Measure Forces

Forces act everywhere.
They cause changes in motion and also act in situations where no motion takes place.

Dictionaries give many definitions for the word force:

strength	intense effort	pull	constrain
power	causes motion	causes acceleration	
compel	impose	push	intensity

Which of these words do you think most accurately describes force in the context of mechanics?

When an apple falls from a tree it accelerates towards the ground. Why?

In response to this question most people reply 'gravity'.
The idea of an apple falling to the ground is often associated
with Newton. Newton's genius was to find a single model
which explained not only the motion of an apple falling from
a tree to the ground, but also that of the Moon about the Earth,
and of planets around the sun.

He conjectured that to keep the Moon rotating
around the Earth, for example, there must be some
form of attraction (force) between them, otherwise
the Moon would travel off into space. Similarly,
the apple falls to the ground because there is a
force of attraction between it and the Earth.

Newton's Universal Law of Gravitation explains that this type of force between two bodies, namely gravity, depends on the mass of each body and the distance between them.

Mass and Weight

An object's **mass** is the amount of matter it
contains. The force of attraction exerted by
the Earth on the object is called the **weight**
of the object. The weight of an object is
proportional to its mass so the Earth exerts
a larger force on an adult than on a baby.
If an astronaut stands on the Moon, his mass
is the same as it would be on Earth, but his
weight is much less. The force of attraction
between the astronaut and the Moon is smaller
because the Moon has less mass than the Earth.

mass m

mass M

weight w

$a = g$
$\approx 9.8\text{ms}^{-2}$
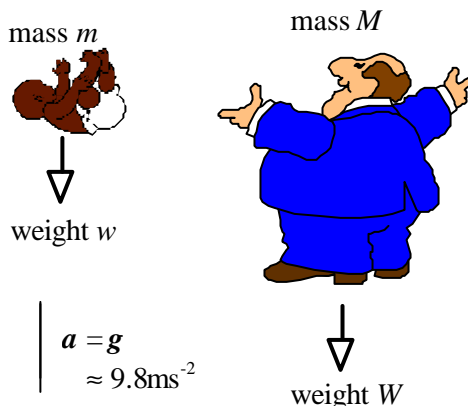
weight W

The weight, *W*, of a body is proportional to its mass.
So $W \alpha m$, or $W = k \times m$, where *k* is the constant of proportionality.

A **newton** is a unit of force such that a body of mass 1 kilogram weighs 9.8 newtons.
When this unit of force is used the constant of proportionality, *k*, has the same numerical
value as *g*, the acceleration due to gravity.

So if the mass of an object is *m* kilograms, then its weight, *W*, measured in newtons, is given
by **$W = mg$**.

You can use weighing devices such as kitchen scales
and spring balances to measure the weight of objects.
The kitchen scales or spring balance compares the force
against a scale that has been calibrated using the weights
of standard masses. For this reason they usually give
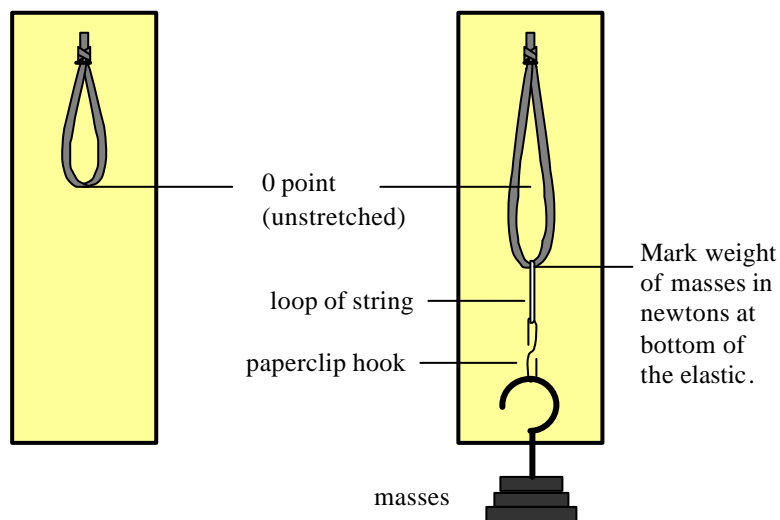readings in kilograms, rather than newtons.
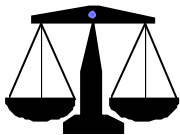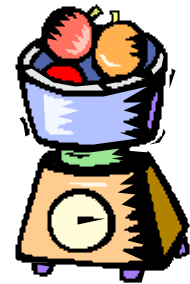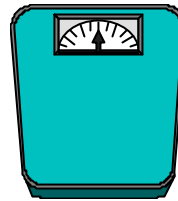
You can also compare masses of objects
using a balance device with scale pans.

The instructions below describe how to make a force meter called an elastoscale.

Making an Elastoscale
You will need a piece of elastic, a piece of string, a paperclip, a mass hanger and some
masses, a rectangular piece of stiff card (about 15 cm by 5 cm), a stapler and sticky tape.

- Stretch the elastic a few times to remove any initial stiffness.
- Double the elastic and tie a knot in the end.
- Staple the elastic to the card just below the knot (as shown below) and use some sticky
  tape to secure it firmly.
- Calibrate using different masses.

0 point
(unstretched)

Mark weight
of masses in
newtons at
bottom of
the elastic.

loop of string

paperclip hook

masses

- Use your elastoscale to find the force needed to lift a book, pull open a door, drag a book
  along a table, lift up an apple etc.

Investigate Forces

Consider two tugs pulling a large tanker into harbour. Model the tanker as a particle, so that the point of attachment of the lines from the tugs is a single point.
(This is a simplification of the actual situation - in practice attaching the tugs to each side of the bows allows the tanker to be rotated.)

What do you think are the answers to the following questions?

forward

To keep the tanker moving forward, which tanker has to pull harder in these cases?

Can 2 tugs pulling in different directions pull the tanker forward?

What would happen if the tugs pulled with the same strength in opposite directions? (not shown in diagrams)

Use two elastoscales and an object (eg book, pencil case) on a table to model this context and investigate the situations shown. Use the elastoscales to measure the sizes of the forces needed to pull the object forward and a protractor to measure the direction between each string and the forward direction. Write a brief summary of what you find.

Were your answers to the tug questions correct?

From this activity you should conclude that, when considering forces, the following factors are important:

- the magnitude of the force
- the direction of the force
- the point at which the force is applied.

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Teacher Notes

Unit   Advanced Level, Dynamics

Notes on Activity
The first page of this activity introduces forces and briefly explains how Newton used the concept of gravity to link the motion of falling objects and orbiting planets. After defining weight and the units (newtons) in which it is measured, this resource then shows how to make and use an elastoscale to measure forces and investigate their effects. If you wish students could use spring balances instead of elastoscales to carry out the activity on page 3.

The instructions for making an elastoscale and the tug examples originally appeared in the book *Mechanics 1* which was funded by the Nuffield Foundation and published by Longman in 1994 (ISBN 0-582-09979-X).