**Safe landing**



Yusuf jumps out of a plane!!!

He uses a parachute to land safely.

These statements are about jumping out of a plane.

Put them in the right order to explain how a parachute jump works.

The jumper falls at a slow steady speed

The jumper is going too fast to land safely

The jumper’s weight is the same size as the drag on the parachute

Drag is made much bigger

The jumper slows down

There is a resultant force upwards

The speed of the jumper goes up quickly

There is a big resultant force downwards

There is no resultant force

The parachute is opened

**Explaining how a parachute jump works - cards**

|  |  |
| --- | --- |
| The jumper falls at a slow steady speed | There is a resultant force upwards |
| The jumper is going too fast to land safely | The speed of the jumper goes up quickly |
| The jumper’s weight is the same size as the drag on the parachute | There is a big resultant force downwards |
| Drag is made much bigger | There is no resultant force |
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*Physics > Big idea PFM: Forces and motion > Topic PFM2: Moving by force > Key concept PFM2.4: Drag*

|  |
| --- |
| **Diagnostic question** |
| **Safe landing** |

**Overview**

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| --- | --- |
| Learning focus: | The drag force on an object moving through a fluid increases with its speed and can be reduced by making the object more streamlined |
| Observable learning outcome: | Explain how using a parachute can make it safe to jump out of an aeroplane |
| Question type: | Explanation story |
| Key words: | Drag, weight, resultant force, speed |

|  |  |
| --- | --- |
| **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?**

When the speed of an object is being increased, students tend to focus on the applied force that appears to be needed to get it going, and keep it going. They often think that a moving object *has* force that keeps it moving, and which runs out when it comes to rest (Gunstone, R and Watts, 1985; Driver et al., 1994a). Osborne (1985) found that as students get older they *increasingly* hold the view that a force, pushing in the direction of motion, is needed to keep an object moving. In a study of 200 students he found 46% of 13 year olds believed this, increasing to 53% of 14 year olds and 66% of 15 year olds.

Instead of concentrating on the applied force students need to think about all the forces acting and how they combine to produce the resultant force. They need to identify when the resultant force acts, when it changes and when it ceases. This involves understanding drag and the direction it acts in in order to recognise how it contributes to the resultant force (Driver et al., 1994b).

For most students the idea that a bigger resultant force produce a bigger effect is intuitive, but it is important to emphasise that resultant force does not produce speed, but a change in speed (Driver et al., 1994b). In other words: any moving object will continue to accelerate whilst a resultant force is acting on it.

The effect of drag on falling objects can be very confusing because although drag (air resistance in air) can significantly affect the motion of an object falling in the real world, students often do not take it into account. In a study, Lee and Kwok (2009) found that when 11- to 12-year-olds (n=204) were asked to label the forces on a falling ball, 90% were able to label the gravitational force, but none of them included any drag force.

This question investigates students’ understanding of how changing the drag force with a parachute (making drag larger than the driving force) affects the motion of a moving object.

**Ways to use this question**

This task is intended for discussion in pairs or small groups. It is best done using sort cards to organise.

Students should read the statements and follow the instructions on the worksheet. Listening in to the conversations of each group will often give you insights into how your students are thinking. Each member of a group should be able to report back to the class.

Feedback from each group can be used, with careful teacher questioning, to bring out a clear description or explanation of the science.

*Differentiation*

The quality of the discussions can be improved with a careful selection of groups; or by allocating specific roles to students in the each group. For example, you may choose to select a student with strong prior knowledge as the scribe, and forbid them from contributing any of their own answers. They may question the others and only write down what they have been told. This strategy encourages contributions from more members of each group.

NB in any class, small group discussions typically improve over time and a persistence with this strategy is often very successful in the medium to long term.

**Expected answers**

1. There is a big resultant force downwards.
2. The speed of the jumper goes up quickly.
3. The jumper is going too fast to land safely.
4. The parachute is opened.
5. Drag is made much bigger.
6. There is a resultant force upwards.
7. The jumper slows down.
8. The jumper’s weight is the same size as the drag on the parachute.
9. There is no resultant force.
10. The jumper falls at a slow steady speed.

**How to respond - what next?**

Several different ideas about forces need to be combined to complete this challenging activity.

The driving force is the weight of the parachutist and is constant all the way through the jump. A few students may think that gravity does not act, or is small, when the jumper is in mid-air.

Drag changes with speed *and* shape of the jumper. It produces a force that opposes the downwards motion.

The force that is acting on the jumper is the resultant force of both weight and drag.

If the resultant force is zero there is no force to change the motion of the jumper. Some students may think that zero force will stop the fall!

The increase in drag caused by the opening of the parachute increases the force that the jumper needs to push with to maintain the same speed, but the driving force is always equal to weight and cannot change.

This means that when the parachute opens the resultant force is upwards. It is surprisingly common for students to suggest that this makes the parachute go up for a short time. This misunderstanding can be reinforced by film footage of parachutists. When filming a parachute opening the footage is often taken by another jumper in freefall. The continued downwards movement of the camera as the parachute opens give the appearance of the parachute moving upwards – and adds to the dramatic effect of the scene.

A resultant force in the opposite direction to motion acts to change the speed, and to make it smaller. As speed decreases so does drag and consequently the resultant force. When drag again equals the weight there is no longer any force left over to change the speed, and the jumper falls at a (slower) steady speed.

If students have misunderstandings about how forces act on a parachute to enable a safe landing, it can help understanding by taking students step by step through each phase of the jump in order to model how they can approach thinking through complex situations. The following BEST ‘response activity’ gives students opportunity to construct and rehearse their own explanations. It could be used in follow-up to this diagnostic question:

* Response activity: Parachutes

**Acknowledgments**

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Images: Peter Fairhurst (UYSEG).

**References**

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