Investigating Impact Force whilst modelling a Mars Lander – Teachers' Guide

For younger students this activity can be treated in a relatively simple manner ignoring ideas of Impulse and Change of Momentum, so that they see that a soft impact can be obtained by lengthening the time of an impact. Here you can get them to think simply in terms of Force = mass × acceleration with a long impact time lessening the deceleration and so the impact force.

For those who have knowledge of Impulse and change of momentum, more complexity can be incorporated by getting the students to measure the areas under the Force-time graphs. If the areas are measured when the heights of fall (and velocity of fall) are the same, but with and without the gasbag (foam sponges) being used, they will **not** be found to be identical. Each area represents the Impulse which is equal to the change of momentum and, although each had the same momentum just prior to impact, the bounce would have resulted in a greater change of momentum and so a much larger impulse. Discussion would be helpful on what exactly was the height of fall and why this needed to be identical in the two cases. In reality the means of setting the height of fall does not take into account a little squashing of the 'gasbags' due to the 'lander's' weight and not the impact force. You might like to get your students to think how they might improve on this. Lower velocities through lower heights of fall can also be investigated. It is not advisable to investigate the effect of increased mass as it would almost certainly produce an impact force beyond the ±50N range of the force sensor, however this could and should be the subject of discussion.

How the force sensor works could be dealt with in greater depth if required. This Vernier version is based on the use of strain gauges and so lends itself to discussion about changes of resistance. Strain gauges are obtainable very cheaply from most electronic component suppliers. The National Instruments website is worth looking at for more detail.

Whilst the context provided is of a Mars landing, attention should also be drawn to airbags in cars, landing mats for pole-vaulters, collapsible front and rear-ends of cars, slightly squashable crash-helmets and the like.

As this is a datalogging task, discussion might also focus on the Rate of sampling and the usefulness of a Trigger. In a school laboratory the Trigger setting often has to be higher than one might anticipate due to 'pick-up' from computers and other apparatus, so you may need to increase it slightly beyond 0.5N.

In the initial designs of this activity I used under-inflated small balloons. The balloons did not perform at all well and so I substituted the foam sponges for them. Their main problems were (i) inability to get a 'good' shape, (ii) that they soon started to deflate and (iii) attachment to the jam-jar lid was not firm enough.

If time is available the NASA Pheonix Mission and the retro-rocket system for its Mars Lander could be discussed.

Typical results and answers to questions

Figure 1 Expanded Force-time graphs with 'gasbags' (left), without 'gasbags' (right), for a drop height of 7.5cm

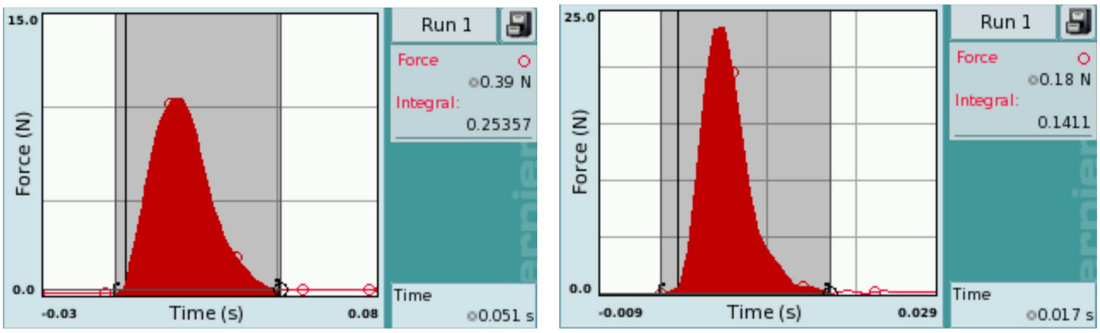

Figure 2 Expanded Force-time graphs with 'gasbags' (left), without 'gasbags' (right), for a drop height of 5cm

Activity	Impulse /Ns	Impact time /s	Maximum force /N
7.5cm drop with 'gasbags'	0.284	0.051	12.03
5.0cm drop with 'gasbags'	0.254	0.051	10.48
7.5cm drop without 'gasbags'	0.169	0.018	24.93
5.0cm drop without 'gasbags'	0.141	0.017	23.41

Figure 3 Collated data in table

Your student's answers will obviously differ a little, the ones given here relate to the graphs I obtained.

Q1 It will have a greater speed on impact.

Q2 The impulses were higher with the 'gasbags'. This is due to the bounce in which the velocity of the Mars lander reversed so increasing the change of momentum and hence the impulse.

Q3 The impact times were longer with the 'gasbags' attached.

Q4 The maximum force with the 'gasbags' attached was much lower than without them. The much longer impact times reduced their value.

Q5 The greater heights of fall (and resulting higher impact velocity) resulted in (i) higher impulses, (ii) little or no change of impact times and (iii) higher maximum forces.

Useful weblinks

Beagle 2 Mission
http://www.beagle2.com/index.htm

British National Space Centre (BNSC) – Beagle 2 Resources
http://www.bnsc.gov.uk/learningzone.aspx?nid=4831

Explore Mars Now
http://www.exploremarsnow.org/

LEGO Resource Page – Robot Space Explorers
http://robots.open.ac.uk/space/lego.html

Mars at the National Space Science Data Center (NSSDC)
http://nssdc.gsfc.nasa.gov/planetary/planets/marspage.html

Mars Exploration Rover Mission
http://marsrovers.jpl.nasa.gov/home/index.html

Mars Express Mission
http://www.esa.int/SPECIALS/Mars_Express/

NASA's Mars Exploration Program
http://mars.jpl.nasa.gov

NASA's Phoenix Mars Lander
http://www.nasa.gov/mission_pages/phoenix/spacecraft/index.html

National Instruments – Measuring Strain with Strain Gauges
http://zone.ni.com/devzone/conceptd.nsf/webmain/C83E9B93DE714DB086256
86600704DB1?OpenDocument

Nine Planets – Mars
http://www.nineplanets.org/mars.html

Particle Physics and Astronomy Research Council (PPARC) - Mars in the Classroom Resources
http://www.pparc.ac.uk/Ed/mars_express.asp

The Mars Society
http://www.marssociety.org/

The Planetary Society's Red Rover Goes to Mars Project
http://planetary.org/rrgtm/

The Society for Popular Astronomy
http://www.popastro.com

The Whole Mars Catalog at Mars Today.com
http://www.marstoday.com

University College London (UCL) – Mars in the Classroom
http://www.ucl.ac.uk/GeolSci/MITC/overview/

Useful books

Mars – The NASA Mission Reports 1. Edited Robert Godwin. Apogee Books 2000. ISBN 1-896522-62-9 £13.26

Mars – The NASA Mission Reports 2. Edited Robert Godwin. Apogee Books 2004. ISBN 1-894959-05-1 £14.66

Patrick Moore on Mars. Patrick Moore. Cassell 1998. ISBN 0-304-351911 £6.52

The Quest for Mars. Laurence Bergreen. Harper Collins Publishers 2000. ISBN 0-00-257030-0 £16.00

Uncovering the Secrets of the Red Planet. Paul Raeburn. National Geographical Society 1998. ISBN 0-7922-7614-0 £11.77

Useful magazines

Astronomy Now. Local newsagents.

ESA Bulletin. Free magazine from the European Space Agency (ESA). Available from ESA Publications Division, c/o ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands.

Frontiers. Free magazine on UK particle physics, astronomy and space science. Available from Strategic Planning and Communications, Particle Physics and Astronomy Research Council (PPARC), Polaris House, North Star Avenue, Swindon SN2 1SZ.

National Geographic. Back issues August 1998 and January 2004.

Popular Astronomy. The quarterly magazine of The Society for Popular Astronomy (also contains Prime Space for younger readers) – see their website listing.

The Planetary Report. The bi-monthly magazine of The Planetary Society – see their website listing.

Other useful resource

Express to Mars teachers' pack. Available free from the Particle Physics and Astronomy Research Council (PPARC), Polaris House, North Star Avenue, Swindon SN2 1SZ. Tel: 01793 442110. E-mail: pr.pus@pparc.ac.uk