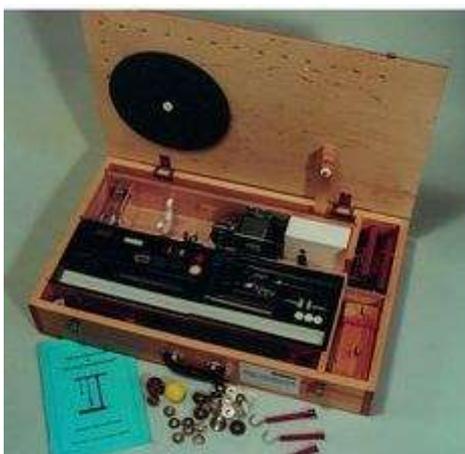


The Cambridge Dynamics Kit – a point of focus for multidisciplinary STEM, the educational use of digital technologies and the Cambridge Centre for Innovation in Technological Education <http://ccite.org>
Steve Hewson, Zsolt Lavicza and Adrian Oldknow aoldknow@yahoo.co.uk 17/02/2012

1. Newton's Mechanics – who needs it? was the subject of a 2-day symposium held at the Møller Centre, Cambridge in June, 2008, chaired by Sir Peter Williams. The report can be downloaded from: <http://mathstore.ac.uk/repository/NewtonMechReportFinal.pdf>. Its concern was the lack of background in mechanics of students entering Higher Education and its principal recommendation was that: **Urgent action is needed to increase access to and uptake of Newton's mechanics at ages 16-19.**

2. We are not aware of any major programme of work which has since been undertaken to address this problem, but in any event it is our view that it provides an excellent platform on which to build a kind of tangible "specimen answer" to what CCITE can make happen, as well as an illustration of the kind of innovative approaches we embrace **and** which builds links at an early stage with some of the important organisations with which we are seeking to engage.

3. The Mechanics in Action Project (MAP) started in the 1980s was based on the Universities of Leeds, Manchester and Sheffield <http://www.nationalstemcentre.org.uk/elibrary/collection/298/mechanics-in-action-project>. Materials from this group were also integrated into the Nuffield Advanced Mathematics course of the 1990s: e.g. <http://www.nationalstemcentre.org.uk/elibrary/resource/3520/mechanics-1>. One of the tangible products from the MAP was a large wooden box containing a turntable, motor, springs, masses and other equipment for a range of practical experiments in mechanics. Examples of this Leeds



Mechanics Kit are at the Gatsby funded National STEM Centre in York, which also has the digitised version of the original handbook: <http://www.nationalstemcentre.org.uk/elibrary/resource/1029/the-teacher-s-guide-to-the-leeds-mechanics-kit>. They can still be purchased from Philip Harris at the price of £590.95 each: <http://www.philipharris.co.uk/unilab/timingmechanics/leeds-mechanics-kit/?ev=search>. The guide features chapters on:

- Combining and Resolving Forces
- Friction
- Impact and Momentum
- Motion in a Horizontal Circle
- Motion in a Vertical Circle
- Simple Harmonic Motion

4. We have had recent discussions with staff from the Gatsby-funded National STEM Centre <http://www.nationalstemcentre.org.uk/>, the Mathematics in Education and Industry (MEI) organisation <http://www.mei.org.uk/> and the Further Maths Network <http://www.fmnetwork.org.uk/> which are all keen for us to develop a modern version of the kit which embraces digital technology and hence will also be much cheaper and lighter than the original. We have now been invited to make a presentation on our plans and development at the MEI annual conference at Keele University in June 2012. We are currently discussing possible collaboration between CCITE and potential partner organisations in and around Cambridge such as the Cambridge Science Centre <http://www.cambridgesciencecentre.org/>, the STEM Team East <http://www.stemteameast.org.uk/>, the East of England Science Learning Centre <https://www.sciencelearningcentres.org.uk/centres/east-of-england>, the Nrich project at DAMTP <http://nrich.maths.org/public/>, the Raspberry Pi Foundation http://en.wikipedia.org/wiki/Raspberry_Pi, and the GeoGebra Institute of Cambridge http://wiki.geogebra.org/en/GeoGebra_Institute_of_Cambridge, as well as with the Association for Science Education (ASE), the Mathematical Association (MA), the Design and Technology Association (DATA), the Computing At School group (CAS), the Youth Sports Trust (YST) and the Institute of Physics (IoP) http://www.iop.org/activity/branches/south_east/eanglia/index.html.

5. The basic starting point is the capture of data from moving objects. This can be done the traditional way using instruments such as rulers, tapes and stop-watches and also digitally using video clips, sensors and data-logging. The data can then be manipulated, represented graphically, analysed and used as the basis for modelling using suitable software. So immediately a whole range of possibilities come into view – from primary school activities involving running, timing and finding average velocities – through GCSE activities involving forces, acceleration and friction and AS/A2 activities involving momentum, impulse and energy using springs, pendulums and collisions - to Further Maths activities involving rotational motion and moments of inertia.

6. Instead of producing, marketing and distributing a physical collection of apparatus, such as the original Leeds Mechanics Kit, we envisage producing a self-assembly guide on paper, CD and the web giving information about where to obtain possible physical components, examples of experiments, video clips, sample data sets, free open-source software tools such as GeoGebra <http://www.geogebra.org/cms/>, Modellus <http://modellus.fct.unl.pt/> and Tracker <http://www.cabrillo.edu/~dbrown/tracker/>, sample files for use with these and other software such as MS Excel, Vernier's Logger Pro and TI-Nspire, guidance on how to use existing tracking and sensing devices, instructions for creating digital sensors, support for all common platforms including mobile and touch devices etc. Some physical prototype kits will be assembled for testing and for use in conferences, hands-on displays etc, but the major product is the blueprint for self-assembly for use inside and outside schools, colleges and academies.

7. One particularly attractive features of the CDK is that it will be designed to include experiments involving students' own activities which can take place in their own time outside school and hence obviate the need for the risk assessment associated with practical work in schools. (Of course, we will not encourage them to try anything reckless!) Another is that the data capture can involve the kinds of devices to which students already have access, such as mobile phones, digital video cameras, GPS and video game controllers such as Nintendo's WiiMote http://en.wikipedia.org/wiki/Wii_Remote and Microsoft's Kinect capture bar <http://www.pil-network.com/Resources/Tools/Details/744b546a-2803-4315-b758-d810e92af2d0>. Support will also be provided for a hobbyist approach to electronics for those who want to build their own experimental kit using products such as the Arduino micro-controller <http://www.arduino.cc/>, the expEYES sensor kit from the Indian Phoenix project <http://expeyes.in/>, and Microsoft's .NET Gadgeteer <http://research.microsoft.com/en-us/projects/gadgeteer/>.

8. The practical activities will also be designed to be cross-curricular e.g. involving sports and biomechanics, D&T building paper plane/rocket launchers and model cars – and rooted in contexts such as the Olympics, Bloodhound SSC, designing playground equipment, stage machinery, mobility aids etc. They can also draw on a raft of kit which students may already have at home – such as Lego, K'nex, Meccano, balsa – as well as bicycle wheels, old turntables, "whizz-wheels" cars and tracks etc. There are also low-cost resources available from the former GTEP project at Mindsetonline (Middlesex University) <http://www.mindsetonline.co.uk/>.

9. There are many charitable organisations which might be prepared to support the development cost of the CDK – which could also align well with the newly announced BBC Computer Literacy initiative <http://www.bit-tech.net/news/bits/2012/02/16/bbc-micro-2/1> which attempts to rekindle the enthusiasm for programming which was engendered by the original series and the BBC microcomputer: <http://www.retro-kit.co.uk/page.cfm/content/BBC-Computer-Literacy-Project/>.

10. Some sample materials can be found on the Intel Skoool Maths and STEM Community website: <http://inteledcentre.co.uk/community/skoool-maths-and-stem-community>.

The basic hand-held wireless input device for the Nintendo Wii games system is called the Wiimote. It contains 3 accelerometers and an infrared camera. The accelerometer data can be accessed via Bluetooth. For general information see the Wiki article at: [http://en.wikipedia.org/wiki/Wii Remote](http://en.wikipedia.org/wiki/Wii_Remote)
More detailed information is in the Wiimote Hacking Guide at: druid.caughq.org/presentations/turbo/Wiimote-Hacking.pdf



The basic unit is available from many suppliers, Amazon's price is £16:

http://www.amazon.co.uk/Nintendo-RVLACJW1-Wii-Controller/dp/B000IMWK2G/ref=dp_cp_ob_vg_h_title_1

You will also need a Bluetooth radio for your laptop – this may already be installed, or if not you can buy a cheap “dongle” such as the Belkin F8T017 (100m range) at £8.60 from Amazon:

http://www.amazon.co.uk/Belkin-Bluetooth-plus-Adapter-range/dp/B001BRV7JE/ref=sr_1_2?ie=UTF8&s=electronics&qid=1270900986&sr=1-2

To access the infra-red positioning sensor data you will also need a wireless sensor bar. You can make your own with standard components, if you have the skills. An alternative is a ready-made one such as the Logic3 bar from Maplin at £11: <http://www.maplin.co.uk/wireless-sensor-bar-for-nintendo-wii-224075>

A major source of support for Wiimote applications is from Brian Peek: <http://wiimotelib.codeplex.com/> which lists many projects including two for Physics, one from the UK, the other from France.

Martyn Wheeler has his own website: <http://wiiphysics.site88.net/index.html> from where you can download his free Wiiphysics software:

<http://wiiphysics.site88.net/download.html>. This requires an installation of Microsoft's free .NET 4.0 Framework if it is not already installed. He also has further pages at <http://wiimotephysics.codeplex.com/>. A useful guide has been produced by Gregor Steele from the SSERC and can be downloaded from: <http://wiiphysics.site88.net/downloads/A%20Wee%20bit%20of%20Physics.doc>

François-Xavier Inglessè has produced Wii-Physique :

<http://negentropic.free.fr/Wii-Physique/> which can also be downloaded free from : <http://negentropic.free.fr/Wii-Physique/Wii-Physique-1.0.0.exe>. There is also a useful article from the French physics teachers' bulletin (BUP): *Utilisation d'une manette de jeu video pour des expériences de mécanique* : http://www.udppc.asso.fr/bupdoc/consultation/article-bup.php?ID_fiche=20060

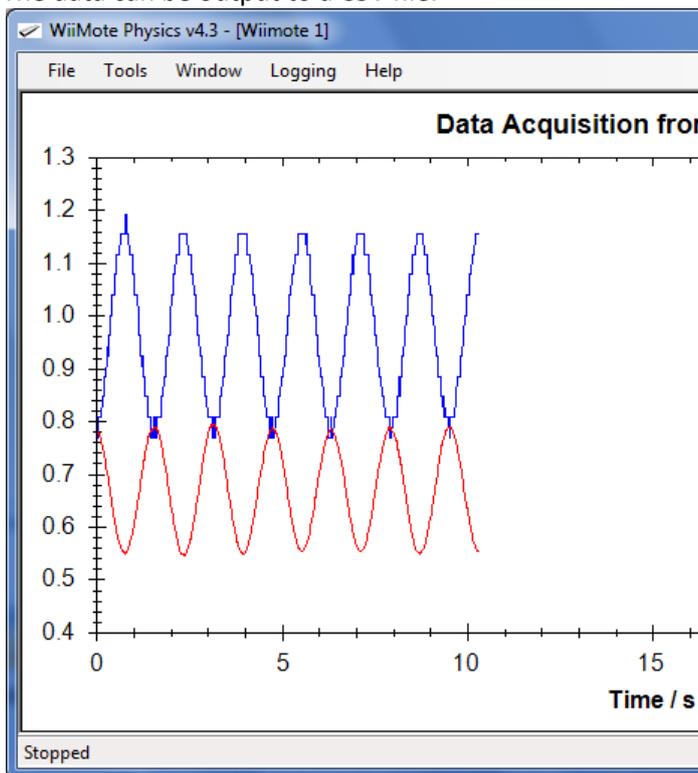
It took me many attempts to get the WiiMote and Bluetooth to establish a stable enough connection to be recognised when the WiiPhysics software was started up. You need to press the 1 and 2 buttons simultaneously to get the blue lights flashing to make the unit discoverable. There is a free utility which you can run to check that the WiiMote is indeed connected:

Wiiinremote: <http://onakasuita.org/wii/index-e.html>

The good news is that once the link has been established for the software to run the first time, it seems to work again more easily thereafter! You may well need to remove the Nintendo device from the Connected Bluetooth list, and then rediscover it to make sure the drivers are loaded correctly each time. So here is an example of the data being captured. The WiiMote is strapped to Ellie's back with rubber bands. Ellie is suspended by a spring above the wireless IR capture bar. The laptop with a Bluetooth dongle is out of shot. It captures the vertical acceleration directly, measured in units of $g=9.8 \text{ ms}^{-2}$. Simultaneously (and in real time) the displacement is captured from the IR camera measuring its distance from the

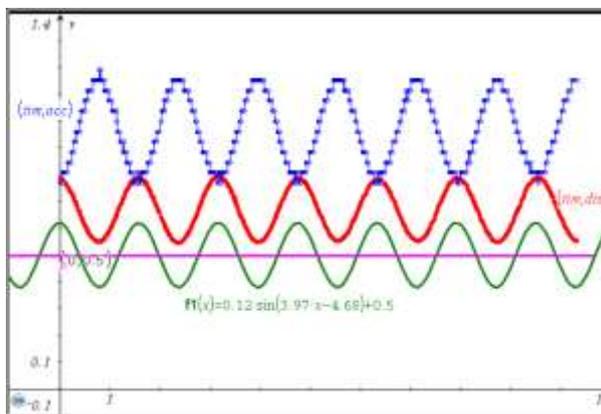
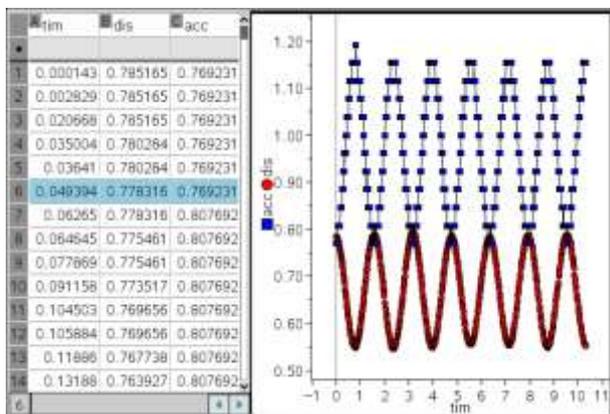
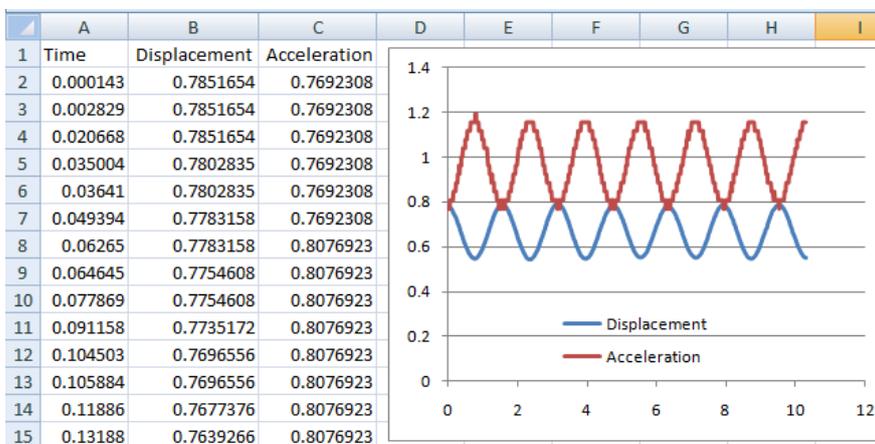


transmitters in the wireless bar. The blue graph show acceleration and the red graph show displacement. The data can be output to a CSV file.

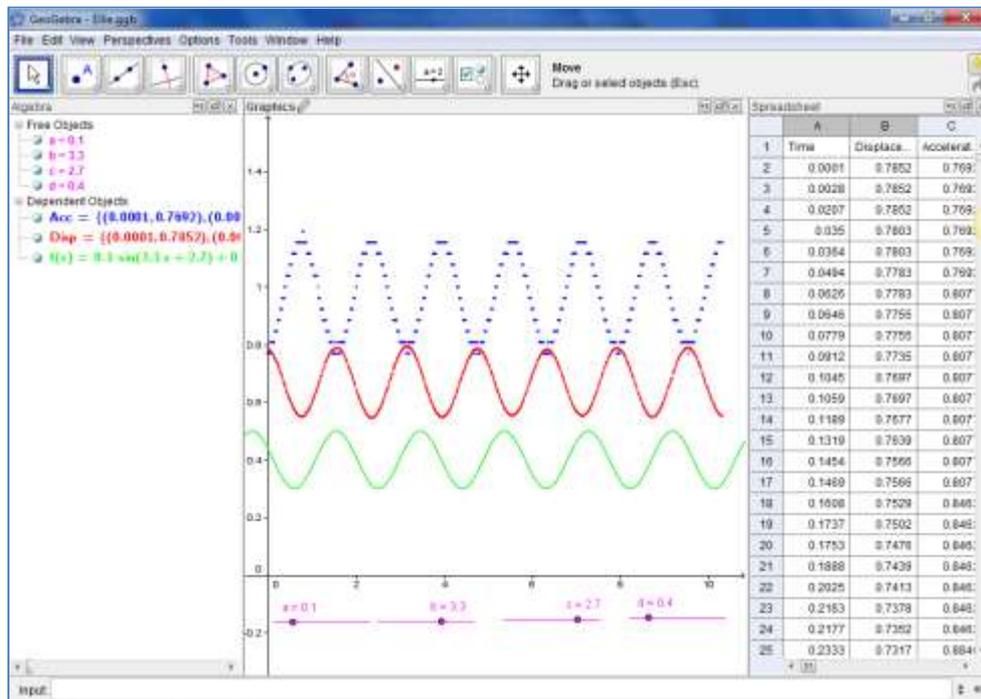


The CSV file was opened in Excel, and the graphs drawn. The data was copied and pasted into a spreadsheet in TI-Nspire CX software. The graphs are displayed both in a Data & Statistics view, and also in a Graphs page. The green sine curve can be manipulated to make a good fit to either graph – and so amplitude, period and phase shift can easily be determined.

The purple line can be dragged by the point P to show the mean value of either data set.



The CSV file can also be opened in the Spreadsheet view of the latest version of GeoGebra. Columns A and B have been converted to the “List of points” called “Disp” which is plotted as the red scattergram. Similarly A and C have been used to create the list “Acc” and its blue graph. Sliders for the variables a , b , c and d are used to manipulate the green graph of the function $f_1(x) = a.\sin(b.x+c)+d$.



GeoGebra also has a range of regression models to provide least-squares fits as shown in the following two windows.

