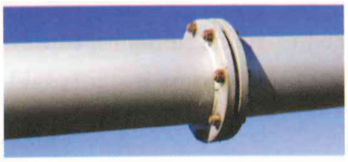
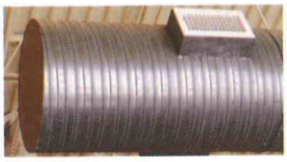
# 37 Fluid containment

## A Pipes, ducts and hoses



A pipe



An air duct

A hose

**Pipes** are rigid tubes, made from materials such as steel and plastic. They carry **fluids** (liquids or gases). Pipes can be fitted together with different **pipe fittings** (see Appendix IX on page 111). Assemblies of pipes are often referred to as **pipework**.

**Mains** are underground pipes for water and natural gas. **Water mains** and **gas mains** run beneath the streets of cities to supply buildings.

**Pipelines** are long-distance pipes, often above ground, for crude oil or natural gas.

**Drains** are underground pipes that carry waste water. Large drains, as found below the streets in cities, are called **sewers**. Drains and sewers rely on gravity to allow them to flow. They therefore have a downward slope, called a **fall**.

**Ducts** are pipes used for moving air that is not under pressure – usually for heating or air-conditioning. **Ductwork** often consists of rectangular cross-section ducts.

**Hoses** are flexible tubes, often made from plastic, for liquids and gases. They are fitted together using **hose fittings** (or **hose couplings**). Examples of hoses are fuel hoses and compressed air hoses – sometimes called **fuel lines** and **air lines**.

**Note:** In everyday English, **fluid** usually means a liquid. In physics and engineering, the word refers to both liquids and gases.

## B Tanks

A **tank** is a container for liquid or gas. It may be **watertight** (will not leak water) and open at the top. It may also be enclosed and **airtight** (will not leak gas), and may contain gas that is under pressure.

A **pressure vessel** is a tank for storing gas – or a mixture of liquid and gas – that is under pressure. The **vessel** must therefore be **sealed** – with no openings, so that gas cannot escape. It must also be strong enough to withstand the pressure inside. Pressure vessels include small portable **gas cylinders** (also called **gas bottles**). Some pressure vessels also function as **boilers** – they heat the liquid inside them in order to boil it and increase pressure – for example, a water boiler that produces high-pressure steam.

## C Pumps, fans and turbines

Liquids can be forced to **flow** (move) along pipes by mechanical devices called **pumps**. For example, in cars, fuel is **pumped** from the fuel tank to the engine by a fuel pump. The **flow** of fluids can be controlled by **valves** (see Appendix IX on page 111). A pump used to increase the pressure of gas is called a **compressor**.

A device powered by a motor which rotates in order to move air or gas – for example, along a duct – is called a **fan**. A **turbine** has the opposite function to a fan – it is designed to be moved by a flow of air or gas. For example, a **wind turbine** revolves due to the wind, and can be used to drive a generator (to generate electricity).

This compressor produces compressed air for powering tools.

**37.1** Complete the emails about the design of a new manufacturing plant using words from A opposite.

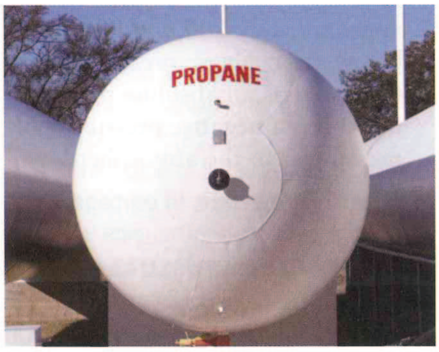
> **New Message**
>
> Air temperature will be high in this area, due to the presence of four large-diameter steel steam (1) .................... running along the ceiling. This opens up the possibility of extracting hot air and transferring it, via (2) ...................., to other areas of the plant, for heating use.

> **New Message**
>
> Given that this machine will move to an extent, due to vibration, it should be connected to the water supply using a flexible (3) ...................., rather than a rigid (4) .................... . The pressure of the supply may also need to be increased, depending on the pressure of water coming into the plant from the (5) .................... .................... .

> **New Message**
>
> Waste water will exit the plant via a (6) .................... on the western edge of the site. This will run into the (7) .................... under the street on the north side of the plant. The survey has confirmed that the level of the site, relative to the street, will allow an adequate (8) .................... .

**37.2** One sentence in each pair is false. Choose the true sentence. Look at A and B opposite and Appendix IX on page 111 to help you.

1 a All gas cylinders are pressure vessels.
  b All pressure vessels are gas cylinders.
2 a Elbows are types of pipe or hose fitting.
  b Pipe or hose fittings are types of elbow.
3 a Any watertight tank will also be airtight.
  b Any airtight tank will also be watertight.
4 a All pressure vessels are types of tank.
  b All tanks are types of pressure vessel.
5 a A pipe is a specific sort of pipeline.
  b A pipeline is a specific sort of pipe.



A propane gas tank

**37.3** Change one word in each of the sentences below to make them correct. Look at C opposite and Appendix IX on page 111 to help you.

1 A fan is designed to be driven by a flow of air or gas.
2 A pump used to increase the pressure in a vessel is called a turbine.
3 A safety valve is an inlet which releases excess pressure.
4 A non-return valve is also called a safety valve.
5 Some valves can be partly closed to stop a flow, reducing its rate.

## Over to you

Think about a machine or installation you're familiar with, in which liquid or gas is stored, supplied or circulated. What equipment is used to contain the gas or liquid? How are flow and pressure managed?

# 38 Fluid pressure

## A Gauge pressure and absolute pressure

**Pressure** is the amount of force acting on an area. When **fluids** (liquids or gases) are **under pressure** they **exert pressure on** the surfaces of the tanks, pipes, etc., that hold them. Examples of **pressurized** fluids are **compressed air** inside air hoses, **compressed gases** such as propane in gas cylinders, and water in water mains. The SI measurement of pressure is the **Pascal**. One Pascal is equal to one newton per square metre (1 Pa = 1 N/m$^2$). However, many **pressure gauges** (devices which measure pressure) use the imperial measurement **pounds per square inch** (**psi**). Pressure can also be measured in **bars**. One bar is roughly equal to **atmospheric pressure** – that is, the pressure of the air in the atmosphere – at sea level. For example, **four bars**, or **four bar** – which can also be described as **four atmospheres** – is four times atmospheric pressure.

When engineers calculate the pressure of a fluid inside a vessel, they usually calculate its **gauge pressure**. This is the **pressure differential** – the difference in pressure – between the fluid inside the vessel and atmospheric pressure outside. Therefore, with gauge pressure, it is assumed that the atmosphere has a pressure of zero Pascals – even though this is not true (see below). Engineers use gauge pressure because they need to know if a fluid inside a vessel is **at a higher pressure** or **at a lower pressure** than **the outside air** (the air in the atmosphere), and if it is, by how much. This allows them to design tanks and pipes so that they do not fail dangerously by **exploding** if their gauge pressure is positive, or by **imploding** if their gauge pressure is negative.

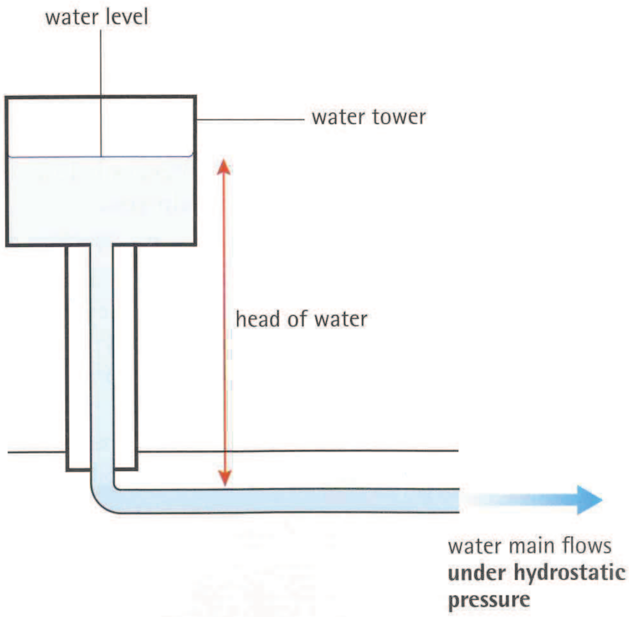
Pressure can also be measured by comparing it with a **vacuum** – a void containing no gas or liquid, as in space, where pressure is truly zero Pascals. Pressure compared with a vacuum is called **absolute pressure**. The absolute pressure of the atmosphere at sea level is approximately 100,000 Pascals (or 100 kilo-Pascals). Therefore a **partial vacuum** – which is below atmospheric pressure but is not a **perfect vacuum** – has a **positive pressure** when it is measured as an absolute pressure, because it has a higher pressure than a perfect vacuum. But it has a **negative pressure** when it is measured as a gauge pressure, because it has a lower pressure than the atmosphere.

**Note:** See Appendix III on page 100 for more on imperial measurements.

## B Hydrostatic pressure and siphonic action

In liquids – most often in water – pressure and flow can be generated by **hydrostatic pressure**.
An example is a water tower which supplies drinking water to homes. Water is stored in the tower at a high level, so that the water pushes down. This is called a **head of water**. It puts the water at lower level (in the water main) under pressure. If the height of the water tower is increased, this will increase the water pressure at low level. Smaller tanks located at a high level to generate hydrostatic pressure – at the tops of buildings, for example – are called **header tanks**.

**Note:** See Appendix X on page 112 for a description of **siphonic action**.



**38.1** Complete the sentences using the words *positive*, *negative* and *zero*.

1 In a perfect vacuum, absolute pressure is .............................. and gauge pressure is .............................. .
2 In a partial vacuum, absolute pressure is .............................. and gauge pressure is .............................. .
3 At atmospheric pressure, absolute pressure is .............................. and gauge pressure is .............................. .
4 In compressed air, absolute pressure is .............................. and gauge pressure is .............................. .

**38.2** Use the expressions in the box to complete the article about pressurized aircraft cabins, taken from an engineering journal. Look at A opposite to help you.

| | | | |
|---|---|---|---|
| at a higher pressure | compressed air | gauge pressure | pressurized |
| at a lower pressure | exert pressure on | one atmosphere | outside air |
| atmospheric pressure | explode | pressure differential | |

### *Ever wondered about ...* pressurized aircraft cabins?

It's a well-known fact that the cabins of commercial aircraft are (1) .............................. . This is an obvious requirement, given that at high altitude the air is (2) .............................. than (3) .............................. at ground level. If passengers were exposed to these conditions while flying at altitude, they would suffer numerous health problems. Hence the need, at high altitude, to maintain the air inside the fuselage (4) .............................. than the (5) .............................. . But how is this achieved and controlled?

At the moment an aircraft's doors are closed at the airport, the cabin pressure is clearly equivalent to (6) .............................., meaning the (7) .............................. of the cabin is zero. Once the aircraft takes off and begins to climb, the pressure of the outside air will begin to decrease, while air pressure inside the aircraft remains the same thanks to the airtight fuselage.

However, maintaining the air pressure simply by keeping the same air inside the aircraft for the duration of a flight would be problematic – firstly because the air needs to be continually renewed for the comfort of passengers, and secondly because at very high altitude the significant (8) .............................. between the inside and outside of the cabin would (9) .............................. the inside of the fuselage to an unacceptably high degree. Although the resulting stresses would not be high enough to cause the fuselage to (10) .............................., they would result in a high rate of metal fatigue. Consequently, as the aircraft climbs, air is released through valves in the fuselage until a slightly lower pressure is attained – equivalent to the pressure of the outside air at an altitude of between 5,000 and 8,000 feet. Air is then constantly renewed during the flight by releasing it through the valves, and replacing the equivalent volume with (11) .............................. pressurized to the same level by the aircraft's engines.

**38.3** Match the two parts to make correct sentences. Look at B opposite and Appendix X on page 112 to help you.

1 Header tanks are designed to
2 To *prime* means to
3 Siphonic action is able to
4 Water towers are large tanks designed to

a make liquid flow upwards from its surface.
b generate hydrostatic pressure in a building.
c supply large numbers of buildings.
d fill a pipe or hose to its full bore, removing the air.

### Over to you

Think about a system you're familiar with which contains fluid that is at a higher or lower pressure than atmospheric pressure. What is the reason for having a positive or negative pressure? How great is the pressure differential, relative to atmospheric pressure? How is the pressure differential generated and maintained?

# 39 Fluid dynamics

## A Fluid dynamics and aerodynamics

**Fluid dynamics** is the study of how gases and liquids flow around objects. The branch of fluid dynamics concerned with **airflow** – called **aerodynamics** – is relevant to the design of aircraft, vehicles and structures. Aerodynamic tests can be done in **wind tunnels** – tunnels through which air is blown at high velocity. Analysis can also be done using **computational fluid dynamics** (**CFD**) – computers with complex simulation software.

## B Drag

**Aerodynamic drag** (or **drag**) is the resistance of an object to an airflow. It is measured by the **drag coefficient**. Objects with a low drag coefficient have little force exerted on them by an airflow. We say they are **streamlined**. There are different types of drag:

- **Form drag** is due to the shape of the object.
- **Skin friction** is the drag caused by air flowing over the surface of the object.
- **Pressure drag** is the pressure differential between the air **upstream of** the object (flowing towards it) and the air **downstream of** it (flowing away behind it). The lower-pressure zone close behind a moving object is often called the **slipstream**.
- **Interference drag** depends on the amount of **turbulence** around the object.

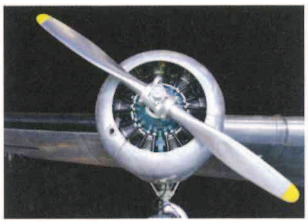
## C Laminar flow and turbulent flow

In aerodynamics, engineers focus on the airflow in the **boundary layer** – the air close to the surface of an object. If the object is streamlined, the airflow in the boundary layer will be **laminar**, following a direct, clean path. With a less streamlined object, the airflow will be **turbulent**, flowing in a disturbed, messy fashion. A **turbulent flow** produces more drag than a **laminar flow**, and generates a bigger **wake** – that is, the V-shaped zone of turbulent air behind the object. Wakes contain **vortices**. A **vortex** is a twisting flow – like water going down the plughole in a bath.

## D Aerofoils

**Aerofoils** are components designed to make air flow in specific ways. They include:

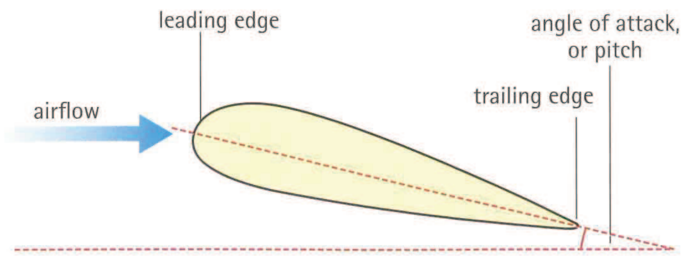
- aircraft **wings**, which generate **lift** – that is, upward aerodynamic force
- the **blades** of plane **propellers**, and helicopter **rotor blades**, which generate **thrust** to **propel** aircraft through the air
- wings on racing cars, which generate **downforce** – downward aerodynamic force.



An aircraft propeller with two blades

Aerofoils have specially designed **profiles** (cross-sectional shapes), often with their **leading edge** – the front edge, relative to the airflow – shaped differently to their **trailing edge**, at the rear. The behaviour of air around an aerofoil depends on the velocity of the airflow, and also on the **angle of attack** (or **pitch**) of the aerofoil – its angle relative to the airflow.

BrE: aerofoil;
AmE: airfoil




The section of an aircraft wing – an example of an aerofoil

## 39.1 Sort the terms in the box into categories (1–5). Look at A, B, C and D opposite to help you.

| | | | | |
|---|---|---|---|---|
| CFD | form drag | rotor | slipstream | wind tunnel |
| downforce | lift | skin friction | wake | wing |

1 Types of aerodynamic resistance: .................................... and ....................................
2 Aerodynamic forces acting in specific directions: .................................... and ....................................
3 Aerodynamic effects downstream of an object: .................................... and ....................................
4 Types of aerofoil: a .................................... and a ....................................
5 Aerodynamic analysis tools: .................................... and a ....................................

## 39.2 Use one term from each category in 39.1 to complete the sentences below. Look at A, B and C opposite to help you.

1 The widening zone of turbulent air behind a fast-moving vehicle is called the .................................... .
2 In very strong winds, the low pressure generated just above the sheltered sides of the roofs of buildings generates ...................................., which can cause the roof to 'explode' outwards due to the higher-pressure air inside the building.
3 The aerodynamic effectiveness of designs can be tested in a .................................... .
4 On an aircraft fuselage, the heads of rivets are designed to be as flat as possible in order to limit .................................... .
5 Most helicopters have either two or three main .................................... .

## 39.3 Use the words in the box to complete the article, taken from a popular science magazine. You will need to use some words twice. Look at B, C and D opposite to help you.

| | | | | | | |
|---|---|---|---|---|---|---|
| aerofoil | angle | boundary | drag | laminar | leading | trailing |
| airflow | attack | downforce | flow | layer | pitch | turbulent |

In aerodynamic-speak, the term 'spoiler' is slightly confusing, as it has two different meanings. In automotive engineering, a spoiler is a wing-like (1) .......................... on the back of a car. Unlike the wings on racing cars, the purpose of spoilers on road cars is not to generate (2) .........................., but to 'spoil' or disrupt the (3) .......................... within the (4) .......................... – the air close to the surface of the car's body. While this may seem strange, by turning what would otherwise be a smooth, (5) .......................... .......................... into a messy, (6) .......................... .........................., the car's (7) .......................... coefficient can be reduced, and the vehicle's handling can be made more stable at higher speeds.

In aeronautical engineering, spoilers – also called airbrakes – are aerofoils mounted on the tops of an aircraft's wings. When deployed – most often at the moment a plane lands – they rotate in an angular motion, with their (8) .......................... edge (near the front of the wing) acting as a pivot, while the (9) .......................... edge (at the rear) lifts, increasing the spoiler's (10) .......................... . Spoilers serve a dual purpose. Firstly, they generate (11) .........................., helping to push the aircraft down onto the runway. Secondly, they create (12) .........................., increasing air resistance and helping to slow the aircraft down.

Spoilers are therefore different to flaps, which are deployed from the rear of an aircraft's wings as it descends and slows down before landing. Flaps are rotated downwards, at a progressively increasing (13) .......................... of .........................., in order to provide increased lift at lower speeds.

### Over to you

Describe how a specific aircraft, vehicle or structure is affected by airflow. How does air flow around it? Which aerodynamic issues do you think engineers needed to consider in its design?

# 40 Engines and motors

## A Types and functions of engines and motors

The term **engine** usually refers to **petrol engines**, **diesel engines** and **jet engines** (or **jets**). In engineering, **motor** usually means **electric motor** – but in general language, 'motor' can also refer to petrol and diesel engines. Engines and motors **power** (or **drive**) machines by generating rotary motion – for example, to drive wheels. In jet engines, compressors and turbines rotate to generate **thrust** – pushing force, produced by forcing air from the back of the engine at high velocity.

A jet engine

As an engine produces a **couple** – rotary force – the moving parts of the machine it is driving will produce resistance, due to friction and other forces. As a result, **torque** (twisting force) is exerted on the output shaft of the engine. Torque – calculated as a turning moment, in newton metres – is therefore a measure of how much rotational force an engine can exert. The rate at which an engine can work to exert torque is the **power** of the engine, measured in **watts**. Although engineers normally calculate engine power in watts, the power of vehicle engines is often given in **brake horsepower** (**bhp**). This is the power of an engine's output shaft measured in **horsepower** (**hp**) – a historic measurement of power (see Appendix III on page 100).

Note: See the following units for more information: Unit 33 (turning moments), Unit 34 (rotary motion), Unit 35 (power), and Unit 41 (shafts).

BrE: petrol; AmE: gasoline
BrE: petrol engine; AmE: gasoline engine

## B Internal combustion engines

Petrol and diesel engines are **internal combustion engines**. This means they are driven by the **combustion** (burning) of fuel in enclosed, sealed spaces called **combustion chambers**. In petrol and diesel engines, the combustion chambers are **cylinders** surrounded by a **cylinder block** and closed at the top by a **cylinder head**. Each cylinder contains a **piston**. The number of **piston cylinders** in an engine varies – engines in small motorcycles have only one, while sports car engines may have twelve.

Fuel is supplied to each cylinder from a tank. In most engines, the flow of fuel is generated by a pump, which forces it – at high pressure – through **fuel injectors**. These vaporize the fuel, allowing it to mix with air. Using this **mixture** (of fuel and air), most engines function as **four-stroke engines**. This means they work on a **cycle** of four stages – or four **strokes**. A stroke is an upward or downward movement of a piston.

**1 Induction** or **intake**
The **intake valve** opens. The mixture enters the cylinder through a **port** (opening) in the cylinder head while the piston moves downwards.

→

**2 Compression**
The intake valve closes. The piston moves upwards, compressing the mixture.

→

**3 Power** or **ignition**
The **spark plug** produces a spark, which **ignites** (lights) the mixture. On ignition, the mixture explodes, generating a sudden pressure which forces the piston down.

→

**4 Exhaust**
The **exhaust valve** opens, and the piston moves upwards, forcing the **exhaust gases** – those produced during combustion – out of the cylinder via the exhaust port. The exhaust valve then closes and the cycle begins again.

The cycle of a four-stroke petrol engine

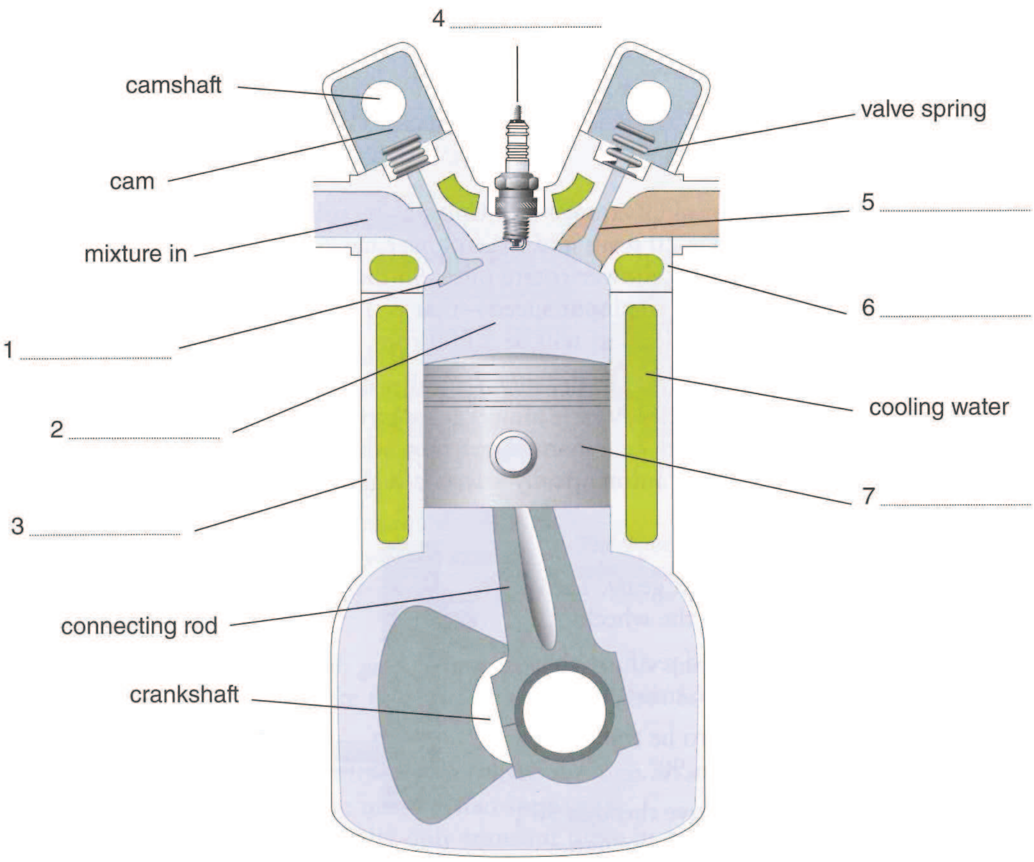
Notes: See exercise 40.2 opposite for an illustration of a cylinder.
See Unit 42 for more on **cam**, **camshaft**, **connecting rod** and **crankshaft**.

**40.1** Complete the text about diesel engines using words from A and B opposite.

Diesel engines differ from (1) .................................. engines in one key respect: they are not fitted with a (2) .................................. , in each cylinder, to ignite the fuel. This is because when a (3) .................................. of diesel and air is compressed inside a hot (4) .................................. , it will explode spontaneously, without the need for a spark to provide (5) .................................. . A diesel engine must therefore work in a way which prevents the diesel from exploding before the piston is at the top of the cylinder. To achieve this, the engine takes in only air during the (6) .................................. stage of the cycle. Therefore, during the (7) .................................. stage, only air – and not an air–fuel mixture – is pressurized. It is only at that last instant, when full compression has occurred, that the (8) .................................. above each cylinder forces vaporized diesel into the combustion chamber, where it ignites.

Diesel engines operate at lower speeds than petrol engines, making them less suitable for high-speed applications. However, they are more able to (9) .................................. heavy vehicles, as they can produce greater amounts of (10) .................................. than petrol engines.

**40.2** Look at the cross-section of an engine, and label it using words and expressions from B opposite.




One cylinder of a four-stroke internal combustion engine

## Over to you

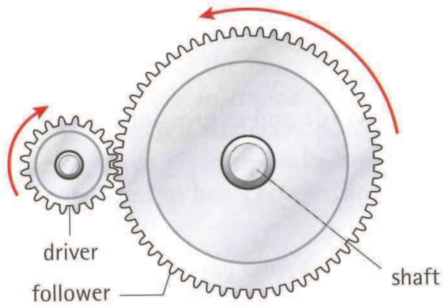
Think about the engine in a vehicle you're familiar with. Describe specific aspects of it – the type of fuel it uses, the number of cylinders it has, and how much power and torque it produces.

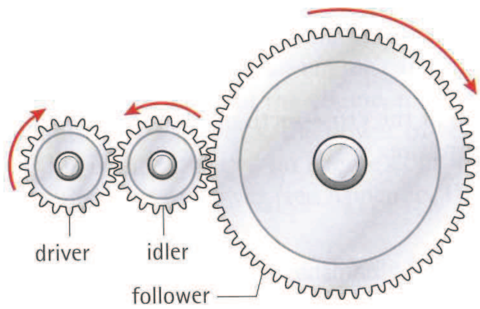
# 41 Transmission 1

## A Gears

**Gear wheels**, or **gears**, are wheels with **teeth** (or **cogs**). The teeth **interlock** (fit together) with those of other gear wheels. When one gear wheel revolves, the other revolves with it – in the opposite direction – as their teeth **mesh together**. Gears are normally fitted to **shafts**. They **transmit** rotary motion from one shaft to another – that is, they transmit **drive**. Drive, usually supplied by an engine or motor, causes a shaft to revolve. A shaft connected directly to an engine or motor is called a **driveshaft** – or an **input shaft**. A gear wheel on a driveshaft is called a **driver**. The second gear wheel, which **meshes with** the driver, is called a **follower** – the driver **drives** the follower.

An assembly of several shafts and gear wheels is called a **gear train** or **transmission system**. It begins with an input shaft and ends with an **output shaft**. The system may contain **idler gears** (or **idlers**). These change the direction of a follower.



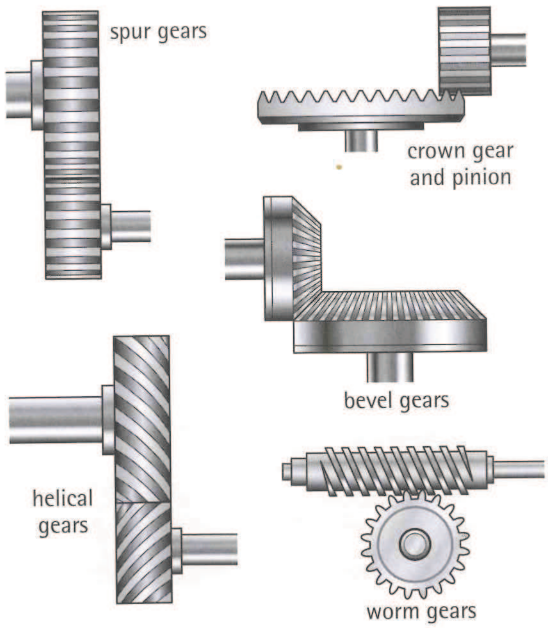

## B Gear ratios

Gears can provide a mechanical advantage (see Unit 33) by using different **gear ratios**. In the diagrams above, the driver has 20 teeth and the follower has 60 teeth. Therefore the driver rotates three times to make the follower rotate once. So the gear ratio is **3:1** (**three to one**). This means that if, for example, the **input speed** – that is, the speed of the driver – is 3,000 rpm, the **output speed** (of the follower) will be 1,000 rpm.

In some machines, a **gearbox** is used to provide a number of different gear ratios. A gearbox has a **gear selection** system, which allows gears to be **changed** (or **shifted**) while the transmission is running. This may be a **manual gearbox**, where gears are changed by a person, or an **automatic gearbox**, which automatically **selects** a **higher gear** or **lower gear**, as needed.

## C Types of gear wheel

- **Spur gears** are the simplest gears. The teeth run straight across the wheel.
- **Helical gears** have curved teeth, so that they mesh together more smoothly.
- **Bevel gears** allow drive to be transmitted through an angle – often 90°.
- **Crown gears** transmit drive through 90°, often to a small gear called a **pinion**.
- **Worm gears** transmit drive through an angle. They also allow a low output speed relative to the input speed of the **worm**. They can provide a 'one way' drive, as a worm can drive a gear but a gear cannot drive a worm (the mechanism will lock).



**41.1** Change four words in the text below to make it correct. Look at A opposite to help you.

An engine is connected to a driveshaft. Fitted to this output shaft is a gear wheel called the idler. As this gear wheel turns, it drives another gear wheel alongside it called a driver, which is fitted to an input shaft.

**41.2** Complete the text about continuously variable transmission using the words in the box. Look at A, B and C opposite to help you.

| | | | | |
|---|---|---|---|---|
| automatic | higher | ratio | shafts | transmit |
| helical | manual | selection | shift | wheels |

### CONTINUOUSLY VARIABLE TRANSMISSION (CVT)

(1) ............................ gearboxes allow the driver of a vehicle to (2) ............................ gears as required. If a (3) ............................ gear is selected, the speed of the output shaft will increase relative to the input shaft, for a given engine speed. In a typical (4) ............................ gearbox, however, the gear (5) ............................ system is automated, requiring no action by the driver. In addition, most automatic transmission systems use so-called planetary gears. In basic terms, these allow the transmission to remain connected at all times – unlike manual gearboxes, in which pairs of (6) ............................ gears are momentarily disconnected each time a shift is made.

The principle of continually variable transmission (CVT) is entirely different to both manual and automatic systems. Instead of having a fixed number of different gear (7) ............................ , each with different numbers of teeth, CVT uses a special mechanism to continuously and progressively adjust the gear (8) ............................ between the input and output (9) ............................ . Therefore, as the vehicle accelerates or decelerates, continual adjustments are made to the transmission automatically. This allows the engine to be maintained at a constant speed for optimum power and fuel efficiency while the system is able to continuously (10) ............................ drive to the vehicle's wheels.

**The Case-IH Puma CVX tractor is equipped with continuously variable transmission.**

**41.3** Make word combinations with *gears* using words from A and C opposite. Then use the word combinations to complete the sentences (1–4) below. Sometimes there is more than one possible answer.

1 ............................ **gears** are used to transmit drive through an angle.
2 ............................ **gears** run more quietly than spur gears.
3 ............................ **gears** can generally only transmit drive in one direction.
4 ............................ **gears** allow drivers and followers to revolve in the same direction.

## Over to you

Think about the transmission system in a machine or vehicle you're familiar with. Describe how drive is transmitted from the input shaft to the output shaft.

# 42 Transmission 2

## A Chains, sprockets and pulleys

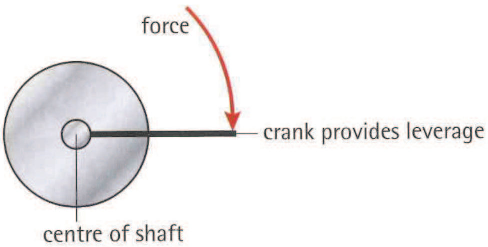
Drive can be transmitted from one shaft to another, across a distance, by **roller chains** (or **chains**). Chains drive, or are driven by, toothed wheels called **sprockets**. Pairs of sprockets with different numbers of teeth can provide different gear ratios. A bicycle is an example of a machine with **chain drive.**

**Belt drive** works in a similar way to chain drive. **Belts** are usually smooth and are fitted around smooth **pulley wheels** (or **sheaves**). However, **toothed belts** and toothed pulley wheels can be used in applications where a smooth belt could slip. A combination of several **pulleys** can give a mechanical advantage – for example, in cranes to lift heavy loads. In this case, **cables** – also called **wire ropes** – are used instead of belts.

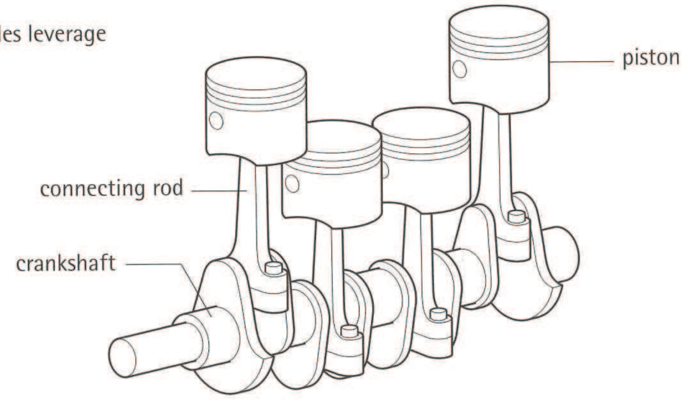
Notes: **Pulley** may refer to pulley wheels and belts together, or to a pulley wheel only.
See Unit 33 for more on mechanical advantage.

## B Conversion between reciprocating and rotary motion

The reciprocating linear motion of pistons is converted to rotary motion by **connecting rods** (or **conrods**) and a **crankshaft.** The shape of the crankshaft allows the connecting rods to exert force at a distance from its centre. This increases the turning moment they generate. Bicycle pedals are an example of a simple **crank.**

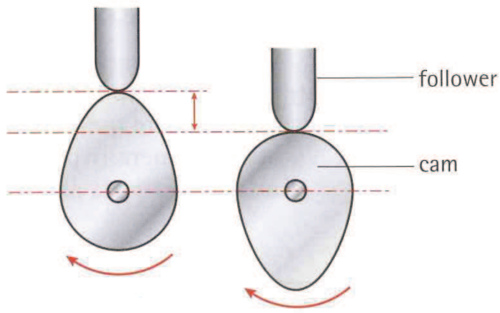



The principle of a crank




In an engine, a heavy wheel – called a **flywheel** – is fitted to the end of the crankshaft. This provides momentum, giving the pistons more constant motion.

As well as driving a machine or vehicle, the motion of an engine's crankshaft is used to open and close the valves in the cylinder head. Rotary motion is transmitted, often via a toothed belt or chain, to the **camshaft** at the top of the engine. The **cams** fixed on the camshaft cause **followers** – which are connected to the valves – to move up and down as the cam revolves. As they move, they open and close the valves.




Notes: See the following units for more information: Unit 33 (momentum and turning moments), Unit 34 (rotary and reciprocating motion), and Unit 40 (internal combustion engines).
See Appendix XI on page 113 for more on mechanisms used with rotary motion.

**42.1** Circle the correct words to complete the text about how chain drive works on bicycles. Look at A opposite and Appendix XI on page 113 to help you.

On a bicycle, the pedals – which provide support for the rider's feet – are fitted to a (1) *crank / sheave* at either side of the frame. These are fixed together by a short shaft, called a spindle, which runs through a tube at the bottom of the frame. The tube contains (2) *bearings / roller chains*, which allow the spindle to turn freely. A (3) *pulley / sprocket*, fitted to the shaft, drives a (4) *cable / chain*, which drives a second (5) *crank / sprocket* at the rear of the bike. This turns the rear wheel.

**42.2** Complete the text about the advantages of chain drive on bicycles, using the words in the box. You will need to use some words more than once. Look at A opposite to help you.

| | | | | | |
|---|---|---|---|---|---|
| belt | chain | pulley | sprocket | toothed | wheel |

The advantages of using chain drive on bicycles are:

- its ability to transmit drive over a distance – from the centre of the bike to the rear
- that a (1) .................... will not slip as it travels around a (2) .................... – unlike a (3) ...................., which is more likely to slip as it travels around a (4) .................... ....................
- that the teeth on a (5) .................... will force dirt out of the holes in a (6) .................... , whereas dirt would become trapped between a (7) .................... and a (8) .................... .................... – a problem which would make a (9) .................... belt unsuitable for overcoming the problem of slipping.

**42.3** Answer the questions below using words from B opposite and Appendix XI on page 113.

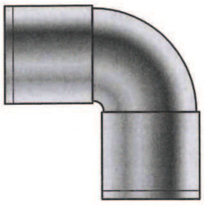
1 In an engine, which revolving component generates the up-and-down motion required to open and close a valve in the cylinder head?
2 How can the motion of an engine's crankshaft be transmitted to the camshaft?
3 What term is given to a component which presses against a cam and moves with a reciprocating action?
4 Which component is heavy and helps an engine to run smoothly?
5 Which two engine components are joined by a connecting rod?
6 What component could be used to connect the end of a crankshaft to a driveshaft that is at 20 degrees to the crankshaft?
7 In vehicles, what friction mechanism (controlled by the driver) is used to gradually transmit drive to the wheels, via the gearbox?
8 In disc brakes, what term is given to the components that are pressed against the brake disc to generate friction?

## Over to you

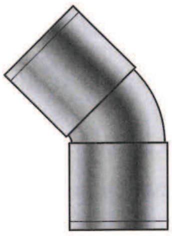
Think about a machine you're familiar with which uses chain or belt drive, or one which converts reciprocating motion to rotary motion (or vice versa). Describe the mechanisms used, and explain their functions.

# Appendix IX Pipe and hose fittings and valves

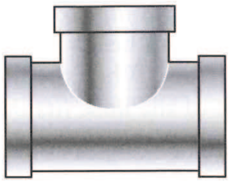
## Pipe and hose fittings



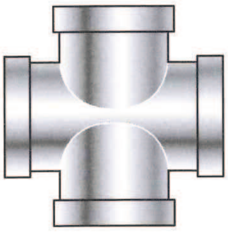
a ninety-degree elbow



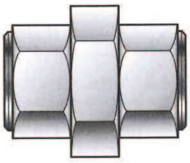
a forty five-degree elbow



a tee

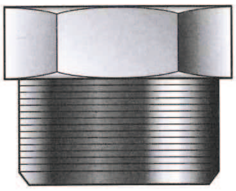


a cross

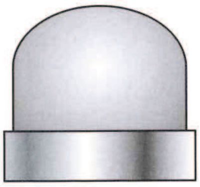


a union

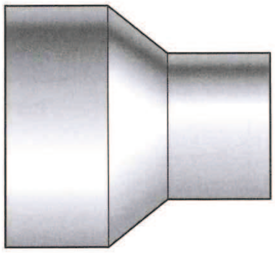
**a flange:** allows larger pipes to be bolted together, end to end



**a plug:** fits inside the end of a pipe to close it



**a cap:** fits over the outside of the end of a pipe to close it



**a reducer:** allows two pipes of different diameters to be connected

## Valves

The flow of liquid through pipes and hoses can be controlled by **valves**. According to their type, these devices can:

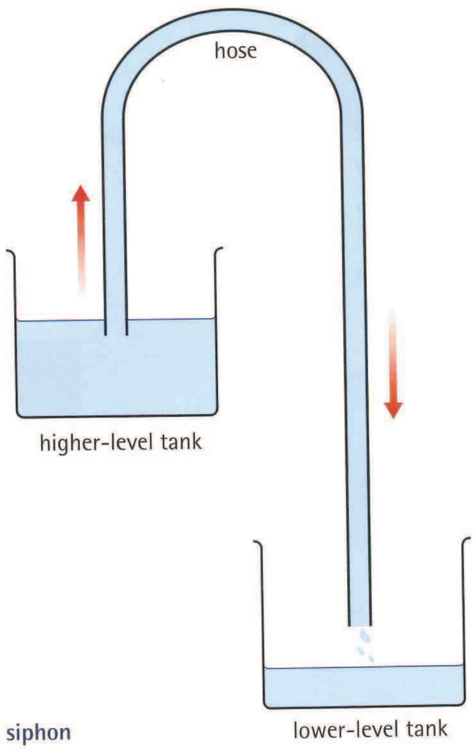
- be fully opened to allow a flow, or fully closed to **shut off** (stop) the flow
- be partly opened/closed to **regulate** the **flow rate** (control the volume of flow)
- **direct the flow**, by allowing it to go along one pipe or another at a junction
- provide an **inlet**, allowing liquid or gas to enter a pipe or tank, or an **outlet**, allowing liquid or gas to exit
- act as a **safety valve** in a pressure vessel, allowing gas to escape if a dangerously high pressure is reached, to prevent an explosion
- act as a **check valve** (or **non-return valve**), allowing liquid or gas to flow in only one direction.

Appendix X

# Siphonic action

Hydrostatic pressure allows liquids to be **siphoned**. The principle of **siphonic action** can be shown using a hose – called a **siphon** in this situation – to make liquid flow upwards from its **surface level**, over the side of a tank and then downwards. The hose must first be **primed** – that is, completely filled with water. The top end of the hose must then be **immersed** in the liquid (put below the surface). The bottom end may also be immersed, although this is not necessary. When the flow begins, the liquid in the hose must run **at full bore** – that is, the **bore** of the hose (its inside diameter) must be completely filled with water, with no air in it.

Siphonic action is often used to drain rainwater from the roofs of large buildings. Unlike normal rainwater pipes, the pipes of **siphonic drainage** systems are designed to run at full bore, which allows them to flow much faster. This means smaller-diameter pipes can be used. These take up less space in the building.




A siphon

Appendix XI

# Managing rotary motion

The following mechanisms are often used in machines that have rotating shafts and wheels.

| Mechanism | Notes |
|---|---|
| a **bearing** | • allows a shaft, such as a driveshaft or an **axle** (a shaft to which a vehicle's wheels are fixed) to revolve inside a hole<br>• may require a **lubricant** – oil or **grease** – to help reduce friction |
| a **universal joint** | • used to connect the ends of two shafts that are at an angle to each other, allowing drive to be transmitted, through the angle, between the two shafts |
| a **clutch** | • allows drive to be transmitted progressively (by friction), from a constantly revolving driveshaft, to wheels that are not yet revolving<br>• may be operated manually, or may be an automatically operated **centrifugal clutch** |
| brakes | • used to slow down and stop rotary motion, usually by friction<br>• in **disc brakes**, a pair of **brake pads** is pressed against the sides of a metal **brake disc** which is fixed to the shaft<br>• in **drum brakes**, brake pads are pressed against the inside of a hollow cylinder, called a **drum** |

A universal joint