*Physics > Big idea PFM: Forces and motion > Topic PFM3: More about force*

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| **Key concept (age 11-14)** |
| **PFM3.2: Hidden forces** |

**What’s the big idea?**

A big idea in physics is force, because it is the key to explaining changes in the motion or the shape of an object. The motion of an object can be explained or predicted if you know the sizes and directions of all the forces that act on it. Understanding forces helps us to predict and control the physical world around us.

**How does this key concept develop understanding of the big idea?**

This key concept helps to develop the big idea by using bridging analogies to build an understanding of the ‘at rest’ condition in physics.

The conceptual progression starts by checking understanding of the force we need to exert on an object to hold it at rest. It then supports the development of a more general application of this rule with examples of springs and objects that visibly squash or distort, in order to enable understanding of how a surface can exert an upwards force on an object because at a microscopic level it is springy.

**Using the progression toolkit to support student learning**

Use diagnostic questions to identify quickly where your students are in their conceptual progression. Then decide how to best focus and sequence your teaching. Use further diagnostic questions and response activities to move student understanding forwards.

**Progression toolkit: Hidden forces**

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| **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. | | | | |
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| **As students’ conceptual understanding progresses they can:** | **C o n c e p t u a l p r o g r e s s I o n** | | | | |
| Describe how a person’s hand uses force to support different sized weights. | Describe how the size of force exerted by a spring changes as it is squashed. | Explain how a ruler, made into a bridge, changes to support weights of different sizes. | Explain how objects of different weights can all be supported by the same floor. | Explain how a string can support objects of different weights and hold each one at rest. |
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| **Diagnostic questions** | A big weight | Squashing a spring | Ruler bridge | Heavy crate | Ball on a rope |
|  |  |  | Light crate, heavy crate |  |
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| **Response**  **activities** | Adding more weight |  | John’s plank | Squashing a mattress | Hanging ball |
| Holding a book |  |  | Box on a table |  |

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| **A big weight** | **Squashing a spring** | **Ruler bridge** | **Heavy crate** | **Light crate, heavy crate** |
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| Simple multiple choice | Simple multiple choice | Confidence grid | Simple multiple choice | Confidence grid |
| **Ball on a rope** | **Adding more weight** | **Holding a book** | **John’s plank** | **Squashing a mattress** |
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| Simple multiple choice | Predict, explain, observe, explain | Talking heads | Explanation story | Critiquing a representation |

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| **Box on a table** | **Hanging ball** |  |  |  |
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| Talking heads | Talking heads |  |  |  |
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**What’s the science story?**

If a force is exerted on a spring (or a springy object), which is fixed at its other end, to stretch or compress it, the spring/object exerts a force of the same size in the opposite direction on whatever is doing the stretching or compressing.

In fact all materials are springy or stretchy, at the microscopic level. An object sitting on, or pressing against, another one (e.g. the floor) compresses it a little, and an object hanging from another one (e.g. a string) stretches it a little. So both objects experience a force.

The force exerted by a hard surface on an object sitting (or pressing) on it is called the normal reaction of the surface. (‘Normal’ here means ‘at right angles to the surface.) The force exerted by a string on an object that is stretching it is called the tension of the string.

**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.

To overcome the misunderstanding that an inert object at rest cannot exert force often requires a change in a student’s basic beliefs (Savinainen, Scott and Viiri, 2004). There needs to be a concept change away from thinking about force as a property of the object, in which an object can exert force because it is moving or has weight, to thinking about force being due to the process of interactions between different objects (Chi, Slotta and de Leeuw, 1994).

Thinking about force being due to an ‘interaction’ between two objects implies that each object exerts a force on the other. This leads to the idea that forces always act in pairs, and to Newton’s third law of motion. Students often accept this rule for special cases, but disregard it for others depending on the context. The next step in a learning sequence is to develop the notion that Newton’s third law is generally applicable to all situations.

The use of bridging analogies to develop students’ understanding of Newton’s third law and the ‘at rest’ condition appear to make the underlying physics more intelligible and plausible to students and increase their confidence in applying this learning to new situations (Savinainen et al., 2004; Bryce and MacMillan, 2005).

Bridging analogies gradually take the learner 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 (Bryce and MacMillan, 2005). A target question can be used to make explicit students’ alternative conceptions about the topic under consideration and an analogous case suggested by the teacher to scaffold and develop understanding. Targeted questioning and dialogue can lead students to make connections between the analogy and the target concept, and where necessary additional bridging steps (base analogies) added by the teacher, in order to reach or strengthen understanding of the target concept. (Savinainen et al., 2004)

Series of bridging steps developed by different researchers for understanding the ‘at rest’ condition are strikingly similar (Bryce and MacMillan, 2005). Holding a weight on an outstretched hand and feeling the upwards force necessary to hold it still appears to help learners understand that an upwards force is necessary to keep an object at rest on a table. 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. Placing weights on a stiff ruler, that is supported at each end, to show deformations associated with the upwards force generated can be very small help to reinforce this understanding. (Minstrell, 1982; Bryce and MacMillan, 2005)

The common analogy of hanging weights from a spring to equate increased stretching with heavier weights with a corresponding increased upwards force was found by Bryce and MacMillan (2005) to be problematic. They found that many students had difficulty making connections between forces resulting from a spring being stretched and those from a surface being squashed. Bryce and MacMillan suggested this would be a useful example to discuss after students had formed a good scientific understanding, in order to consolidate their understanding in a new context.

**Guidance notes**

The first four steps in this learning progression are bridging analogies leading to the learning focus. The final step in the learning progression gives students the opportunity to apply their understanding in a new context.

A good time for the stretching springs experiment might be immediately after this key concept.

**References**

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