

## Chapter 9

# Forces and Machines

**We are stuck with machines. Machines make our lives easier.**

### Student Learning Outcomes

After completing this chapter, you will be able to:

- Recognize wheel and axle and identify their uses.
- Describe pulleys and their kinds.
- Identify the uses of pulleys in daily life.
- Describe the functions of pulley systems and gear systems.
- Describe how motion in a system of pulleys of different sizes is transferred to motion in another system of various gears in the same structure.
- Investigate with the help of an experiment the effort required by different gear systems to lift the same load.
- Find out how the action of a pulley system is altered by changing the tension of the band connecting two pulleys.
- Design and make a system of pulleys and/or gears for a structure that moves in a prescribed and controlled way and performs a specific function.
- Identify and make modifications to your own pulley and gear systems to improve the way you move a load.
- Describe how a bicycle functions.
- Identify common devices and systems that incorporate pulleys and/or gears.

We know that a machine is anything that makes our work simpler and easier. A **simple machine** is a simple tool used to make our work easier. Lever, wheel and axle, pulley, inclined plane, wedge and screw are simple machines. All the complex machines like tractors, cars and fans are made of simple machines. We have learnt about lever, inclined plane and wedge in class five. Here we shall discuss wheel and axle, pulley and gears.

## Wheel And Axle

The most important invention of the human history is the “invention of the wheel”. Wheels can move heavy objects easily.

Wheels are used in a simple machine called wheel and axle.

A **wheel and axle** consists of a large wheel fixed to a smaller wheel called the axle.

When the wheel turns, the axle also turns. A wheel has bigger diameter than that of the axle (Fig. 9.1).

We use wheel and axle in two ways.

1. To lift a heavy load, we apply force on the wheel to turn the axle.
  2. To increase the speed, we apply force on the axle to turn the wheel.
- A screwdriver is an example of wheel and axle. The broad part of the screwdriver works as a wheel. The narrow part of it acts as the axle. A small force on wheel provides a bigger force at the axle to push the screw into the wood.
  - The steering wheel of motor vehicles is also an example of wheel and axle (Fig.9.3). A small force on steering wheel provides a big force to the axle that easily turns the wheels of the vehicle.
  - A mincing machine, a tap handle, a hand drill and crank on a well are examples of

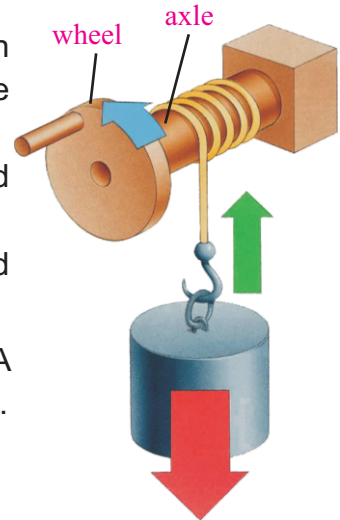


Fig.9.1: A wheel has bigger diameter than that of the axle.

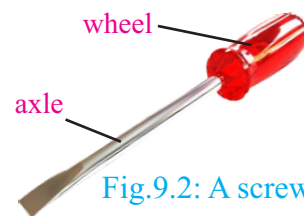


Fig.9.2: A screwdriver

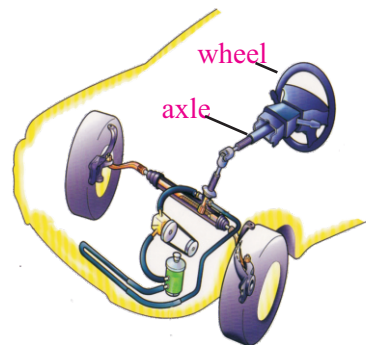


Fig.9.3: Steering wheel

wheel and axle. Buses, cars and bicycles also contain wheels and axles.

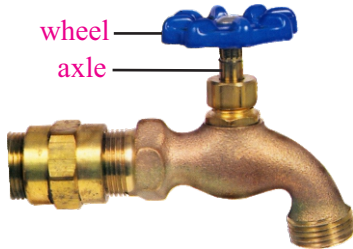


Fig.9.4: A tap handle is a wheel.

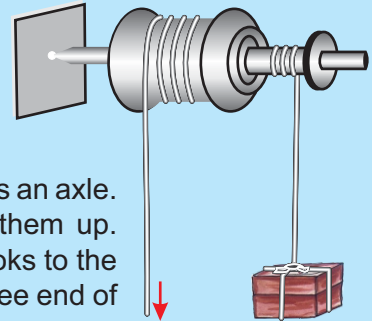


Fig.9.5: The wheel and axle in this tricycle means it can roll smoothly along the ground.



Fig.9.6: The crank on the well is a kind of wheel and axle. It reduces the force needed to raise the bucket.

To make a simple wheel and axle take one thread reel of large diameter and one of small diameter. Now fix them together firmly. Pass a thin and strong stick through the reels. Take two strings, tie one end of each string to each reel and roll them around the reels as shown in the figure. In this case the big reel will act as a wheel and small reel as an axle. Take some books and tie them together and try to lift them up. Estimate the effort needed to lift them up. Now tie the books to the free end of axle string. Rotate the big reel by pulling the free end of the string rolled around it. Can you lift the books easily?



## Pulley

Instead of axle, the wheel could also rotate a rope or cord. This variation of the wheel and axle is the pulley.

A **pulley** is the wheel with a groove in its edge through which a cord is passed. The pulley turns around an axle.

We can use pulleys to raise and lower objects. A pulley changes the direction of force and makes our work easier.

- Pulley is used to lift construction material to upper stories on a construction site.
- Motor mechanics and engineers use pulleys to lift and place heavy engines in the cars.



A pulley

Fig.9.7: Pulley is a simple machine which can be used to lift loads easily.

- The pulley on a flag-pole changes the direction of applied force. We pull down one end of the rope that passes over the pulley, the flag attached to the other end goes up (Fig.9.8).
- A crane uses a pulley system in which fixed and moveable pulleys are used to lift very heavy loads (Fig.9.9).

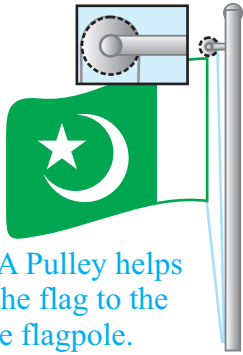


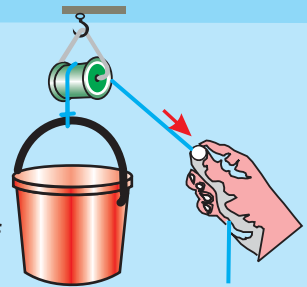
Fig.9.8: A Pulley helps to raise the flag to the top of the flagpole.



Fig.9.9: The crane uses pulleys to work.

Fill a small bucket half with water. Try to lift the bucket. Is it very easy? Ask an adult to bend a wire into a triangle. Push the ends of wire into a thread reel. Hang your pulley with some support. Tie the bucket with the end of a string.

Pass the string over the pulley. Pull the string downward to lift the bucket. Is it easier now? In some areas of our country people use pulley to draw water from a well.



## Types of Pulley

There are two kinds of pulleys, i.e. fixed pulley and moveable pulley.

### i. Fixed Pulley

The axle of this pulley is fixed with some support. The load is tied on one end of the rope which is passing over the pulley. The force is applied on the other end of the rope to lift the load (Fig.9.10). A fixed pulley is used to change the direction of applied force.



Fig.9.10: Fixed pulley

### ii. Moveable Pulley

This kind of pulley has a hook to tie the load. The moveable pulley moves together with the load. In this kind, the rope is attached to some support while pulley moves. A moveable pulley does not change the direction of a force. The applied force and the load move in the same direction (Fig.9.11).

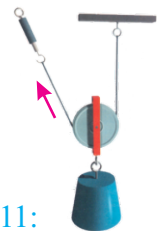


Fig.9.11: Moveable pulley



## Pulley System

To make our work more easier, we can use pulley system. It consists of a fixed pulley and a moveable pulley. It is also called “block and tackle”. The load is attached to the moveable pulley (Fig.9.12). Can you suggest a way in which we might apply force in downward direction in a pulley system?

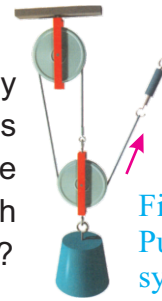


Fig.9.12: Pulley system

### Do you know?

Some times two pulleys work in such a way that they are connected with a belt. One pulley moves and causes the other pulley to move. For example in a water pump, a small pulley is attached to a motor. When motor runs the small pulley moves and causes the large pulley to move.

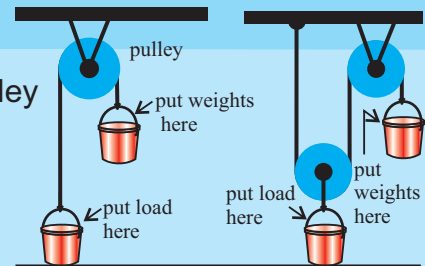
**You will need:** ] 1 fixed pulley and 1 moveable pulley  
] 15 weights ] 1 rope ] 2 small buckets  
] some amount of sand as a load

### Procedure:

1. Hang the fixed pulley to some support.
2. Tie the rope to 1 small bucket and put the load in it.
3. Pass the rope over the pulley and tie the second bucket to its free end. Make the rope short enough so that the second bucket is near the fixed pulley.
4. Gently put the weights into the second bucket one at a time until the load just lifts off the ground. Record the number of weights you needed.
5. Repeat this experiment with one moveable pulley and one fixed pulley as shown in the figure. In this case the load is attached to the moveable pulley.

Record the number of weights you needed.

What do you conclude about the lifting of load using one pulley and using two pulleys?



## Gears

A gear is also a modification of the wheel and axle. Gear wheel has teeth around it. The teeth of one gear usually fit into the teeth of another gear. Gears are used to transfer the force from one wheel to another. They can also increase or reduce the speed.

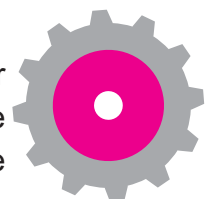


Fig.9.13: A gear

## The Gear Train

Gears work in teams. When two or more gears work together, it is called a **gear train** or gear system. One gear is called driving gear to which force is applied. The other gear is called driven gear which turns due to the movement of the first gear.

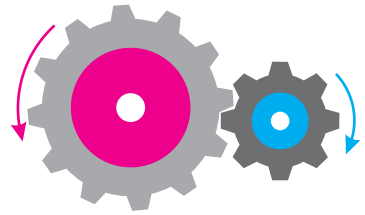
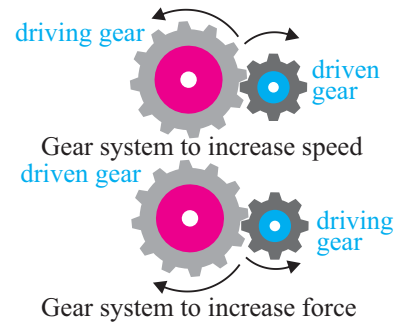


Fig.9.14: Gear train

We can use a gear system in two ways.

1. When the driving wheel is larger and the driven wheel is smaller, the gear system is used **to increase the speed**.
2. When the driving wheel is smaller and the driven wheel is larger, the gear system is used **to increase the force**.



**You will need:** ] 1 set of gears

] 2 labels (stickers)

### Procedure:

1. Put one axle in each of the four small gears.
2. Make a mark on one tooth on each gear.
3. Use the stickers to label one gear as the driving gear "D" and one as the driven gear "d".
4. Put these two gears on the base board with the marked teeth touching as shown in the figure 1.
5. Turn the driving gear one complete time around in a clockwise direction. Watch the driven gear as you do. Record how many times the driven gear turns and in what direction.
6. Now put another gear between the driving and the driven gears as in figure 2. Turn the driving gear as in step 5 and record what happen to the driven gear.
7. Finally, repeat this procedure with two gears between the driving and driven gears. See figure 3.

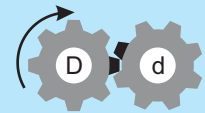


Fig. 1



Fig. 2



Fig. 3

No. of gears in between	Turns	Direction
0		
1		
2		

## Uses of Gears In Everyday Life

Gears usually make part of a more complicated machine. They transfer energy from one wheel to the other to change the direction of force.

- A hand-drill consists of two mutually perpendicular gears. When its larger gear is rotated in a vertical plane, the smaller gear linked with it rotates very fast in the horizontal plane. A hand-drill is used to make holes in wood.
- Your bicycle moves with the help of gears. Two gears are linked with each other by a chain. The chain makes it possible for the small gear to move in the same direction as that of the big gear. The front gear is a large wheel with teeth in which pedal is fitted. The rear gear is a small toothed wheel which is present in the rear wheel of the bicycle. When you pedal the bicycle, you turn the big gear. The big gear turns the chain, which turns the rear small gear. When this small gear turns, the bicycle moves forward.

In a racing bicycle, more than two wheels work in the gear system.

- A wind-up clock consists of many gears. The minute wheel is a smaller gear with a few teeth, while the hour wheel is a bigger gear with many teeth. The minute wheel rotates the minute hand and hour wheel rotates the hour hand.
- Gears are also used in motor vehicles, factory machines and many other instruments.

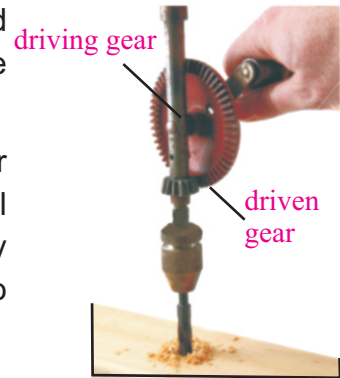


Fig.9.15: A hand-drill



Fig.9.16: Gear system in a bicycle



Fig.9.17: Gear system in a wind-up clock

### Point to think!

Which parts of a bicycle are wheel and axle, pulleys and gears?



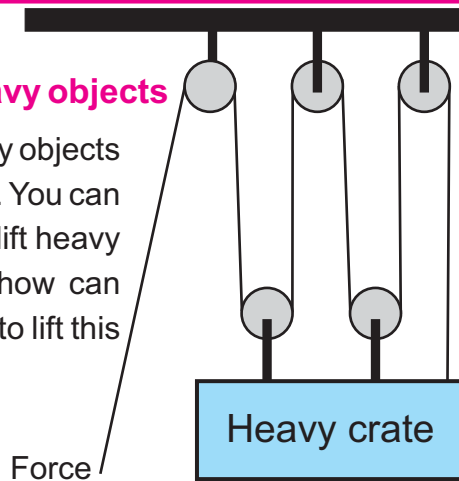
**Do you know?**

Have you ever seen a racing-bicycle? When a racer wants to increase the speed of a bicycle, he/she changes the gears or pulleys in such a way that the pedal gear is a larger wheel and the rear gear is the smallest wheel.



### Design of a system to lift heavy objects

A common way to lift heavy objects is shown in a schematic diagram. You can also design your own system to lift heavy objects. Also tell your teacher how can you reduce the effort even more to lift this heavy crate.



1. A wheel and axle is made up of a large wheel that is connected to a circular rod called axle.
2. Pulley is also a wheel with a groove in its edge. A rope passes over a pulley.
3. There are two kinds of pulleys: fixed pulley, moveable pulley.
4. Gear is a toothed wheel. Gear system is a kind of wheel and axle.
5. Pulleys and gears can change the direction of force.
6. We use pulley systems and gear systems in a number of ways.
7. A hand-drill, a bicycle, a wind-up clock and many other machines use gears.



**1. Write proper term/word against each statement.**

- i. Wheel and axle, pulley, gear \_\_\_\_\_
- ii. Two or more gears working together \_\_\_\_\_
- iii. A grooved wheel which moves around an axle \_\_\_\_\_
- iv. Helps to rotate object faster and easily \_\_\_\_\_
- v. A wheel of a smaller diameter in wheel and axle \_\_\_\_\_

**2. Circle the letter of the best answer.**

- i. Which of the following is not a simple machine?  
(a) a tap handle (b) a jar lid  
(c) a screwdriver (d) a gear
- ii. Which simple machine can help us to move a sail on a sailboat?  
(a) a lever (b) a wheel and axle  
(c) a gear (d) a pulley
- iii. Gear system is a kind of:  
(a) lever (b) wheel and axle  
(c) compound machine (d) wedge
- iv. The chain of your bicycle is a:  
(a) pulley (b) lever  
(c) screw (d) wheel and axle
- v. Which pulley system can make our work more easier?  
(a) a pulley system with 2 pulleys (b) a pulley system with 3 pulleys  
(c) a pulley system with 4 pulleys (d) a pulley system with 5 pulleys

**3. Answer the following questions in detail.**

- i. Write some uses of a wheel and axle in our daily life.
- ii. Describe two kinds of pulleys and their working.
- iii. Define a gear and write its characteristics.
- iv. Write briefly about the working of a hand drill and a bicycle

**4. Extend your thinking.**

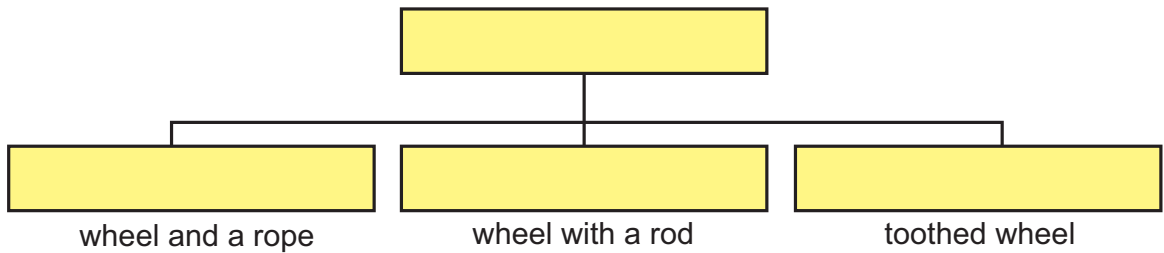
- i. A doorknob is a wheel and axle. How does it work?
- ii. What type of simple machine would be used to lower an empty bucket into a well and then lift the bucket full of water?

- iii. When you let water into a bathtub, what kind of machine helps you open the tap?
- iv. If the driving wheel and the driven wheel of a gear system are of the same size, which gear will move faster?
- v. How are compound machines different from simple machines?
- vi. How are wheel and axle, pulley and gear alike?

**5. Concept Map**

Fill the concept map using the following words:

gear, wheel and axle, simple machines, pulley



- 1 Visit a machine shop. Report the types of simple machines you see. Paste pictures of all the six simple machines in your science copy.
- 2 Visit a nearby mechanical workshop. Observe the machines which use wheel and axle, pulley system and gear system. How do these simple machines make the work of a mechanic easier?
- 3 Observe a gear system in an egg-beater and a mincing machine. How does gear system make your work easier?

**Computer Links**

- [www.mikids.com](http://www.mikids.com)
- <http://www.handworx.com.au/gearworx/mechanics/gears.html>