33 Motion and simple machines

A Acceleration and motion

If an object is **at rest** (not moving) and is free to move (not fixed), an **external force** – a force from outside – will make the object **accelerate.** This means the **velocity** of the object (the speed of its movement in a given direction) will increase. Velocity is measured in **metres per second (m/s).** If **acceleration** is constant – that is, if the **rate of acceleration** remains the same – it is measured as the increase in velocity (in metres per second) that is achieved each second. The unit of acceleration is therefore metres per second per second – stated as **metres per second squared** (m/s^2).

If an object is **in motion** (moving) and is subjected to an **opposing force** – that is, one acting on it in the opposite direction – the object will **decelerate.** As with acceleration, **deceleration** is measured in m/s^2. If something moves in a straight line, we say its movement is **linear** – a car accelerating and driving along a straight road is an example of **linear acceleration** and **linear motion.**

On earth, **acceleration due to gravity** is roughly $10\,m/s^2$. In other words, if an object is dropped and left to **free fall,** its velocity will increase by 10 m/s every second (not allowing for air resistance). Acceleration and deceleration, such as that generated by aircraft and cars, can be compared with acceleration due to gravity. This relative measure is called **G-force** (G stands for gravity). An acceleration of $10\ m/s^2$ is measured as **1 G**, $20\ m/s^2$ as **2 G** (or **2 Gs**), and so on.

B Inertia

The greater the **mass** of an object (see Unit 9), the greater the external force required to cause it to accelerate or decelerate. Resistance to acceleration or deceleration, due to the mass of an object, is called **inertia.** When an object is in motion, its resistance to deceleration, due to inertia, is often called **momentum.**

C Simple machines

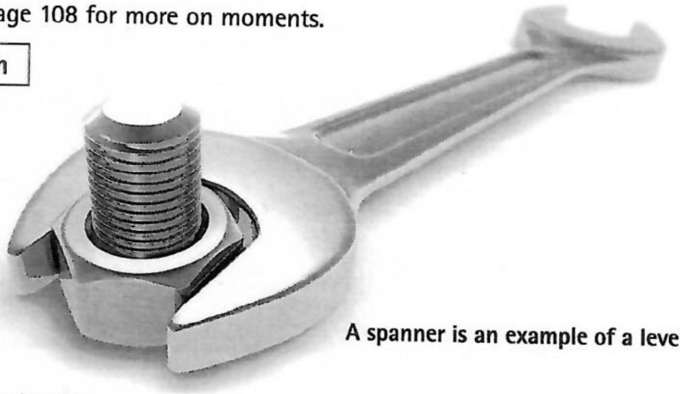
The word **machine** generally refers to an assembly which has parts that move. However, a **simple machine** can be a very basic device. A simple machine is something which provides a **mechanical advantage** – that is, the **load** generated by the machine (the force it puts out, or output) is greater than the **effort** (the force put in, or input) required to generate the load.

An example of a simple machine is a **lever,** which is used with a **fulcrum** – a point which acts as a support, and allows the lever to **pivot** (turn around the support). If the lever is placed so that the distance between the effort and the fulcrum is greater than the distance between the load and the fulcrum, a mechanical advantage is created.

In general language, the turning force generated by a lever is called **leverage.** In engineering, a turning force is called a **turning moment** (or **moment**). Moments are calculated by multiplying the distance from the fulcrum, in metres, by the magnitude of the force, in newtons. They are measured in **newton metres (Nm).**

Note: See Appendix VI on page 108 for more on moments.

BrE: spanner; AmE: wrench



A spanner is an example of a lever.

33.1 **Complete the article about the *Titanic*, taken from a popular science magazine. Look at A and B opposite to help you.**

It's been suggested that the passenger liner *Titanic* wouldn't have sunk after colliding with an iceberg in 1912, if it had hit the obstacle head on and damaged only the front of the ship. As history tells, the crew tried to turn to avoid the iceberg, and 1,517 lives were lost. But how severe would a frontal impact have been for the passengers? The answer depends on several questions:

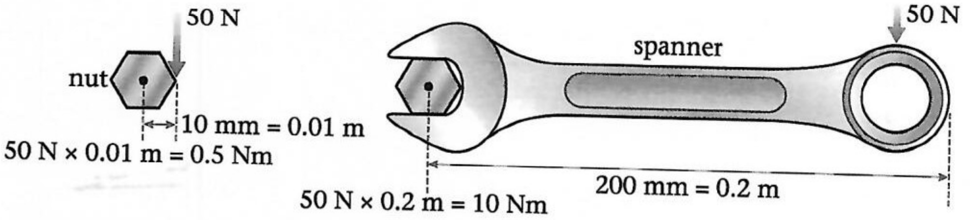
- The ship tried to slow while turning. Would (1) .... deceleration have been more effective, allowing the ship to (2) .... more rapidly?
- Based on this (3) .... of deceleration (and assuming the ship would not have stopped in time), what would the (4) .... of the ship have been at the moment of impact?
- What was the (5) .... of the iceberg? Calculating the approximate number of kilograms of ice would allow the (6) .... of the iceberg to be compared with the momentum of the *Titanic*. This would show whether the impact would have caused the iceberg to (7) .... to any significant degree, and so absorb some of the shock as it was pushed forward.

Clearly, the above questions depend on numerous unknown variables. So let's make a rough estimate. Let's assume the impact would have occurred at a pretty fast 25 kilometres per hour – that's seven (8) .... And allowing for some shock absorption from bending steel and crushing ice, let's say the ship would have stopped within three seconds (although it would probably have taken longer). This would have resulted in a deceleration of 2.3 (9) .... Expressed as a (10) ...., that gives 0.23 – less than one-third of the deceleration generated by a car braking heavily. So the impact probably wouldn't have caused too much of a shock to the passengers. Whether or not the ship would have sunk, however, is another question.

33.2 **Replace the underlined words and expressions with alternative words and expressions from A and B opposite.**

The first diagram below illustrates how a worker is able to apply a total (1) <u>force</u> of 50 newtons to the corner of a nut using just his fingers. The distance from the centre of the nut – the point around which the nut (2) <u>turns</u> – and the corner of the nut is 10 mm. This results in a (3) <u>force of leverage</u> of 0.5 newton metres. This is insufficient to tighten the nut properly.

The second diagram shows how a spanner can be used as a (4) <u>tool</u> to provide a (5) <u>boost in force</u>. Applying the same 50-newton force to the end of the 200 mm spanner, which acts as a (6) <u>turning tool</u>, generates 10 newton metres – a force 20 times greater, and enough to tighten the nut.



Over to you

Think about a simple machine you use or are familiar with. How does it provide a mechanical advantage, and how great is the advantage?