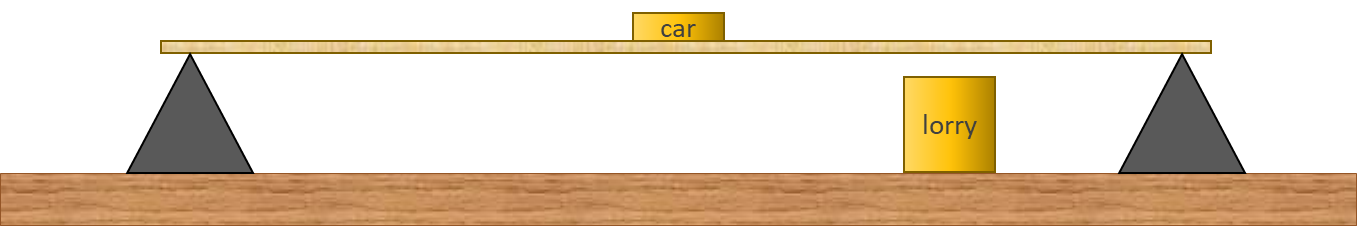
**Ruler bridge**

A metre ruler is used to model a road bridge.

Weights are added to show what happens when cars or lorries are on the bridge.

A small weight is used for a car. A big weight is used for a lorry.



What do you think about the ruler when each weight is added?

For each statement, tick (✓) **one** column to show what you think*.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | I am **sure** this is right | I think this is right | I think this is wrong | I am **sure** this is wrong |
| **A** | The ruler bends with the heavy weight on it. |  |  |  |  |
| **B** | The ruler bends with just the small weight. |  |  |  |  |
| **C** | The ruler pushes up on the small weight. |  |  |  |  |
| **D** | The ruler pushes up harder on the big weight. |  |  |  |  |

*Physics > Big idea PFM: Forces and motion > Topic PFM3: More about force > Key concept PFM3.2: Hidden forces*

|  |
| --- |
| **Diagnostic question** |
| **Ruler bridge** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | An object resting on the floor squashes it a little and, because at a microscopic level the floor is springy, it pushes back on the object with an equal sized force in the opposite direction to the object’s weight. |
| Observable learning outcome: | Explain how a ruler, made into a bridge, changes to support weights of different sizes. |
| Question type: | Confidence grid |
| Key words: | force, weight |

**What does the research say?**

Research by Terry *et al (1985)* has shown that expressing Newton’s third law in the form: “for every action (force) there is an equal and opposite reaction” is confusing for students aged 11-16. It is far clearer to describe in full: the force of object A on object B is equal in size, and opposite in direction to the force of object B pushing on object A.

When thinking about one object resting on a surface, students typically apply a concept of force that is different to the one they use for objects in motion. In a study of 1000 Norwegian upper secondary students, Sjoberg and Lie (1981) found that just 50% of the young people recognised ‘passive’ forces acting when there was no movement.

When Minstrell (1982) asked two US high school physics classes (aged 14+) about forces on an object resting on a table, most of the students understood that gravity was exerting a downwards force on the object, but only about half described the table exerting an upwards force. Students who did not identify an upwards force mostly described the table as ‘getting in the way’ (Driver et al., 1994). Typically those who recognised an upwards force from the table described the downwards force as bigger. In a further study, Montanero et al. (2002) found that only a very small minority of 11- to 16-year-olds (n=240) consistently applied the correct scientific understanding that the upwards force of a surface is the same size (and in the opposite direction) to the weight of an object that it supports.

Bridging analogies gradually take learners through a series of easily understood ‘base analogies’, in order to lead them to an understanding of a challenging ‘target concept’, which is outside the realm of their usual experience or understanding. Squashing a spring or seeing a ruler flex more as extra weight is added seems to make it plausible to them that a table surface flexes in a similar way in order for an upward force to be created (Bryce and MacMillan, 2005).

This question investigates students’ understanding of the forces exerted when a ruler is flexed by different sized weights.

**Ways to use this question**

Students should complete the confidence grid individually. This could be a pencil and paper exercise, or you could use an electronic ‘voting system’ or mini white boards and the PowerPoint presentation.

If there is a range of answers, you may choose to respond through structured class discussion. Ask one student to explain why they gave the answer they did; ask another student to explain why they agree with them; ask another to explain why they disagree, and so on. This sort of discussion gives students the opportunity to explore their thinking and for you to really understand their learning needs.

The ruler bridge could then be demonstrated to confirm (or challenge) students’ thinking.

*Differentiation*

You may choose to read the questions to the class, so that everyone can focus on the science. In some situations it may be more appropriate for a teaching assistant to read for one or two students.

**Equipment**

For the class:

* Metre ruler (a wooden ruler works well)
* Supports for each end of the ruler (e.g. piles of books)
* 2N weight (200g mass) – it is important that it is hard to detect flexing of the ruler when this weight is added, so its size may need to be adjusted to suit the particular equipment used.
* 10N weight (1kg mass)

**Expected answers**

All four statements are correct.

**How to respond - what next?**

Most students will know from experience that the ruler bends when a heavy weight is added, and expect that the small weight will bend the ruler less.

With the ruler slightly flexed but not moving under the small weight, some students may not identify that an upwards force is acting. The proportion of students who think this is potentially quite large.

With a larger weight the ruler pushes back harder because the force it pushes back with is dependent on the ruler’s interaction with the weight. Some students are likely to think that the force is dependent only on the properties of the ruler and think the ruler pushes back on all sizes of weight with a force of the same size. They may explain the extra flexing using the misunderstanding that the weight pushes the ruler harder and therefore moves it more. They are not applying the general understanding, from the BEST key concept: *PFM1.1.1 What forces do*,that ‘forces make things change’.

If students have misunderstandings about how the ruler flexes to support weights of different sizes, it can help to demonstrate what happens. Adding more weight should clearly show that the ruler flexes more and more as extra weight is added (until its breaking point). It is less clear that as it flexes more, it also pushes back with more force. One strategy to show that a ruler pushes back with more force is to use one end of a flexed ruler to flick a small object, such as an eraser. The more it is initially flexed, the more force it flicks with.

Reducing the mass so that the ruler barely flexes helps bridge to the idea that the floor pushes up on objects resting on it, even when it cannot be seen to flex. Very small distortions of the ruler can be seen more easily if a straw is used to multiply the visible movement as shown below. The optics pin through the straw can be held in a clamp, or stuck into a block of wood.

Weight

Ruler

(cross-section)

Straw

Optics pin

The following BEST ‘response activity’ could be used in follow-up to this diagnostic question:

* Response activity: John’s plank

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

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