|  |  |
| --- | --- |
| **Lesson Plan** | |
|  | Timeline  Description automatically generated with medium confidence |
| **Motion and Forces**  Using bridging analogies to teach about balanced forces  Pupils should be taught about: using force arrows in diagrams, adding forces in one dimension, balanced and unbalanced forces.  Science (Physics) – KS3 |

|  |  |
| --- | --- |
| **Research recommendation(s) and rationale** | The topic of forces is inherently difficult (Tao & Gunstone, 2000). A common misconception is that an absence of motion means that forces are absent (Demirci, 2005; Nie et al., 2019). To tackle this misconception research suggests using bridging analogies (Brown & Clement, 1989; Bryce & MacMillan, 2005; Minstrell, 1982). |
| **Lesson aim** | To use bridging analogies to teach about balanced forces. |
| **Learning objective** | To understand that an absence of motion does not mean an absence of forces. |
| **Intended learning outcomes** | At the end of the lesson, pupils will be able to:   1. Describe the magnitude and direction of forces acting on a stationary object. 2. Be able to use vector arrows to draw those forces acting on a stationary object. |
| **Scientific vocabulary** | Balanced forces – forces are of equal size but opposite in directions.  Force – a push or a pull.  Reaction force – force exerted in the opposite direction to an action force. |
| **Suggested lesson sequence and activities** | The lesson plan is adapted from the work of Bryce and MacMillan (2005), and Minstrell (1982), each analogy is designed to progressively encourage the pupils to think through (or in some instances actively change) their ideas about upward force.  **Draw out pupils’ pre-conceptions** of forces when an object is stationary.  Task: Ask what forces are acting on the book? Illustrate using vector arrows the forcing acting on the book.  **Practical Analogies**  **For each analogy, ask pupils to think about the forces involved and then draw the forces acting on the object to explain its stationary position.**   1. **Book held up by a hand**   Ask pupils to hold a book up and keep it stationary and think about how it feels. This task gives an easy introduction to upward force, as the upward force of their hand is a familiar experience to pupils. (If pupils are struggling, stack more books on the pupil’s hand one at a time).   1. **Book suspended from a spring**   Suspend a book from a spring. Builds on the previous analogy and demonstrates that the upward force can come from an object in contact with a stationary object – whether that object is above or below it. Also, it introduces the idea that the reaction force was caused by the deformation of the material that provided the upward force.   1. **Spring being pushed down by a hand** (until at rest and spring is compressed approximately x1.5 original length)   Pupils push their hands down on the spring, demonstrating the existence of the upward force – through experience.  Initiates idea that table is being deformed when the book was placed on it (allude to by placing a book on spring)   1. **Book on a bendy table**   Construct a bendy table, using two makeshift table legs, and a piece of pliable wood. Then place a book on the piece of wood and ask pupils to observe the bending. This analogy emphasises the cause of the upward force. This analogy is now missing the experiential “feel” of upward thrust from the previous three analogies.  **Putting it all together:** Using the example, why does a book remain stationary of a table.  Return to the original example of a book on a table and allow pupils to explain why the book is stationary. Offer pupils new context to apply their thinking to, for example, a person is standing on a concrete floor (this is challenging because concrete is thought of as a rigid structure). |
| **Key questions** | **Initial situation: what would happen if the table weren’t there?** Students should realise that the book will accelerate towards the floor (or more accurately, towards the centre of the Earth). The key idea here is that unbalanced forces cause accelerations.   1. **Book on hand: what forces are acting here?** Students should realise that since the book is still in a gravitational field there is a force acting upon it (which we call weight).   **Is there any upward force on the book?** Students should realise that it takes effort to hold up the book against the weight of the book.  **How big is the upward force compared with the downward force on the book? Larger/smaller/the same size?** Since forces cause accelerations, and the book isn’t accelerating, the forces must be balanced.   1. **Is there a downward force on the book?** Students should realise that gravity is still acting so the book has weight.   **Is there an upward force on the book?** Students can be helped to understand that the spring has deformed because a weight is pulling it down. If they are insecure about whether the spring is pulling back, you can ask them why the spring doesn’t just keep stretching until it is a wire.  **What is causing the upward force?** This is harder. However, if student have looked at atomic structure or solids, liquids and gases, they may be able to see that the metal atoms are normally closely packed and are being pulled apart, so the electrostatic forces between them are pulling back against the displacement forces.  **How big are the two forces relative to each other?** Students should see that the forces are balanced. A key misconception here is that forces cause movement. In fact, they cause acceleration (change of speed or direction).   1. **Why is the spring being compressed?** Students should see the link between pushing and compression.   **What would happen if you pushed with one hand only?** This is the crucial point. The spring would not be compressed unless there was a pair of forces acting in opposite directions.   1. **Why does the table bend?** Draw out the analogy with the spring. The key point here is that all objects compress a bit when you place a weight on them. A sponge will deform fairly obviously whereas in a block of concrete the deformation is microscopic (but still there). 2. **Why does a book remain stationary on a table?** Students should now see that there is a pair of balanced forces in each situation where an object is stationary. You can now test this understanding with a circus of experiments where the students add force arrows to each situation. |
| **Assessment suggestions** | Make a number of differently sized arrows to represent forces.  Students can look at a circus of activities in which they add force arrows with blu-tac to a number of stationary objects such as:   * **A mass on a spring** (weight downwards from centre of mass and equally sized elastic force upward from the point of contact between the spring and the mass) * **A ball on a sponge** (weight force downwards from centre of mass of ball, equally sized upward reaction force from the surface of the sponge) * **A ball on a table** (weight force downwards from centre of mass of ball, equally sized upward reaction force from the surface of the table) * **A cork floating in a bowl of water** (weight force downwards from the centre of mass of the cork, equally sized buoyancy force upwards from the surface of the water – students can stick the arrows on the outside of the bowl to represent the forces) * **A mass at the bottom of the bowl** (weight force downwards from the centre of mass of the object, equally sized reaction force upwards from the base of the bowl – students can stick the arrows on the outside of the bowl to represent the forces. Alternatively, they could place the weight force downwards and two force arrows pointing upwards – buoyancy and reaction force providing these two arrows add together to the same length as the downwards arrow) * **Two magnets repelling** (two equal and opposite magnetic force arrows pointing away from each other) * **A magnet held in a clamp attracting a paperclip on a thread that has been stuck to a bench** - see diagram below. (weight force acting downwards from the centre of the paperclip and an equally sized arrow pointing upwards from the top of the paperclip to represent the magnetic attractive force   In each case, students should realise that they need a pair of arrows of equal size acting in opposite directions. Brighter students can be asked where the back of the arrow should be placed   * Contact forces should originate at the point of contact. * Non-contact forces such as weight act from the centre of mass of the object. * Non-contact forces such as magnetism can be placed at the surface of the magnet. |
| **Resources**  **H&S considerations** | * Book suspended from spring – book, hook, string, spring * Makeshift bendy table - table legs, pliable wood, book * Circus of force experiments * Laminated or card arrows to represent forces   Hazards: springs catching fingers/eyes, trip hazard makeshift table  Ensure that all activities are carried out safely and calmly. Follow all your school’s health and safety protocols. Please discuss health and safety with your mentor. |