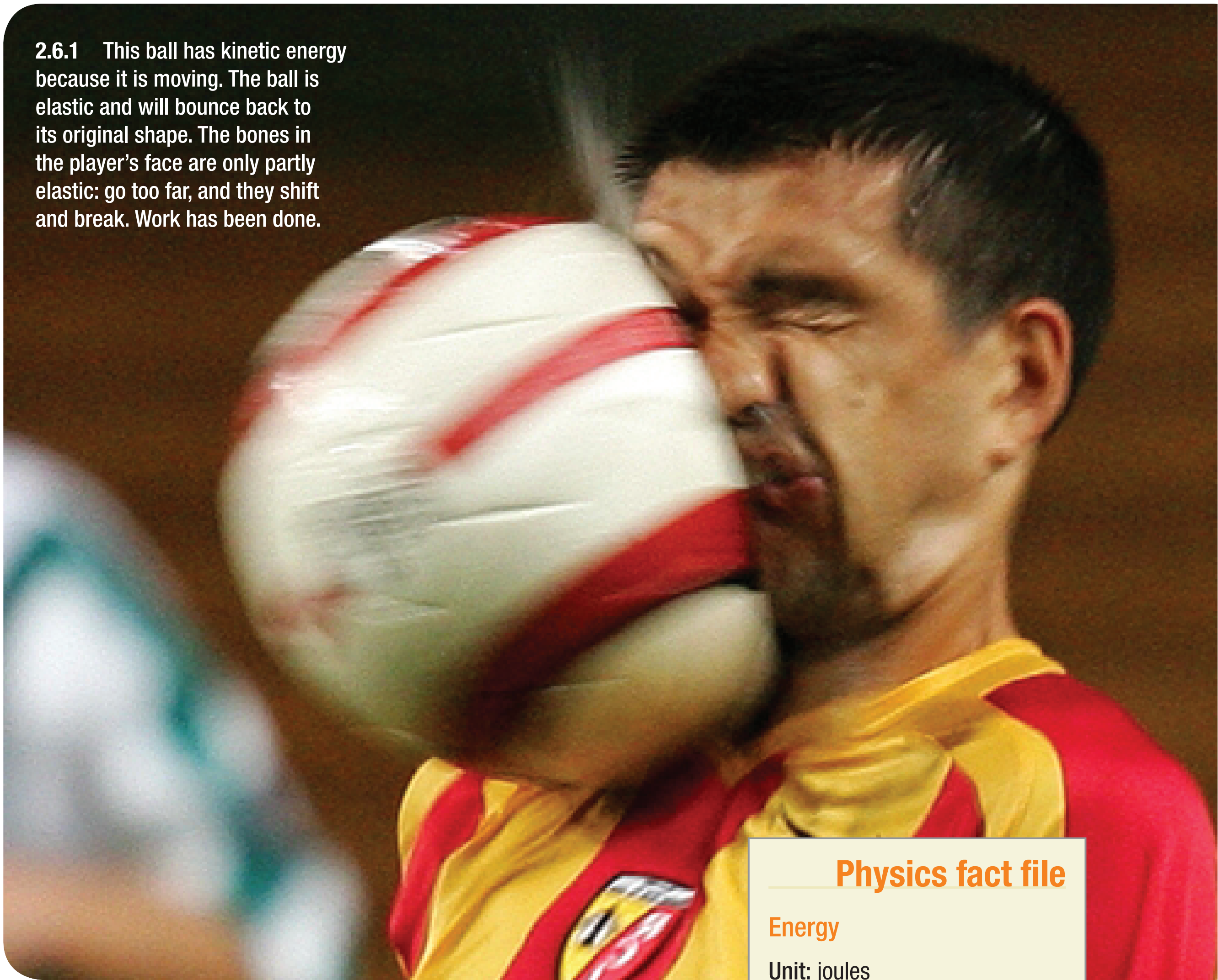
# Unit 2.6 Movement needs energy

**Energy comes in many different forms and can be converted from one form into another. Energy is what makes things happen. It cooks sausages, powers chemical reactions, causes light bulbs to glow and it can get things moving. All movement involves energy. Energy is the ability to do work.**



**2.6.1** This ball has kinetic energy because it is moving. The ball is elastic and will bounce back to its original shape. The bones in the player's face are only partly elastic: go too far, and they shift and break. Work has been done.

**Physics fact file**

**Energy**

**Unit:** joules

**Unit abbreviation:** J

## Work

**Work** is done whenever things are shifted or rearranged by a force. The bigger the force, the more work done. If something is shifted a long way, then more work is done than if it only moves a little. If it doesn't move, then no work has been done on it.

Work = force applied × distance shifted

or $W = Fx$

Force is always measured in newtons (N) and distance in metres (m). Work is a form of energy and, like all energy, is measured in joules, abbreviated as J.

For example, if a heavy crate takes a force of 500 N to shift it 3 m, then the work done on it is:

$W = 500 \times 3 = 1500$ J

The work done in a car crash is very obvious. The car and its occupants can undergo radical rearrangement: bonnets crumple, windscreens shatter, bones break. Forces are applied and things are shifted. Work is done. Where did the energy to do this work come from?

## Kinetic energy

Movement is needed for cars to crash: no accident can happen if everything is stationary. When something moves it has **kinetic energy**. The heavier the car, the more kinetic energy it has and the more work and damage it can do. Likewise, the faster it travels, the more work will be done. If its speed doubles, then the work done in a collision and the damage caused will be four times what it was at the slower speed.

Kinetic energy = ½ × mass × speed × speed

or $KE = \frac{1}{2} mv^2$

Kinetic energy is measured in joules (J), mass in kilograms (kg) and speed in metres per second (m/s).

For example, the kinetic energy of a typical 1.5 tonne (1500 kg) car travelling at 50 km/h (13.9 m/s) is:

$$KE = \frac{1}{2} \times 1500 \times 13.9^2$$
$$= 144\,908 \text{ J}$$

On braking, all this kinetic energy is converted into heat energy that is released or dissipated by the brake pads or discs. In a collision, it converts into heat and sound, but mainly into work as it crumples or crumples other cars or objects—a lot of rearranging is done in an accident.

## Gravitational potential energy

Similar damage would be sustained if a car ran off a cliff. The higher the cliff, the worse the situation. Obviously height gives the car energy, too.

**Potential energy** is stored energy—it gives the object the potential to do work. An object is given **gravitational potential energy** whenever it is lifted. The heavier the object is and the higher it is lifted, the more energy it will have, and the more damage it will cause when let go. This can be written mathematically as:

gravitational potential energy = mass × acceleration due to gravity × height

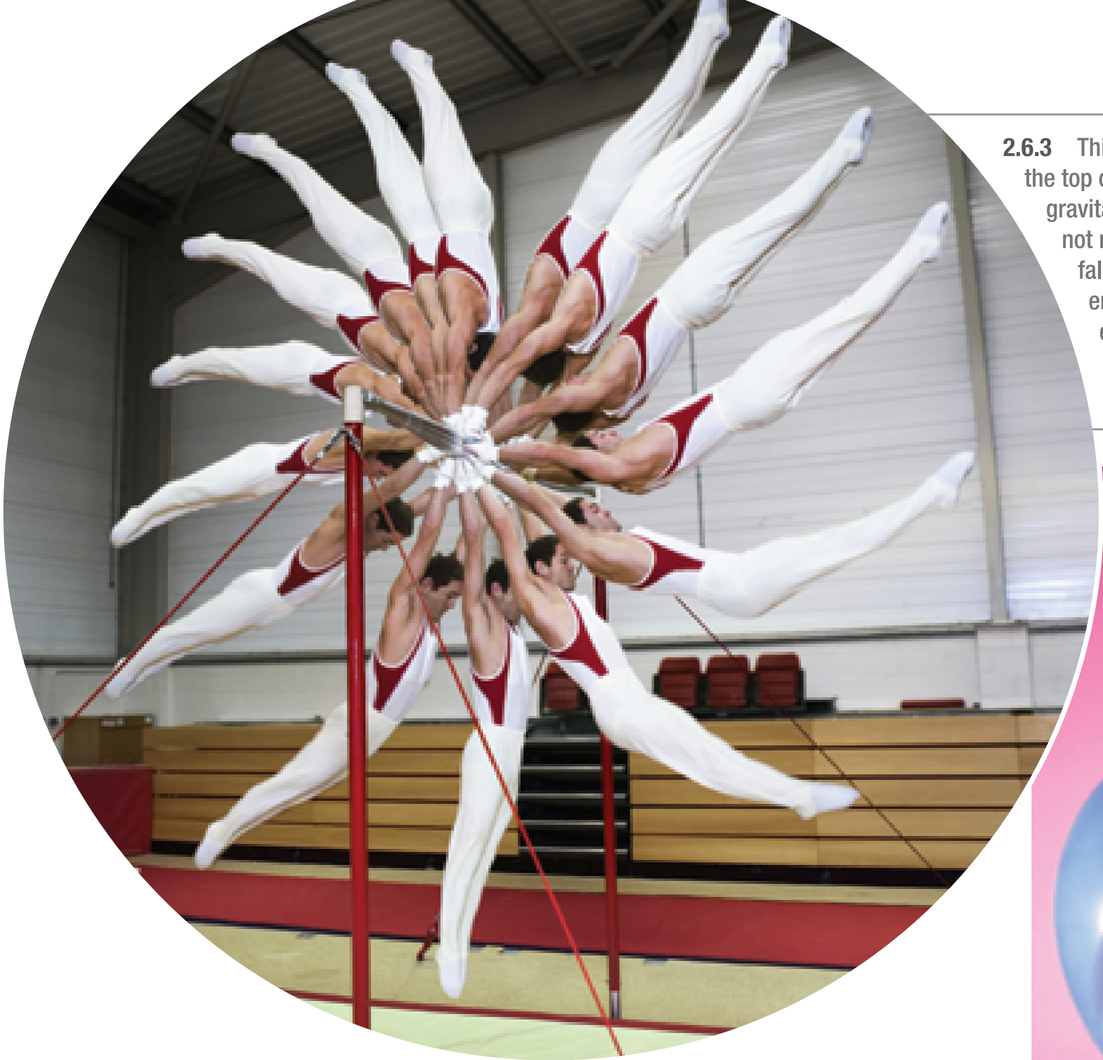
or

$$GPE = mgh$$

$GPE$ is measured in joules (J), $m$ in kilograms (kg) and $h$ in metres (m). Like all accelerations, $g$ is measured in metres per second squared (m/s$^2$). On Earth, $g$ is 9.8 m/s$^2$.

As something falls, it picks up speed. Its gravitational potential energy is converted into kinetic energy. When it hits the bottom, most of its energy will be converted into work done on the ground and on the object itself. Both the ground and the object will dent and change shape or break.

**2.6.2** Anything moving has kinetic energy. This energy has to come from somewhere. Cyclists use chemical energy gained from food to pedal their bikes. Chemical energy is converted into kinetic energy.



2.6.3 This gymnast is slowest at the top of his swing: he has lots of gravitational potential energy but not much kinetic energy. As he falls, gravitational potential energy converts into kinetic energy. As a result, he travels fastest at the bottom of his swing.

2.6.4 A balloon stores elastic potential energy as it stretches, ready to release it as it bounces back to its original size and shape when let go or when it is burst.

## Elastic potential energy

Elastic bands and springs store energy when they are stretched or extended. They store this energy as **elastic potential energy**. They have the potential to release energy and do work when let go, bouncing back to their original shape. This is very obvious when a slingshot is stretched and let go. Energy is put into stretching the elastic band. The more a slingshot is stretched, the more energy it stores, the more kinetic energy the projectile will have, the faster it will go and the more damage (work done) it will do.

Springs also store energy when squashed or compressed. Tennis balls act as a store of elastic potential energy when compressed on a bounce or when hit. The more the ball stores, the more it releases and the higher it will bounce. Some of this energy is converted into heat.

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## Efficiency

Friction between moving surfaces wastes useful energy, converting some of it into heat and sound. **Efficiency** is a measure of how much useful energy is retained in a conversion:

$$\text{Efficiency} = \frac{\text{useful energy after the conversion}}{\text{energy before the conversion}} \times 100\%$$

A rolling ball eventually stops due to friction. All of the kinetic energy it once had has been converted into heat and sound: the efficiency is zero. A machine that was 100 per cent efficient would be perfectly quiet and would run forever because all the energy conversions would be perfect.

A ball loses a little of its useful energy each time it bounces. Squash balls have very little bounce and are incredibly inefficient, losing most of the energy to heat. The ball gets hot quickly, which then gives it more elasticity and better bounce.

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# Unit 2.6 Review questions

## Revision questions

### Work

1 Which of the following situations does not involve any work being done?
   - a A 10 kg crate is lifted up 2 m.
   - b A car is pushed along a road.
   - c A spacecraft travels through the Solar System without being affected by air resistance or gravity.
   - d A skateboard rolls to a stop.
   - e A book sits on a desk.

### Kinetic energy

2 What factors make an accident worse?

3 Write the formula for kinetic energy, defining each term used and the unit it is measured in.

### Gravitational potential energy

4 Why is gravitational energy referred to as a potential energy?

5 Write the formula for gravitational potential energy, defining each term used and the unit it is measured in.

### Elastic potential energy

6 Identify two ways in which a slinky spring can store elastic potential energy.

7 A slingshot holding a stone is stretched and let go. Into what forms is the elastic potential energy converted?

### Efficiency

8 a If a tennis ball was 100 per cent efficient it would bounce forever. Explain why.
   - b In reality, a tennis ball will bounce a little less each time. Energy is wasted. What is it being converted to?

## Thinking questions

9 Suggest what type of energy can be referred to as:
   - a 'moving' energy
   - b 'spring' energy
   - c 'height' energy
   - d 'rearranging' energy.

10 Crumple zones are incorporated into the front and rear of modern cars to convert the energy of the collision into work on the panels. It does this by allowing them to buckle instead of remaining rigid. If these zones were not there, what would crumple to absorb energy?

11 'If speed is doubled, the car accident will be twice as bad.' Use kinetic energy to support or contradict the statement.

12 How can you tell that the gymnast is travelling faster at the bottom of the swing in 2.6.3 than at the top?

## Analysis questions

13 Calculate the work done in shifting a trolley 5 m with a 20 N force.

14 What is the kinetic energy in the following?
   - a Nathan is on a 400 kg motorbike, travelling at 25 m/s.
   - b Travis is a 50 kg skateboarder, freewheeling at 9 m/s.

15 Calculate the gravitational potential energy that the following objects have.
   - a Carol (55 kg) is on the Q1 observation deck, 323 m above the street.
   - b Yee is piloting Flight 007 at a height of 9500 m. Her mass is 70 kg.

16 Tanya is about to dive off the 10 m board. Her mass is 50 kg.
   - a Calculate her gravitational potential energy before the dive.
   - b This energy had to come from somewhere. Suggest where. (Hint: How did she get there?)
   - c When she dives, into what form does the potential energy convert?
   - d What proof is there?
   - e What should be her kinetic energy just before she enters the water?
   - f Where does all this go when she enters the water?

17 A 0.5 kg ball is dropped from 2 m and bounces back to a height of 1.5 m. Calculate the gravitational potential energy before and after the bounce. Calculate its efficiency.

**Workbook** Activity 2.6 **Workbook** Activity 2.7 **Workbook** Activity 2.8

# Unit 2.6 Practical activities

## Prac 1 Unit 2.6

### Extension of an elastic band

**You will need**

Two elastic bands, retort stand, boss heads and clamps, 50 g masses, ruler

**What to do**

1 Copy the table below.

| Mass attached (g) | Length (mm) | Extension of single band (mm) | Extension of two bands end-to-end (mm) | Extension of two parallel bands (mm) |
|---|---|---|---|---|
| 0 | | | | |
| 50 | | | | |
| 100 | | | | |
| 150 | | | | |
| 200 | | | | |
| 250 | | | | |

**Part a**

2 Measure the natural, unstretched, length of an elastic band.

3 Hang a single band from the retort stand and attach a single 50 g mass.

4 Measure its new length and calculate the extension the 50 g mass has caused.

5 Repeat for 100 g, 150 g, 200 g and 250 g.

6 Plot a graph of mass (g) (vertical axis) against extension (mm). Draw a line of best fit through the points.

**Part b**

7 Repeat the process for the other elastic band arrangements shown.

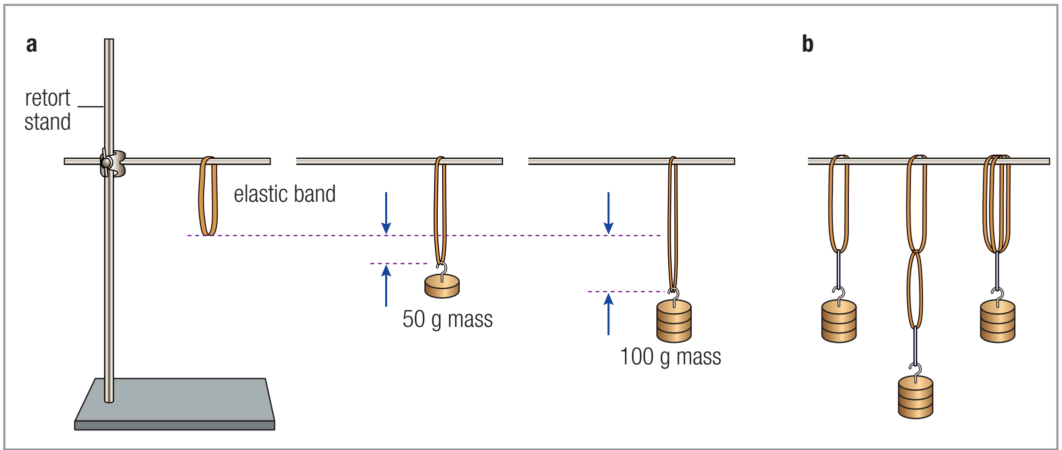
8 On the same graph, plot the graphs of these arrangements.

**Questions**

1 What energy is being stored in this experiment?

2 Stiff materials are those that take a lot of force to stretch. Which was the stiffest arrangement of bands?

3 Which arrangement of bands produced the steepest graph?




2.6.5