G-forces in flight teacher notes

Key Stage 3

Science:

- Forces and motion

Overview

Young people consider the forces that apply to an aircraft during flight. The context for the activities is the RAF's Red Arrows display team. Young people consider the effects of rapid changes in motion on the forces experienced by the pilots.

1. RAF Red Arrows and the forces on an aircraft
2. Forces and motion
3. G-forces and flight

NOTE: a suitable risk assessment must be performed before carrying out any practical activity.

Activity 1: Forces on an aircraft

Use the presentation to summarise the forces acting on an aircraft in flight. These are:

- forward thrust from the engine
- rearward drag caused by air resistance
- downward weight of the aircraft
- upward lift generated by the wings (or helicopter blades)

When flying level, and at a constant speed, the forces are balanced. Changes in direction require the forces to become unbalanced so that there is an overall force in the direction of the change.

Preparation

- Flying forces presentation
- Internet access to show Red Arrows video clip

Activity Notes

Use the presentation to introduce and summarise the forces acting on an aircraft during flight.

Use two video clips of the RAF Red Arrows to illustrate the extreme forces due to high speed changes in direction. Each clip is just over two minutes in duration.

What forces would the pilots feel? Why do pilots need to be strapped in? What forces have they felt on fairground rides or when cycling?

Clips are at:

Introduction to the Red Arrows: http://news.bbc.co.uk/1/hi/uk/8355531.stm

Plymouth air display: http://news.bbc.co.uk/1/hi/england/8236895.stm

Extension

Have young people practise using force meters to measure a variety of forces, to include:

- weight of a variety of suspended objects
- pulls by hand to experience the size of a particular force
- pulls by elastic bands attached to the force meters
- forces needed to drag objects across a range of surfaces and so give an indication of the force of friction

Activity 2: Forces and motion

Young people use plastic tubs as models for moving objects such as an aircraft.

A simple launcher (see student activity sheet) is used to look at forces and movement in a straight line. Tethering the tub to a central point allows young people to investigate forces on a turning object.

Throughout, the context is to model the forces on a pilot undertaking fast manoeuvres.

Preparation

- Tub launcher activity sheet
- Large rubber band
- Plastic tub (margarine tub or similar)
- Plasticine (to produce a sausage-shaped 'model pilot')
- String

Activity notes

Have young people set up the tub-launcher and investigate the effects of different forces on the motion of the tub. Young people should think about the forces acting on the tub and their resultant effects.

Use a simple rolled plasticine sausage shape to model a pilot inside their cockpit. What is their motion like? What forces act on the pilot? What happens when the pilot is not tethered in with seat belts? Have young people conclude that the pilot's motion continues when the tub hits a barrier or slows down due to friction with the surface it is sliding upon. So pilots are therefore tethered with seat belts that exert a force on the pilot as the aircraft (tub) changes its motion.

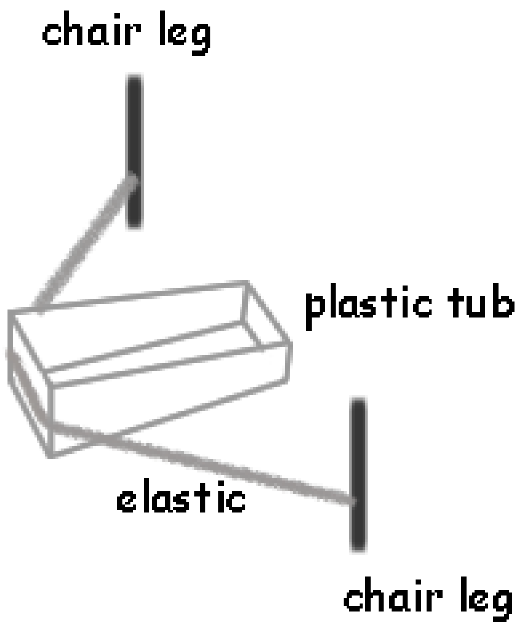
When the tub is tethered by string and pushed by hand it will move in an arc (or judder and change direction more violently). Using an un-tethered model pilot will further illustrate how the pilot's motion continues as the tub changes direction due to the forces applied through the string.

Extension

Use data loggers and motion sensors to measure the motion of the tub.

Use a video camera to capture the motion of the tub and use a slowed-down video clip to analyse its motion in detail.

Forces and movement



Make a launcher like the one shown in the diagram on the left.

Use it to launch the plastic tub along the floor.

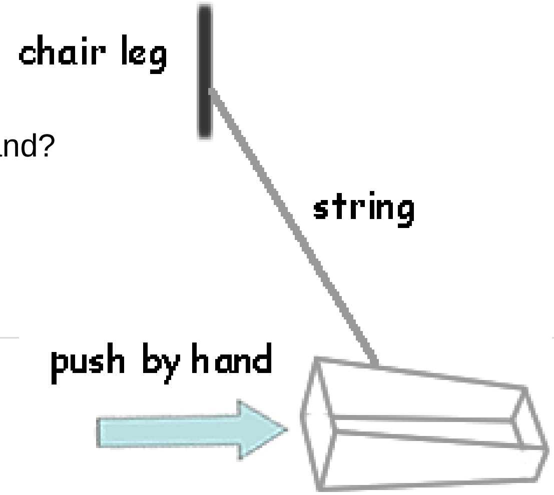
- Describe the forces acting on the tub when it is pulled back, ready for launch.
- What forces act on the tub when it is sliding along the floor?

Make a plasticine sausage shape as a 'model pilot' and put them in the tub.

- What happens to the pilot when the tub is launched and moves across the floor?
- What forces are acting on the pilot?
- What happens to the pilot if the tub is crashed into a barrier?
- Why does this happen to the pilot?
- Suggest and test how the pilot could be protected.

What is the motion of the tub like when it is tied to a leg and pushed by hand?

- Explain how the forces on the tub cause this motion.
- What happens to your model pilot?
- Describe the forces acting on your model pilot.
- How may these types of forces affect a real pilot?



Activity 3: G-forces

This simple activity helps young people understand the force of gravity and how changing the motion of an object can change its apparent weight. The context is the forces experienced by pilots as they perform high-speed manoeuvres.

Preparation

- Force meters (suitable range depends on the objects used – typically 0-10N is adequate.
- Range of masses
- 2 litre plastic bottles filled with water (2kg masses)
- Internet access for video clip of NASA 'Vomit comet' at: http://videos.howstuffworks.com/discovery/31724-spacewalkers-the-vomit-comet-video.htm

Activity Notes

What does '1G' feel like?

Introduce gravity as a force that attracts one object to another. On Earth, this is effectively the attraction of objects downwards towards.

The force of gravity gives an object its weight.

Have young people measure the weights of a range of familiar objects.

Have young people measure the weight of a 1kg mass to show that it is 10N.

Stress the point that mass is a constant whereas the weight of an object will vary depending on the gravitational pull it is under. e.g. 1kg would weigh less than 10N on the moon as its gravity is less than the earth.

Apparent 'weight' is also dependent on the object's motion.

What happens when an object is moving?

Have student suspend a 100g mass from their force meter and measure its weight.

Young people then pull the force meter upwards to accelerate the mass upwards. They are applying a force to change the objects' motion. What happens to the force meter? Does it go above the initial weight? Has the mass of the object changed?

Conclude that the apparent 'weight' of an object depends on its motion. So when pilots change direction, they experience their body as being heavier (or lighter) than normal. This gives rise to the term 'Pulling G.'

What would it feel like?

In racing cars, lateral G-forces around a corner can be in the region of 3G.

Assuming the mass of a person's head is about 5kg, what would they feel the weight of their head to be? This apparent weight (150N rather than 50N at 1G).

Have young people lift the 2kg plastic bottles to get a feel for the types of forces involved when.

Pilots in fast jets can experience 7G. How heavy would their head feel?

At high G-forces in a turn, a pilot's blood will be forced down to their lower body. This can starve the brain of blood and cause the pilots to black out. Pilots train to tense their abdominal muscles during manoeuvres or wear a pressure suit which applies pressure to the legs and abdomen to help prevent blood from pooling.

Have young people consider the effects on apparent weight of an object when it is falling towards earth. Use a video clip of NASA's 'Vomit Comet' to illustrate the point. This is a passenger jet that climbs to altitude and then dives downwards to achieve reduced gravity for its passengers. It is used for training astronauts.

A video clip can be viewed at:
http://videos.howstuffworks.com/discovery/31724-spacewalkers-the-vomit-comet-video.htm

Extension

Have young people research the accelerations and G-forces felt in a variety of activities, such as:

- Driving a road car
- Cycling
- Rollercoaster rides
- Passenger jets
- Space Shuttle take off