sensor hook by making loops in the end of the elastic.
4. Measure the mass of the ‘jumper’ to be used in the investigation.
5. Securely attach the mass to the lower end of the elastic .
6. Drop the ‘jumper’ from a point as near to the hook as you can. Make sure that it will bounce clear of the bench.
7. Click on the **'Launch'** button to start the *Graph* software application.
8. Support the mass on the bench. Select **Test** mode from the **Tools** menu and use the tare control on the Sensor housing to set zero.
9. Click on the **start** icon to begin logging and then drop the mass from a point as close to the Force Sensor as possible.
10. This will give Graph 1. Save this data and continue the experiment as follows:-
11. Zero the Force Sensor with the mass supported by the elastic.
12. Click on the icon, followed by **Finish.**
13. Support the mass ready for the drop as before.
14. Click on the **start** icon and then drop the mass.
15. This will give Graph 2. Save this data.



Results analysis

1. Select **Auto Scale** from the **Display** menu to re-scale the graph.
2. Use the **Smooth** function from the **Tools** menu to remove any noise form the data.
3. Read off values from the graphs using **Values** from the **Analysis** menu.
4. The results and graphs can be saved, printed or copied (**Edit**, then **Copy Graph** or **Table**) into your report document.

Using the two graphs you have obtained, answer the following questions:

Information: (gravity, $\mathbf{g} = 9.81ms^{-2}$*)*

1. Use information from Graph 1, and the value of the jumper’s mass to calculate the following forces acting on the ‘jumper’.

   a. Maximum upward force in the elastic.
   b. The force acting downwards on the ‘jumper’.
   c. The net maximum resultant force acting upwards on the masses.
   d. Which of these forces will be equal to the tension the ‘jumper’ would feel in his legs.

2. Using information from Graph 2 - it measures the resultant upward force on the jumper.

   a. What is the maximum resultant upward force on the jumper?
   b. Compare this value with the value obtained in 1.c. Hint: Does zeroing have an effect?
   c. For how long was the elastic under tension during the first fall?
   d. Calculate the time taken for the jumper to fall to the unstretched length of the elastic.

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

   e. Calculate the total time for the jumper to complete the first 'bounce'.

Questions

1. Calculate the following:
   a. The maximum upward acceleration of the mass.
   b. The maximum downward acceleration of the mass.

   Remember:- Force = mass x acceleration (**f = m x a**).
2. A real person will experience a slower slow down and rise. Try to explain what a bungee jumper will feel in his legs as he slows down and rises. Will he feel as if his legs are going to be pulled out of their sockets? Explain your answers.
3. Bungee jumping has been a very safe activity because the operators have designed the equipment well. The bungee rope has to be able to withstand the forces exerted on it, and allow the person to slow down over a big distance, without causing the jumper significant discomfort. Using the results from the experiment suggest the minimum breaking force of a bungee, if it is to be used with people up to 75kg mass. Explain how you arrived at your value.