Unit 6 Mechanical systems and control: investigation

gear ratio – the number of turns of one gear compared to the other is known as gear ratio

speed ratio – the gear ratio of a gear train, also known as its speed ratio, is the ratio of the angular velocity of the input gear to the angular velocity of the output gear

velocity ratio – same as gear ratio

In this unit you will investigate gears, cams and cranks. You will also communicate the results of your investigation using graphic skills.

1 Gear ratios

Mechanisms and machines that use gears and gear systems will be with us for many years to come. In this unit you will learn about mechanisms that change the direction of movement.

You all know what a bicycle looks like. A bicycle cycles easier uphill when the gears are changed. Why? When you change the gears, the **gear ratio**, **speed ratio** or **velocity ratio** also changes. This is determined by the number of teeth on each gear wheel.

When A makes a complete rotation the 15 teeth move past point Y in **FIGURE 40**. Because the gears engage and cannot slip, the 15 teeth on the driven gear also move past point Y. For each full rotation that the driver gear makes, the driven gear makes a quarter turn. If the driven gear makes a quarter rotation while the driving gear makes a full rotation, the driven gear will rotate at a quarter of the speed of the driver gear. You can calculate the speed ratio, also called the gear ratio, of the given system by means of the following equation:

$$\text{Gear ratio} = \frac{\text{number of teeth of the driven gear}}{\text{number of teeth of the driver gear}}$$

$$\text{Gear ratio} = \frac{15}{60}$$

$$= \frac{1}{4}$$

$$= 1 : 4 \text{ (driven gear : driver gear)}$$

An easy way to understand this is to have a close look at **FIGURE 43**. If the pedal gear revolves once, how many times will the sprocket (back wheel) revolve?

The following formula can be used to determine the answer:

$$\frac{\text{Number of teeth on the sprocket (30 teeth)}}{\text{Number of teeth on the pedal gear (60 teeth)}}$$

As 30 divides in to 60 twice, the gear ratio or speed/velocity ratio will be: 1 : 2.

That means the ratio of the pedal gear to the sprocket gear is 1 to 2.

Revision

Different sized gears result in a change in the velocity ratio as well as an opposite change in the force ratio – if force increases, speed decreases, and vice versa.

In your groups study the given MA symbols of equal and unequal gears. Try to work out the following questions:

1 Find out which MA is right and which one is wrong? < or > 1.
2 Can both be correct? If so, why?

gear train – system made up of two or more gears

What will happen if a cyclist going up a hill changes gear from a larger to a smaller gear wheel? Will it be easier or harder to pedal? The reason bicycles are easier to cycle up a hill when the gears are changed is due to what is called gear ratio. A gear ratio is also called a velocity ratio.

Velocity ratio can be worked out in numbers. Basically, the ratio is determined by the number of teeth on each gear wheel.

Velocity ratio can be determined as follows:

$$\text{Velocity ratio (gear ratio)} = \frac{\text{number of teeth of the driven gear}}{\text{number of teeth of the driver gear}}$$

Let us imagine a gear system where the driver gear is the pinion with 15 teeth, and the driven gear is the wheel with 60 teeth. You can work out the velocity ratio by using the given formula:

$$\text{Velocity ratio (gear ratio)} = \frac{\text{number of teeth of the driven gear (60 teeth)}}{\text{number of teeth of the driver gear (15 teeth)}}$$
$$= \frac{60}{15}$$
$$= \frac{4}{1}$$
$$= 4:1 \text{ (driven gear : driver gear)}$$

This means that the driven gear will turn 4 times for every 1 rotation the driver gear makes.

In the illustration of bicycle gears you can see that the pedal gear or front gear, also called the driver gear, differs in size from the back gear. Changing the velocity ratio forces the cyclist to use more force on the driver gear which is the bigger gear.

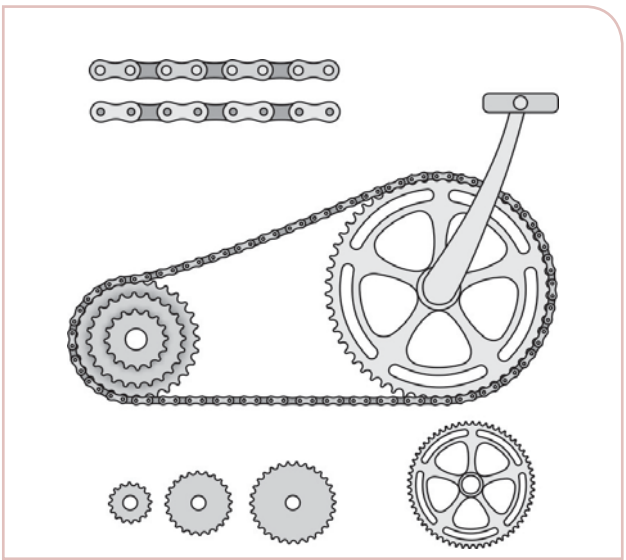

FIGURE 11 Velocity ratios in bicycles

3.2 Two spur gears connected via an idler

A gear train is usually made up of two or more gears. The first gear may be rotating in a clockwise direction. The second gear then rotates in an anti-clockwise direction. The third gear would rotate in a

FIGURE 17 100 g is equal to 1 Newton.

An easy method to calculate the mechanical advantage of a mechanism is to use the following equation:

$$\text{MA (mechanical advantage)} = \frac{\text{load}}{\text{force}}$$

Which of these two will have the biggest mechanical advantage: a force multiplier or a distance multiplier?

We measure load as well as force in **Newton** (N).

A force that is 1 N strong is equal to the weight (which is the force of gravity) of 100 g mass. Experience 1 N force next time you go to a shop. Hold a 100 g slab of chocolate in your hand and feel how heavy it is. That is 1 N.

Newton – the unit of force

Exercise 1

Do this exercise in your workbook:

1 A man can lift a load of a 1 000 N using a force of only 200 N if he uses a lever. What is the weight of the load in kilograms? Apply the equation as follows to determine the real-life situation:

$$\text{MA (mechanical advantage)} = \frac{\text{load}}{\text{force}}$$

The man, force, lifts a load of 1 000 N. He used 200 N to lift the load.

$$\text{MA} = \frac{1\,000\text{ N}}{200\text{ N}} = 5 \times 100\text{ g} = 500\text{ g} = \frac{1}{2}\text{ kg}$$

The MA will, therefore, be 1 000 N : 200 N = 5 : 1.

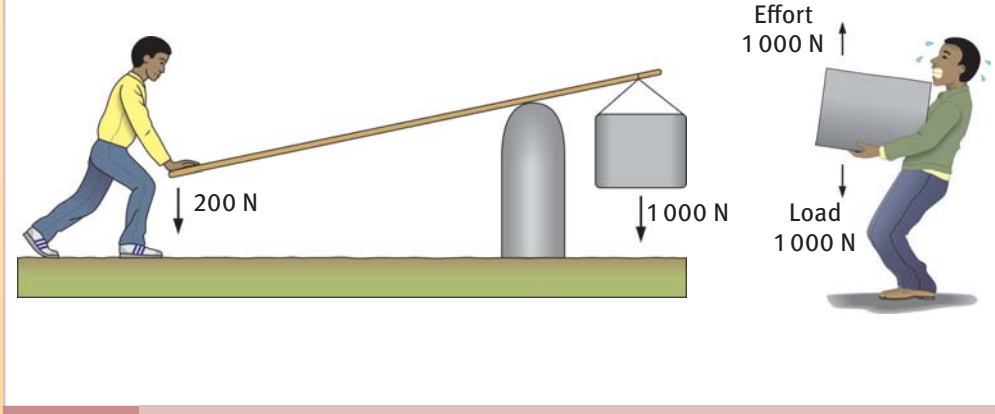

FIGURE 18 Determining Newton forces

Exercise 1 continues ▶

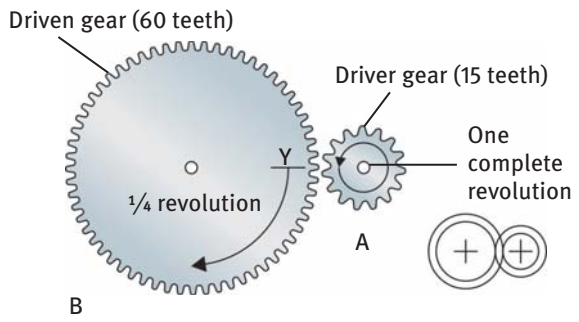

FIGURE 22 Use this diagram to help you calculate gear ratios by means of tooth ratios.

3.1 Calculations using tooth ratios

Use the illustration to calculate how the number of teeth can influence the speed ratio of mechanisms.

Use the number of teeth in the illustration to calculate the gear ratio by means of tooth ratios in gears.

Use the following equation:

$$\text{Gear ratio (velocity ratio)} = \frac{\text{number of teeth of the driven gear (60 teeth)}}{\text{number of teeth of the driver gear (15 teeth)}}$$

$$= \frac{60}{15}$$

$$= \frac{4}{1}$$

$$= 4:1 \text{ (driven gear : driver gear)}$$

MA ratio will be 4 : 1.

3.2 Calculating gear wheel diameter

A gear's most important feature is that gears of unequal sizes (diameters) can be combined to produce a mechanical advantage, so that the rational speed and torque of the second gear are different from that of the first. A different arrangement of different gear sizes is also referred to as the 'gear ratio', using the number of teeth or gear diameter as units. By using different gear diameters to work as a pair one can easily change or determine the mechanical advantage of a particular gear combination.

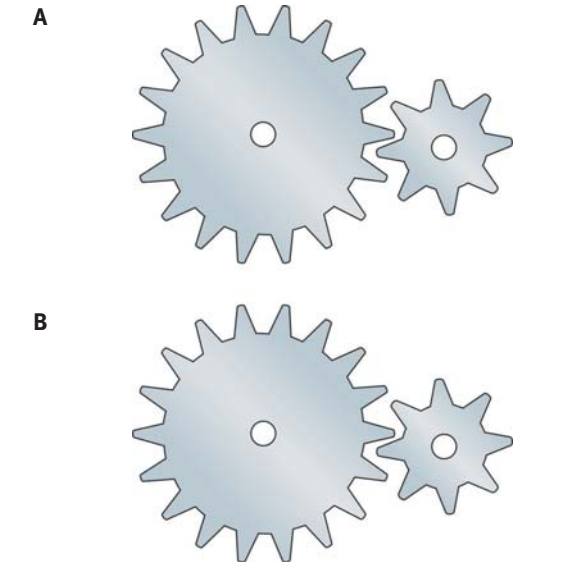

FIGURE 23 Use these diagrams to calculate gear wheel diameter.

Analyse A and B to see whether you understand the following:

1 In A the driven is the bigger gear with 60 teeth.
2 In B the driver is the smaller gear with 15 teeth.

The mechanical advantage (MA) that allows machines to perform more work with less effort, will, therefore, not be the same. Use the following equation to work out the mechanical advantage of both illustrations.

$$\text{MA} = \frac{\text{output force}}{\text{input force}}$$

Unit 4 Design and investigation skills

jockey rollers – tension rollers on a bicycle

This unit focuses on skills that are needed in designing and investigating problems in technology. You will analyse bicycle gear systems and draw systems diagrams. You will also learn how to plan a mechanical system that produces a specific output.

Activity 1 Sketches

Revise all the work that you have done on gears. Once you are sure that you understand everything, you are ready to sketch the various gear systems.

1 Make 2D sketches showing systems that:

a Provide an output force four times greater than the input force (MA = 4 : 1).

In this illustration your system works as follows:

Driver gear = 15 teeth: Input force gear

Driven gear = 60 teeth: Output force gear

Required ratio wanted: $4:1\ [\frac{\text{Output } 4}{\text{Input } 1}]$

4 : 1 (driven : driver)

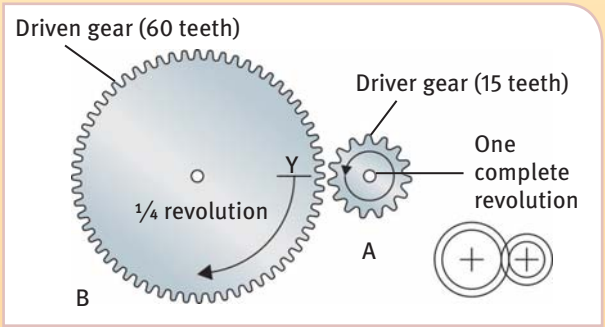

FIGURE 31 The components of a gear system

Analyse the illustration and you will understand how to obtain an output force that will be four times bigger than the input force, MA = 4 : 1.

b Provide double the rotation rate on a driven axle at 90° to the driver axle.

The bigger gear, the driver, must have 40 teeth. The smaller gear, driven, must have 20 teeth.

$$\text{Ratio} = \frac{20 \text{ driven}}{40 \text{ driver}}$$

$$= \frac{1}{2}$$

= 1 : 2 (driven : driver)

Provide double the rotation rate on a driven axle at 90° to the driver axle.

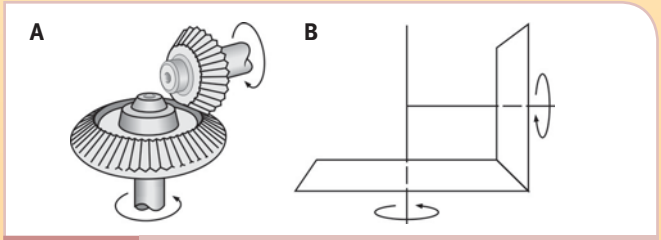

FIGURE 32 Provide double the rotation rate on a driven axle at 90° to the driver axle.

FIGURE 33 System analysis of a bicycle gear system

1 System analysis – bicycle gear system

The gear system of a bicycle provides a good example of a system that we can analyse. Before you analyse the system, try to have a good look at the gears of a real bicycle. The picture in **FIGURE 33** will also help you. This picture shows all the different mechanisms