**Stage 1 Physics**

**Science as a Human Endeavour Task**

This investigation is about resonance in a bridge and how it can show science as a human endeavour; mainly the communication and collaboration between scientists and the way that when different parts of science work together it can lead to the development of new or improved structures.

Topic and key features of SHE identified.

All objects have natural frequencies that they vibrate at. The natural frequency depends on many properties of the object including its shape, what it is made of and the temperature of the object. Sometimes the object has only one natural frequency like a musical instrument but other objects like a bridge have a whole set of different frequencies making up the natural frequency.

Relevant science discussed.

Nearly all objects can be made to vibrate when an external force is applied. Sometimes it is not easy to detect the vibration because the amplitude or how much the particles are displaced by is very small. However these vibrations allow energy to be transferred through the object from the side where the force is applied. The energy spreads out through the object.

Sometimes the external force interferes with the natural frequencies but sometimes it makes the particles in the object vibrate with the exact same frequency as the natural frequency. When this happens the natural frequency is magnified and this is called resonance.

Resonance is useful in musical instruments because it means that a small force such as plucking or blowing produces a large amplitude and people can hear it. But sometimes resonance can cause problems such as in buildings, radio towers or bridges.

An example of resonance causing problems is the millennial bridge in London. When it was designed the engineers factored in all natural elements such as making sure that it had a high vertical natural frequency. They made sure wind would not affect it. Or other things that caused downward forces on the bridge like trains and traffic. The one thing not factored in was that on the day the bridge opened June 10, 2000, hundreds of people would be walking on the bridge at once causing the bridge to slightly wobble horizontally.

What happened was that when thousands of people started to walk across the bridge, the slight wobble caused people to lean the opposite way to the wobble to make up for the unevenness caused by the wobble. Then everyone was doing this at the same time. Without realizing it they all walked with the same rhythm. This rhythm had the same frequency as the bridge and this caused a sideways resonance with the bridge.

This is an example of poor communication and collaboration between the scientists and engineers designing the bridge as this same thing had happened before, as long ago as 1850 when the Angers Bridge in France collapsed.[1]

Illustration of how this shows a link to ***Communication and Collaboration***

Because there was little or no international communication, the problem happened again in London. If there had been better communication, this problem could have been solved before it was even a problem for the Millennial Bridge. It could have been avoided if the engineers and designers behind the millennial bridge or the government who make the guidelines and laws concerning suspension bridges had collaborated and done more extensive research on the collapse suspension bridges throughout the world.

Since the problem with the Millennium Bridge, there has been much more communication about the problem of sideways resonance in bridges [2]. It has been found that it doesn’t matter what type of bridge it is (suspension, arch, truss or cable-stayed), lateral vibration can lead to damage. This kind of communication can help to prevent damage to bridges built in the future. Scientists have determined that the frequency of the lateral forced dues to pedestrians is between 0.7 and 1.2 Hz so by communicating finds such as these, engineers are able to make sure that the natural lateral frequency of the bridge does not fall in this range and safer bridges can be built.

Further explanation of relevant physics concepts.

Explanation of how this is evidence of the ***Development*** key SHE concept.

It also shows science as a human endeavour through development. There needed to be changes made to the design of the bridge to prevent the bridge from wobbling again. Once the issue with the design was discovered, the bridge the bridge was closed while the scientists and engineers developed ways to improve the structure of the bridge.

At first they suggested the number of people on the bridge at any one time could be reduced and controlled by placing street furniture on the bridge. [3] Then they proposed that the entire structure could be stiffened so that the natural frequency of the bridge was changed to a frequency outside the likely frequency caused by people walking across it. This idea were discarded because the changes would change the intended shape of the bridge and affect its visual impact and this was one of the most appealing factors of the bridge. This shows an example of society influencing the way that science is put into action.

Explanation of how the complex model required a range of evidence.

David Newland from the Department of Engineering at University of Cambridge [4] carried out some research on the problems that other bridges had. He used mathematics to calculate the forces and frequencies involved in the resonance on the Millennium Bridge and worked with the engineering designers on the modification of the bridge. He determined and tested the performance targets for the modifications and reported on them in two papers. [4 and 5] This kind of communication is essential for scientists so their work can be reviewed by peers and results verified.

It was important for scientists to research the different ways of solving the problem and understand how different kinds of dampers work. In the end, engineers working with mathematicians and scientists finally decided that two different kinds of damping mechanisms would solve the problem without drastically changing the appearance of the bridge because the mechanisms could be mostly placed under the bridge out of the public’s view. One kind of damper behaves like giant shock absorbers which absorb the force due to the pedestrians. The other kind involved a large mass stiffened by springs. The dampers absorb both horizontal and vertical movement.

Evidence from difference disciplines used to develop final solution.

This incident on the Millennium Bridge is a good example of Science as a Human Endeavour because it shows how scientists of different kinds could and should communicate and work collaboratively so that problems can be avoided or if problems occur then they can be fixed.

1. Angers Bridge

<https://en.wikipedia.org/wiki/Angers_Bridge>

Accessed 23 June 2017

1. Lateral Vibrations of a Cable-Stayed Bridge under Crowd Excitation

[Lijun Ouyang](https://www.hindawi.com/60327690/), [Caihong Wang](https://www.hindawi.com/96741703/), [Bin Zhen](https://www.hindawi.com/73563089/), and [Jian Xu](https://www.hindawi.com/36562523/)

Mathematical Problems in Engineering
Volume 2015 (2015)

<https://www.hindawi.com/journals/mpe/2015/309645/>

Accessed: June 12, 2017

1. <http://news.bbc.co.uk/hi/english/static/in_depth/uk/2000/millennium_bridge/solution.stm>

Accessed: June 12, 2017

1. David E Newland

Department of Engineering
University of Cambridge

VIBRATION OF THE LONDON MILLENNIUM FOOTBRIDGE: PART 1 - CAUSE

<http://www2.eng.cam.ac.uk/~den/ICSV9_06.htm>

Accessed: June 17, 2017

1. David E Newland

VIBRATION OF THE LONDON MILLENNIUM FOOTBRIDGE: PART 2 - CURE

Department of Engineering
University of Cambridge

<http://www2.eng.cam.ac.uk/~den/ICSV9_04.htm>

Accessed: June 17, 2017

Other sources accessed:

Alexander Blekherman

[Journal of Bridge Engineering](http://ascelibrary.org/journal/jbenf2)

[Volume 12 Issue 6 - November 2007](http://ascelibrary.org/toc/jbenf2/12/6)

Autoparametric Resonance in a Pedestrian Steel Arch Bridge: Solferino Bridge, Paris

<https://www.sciencedaily.com/releases/2005/11/051103080801.htm>

Accessed June 23, 2017

Performance Standards for Stage 1 Physics

| - | Investigation, Analysis and Evaluation | Knowledge and Application |
| --- | --- | --- |
| A | Critically deconstructs a problem and designs a logical and coherent physics investigation with detailed justification. Obtains, records, and represents data, using appropriate conventions and formats accurately and highly effectively.Systematically analyses and interprets data and evidence to formulate logical conclusions with detailed justification.Critically and logically evaluates procedures and their effect on data. | Demonstrates deep and broad knowledge and understanding of a range of physics concepts.Applies physics concepts highly effectively in new and familiar contexts.Critically explores and understands in depth the interaction between science and society.Communicates knowledge and understanding of physics coherently, with highly effective use of appropriate terms, conventions, and representations. |
| B | Logically deconstructs a problem and designs a well-considered and clear physics investigation with reasonable justification.Obtains, records, and represents data, using appropriate conventions and formats mostly accurately and effectively. Logically analyses and interprets data and evidence to formulate suitable conclusions with reasonable justification.Logically evaluates procedures and their effect on data. | Demonstrates some depth and breadth of knowledge and understanding of a range of physics concepts. Applies physics concepts mostly effectively in new and familiar contexts.Logically explores and understands in some depth the interaction between science and society.Communicates knowledge and understanding of physics mostly coherently, with effective use of appropriate terms, conventions, and representations. |
| C | Deconstructs a problem and designs a considered and generally clear physics investigation with some justification.Obtains, records, and represents data, using generally appropriate conventions and formats, with some errors but generally accurately and effectively. Undertakes some analysis and interpretation of data and evidence to formulate generally appropriate conclusions with some justification.Evaluates procedures and some of their effect on data. | Demonstrates knowledge and understanding of a general range of physics concepts. Applies physics concepts generally effectively in new or familiar contexts.Explores and understands aspects of the interaction between science and society.Communicates knowledge and understanding of physics generally effectively, using some appropriate terms, conventions, and representations. |
| D | Prepares a basic deconstruction of a problem and an outline of a physics investigation.Obtains, records, and represents data, using conventions and formats inconsistently, with occasional accuracy and effectiveness.Describes data and undertakes some basic interpretation to formulate a basic conclusion.Attempts to evaluate procedures or suggest an effect on data. | Demonstrates some basic knowledge and partial understanding of physics concepts. Applies some physics concepts in familiar contexts.Partially explores and recognises aspects of the interaction between science and society.Communicates basic physics information, using some appropriate terms, conventions, and/or representations. |
| E | Attempts a simple deconstruction of a problem and a procedure for a physics investigation.Attempts to record and represent some data, with limited accuracy or effectiveness.Attempts to describe results and/or interpret data to formulate a basic conclusion.Acknowledges that procedures affect data. | Demonstrates limited recognition and awareness of physics concepts. Attempts to apply physics concepts in familiar contexts.Attempts to explore and identify an aspect of the interaction between science and society.Attempts to communicate information about physics. |