**Falling weight**

Albert is on a fun-fair ride called ‘Shock Drop’.

It drops the riders from the top of a tall tower.

Albert sits on bathroom scales to weigh himself!

The ride starts to fall.

**a.** What happens to the weight Albert measures?

Put a tick (✓) in the box next to the best answer.

|  |  |  |
| --- | --- | --- |
| **A** | His weight goes up. |  |
|  |  |  |
| **B** | His weight stays the same. |  |
|  |  |  |
| **C** | His weight goes down. |  |
|  |  |  |
| **D** | He becomes weightless. |  |

**b.** What is the best reason for your last answer?

Put a tick (✓) in the box next to the best answer.

|  |  |  |
| --- | --- | --- |
| **A** | Albert speeds up very quickly. |  |
|  |  |  |
| **B** | The force of gravity on Albert stays the same. |  |
|  |  |  |
| **C** | Albert’s seat falls as he falls. |  |

*Physics > Big idea PFM: Forces and motion > Topic PFM3: More about force > Key concept PFM3.1: Mass and weight*

|  |
| --- |
| **Diagnostic question** |
| **A very tall tower** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Mass is a measure of the amount of matter an object or substance is comprised of and weight is the force needed to support the object or substance. |
| Observable learning outcome: | Explain why an astronaut orbiting the Earth is weightless. |
| Question type: | Two-tier multiple choice |
| Key words: | mass, weight, gravitational force |

|  |  |
| --- | --- |
| **B** | **BRIDGING**  This diagnostic question probes understanding of ideas that are usually taught at age 14-16, to build a bridge to later stages of learning. |

**What does the research say?**

In most text books (Galili and Kaplan, 1996; Tural, Akdeniz and Alev, 2010; Stein, Galili and Schur, 2015) and in many syllabuses and curricula (Department for Education, 2013; Department for Education, 2014) weight is defined as the gravitational force acting on a mass. The equation weight = mass x gravitational field strength (w = mg) clearly shows that an object with more mass feels heavier and has more weight. This is logically correct because ‘bigger mass’ describes an object which contains more matter which requires more force to lift.

There is however a problem with this definition in that it also suggests that an astronaut will be weightless only when there is zero gravity; and this is not the case. On the International Space Station (ISS) astronauts clearly experience weightlessness, yet the ISS orbits so close to the surface of Earth (about 400 km) that the gravitational force on it and on the astronauts inside is still 89% of what it is on the Earth’s surface.

Defining weight as the gravitational force on an object does not work in all situations and reinforces the misunderstanding that there is no gravity in space (Stein et al., 2015). An alternative definition of weight that is often used by teachers is: weight is the force needed to pick up an object; or alternatively weight is the force which an object pushes down on a surface. This definition works well to explain what is happening to the astronaut in the ISS. The ISS and the astronaut are orbiting at the same speed and are following the same path, so as the astronaut falls - the ‘floor’ of the space station falls away from her at exactly the same speed. The experience of the astronaut is explained, but the equation w=mg does not work.

Driver et al. (1994) note several studies that show students do not generally think of weight as a force of gravity (Stead and Osborne, 1980; Ruggiero et al., 1985; Watts, 1982) instead this is a concept that is introduced through teaching. Watts (1982) found secondary students do not use the concept of gravity consistently, applying gravity differently to different objects and not always in the same way at all times to a particular object. When weight is defined as equal to mass multiplied by gravitational field strength and students understand that mass is unchanging, then it becomes necessary for them to apply a non-scientific and flexible approach in order to make sense of situations such as the weightlessness of an astronaut in Earth orbit.

Stead and Osborne (1980) found in a study of 11- to 14-year-olds that it is common for eleven-year-olds to think that gravity only relates to the Earth. At age thirteen (n=258) 44% do not think there is gravity on the Moon, and they commonly think that not all planets have gravity. 81% of 13-year-olds and 75% of 14-year-olds in the study did not think that there is gravity in space (Stead and Osborne, 1980; Driver et al., 1994). Similarly, Galili (1995) found that the majority of students aged 14-15 (n=34) understood weightlessness to depend solely on an object’s location (a place with little or no gravity).

This question is based on Einstein’s ‘imaginary elevator’ thought experiment and investigates students’ understanding of how gravitation force and acceleration combine to give the ‘measured weight’.

**Ways to use this question**

Students should complete the questions 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. The follow on question will give you insights into how they are thinking and highlight specific misconceptions that some may hold.

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.

*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:

* A ‘tower-drop’ fun-fair ride! (members of your class may be visiting a theme park in the near future).
* Bathroom scales (but ***not*** for use on the tower-drop ride).

**Expected answers**

These answers refer to his measured weight as the ride *starts* to fall. Later in the fall his weight will change.

**a.** C: His weight goes down.

**b.** C: Albert’s seat falls as he falls. (Answer D suggests mostly correct thinking.)

**How to respond - what next?**

Some students may apply the formula *weight = mass x gravitational strength* to deduce that Albert’s weight remains constant – because his mass and the gravitational strength of the Earth do not change (answers B, B).

Others may, perhaps following the diagnostic question *Blast off!*, associate acceleration with a bigger weight (answers A, A). In this example the seat is accelerating in the same direction as Albert, so its acceleration relative to his is very small.

Answer D to part a is not correct because air resistance and friction mean that the mechanism accelerates less quickly than the acceleration of free-fall.

If students have misunderstandings about why Albert’s measured weight goes down at the start of the fall, it can help to examine a set of bathroom scales to elicit the fact that they are measuring the size of the ‘squash’ between the top and bottom surfaces. Discussion could probe what happens to the size of this squash if the scales are pushed up or pulled down whilst weighing an object.

The following BEST ‘response activity’ is a practical that investigates weight, measured on a scale, being accelerated upwards and downwards, and could be used in follow-up to this diagnostic question:

* Response activity: Moving weight

**Acknowledgments**

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Images: Shock drop: <https://pixabay.com/photos/shock-drop-rides-fun-carnival-ride-3613192/>

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