

## Investigating Force and Acceleration with an Action Man® Bungee Jumper – Teachers' guide

A bungee jump provides an excellent opportunity to let students see and discuss a link between force and acceleration, assuming that they first have an understanding of what each means.

Many dataloggers make use of accelerometers to collect acceleration data. Here, however, there is an initial problem to overcome – the fact that accelerometers used in the vertical plane do not register accelerations as expected. They invariably measure what is commonly called the *g-force*, the normal force per unit mass and **not** the net force per unit mass. So, whilst at rest in the vertical plane, such accelerometers will show a so-called *g-force* of  $\pm 1g$  and an acceleration of  $\pm 9.8\text{m/s}^2$  dependent on which way up the accelerometer is orientated. It is simple to cope with by adding or subtracting 9.8 from each piece of data, but still quite confusing to most.

However, with the ALBA system the acceleration is measured using an ultrasonic motion sensor, the ALBA Ranger, which measures distances. It is useful to discuss how this is achieved by recording the time of travel and assuming a value for the speed of sound. To obtain the acceleration from this data the program calculates and plots the second derivative with respect to time of this distance data. For most I would not worry them with how this is done, but post-16 A/AS students may well be interested.

Discussion on such matters as 'Logging Interval', 'Recording time' and 'Triggering' is advisable. A Logging Interval of 100ms for both the ALBA Ranger and the ALBA Interface and Logger works well. 10 seconds appears to be a reasonable recording time as the oscillations of the model bungee jumper have a low amplitude after that time with the rubber cord that I used: it might be different with whatever cord you have available. It is advantageous to not have any triggering, bar clicking on the **GO** icon, as the graphs can then be seen before the 'jump' is made as well as during it. The problem of using Force to trigger the commencement of a plot should be broached – namely that the initial fall would not be recorded until the cord was no longer slack.

The software allows the reassignment of a reference point which is helpful in that the measurements of distance can then be from the bungee jumper's original position and not from the motion sensor.

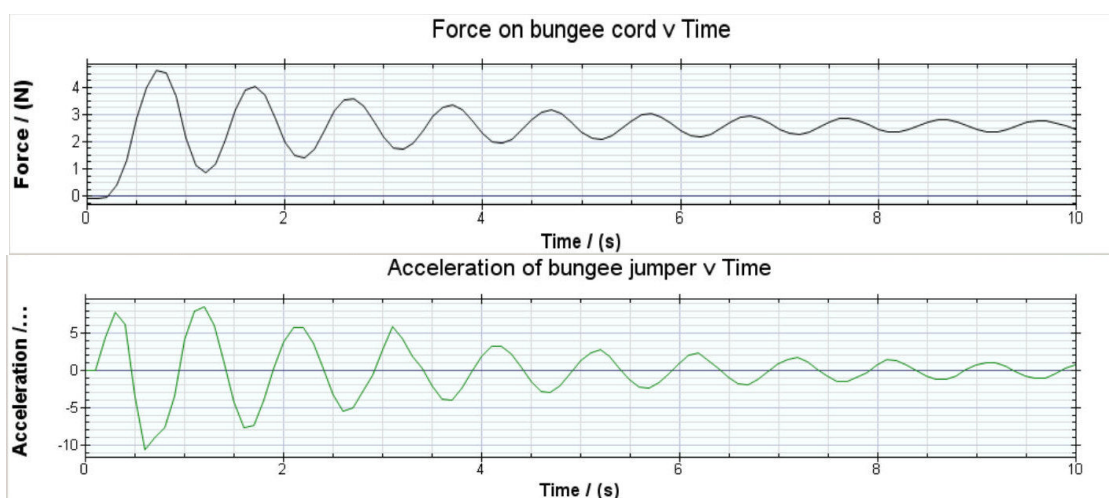
All the students should note the periodicity of the oscillations and the damping effect. Hopefully most will also note that the forces are maximised (negatively and positively) near enough when the accelerations and decelerations are maximised.

The comments on energy have been kept deliberately vague in order to avoid students thinking in terms of energy conversions or indeed of energy as a substance which can be moved from place to place. The idea of work being done by gravity and by a stretched piece of elastic is easy to appreciate, as is the fact that when work is done energy – whatever it is – is transferred. I prefer to think of energy much as an accounting system. Whatever there was initially there must be afterwards, it's just spread about more afterwards.

A number of weblinks have been provided which give information on the technology of bungee jumping, its history, some fantastic images and the physics involved. Additionally others relate to the integrated circuit used in accelerometers, the strain gauge used in many force sensors, plus some other ways of designing accelerometers, a little on ultrasonic motion sensors and autofocus cameras, and information on the piezoelectric effect. There is also one reference to CHIRP sonar which may be of interest to some students. For those who would like more of the physics involved, the 'Bungee Jumping: The Forces' weblink is worth looking at.

## Results

Hopefully students will obtain graphs similar to those shown in Figure 1.



**Figure 1** Graphs of Force-time and Acceleration-time obtained with a Force sensor and the ALBA Ranger Ultrasonic motion sensor

## Useful weblinks

### Accelerometers and how they work

<http://www2.usfirst.org/2005comp/Manuals/Acceler1.pdf>

Useful guide from Texas Instruments, lists some applications too.

### Analogue Devices

<http://www.analog.com/en/prod/0%2C2877%2CADXL105%2C00.html>

Details here of the ADXL105 accelerometer integrated circuit.

### Bungee.com

<http://www.bungee.com/bzapp/press/pt.html>

Within this website is a copy of an article from *The Physics Teacher* called The Physics of Bungee Jumping. It is useful at KS5 and beyond. Additionally there are lots of photographs, video clips and jumpers' accounts.

### Bungee Extreme

<http://www.bungee.co.uk/>

This is the website of a professional bungee jumping company. There is lots of information about bungee jumping, who can jump, where it can be done, together with lots of pictures and weblinks.

### **Bungee Jumping: The Forces**

[http://www.pa.uky.edu/~moshe/phy231/lecture\\_notes/bungee\\_forces.html](http://www.pa.uky.edu/~moshe/phy231/lecture_notes/bungee_forces.html)

For those students studying physics post-16, and indeed the most able pre-16, this website takes them through the mathematics and physics involved to see how the forces on the bungee jumper itself changes, and from that their acceleration. A final optional section makes use of calculus.

### **Bungee Zone: The Bungee Jumping Resource**

<http://www.bungeezone.com/>

There is a wealth of information here on the equipment used, types of jump that can be performed, photographs, history, disasters, links and various FAQs.

### **How Autofocus Cameras Work**

<http://electronics.howstuffworks.com/autofocus2.htm>

This ubiquitous website has a section on the use of ultrasonic distance sensors in early autofocus cameras such as those produced by Polaroid®.

### **How Sensors Work – Accelerometer**

<http://www.sensorland.com/>

Brilliant website for information on sensors. Click on the 'How they work' menu and then entries for accelerometers. Key ones are 'Compression mode' and 'shear mode' – the piezoelectric type, and 'Capacitive'.

### **National Instruments – Measuring Strain with Strain Gauges**

<http://zone.ni.com/devzone/conceptd.nsf/webmain/C83E9B93DE714DB08625686600704DB1?OpenDocument>

Useful article on strain gauge measurement.

### **PCB Piezotronics**

[http://www.pcb.com/techsupport/tech\\_accel.php](http://www.pcb.com/techsupport/tech_accel.php)

[http://www.pcb.com/techsupport/tech\\_force.php](http://www.pcb.com/techsupport/tech_force.php)

Useful information here on the piezoelectric effect and its use in accelerometers and force sensors.

### **Reporter's Notebook: South Pacific Ritual Bungee Jumping**

[http://news.nationalgeographic.com/news/2002/11/1125\\_021126\\_TVVanuatu.html](http://news.nationalgeographic.com/news/2002/11/1125_021126_TVVanuatu.html)

This is a news report on the land diving ritual, the Naghol, performed on Pentecost Island, one of many making up Vanuatu.

### **Steve Fettke Bungee Jumping**

<http://www.fettke.com/bungee/equip.htm>

Lots of bungee facts here together with details about the equipment used and plenty of photographs and videos.

### **The Oxford Stunt Factory**

<http://www.oxfordstuntfactory.com/html/stunts.htm>

This organisation performed the bungee jump shown in the Bond movie *GoldenEye* and images of it are shown here together with other stunts they have performed.

### **Vertige Aventures**

<http://www.bungee-jump.com/xvms.htm>

Information here on the construction of bungee ropes from this manufacturer.

**What are CHIRP Sonars?**

<http://www.tritech.co.uk/products/chirp>

This article by Tritech International explains the benefits of using CHIRP (Compressed High Intensity Radar Pulse) acoustic techniques in ultrasound distance sensors.

**6500 Series Sonar Ranging Module**

<http://www2.vernier.com/pdf/polaroid.pdf>

Here are technical details of the Polaroid<sup>®</sup> sonar ranging module used in most datalogging ultrasound sensors.