

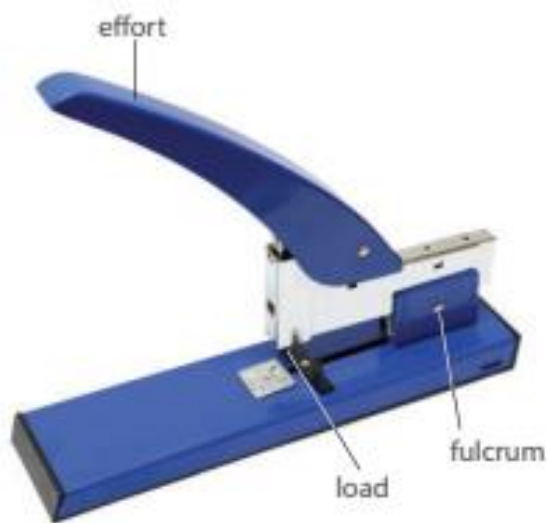


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# GRADE 8 TECHNOLOGY ACTIVITIES - 2022 TERM 3

## MEMORANDUM

### MECHANICAL SYSTEMS & CONTROL



# WEEK 1: BASELINE ASSESSMENT

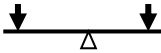
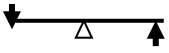
## ACTIVITY 1

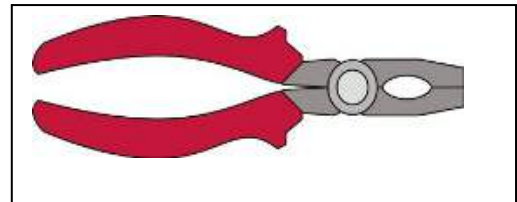
Read the following statements/questions and underline the correct answer. (11)

1.1. In this type of lever, you will always apply more effort/force than the load in order to move/lift the load.

- A. 1st Class.
- B. 3rd Class.**
- C. 2nd Class.
- D. 1st and 2nd Class.

1.2. Identify the correct symbol for the lever in the picture below.

- A. 
- B. **
- C. 
- D. 



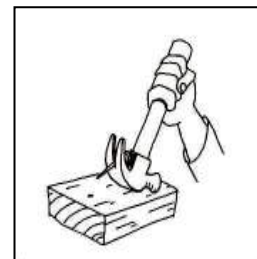
1.3. A wheelbarrow is a second-class lever because .....

- A. It assists me in moving a heavy load.
- B. The load is between the effort and the fulcrum.**
- C. The fulcrum is on the front end.
- D. It does not provide a mechanical advantage



1.4. The picture below is an example of a...

- A. Second class lever.**
- B. Third class lever.
- C. First class lever.
- D. None of the above.



1.5. Identify the class of lever illustrated.

- A. Class 1
- B. Class 2**
- C. Class 3
- D. Class 4



1.6. Which of the following statements is applicable to the gears illustrated below?

- A. The gears will not provide some mechanical advantage or increase in velocity ratio.
- B. The major advantage lies in the fact that the worm is always the driver gear.
- C. The pinion rotates in a fixed position and the rack is free to move.
- D. The gears transfers the axis of rotation through 90°.**

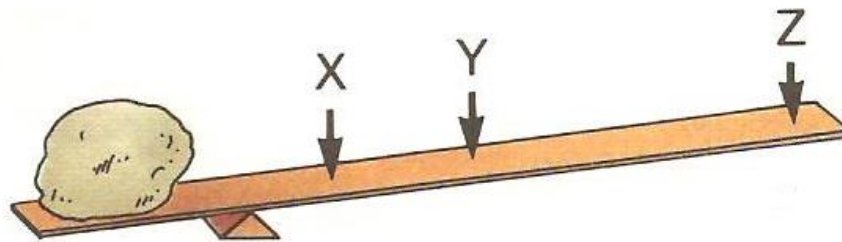


1.7. Gear B is known as ... gear.

- A. A driver
- B. A driven
- C. An idler**
- D. A train

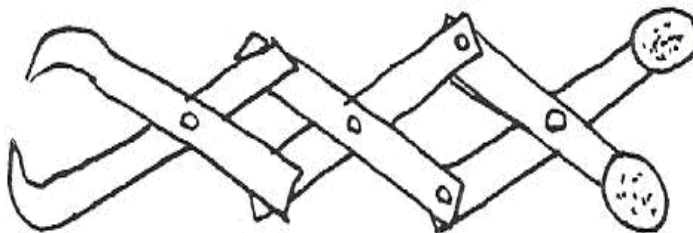


1.8. Where would be the best position to press down on the lever to gain mechanical advantage?



- A. at X
- B. at Y
- C. at X or Y
- D. at Z**

1.9. Look at the following linkage mechanism and explain how it helps us.



- A. A small input force is changed into a large output force.
- B. A large input force is changed into a small input force.
- C. A large input distance is changed into a small output distance.
- D. A small input distance is changed into a large output distance.**

- 1.10. In the following pictures: two people are opening the lid of a tin of paint using screwdrivers.



- A. Person A will open the lid easier because of the short effort distance.  
 B. Person A will open the lid easier because of more force applied.  
**C. Person B will open the lid easier because of long leverage.**  
 D. Person B will apply more force than Person A to open the lid.

- 1.11 Match items in Column A with descriptions in Column B. Indicate the letter of the correct description in the Answer Column. (6)

| Column A                          | ANSWER   | Column B                                                       |
|-----------------------------------|----------|----------------------------------------------------------------|
| 1.11.1 Single first-class lever   | <b>E</b> | A. Mechanical Advantage < 1                                    |
| 1.11.2 Linked third-class levers  | <b>A</b> | B. No Mechanical Advantage                                     |
| 1.11.3 Single second-class lever  | <b>F</b> | C. Never gives any Mechanical Advantage                        |
| 1.11.4 Linked first-class levers  | <b>B</b> | D. Mechanical Advantage > 1                                    |
| 1.11.5 Single third-class lever   | <b>C</b> | E. Mechanical Advantage depends on the position of the fulcrum |
| 1.11.6 Linked second-class levers | <b>D</b> | F. Always gives some Mechanical Advantage                      |

- 1.13 Draw lines to match the type of lever in the table to the correct picture. (3)

| Linked 1 <sup>st</sup> class lever                                                  | Linked 2 <sup>nd</sup> class lever                                                  | Linked 3 <sup>rd</sup> class lever                                                    |
|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
|  |  |  |

1.14 Study the pictures below and answer the questions that follow.



Figure 1



Figure 2

1.14.1 Which of the above paper punches will give you the biggest mechanical advantage?

Figure 1

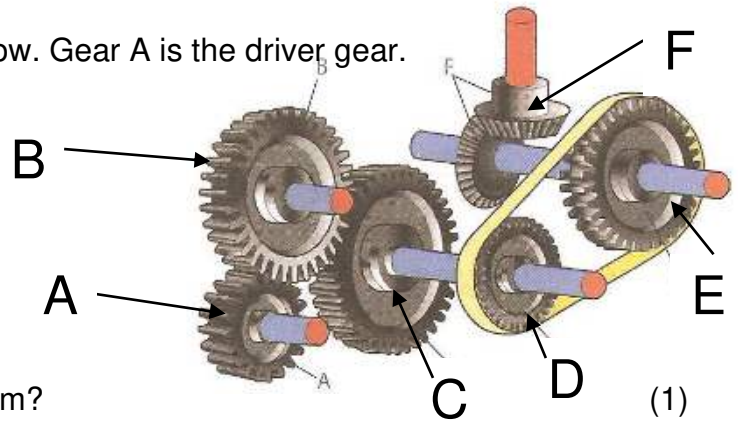
(1)

1.14.4 Explain why do you think so?

(1)

Because it has a long leverage (longer arm of effort)

1.15 Look at the gear system shown below. Gear A is the driver gear.



1.15.1 What is gear B called in this system?

(1)

Idler gear

1.15.2 What influence does gear B have on the rotation of gear A and gear C?

(1)

Gears A and C will rotate in the same direction because of the idler gear.

1.15.3 Gear A is small and rotates fast, will gear B rotate fast or slow?

(1)

Slow

1.15.4 If gear C rotates clockwise, what direction will gear D rotate?

(1)

Explain your answer

(1)

Clockwise

Gear C and D are on the same axis that rotates clockwise

1.15.5 What type of gear system is shown by F?

(1)

Bevel gear

1.15.6 Explain what the main difference is between gear F and all the other gears in the system.

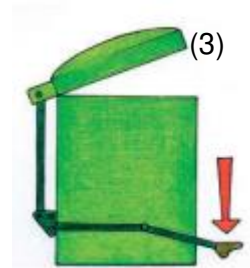
(1)

Bevel gears transfers and changes direction of the rotation with 90°

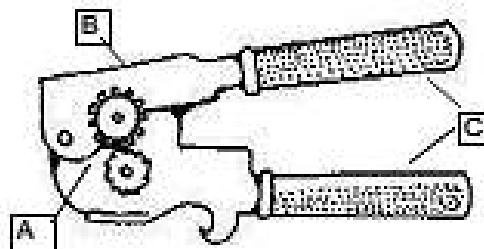
- 1.16 Complete the table below by matching the definitions with terms. Write the letter of the correct term next to the correct description in the answer block. (6)

| DEFINITIONS                                                                                      | ANSWERS  | TERMS          |
|--------------------------------------------------------------------------------------------------|----------|----------------|
| 1.16.1 Something that happens at the same time in the same way.                                  | <b>B</b> | A. Idler gear  |
| 1.16.2 The gear that is caused to rotate as it meshes with the input gear.                       | <b>E</b> | B. Synchronise |
| 1.16.3 A gear between two gears which cause the two outer gears to rotate in the same direction. | <b>A</b> | C. Driver gear |
| 1.16.4 The smaller of the two gears in a set of spur gears.                                      | <b>F</b> | D. Gear train  |
| 1.16.5 The gear which is connected to the energy source or input source.                         | <b>C</b> | E. Driven gear |
| 1.16.6 Two or more gears that are meshed together.                                               | <b>D</b> | F. Pinion      |

- 1.17 Draw the system diagram for a pedal rubbish bin being used. (3)



- 1.18 The can opener is an example of a complex machine. Identify three simple machines in the can opener. (3)



- Wedge
- Wheel and axle
- Lever

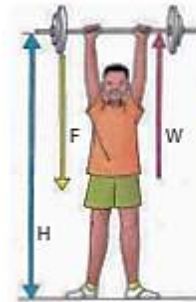
## WEEK 2: MECHANICAL ADVANTAGE

- Mechanisms are parts of machines that **help us to move things**. Machines are **usually made of many connected mechanisms**.
- Mechanisms are useful because they help us to **move things further, faster or by using less force**.

### DO YOU REMEMBER WHAT MECHANICAL ADVANTAGE IS?

- The **two main factors that enable work to be done more easily are force and distance**.

- If we use **more force**, we need **less distance to do work**.
- If we use **less force**, we need **more distance to do work**.



W = Work or effort to lift weights  
F = Force of gravity pulling weight down  
H = Distance weight is lifted

Figure 5 Work = force × distance

- If the **input force is smaller than the output force**, there is a **mechanical advantage**. You can say the **mechanical advantage is bigger than 1**.
- If the **input force is bigger than the output force**, there is **NO mechanical advantage**, but **rather a distance advantage**. You can say the mechanical advantage is smaller than 1.
- The **mechanical advantage (MA)** is
- You can also say that the mechanical advantage is the **ratio between the output force and the input force**.

$$\text{MA} = \frac{\text{output force} / \text{Load}}{\text{input force} / \text{Effort}}$$

## A. LEVERS

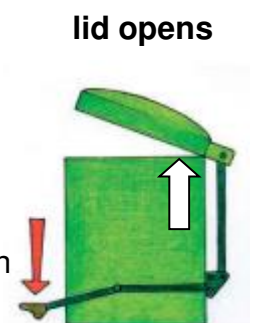
- A lever is a **simple mechanism** consisting of a **rigid bar that pivots around a fixed point called a fulcrum**.

### LINKAGES

- A mechanism that is made by **connecting levers** is called a linkage.
- Linkages are **used to**:

- change the **direction** of movement,
- **increase** the **size** of movement.
- change the **amount of input force**
- change the **distance** of movement. (A pushing movement can be changed to a pulling or turning movement.)

push lever down



## CLASSES OF LEVERS

You can apply a small input force to a lever and generate a much larger output force.

### 1<sup>st</sup> CLASS LEVERS

- The **FULCRUM / PIVOT** is between the effort and the load e.g. seesaw.
- 1<sup>st</sup> Class levers may or may not create a MA, it depends on the position of the fulcrum/pivot.

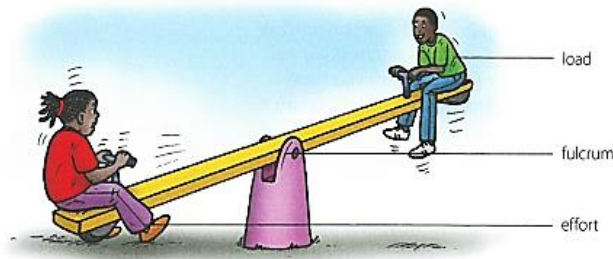
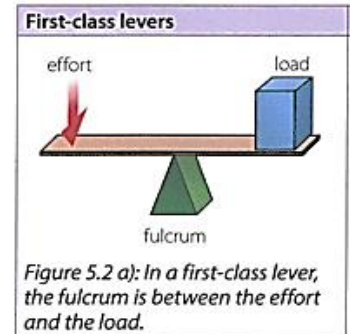


Figure 5.3: A see-saw is an example of a first-class lever system.



- If the **fulcrum/pivot** is closer to the load than the effort – a **mechanical advantage** may be given.

### LINKED 1<sup>ST</sup> CLASS LEVERS

- Two levers are linked at the fulcrum/pivot.
- Scissors** (blades are equal in length to the handle – **NO MA** is achieved)
- A pair of **pruning scissors** (long handles and short, strong blades – less force to get the work done → there is a MA > than 1). The fulcrum is closer to the load. The **length of the blade and the length of the handles can reduce the force needed to do work**, or they can **increase the distance over which work can be done**.

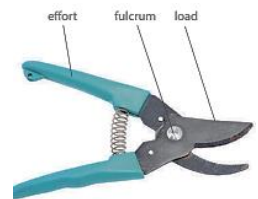
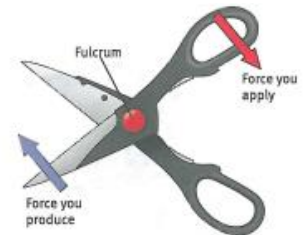
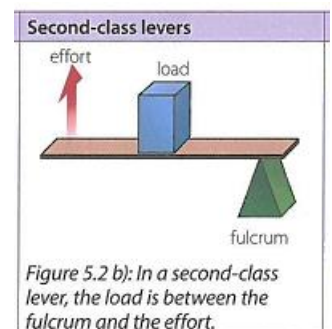


Figure 13 A pair of secateurs

### 2<sup>nd</sup> CLASS LEVERS

- The **LOAD** is between the effort and the fulcrum / pivot e.g. wheelbarrow, paper punch, nut cracker, bottle opener

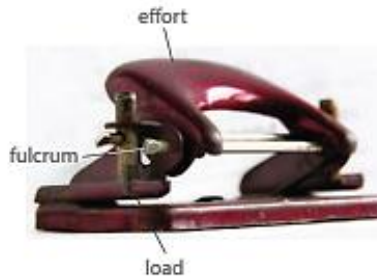


- A 2<sup>nd</sup> class lever **ALWAYS** gives an **mechanical advantage** as the effort force **increases**.

- Mechanical advantage will be **determined by how close the load is to the fulcrum.**
- This advantage can be used for **lifting, crushing, or squeezing** objects.

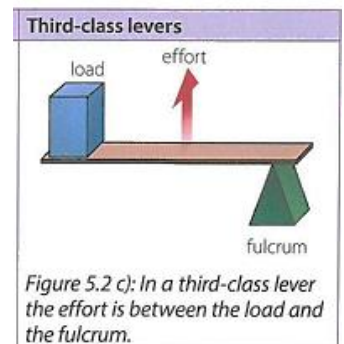
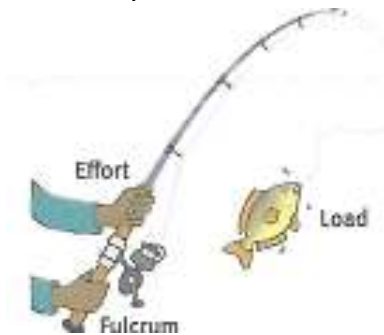
## LINKED 2<sup>nd</sup> CLASS LEVERS

- A **office punch** and nail clipper **are** examples of a linked 2<sup>nd</sup> class lever.



## 3<sup>rd</sup> CLASS LEVERS

- The **EFFORT** is between the fulcrum/pivot and the load.
- A 3<sup>rd</sup> class lever **NEVER** gives a **mechanical advantage** rather a **DISTANCE advantage**.
- An example of a 3<sup>rd</sup> class lever is a **fishing rod, pair of tweezers**



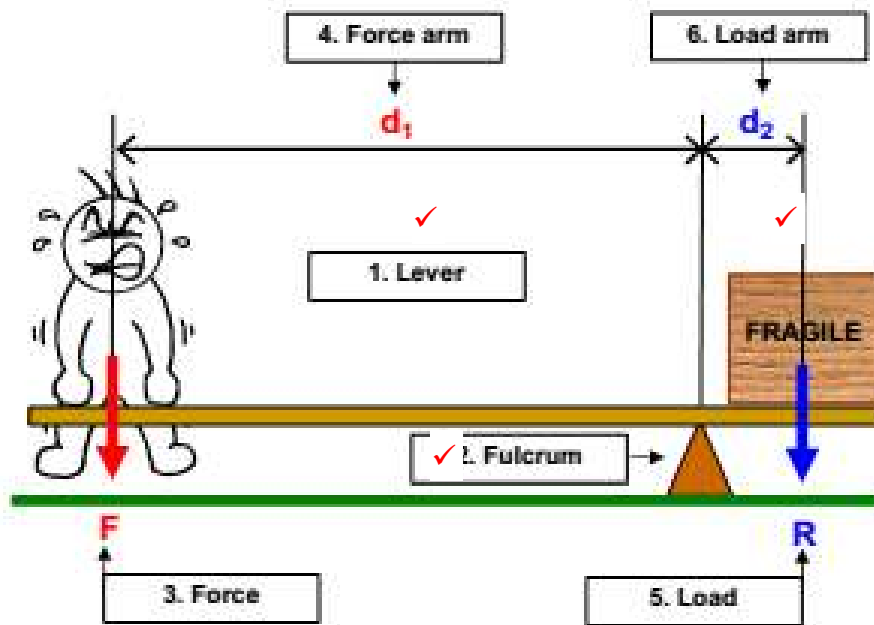
## LINKED 3<sup>RD</sup> CLASS LEVERS

- Two 3<sup>rd</sup> class levers are linked at the fulcrum / pivot.
- The distance of the load to the fulcrum means **more effort is needed to do the work.** **No mechanical advantage is possible.**
- These levers are **used for gripping, pinching or sweeping objects**, as a pair of tongs does, for example.
- Examples of a linked 3<sup>rd</sup> class lever is a **office stapler / heavy duty stapler.** The effort is too close to the fulcrum to give a mechanical advantage.



## ACTIVITY 2

- 2.1 Indicate the following elements of the lever on the drawing: fulcrum, force, load, force arm and load arm. (5)



- 2.2 UNDERLINE the most appropriate answer. (4)

2.2.1 The claw hammer in the photograph can be used as which type of lever?

- a) **Class 1** ✓
- b) Class 2
- c) Class 3



2.2.2 The sack trolley in the photograph can be used as which type of lever?

- a) Class 1
- b) **Class 2** ✓
- c) Class 3



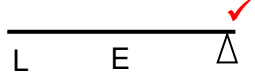
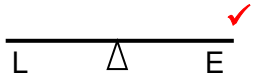
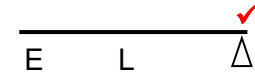
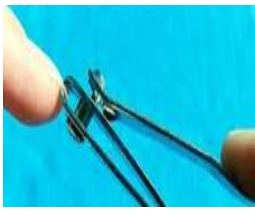
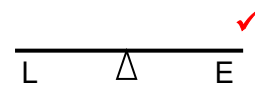
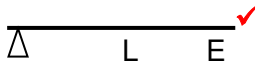
2.2.3 What devices are variants on the lever?

- a) **The pulley and the wheel.** ✓
- b) The wheel and the inclined plane.
- c) The screw and the wedge.

2.2.4 The bigger the distance...

- a) The bigger the force.
- b) **The bigger the work.** ✓
- c) The bigger the speed.

**2.3** Complete the table below by identifying the object, class of lever and drawing the appropriate system diagram.

|       | Lever system                                                                        | Name of object | Class of lever | System Diagram                                                                        |
|-------|-------------------------------------------------------------------------------------|----------------|----------------|---------------------------------------------------------------------------------------|
| 2.3.1 |    | Broom✓         | Class 3✓       |    |
| 2.3.2 |    | Pliers✓        | Class 1✓       |    |
| 2.3.3 |   | Spade✓         | Class 3✓       |    |
| 2.3.4 |  | Wheelbarrow✓   | Class 2✓       |  |
| 2.3.5 |  | Nail clipper✓  | Class 1✓       |  |
| 2.3.6 |  | Bottle opener✓ | Class 2✓       |  |

## CALCULATE THE MECHANICAL ADVANTAGE OF LEVERS

- To provide **mechanical advantage**, a **lever must change the distance over which force must be applied to move an object**.
- Levers can **multiply INPUT FORCES** or **multiply INPUT DISTANCES**, but **NOT AT THE SAME TIME**.

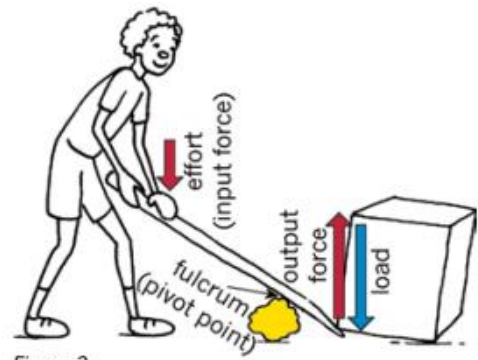


Figure 3

- If a lever makes it **easier** to lift a heavy weight, the **input force is less** than the **output force**, and the **mechanical advantage is greater than 1**.

## THE EFFORT ARM AND THE LOAD ARM OF LEVERS

- A lever is separated into **two parts** on either side of the **fulcrum**.
- The mechanical advantage of a lever **depends on the position of the fulcrum**.
- The **closer the fulcrum is to the effort**, the **greater the mechanical advantage** will be.
- One method** of calculating mechanical advantage is to use the **ratio formula**.
- The **ratio formula** is calculated by identifying the length of the **effort arm** and the **load arm**.

### Key words

- ratio formula** – used to calculate mechanical advantage by using the effort arm and load arm
- effort arm** – the distance between the fulcrum and the point where the input effort is being applied
- load arm** – the distance between the fulcrum and the point where the output load is being applied

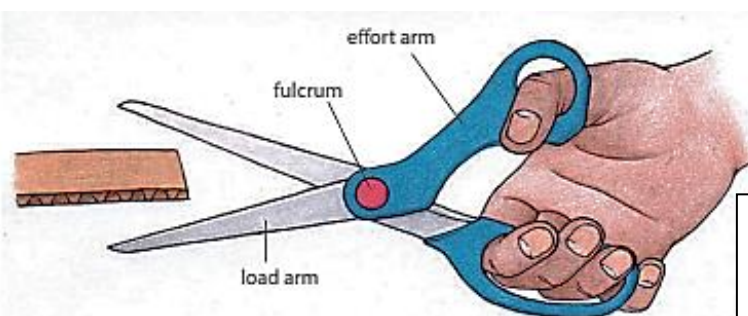
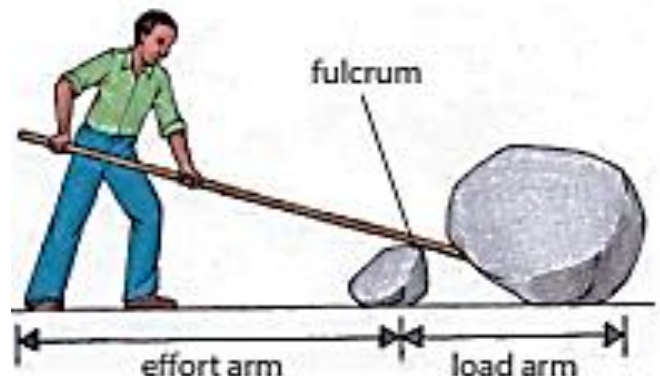


Figure 6 The effort arm and the load arm

$$\text{MA} = \frac{\text{length of EFFORT arm}}{\text{length of LOAD arm}}$$

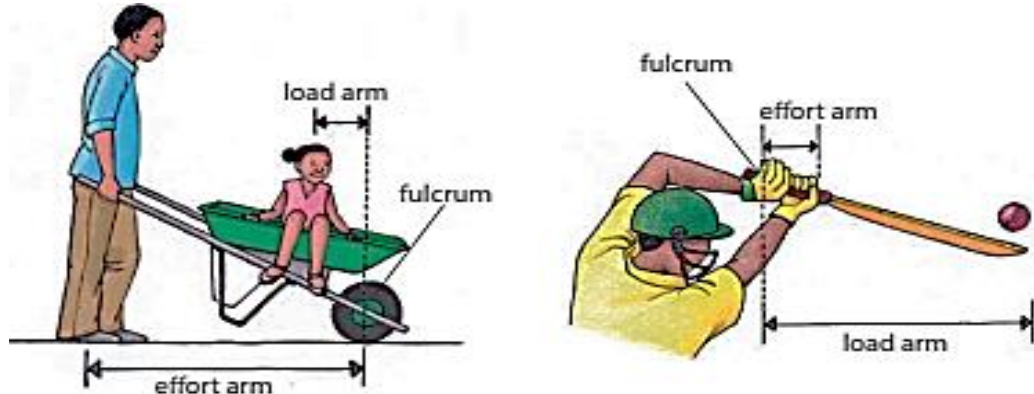
- The **EFFORT ARM** is the distance from the **fulcrum** to the **INPUT**, or **effort** point.
- The **LOAD ARM** is the distance from the **fulcrum** to the **OUTPUT**, or **load** point.



- The **OUTPUT FORCE** is in direct proportion to the **distance between the fulcrum and the input force**.

→ The **greater the distance that is needed to move the lever, the smaller the force will be** that is required to move the load.

→ Study the illustrations below - they show **that a shorter load arm will result in a more powerful effort arm**.



- Therefore, the **shorter load arm** provides **mechanical advantage to the input effort**.
- A **longer load arm** will result in a **less powerful effort arm**.
- EXAMPLE:** A gardener trying to lift a boulder with a stick. Help him to choose the correct length of stick.

The **RATIO FORMULA** is used to calculate mechanical advantage (MA) in levers:

$$\text{Mechanical Advantage} = \frac{\text{length of EFFORT arm}}{\text{length of LOAD arm}}$$

$$= \frac{0.4 \text{ m}}{0.5 \text{ m}}$$

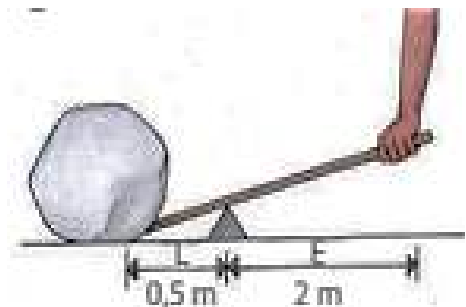
$$\text{MA} = 0.8$$



$$\text{Mechanical Advantage} = \frac{\text{length of EFFORT arm}}{\text{length of LOAD arm}}$$

$$= \frac{2 \text{ m}}{0.5 \text{ m}}$$

$$\text{MA} = 4$$



**CONCLUSION:** A **mechanical advantage**  $< 1$  does not mean the stick is useless. It simply means that, instead of multiplying force, the stick **multiplies distance**.

The gardener should **use the longer stick** because it offers a **greater mechanical advantage**.

The **greater the distance from the fulcrum to the effort**, the **greater the mechanical advantage** will be.

2.4 Solve the following LEVER PROBLEMS:

2.4.1 A lever used to lift a heavy box has an effort arm of 4 meters and a load arm of 0.8 meters. What is the mechanical advantage of the lever? (3)

$$\begin{aligned}\text{Mechanical Advantage} &= \frac{\text{length of EFFORT arm}}{\text{length of LOAD arm}} \\ &= \frac{4 \text{ m}}{0.8 \text{ m}}\end{aligned}$$

$$\text{MA} = 5$$

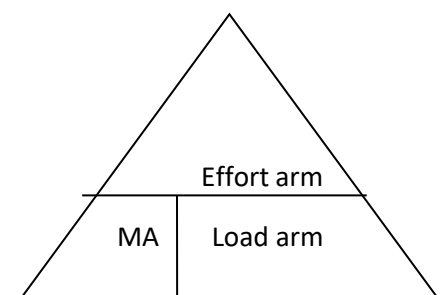
2.4.2 What is the mechanical advantage of a lever that has an effort arm of 3 meters and a load arm of 2 meters? (3)

$$\begin{aligned}\text{Mechanical Advantage} &= \frac{\text{length of EFFORT arm}}{\text{length of LOAD arm}} \\ &= \frac{3 \text{ m}}{2 \text{ m}}\end{aligned}$$

$$\text{MA} = 1.5$$

2.4.3 A lever with an effort arm of 2 meters has a mechanical advantage of 4. What is the load arm's length? (3)

$$\begin{aligned}\text{length of LOAD arm} &= \frac{\text{length of EFFORT arm}}{\text{MA}} \\ &= \frac{2 \text{ m}}{4} \\ &= 0.5 \text{ meters}\end{aligned}$$



- 2.4.4 A lever with a load arm of 0.8 meter has a mechanical advantage of 6.  
What is the length of the effort arm? (3)

$$\begin{aligned}\text{length of EFFORT arm} &= \text{MA} \times \text{length of LOAD arm} \\ &= 6 \times 0.8 \text{ meters} \\ &= \mathbf{4.8 \text{ meters}}\end{aligned}$$

- 2.4.5 A broom with an effort arm length of 0.4 m has a mechanical advantage of 0.5.  
What is the length of the load arm? (3)

$$\begin{aligned}\text{length of LOAD arm} &= \frac{\text{length of EFFORT arm}}{\text{MA}} \\ &= \frac{0.4 \text{ m}}{0.5} \\ &= \mathbf{0.8 \text{ meters}}\end{aligned}$$

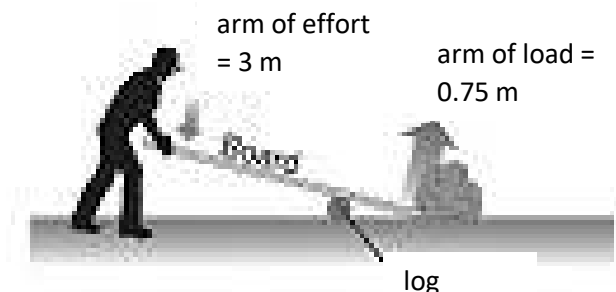
- 2.4.7 A child's toy rake is held so that its load arm is 0.75 meters. If the mechanical advantage is 0.33, what is the effort arm length? (3)

$$\begin{aligned}\text{length of EFFORT arm} &= \text{MA} \times \text{length of LOAD arm} \\ &= 0.33 \times 0.75 \text{ meters} \\ &= \mathbf{0.247 \text{ meters}} \\ &= \mathbf{0.25 \text{ m}}\end{aligned}$$

2.5. **CALCULATE THE MECHANICAL ADVANTAGE** (Show all calculations)

- 2.5.1 A construction worker uses a board and log as a lever to lift a heavy rock. If the input arm is 3 meters long and the output arm is 0.75 meters long, what is the mechanical advantage of the lever? (3)

$$\begin{aligned}\text{MA} &= \frac{\text{arm of effort}}{\text{arm of load}} \checkmark \\ &= \frac{3 \text{ meters}}{0.75 \text{ meters}} \checkmark \\ &= \mathbf{4 \checkmark}\end{aligned}$$



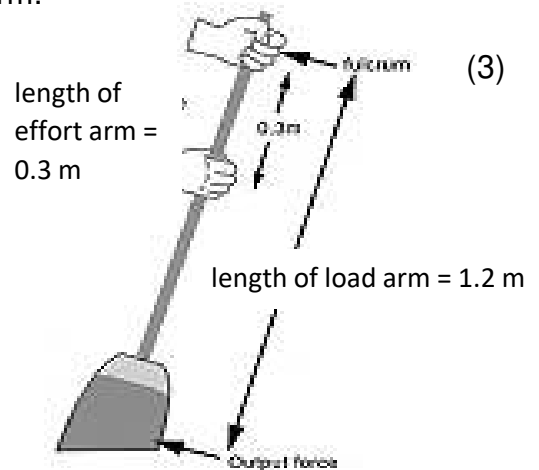
- 2.5.2 Sometimes levers are used to multiply distance. For a broom, your upper hand is the fulcrum, and your lower hand provides the input force: Notice the length of the effort arm is shorter than the length of the load arm.

The mechanical advantage of this broom is:

$$MA = \frac{\text{length of EFFORT arm}}{\text{length of LOAD arm}} \checkmark$$

$$= \frac{0.3 \text{ meters}}{1.2 \text{ meters}} \checkmark$$

$$= 0.25 \checkmark$$



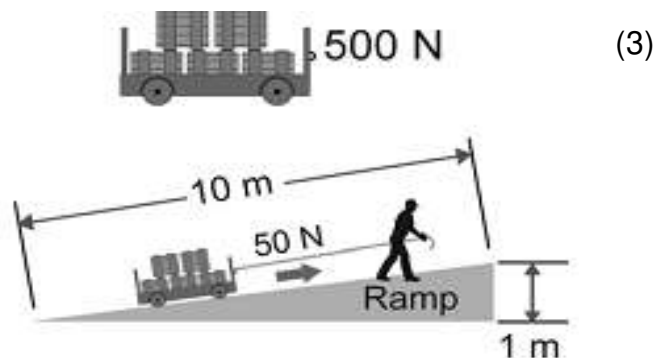
- 2.5.3 A 500-newton cart is lifted to a height of 1 meter using a 10-meter long ramp. You can see that the worker only has to use 50 newtons of force to pull the cart.

Calculate the mechanical advantage.

$$MA = \frac{LOAD}{EFFORT} \checkmark$$

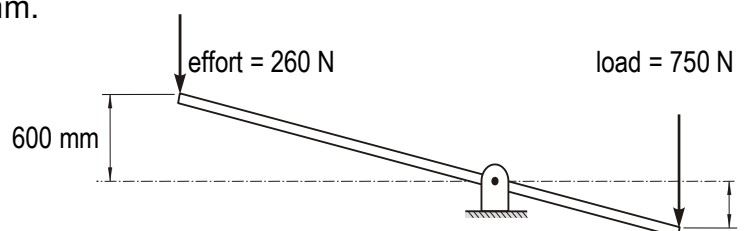
$$= \frac{500 \text{ N}}{50 \text{ N}} \checkmark$$

$$= 10 \checkmark$$



- 2.5.4 The lever below shows a system designed to move heavy machine castings from a lower level to a position of installation.

The castings must be lifted 200 mm.



Find the distance-multiplier ratio for the lever system above.

(3)

$$\text{Movement-multiplier ratio} = \frac{\text{distance moved by the effort}}{\text{distance moved by the load}} \checkmark$$

$$= \frac{600 \text{ mm}}{200 \text{ mm}} \checkmark$$

$$= 3 \checkmark$$

## 2.6 Calculate the distance advantage of a lever

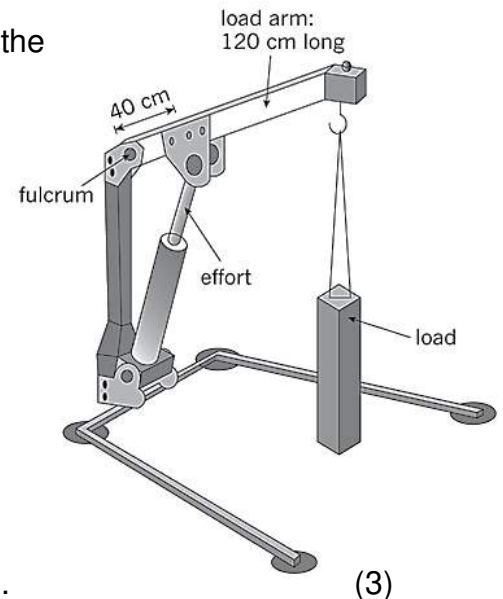
Look at the lifting system illustrated below.

It uses a hydraulic cylinder for the input force.

It is a system that could be used for lifting an engine out of a motorcar.

The lifting lever at the top is a third-class lever, because the input is between the fulcrum and the output.

A third-class lever always gives a distance advantage. It never gives a mechanical advantage.



2.6.1 How long is the input arm on this lever? (1)

40 cm ✓

2.6.2 How long is the output arm? (1)

120 cm ✓

2.6.3 Calculate the mechanical advantage that this lever gives.

$$MA = \frac{\text{arm of effort}}{\text{arm of load}} \checkmark$$

$$= \frac{40 \text{ cm}}{120 \text{ cm}} \checkmark$$

$$= 0.33 \text{ or one third} \checkmark$$

2.6.4 Explain what this MA value tells you about the output and input forces. (1)

- The mechanical advantage is smaller than 1.
- This means that the **output force is smaller than the input force.** ✓

2.6.5 A person wants to use this system to lift an engine out of a car. He needs the engine to be lifted by 90 cm. How far will the hydraulic cylinder at the input need to move for the engine to be lifted 90 cm at the output? Round the distance to the nearest cm.

$$\text{EFFORT} = MA \times \text{LOAD} \checkmark \quad (4)$$

$$= 0.33 \times 90 \text{ cm} \checkmark$$

$$= 29.7 \text{ cm} \checkmark$$

$$= 30 \text{ cm} \checkmark$$

**TOTAL = 45**

## WEEK 3

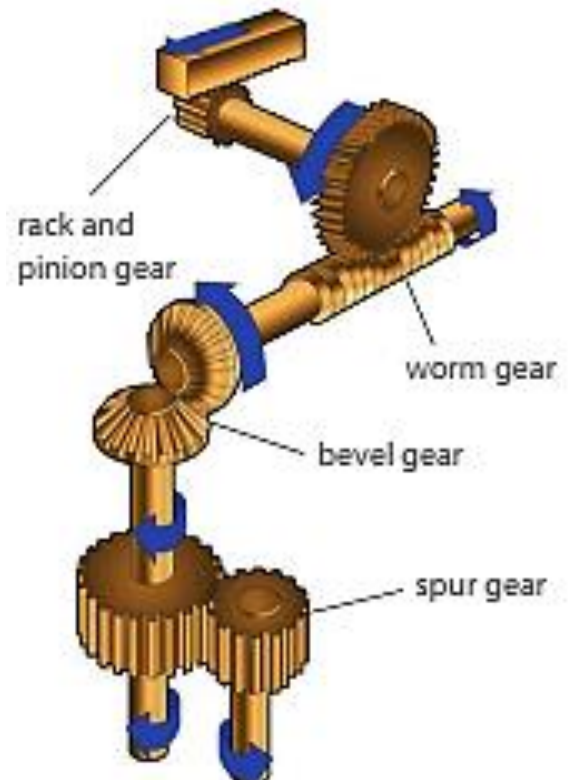
### B. GEAR SYSTEMS

You learnt about gears in Term 1 this year. Do you remember? Here are a few reminders:

- Gear systems uses **toothed wheels** that mesh together.
- A geartrain consists of two wheels that rotate in **opposite directions → counter rotation**.
- When a force is applied, and the **gears rotate around an axis it is called a torque**.
- A gear system **changes an input into an output** and therefore transfer rotating movement.
- When a **chain of two or more gears mesh**, it is called a **gear train**.
- They can increase or decrease the turning speed of a wheel or axle.
- The teeth of two gears mesh together so that if one gear turns, the other gear will turn as well, in the opposite direction.
- **Gear trains are used in many machines**, for example:
  - **power drills,**
  - **food mixers and**
  - **bicycles.**
- Machines we use today **combine many gear trains in one machine**. For example: telescopes

#### Key words

- **gear system** – gears and gear wheels used to change the speed of a turning, or rotational, movement
- **spur gear** – a gear with teeth like spurs on its edge. This is the most common type of gear
- **bevel gear** – a gear used to change rotational movement through 90°
- **rack and pinion gear** – a gear that changes rotational movement into linear movement
- **worm shaft** – part of a shaft that has one continuous groove in the form of a screw thread



## TYPES OF GEARS

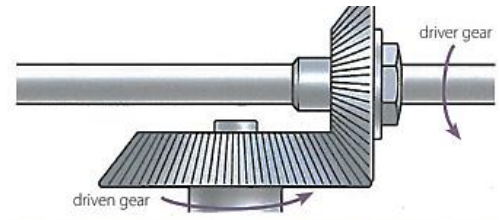
### a. SPUR GEARS

- Notice how the edge of every tooth is straight and aligned parallel to the turning axle.
- Spur gears can **regulate the speed or force of motion**.
- They are the most common type of gear **used in machines**, such as:
  - **washing machines,**
  - **eggbeaters and**
  - **aircraft engines**



### b. BEVEL GEARS

- The side of the gear's teeth is **shaped like a cone**.
- The **smaller gear** usually **drives** the gear system.
- In such cases, the smaller gear is called a **pinion gear**.
- Bevel gears are **used to change the direction of rotation**.
- They are used in:
  - **watches,**
  - **dentist's drills and**
  - **electric typewriters.**



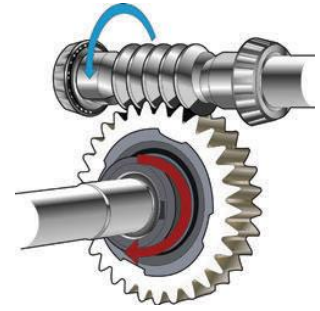
### c. RACK AND PINION GEAR

- The **pinion** is a normal **spur gear** that meshes with a **flat strip of gear teeth** called the **rack**.
- This type of **gear changes rotary motion into linear motion**.
- Either the rack or the pinion can be fixed, allowing the other part to move freely.
- These **gears are used** in:
  - a car's steering mechanism,
  - in train wheels and in
  - milling machines



### d. WORM GEARS

- It is part of a **shaft that has one continuous groove** in the form of a **screw thread**. The shaft is called the **worm shaft**.
- It **meshes with a spur gear** called the **worm gear**, or worm **wheel**.
- This type of gear can **deliver a very strong turning force** with very **little input effort**.
- These gears are used as:
  - the **tuning** heads of **musical instruments such as guitars**, and
  - in the **winding mechanisms of watches**,
  - corkscrews** and
  - toys**.



**torque** – the force applied to move an object around an axis

**counter rotation** – two wheels in a gear rotating in opposite directions

## ACTIVITY 3

3. Answer the following questions on gears

- 3.1. Match the description in COLUMN A to the terms in COLUMN B. Write only the letter of the alphabet in COLUMN B next to its matching description in the ANSWER column. (4)

|       | COLUMN A                                                                                                                                                                              | ANSWER | COLUMN B           |
|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|--------------------|
| 3.1.1 | Wheels with teeth that mesh with each other. They change the speed and direction of a rotating shaft.                                                                                 | B✓     | A. Bevel gears     |
| 3.1.2 | These gears work on the screw principle. A rotation on the screw wheel causes a much slower rotation on the toothed wheel. The input and output shafts are also at 90° to each other. | D✓     | B. Spur gears      |
| 3.1.3 | A gear wheel and a toothed bar to change a rotary movement into a linear movement.                                                                                                    | C✓     | C. Rack and pinion |
| 3.1.4 | These gears change the direction of rotation through 90°. The teeth are angled at 45° so the gears fit together at right angles.                                                      | A✓     | D. Worm gears      |

3.2 Underline the correct answer.

- 3.2.1 Two or more spur gears meshed together are called a ... (1)

- A. Pinion
- B. Gear train✓
- C. Gear ratio
- D. Idler gears

3.2.2 The gear that starts the motion in a gear system is called the ... gear. (1)

- A. Starter
- B. Idler
- C. Driver✓
- D. Driven

3.2.3 What type of gear train is shown in the photograph? (1)

- A. Simple
- B. Compound✓
- C. Bevel
- D. Rack and pinion



3.2.4 A camera tripod uses which type of gears for the height adjustment mechanism? (1)

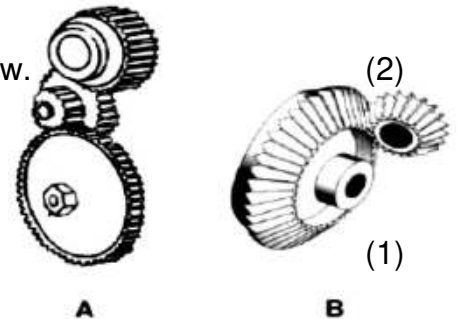
- A. Rack and pinion✓
- B. Bevel
- C. Helical
- D. Worm gear



3.3 Mechanisms are often used for control of motion. A variety of mechanisms are shown below.

3.3.1 Identify the mechanism labelled A and B illustrated below. (2)

- A: A gear train✓
- B: Bevel gears✓



3.3.2 Give an example for the use of mechanism B. (1)

Handmixer / hand drill etc.✓

3.3.3 Do you think geartrain B will provide a speed advantage or a mechanical advantage? Explain your answer. (2)

- It gives a speed advantage. ✓
- Reason: the small output gear will rotate much faster than the big input gear. ✓

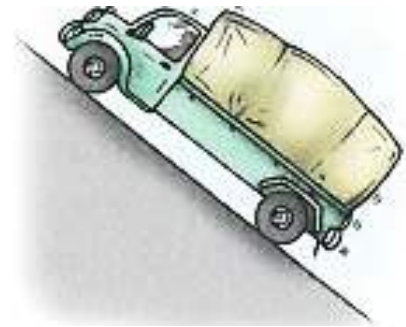
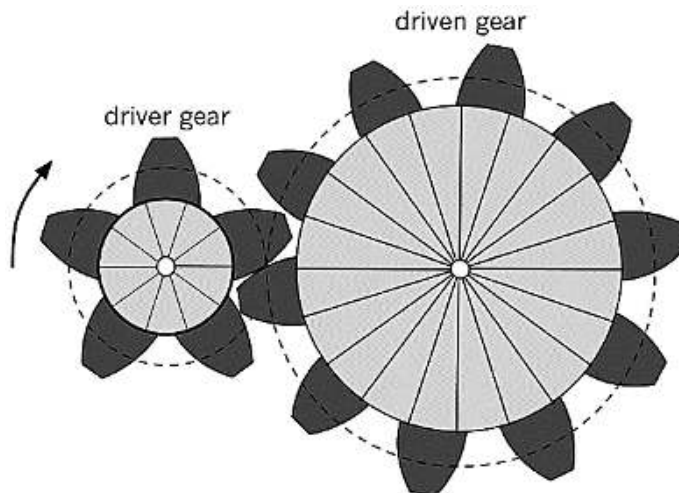
3.3.4 Explain how the bevel gears work. (2)

- This gear system changes the direction of rotation from a rotation around a horizontal axis (for the big input gear) to a rotation around a vertical axis (for the small output gear with 90°).✓

## CONCEPTS IN GEAR SYTEMS

### I. COUNTER ROTATION OF SMALL DRIVER & BIG DRIVEN GEAR TRAINS

- A **small driver gear** connected to a **large driven gear** will change a **fast turning speed into a slower turning speed**.



Greater force / torque

- This gear system will make the **wheels** turn with a **greater turning output force** than the **input turning force of the motor**.
- This system gives a **mechanical advantage**.

#### REMINDER:

A mechanical advantage means that the **turning force at the output axle** is **greater** than the **turning force at the input axle**.

3.5.1 If the driver gear turns clockwise, which way will the driven gear turn? (1)

It will turn in the opposite direction or anti-clockwise. ✓

3.5.2 Calculate the number of revolutions the driver gear needs to turn to make the driven gear turn once. (2)

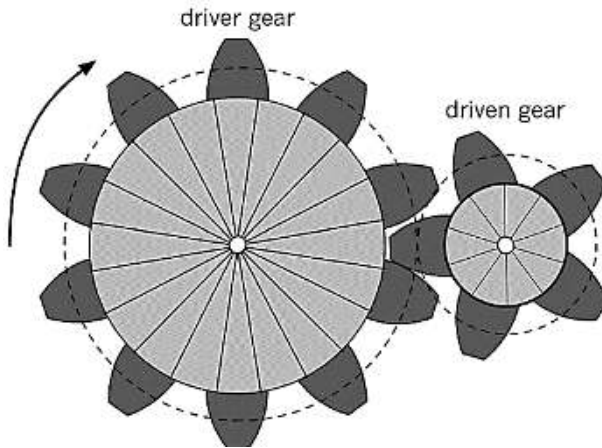
- The driver gear will turn twice for each revolution of the driven gear. ✓
- This is because the 5 teeth on the driver gear will turn the driven gear halfway round, and it has to turn another revolution to turn the rest of the teeth of the driven gear as well. ✓

3.5.3 Will this system give a mechanical advantage? How do you know? (2)

- Yes, ✓
- MOTIVATION: The rotational speed of the output gear is slower than the rotational speed of the input gear. If the rotational speed of the output gear is smaller, it means that the turning force of the output axle is bigger than on the input axle. ✓

## II. COUNTER ROTATION OF BIG DRIVER & SMALL DRIVEN GEAR TRAINS

- A **large driver gear** connected to a **small driven gear** will change a slow turning speed into a faster turning speed.



Small driven gear → speed advantage

- This system gives a **distance or speed advantage**.
- A **turning force is called a torque**, it is measured in **revolutions per minute, or r pm**.

### REMINDER:

A speed advantage means that the speed of rotation of the driven axle (output axle) is **faster** than the speed of rotation of the driver axle (input axle)

- 3.6.1 Will the driven gear in the illustration above turn faster or slower than the driver gear? Explain your answer. (2)

The driven gear will turn faster than the driver gear ✓  
The driven gear has fewer teeth than the driver gear. ✓

- 3.6.2 A driver gear has 10 teeth and the driven gear has 5 teeth. How many revolutions will the driver gear need to turn to make the driven gear turn once? Explain why this happens. (2)

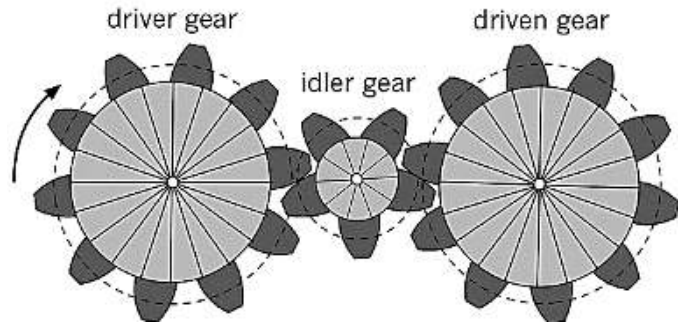
- Half a revolution of the driver gear will make the driven gear turn one complete revolution. ✓
- This is because only half of the teeth of the driver gear will have meshed with all 5 of the teeth of the driven gear. ✓

- 3.6.3 Will this gear system give a mechanical advantage or a speed advantage? How do you know? (2)

This gear system will give a speed advantage. ✓  
The driven gear will turn faster than the driver gear because the driven gear has fewer teeth. ✓

### III. IDLER GEARS

- Two spur gears connected via an idler.
- When an **idler gear connects two spur gears** it is called a **gear train** as illustrated on the right.



- The **driver gear** rotates in a **clockwise** direction. The meshed **idler gear rotates anticlockwise**, and the **driven gear rotates clockwise**.
- Synchronised rotational direction** occurs in a gear train where the **driver gear and driven gear rotate in the same direction**.

### IV. BEVEL GEARS LINKED, TO TRANSFER THE AXIS OF ROTATION TO 90°

- Study the illustration on the right. Notice how the **bottom gear is linked to the top gear**.
- Bevel gears **can change the axis of rotational movement**.
- The gears in the illustration are **mounted on shafts that are 90° apart**.
- The **horizontal rotation** of the bottom gear is **changed by 90° into a vertical rotational direction of the top gear**.
- The bevel gears in the illustration show how **rotational direction can be changed to any angle**.

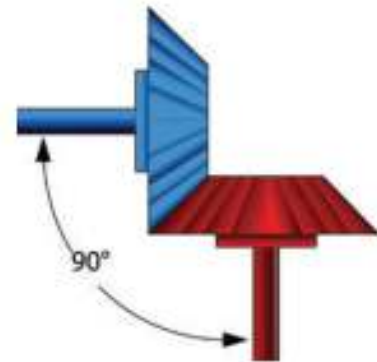
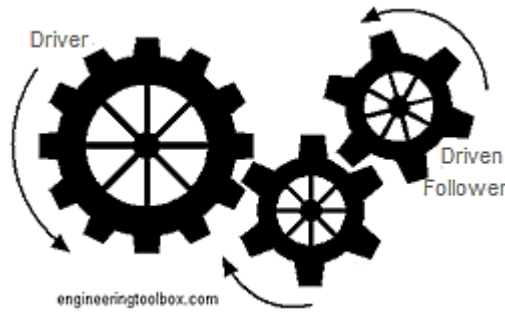


Figure 16 Bevel gears rotated 90°

3.7 Complete the table below by matching the definitions with terms. Write the letter of the correct term next to the correct description in the answer block. (6)

| DEFINITIONS                                                                                     | ANSWERS  | TERMS          |
|-------------------------------------------------------------------------------------------------|----------|----------------|
| 3.7.1 Something that happens at the same time in the same way.                                  | <b>B</b> | A. Idler gear  |
| 3.7.2 The gear that is caused to rotate as it meshes with the input gear.                       | <b>E</b> | B. Synchronise |
| 3.7.3 A gear between two gears which cause the two outer gears to rotate in the same direction. | <b>A</b> | C. Driver gear |
| 3.7.4 The smaller of the two gears in a set of spur gears.                                      | <b>F</b> | D. Gear train  |
| 3.7.5 The gear which is connected to the energy source or input source.                         | <b>C</b> | E. Driven gear |
| 3.7.6 Two or more gears that are meshed together.                                               | <b>D</b> | F. Pinion      |

3.8 Study the gear train below and answer the questions.



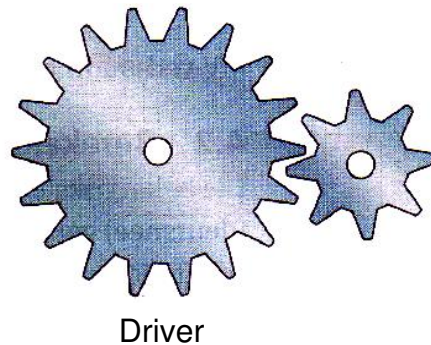
3.8.1 Explain what will happen to the direction the gears turn if the middle gear is removed and the two remaining gears mesh and turn. (1)

The gears will turn in OPPOSITE directions.✓

3.8.2 In relation to the driver will the follower turn faster or slower. (1)

The follower will turn FASTER than the driver✓

3.9. Look at the illustration below and answer the question that follow.



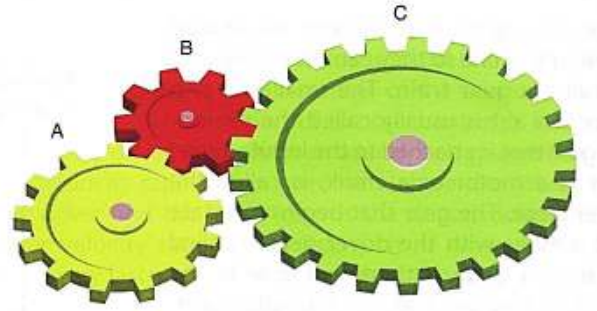
3.9.1 Calculate the output force of the gear system if the input force is 200N. (3)

$$\begin{aligned} \text{Output Force} &= \frac{\text{Number of teeth on driven gear}}{\text{number of teeth on driver gear}} \times \text{Input force} \checkmark \\ &= \frac{8}{18} \times 200N \checkmark \\ &= 88.89N \checkmark \end{aligned}$$

3.9.2 Will this gear system give a force advantage or a speed advantage? Motivate your answer. (3)

- Speed advantage.✓
- When a driver gear is meshed with a smaller gear, the speed is multiplied.✓
- The driven gear turns faster than the driver, but with less force.✓

3.10 Study the picture below and answer the questions that follow.



3.10.1 What do we call the arrangement of gears in the picture above? (1)

Compound gears.✓

3.10.2 What is the gear in the middle called? (1)

Idler gear✓

3.10.3 Which gear will turn the fastest? Explain why. (2)

Gear B✓ Because it is the smallest.✓

3.10.4 Which gear will turn the slowest? Explain why. (2)

Gear C✓

Because it is the biggest and it has more teeth.✓

## WEEK 4: CALCULATE THE MECHANICAL ADVANTAGE OF GEARS

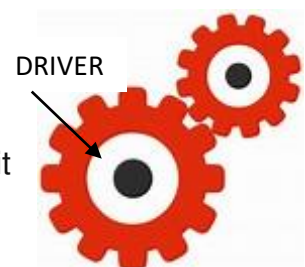
Gear systems can gear up or gear down. This **increases or decreases the amount of torque in the system resulting in mechanical advantage.**

Remember that the mechanical advantage is how much easier the system makes the work. When calculating the mechanical advantage (MA) of a system, the greater the value is above 1, the greater the mechanical advantage will be.

To 'gear up' or "gear down" means **whether or not you want more top-end speed or more low-end torque.**

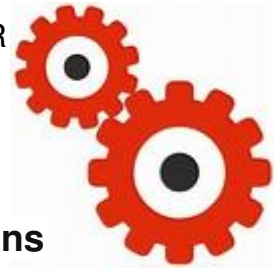
**GEARING UP:** when the torque in the system

- When a **LARGE DRIVER** gear is connected to a motor and it turns a **SMALL DRIVEN** gear (the output gear – maybe connected to a wheel).
- The **smaller gear will turn several times for each rotation of the large gear**. This means that the wheel will turn faster – this is 'gearing up' for speed.
- Gearing up provides a **SPEED ADVANTAGE**.



## GEARING DOWN

DRIVER



- When a **SMALL DRIVER** gear is connected to a motor and it turns a **BIG DRIVEN** gear.
- The **BIG DRIVEN** gear will turn once for several rotations of the **SMALL DRIVER** gear.
- Gearing DOWN provides a **FORCE ADVANTAGE**.

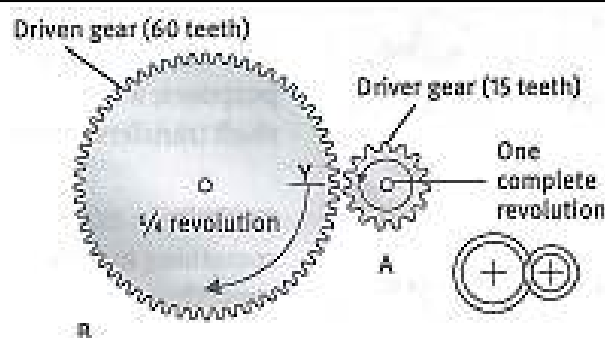
## USING GEAR RATIOS TO DETERMINE THE MECHANICAL ADVANTAGE

- Gear ratio is about **comparing the size of different gears**. Gear ratio calculations can determine the mechanical advantage of gears.
- Gear ratio/ velocity ratio calculations depend on:
  - the **number of teeth on each gear (tooth ratio)**;
  - the **sizes of each gear wheel (gear wheel diameter)** and
  - the **speed of the input gear and output gear (velocity ratio)**.

### A. CALCULATE GEAR RATIOS USING TOOTH RATIOS

- Gear ratio can be calculated with the tooth ratio of the gears in a system.
- Determine MECHANICAL ADVANTAGE / GEAR RATIO using the following tooth ratio formula:

|  |                                                                                                                            |
|--|----------------------------------------------------------------------------------------------------------------------------|
|  | $\text{GEAR RATIO} = \frac{\text{number of teeth on DRIVEN gear (OUTPUT)}}{\text{number of teeth on DRIVER gear (INPUT)}}$ |
|--|----------------------------------------------------------------------------------------------------------------------------|



$$\begin{aligned}
 \text{GEAR RATIO} &= \frac{\text{Number of teeth of DRIVEN gear}}{\text{Number of teeth of the DRIVER gear}} \\
 &= \frac{60 \text{ Teeth}}{15 \text{ Teeth}} \\
 &= 4 : 1 \text{ (driven gear : driver gear)}
 \end{aligned}$$

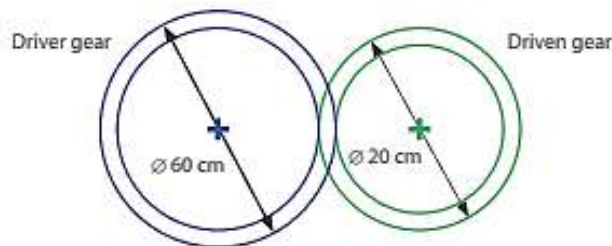
The following observations can be made from the calculation results:

- the **DRIVER** gear revolves **four times** to turn the *driven gear once*
- the **DRIVER** gear is turning **four times faster** than the driven gear
- although the **DRIVEN** gear moves four times more slowly, it moves with **four times greater force** than the driver gear
- when the **speed increases** → *force decreases*

## B. CALCULATE GEAR RATIOS USING GEAR WHEEL DIAMETERS

- Gear ratio can also be calculated using the gear **wheel diameter** of the gears in a system.
- Determine gear ratio using the following gear wheel diameter formula:

$$\text{GEAR RATIO} = \frac{\text{DIAMETER of the DRIVEN gear (OUTPUT)}}{\text{DIAMETER of the DRIVER gear (INPUT)}}$$



$$\begin{aligned} \text{Gear ratio} &= \frac{\text{Diameter } (\varnothing) \text{ of the DRIVEN gear (output)}}{\text{Diameter } (\varnothing) \text{ of the DRIVER gear (input)}} \\ &= \frac{20 \text{ cm}}{60 \text{ cm}} \\ &= 1 : 3 \end{aligned}$$

### Key word

- **gear wheel diameter** – the diameter of the gear wheel relates to its size, which influences the gear wheel's mechanical advantage

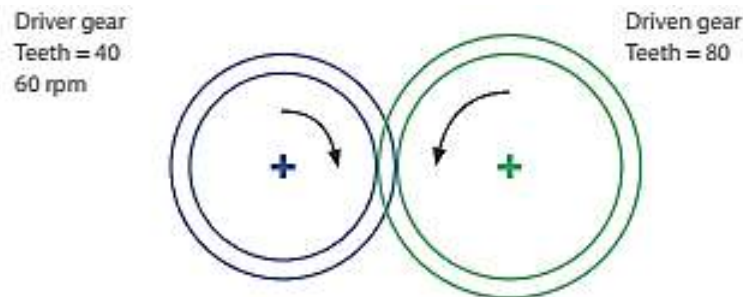
The following observations can be made from the calculation results:

- if the **diameter of the DRIVER gear is three times larger** than the **diameter of the driven gear**, the **mechanical advantage is 3:1, or 3**
- the **output force** will be **three times greater** than the **input force**.

## C. CALCULATE GEAR RATIOS USING VELOCITY RATIO

- Velocity is the **speed at which a gear revolves**.
- In any gear system, the **DRIVER** gear is driven by a **power source**. Many toys are powered with a small motor.
- The **power source** turns the **gear's axle** by a certain number of **revolutions per minute**.
- **Revolutions per minute (rpm)** are the **number of times a gear completes one full turn in one minute**.
- The velocity ratio (VR) is determined by the following formula:

|                                                                                                                    |
|--------------------------------------------------------------------------------------------------------------------|
| $\text{VELOCITY RATIO / SPEED RATIO} = \frac{\text{Speed (rpm) on OUTPUT gear}}{\text{Speed (rpm) of INPUT gear}}$ |
|--------------------------------------------------------------------------------------------------------------------|



- The driver gear has 40 teeth and the driven gear has 80 teeth.
- If the driver gear revolves at 60 rpm, **what is the driven gear's speed?**
- This can be calculated using the gear ratio formula:

$$\begin{aligned}
 \text{GEAR RATIO} &= \frac{\text{number of teeth on DRIVEN gear (output)}}{\text{number of teeth on DRIVER gear (input)}} \\
 &= \frac{80}{40} \\
 &= \frac{2}{1} \\
 &= 2 : 1
 \end{aligned}$$

### Key word

- **revolves** – when a gear wheel rotates one full turn around its own axle

- **Remember that the VELOCITY RATIO / SPEED RATIO of a pair of gears is always the opposite of the gear ratio.**
- This means that the driver gear rotates twice every time the driven gear rotates once.
- This also means that the driven gear will move at half the speed of the driver gear. So, the driven gear will revolve at 30 rpm.

- **VELOCITY RATIO / SPEED RATIO** can be calculated using the GEAR RATIO and the INPUT SPEED of the DRIVER gear:

$$\text{OUTPUT SPEED} = \frac{\text{INPUT SPEED}}{\text{GEAR RATIO}}$$

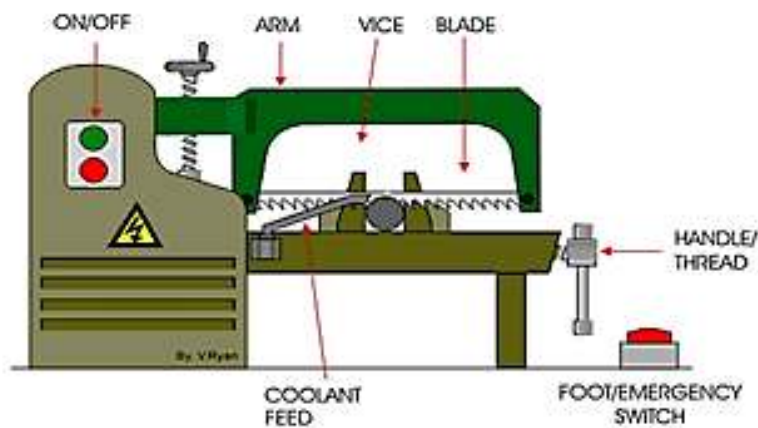
$$= \frac{60 \text{ rpm}}{2}$$

$$= 30 \text{ rpm}$$

- By using driven gears with different numbers of teeth to mesh with the driver, the speed of rotation of the driven gears can be changed.

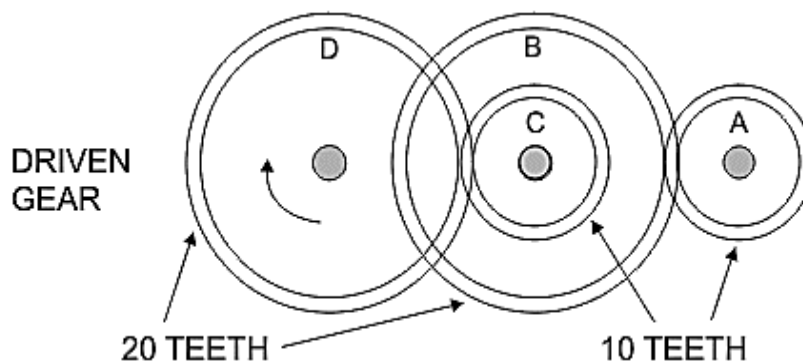
4. Answer the following question on gears

- 4.1. The gear system shown below is to be added to the motor so that the speed of the power hacksaw can be controlled.



4.1.1 Calculate the gear ratio of gears A and B.

(3)

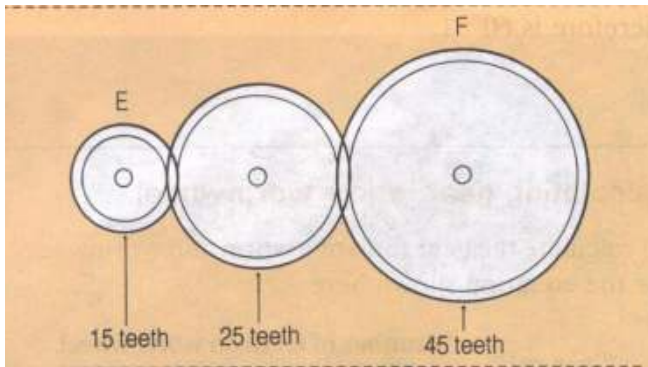


$$\text{GEAR RATIO} = \frac{\text{Number of teeth on the DRIVEN gear}}{\text{Number of teeth on the DRIVER gear}}$$

$$= \frac{20t}{10t} \checkmark$$

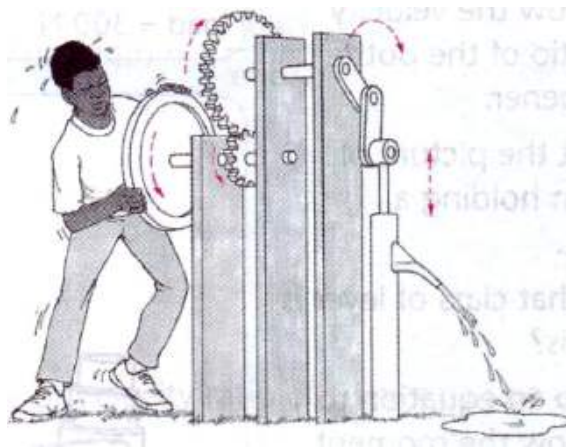
$$= 2 : 1 \checkmark$$

4.2 What is the gear ratio of the transmission system below? (3)



$$\begin{aligned} \text{Gear ratio} &= \frac{\text{\# of teeth on DRIVEN gear}}{\text{\# of teeth on DRIVER gear}} \\ &= \frac{45}{15} \\ &= 3 : 1 \end{aligned}$$

4.3 Study the illustration below and answer the questions that follow.



4.3.1 In which direction does the boy turn the wheel? (1)

Anti-clockwise ✓

4.3.2 Which gear do you think is the input gear? Explain your answer. (2)

- The small gear is the input gear. ✓
- The small gear is attached to the crank which provides the input motion. ✓

4.3.3 Will the top gear turn faster or slower than the bottom gear? (1)

Slower ✓

4.3.4 What can be done to make the two gears turn in the same direction? (1)

A third gear (idler) can be placed between the two gears. ✓

4.3.5 Will the machine still be able to perform its function if the two gears turn in the same direction? Explain your answer. (2)

- Yes. ✓
- The linked levers will turn in the opposite direction but will still move the piston up and down as required. ✓

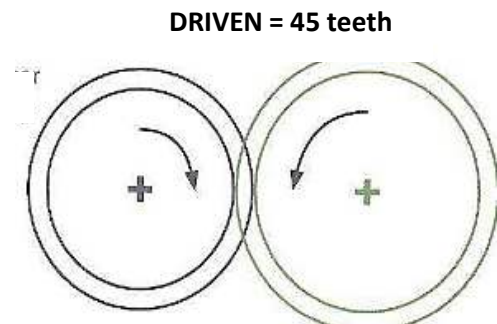
- 4.3.6 Calculate the gear ratio if the small gear has 25 teeth and the large gear has 90 teeth. (3)

$$\begin{aligned}\text{Gear Ratio} &= \frac{\text{Number of teeth on driven gear}}{\text{Number of teeth on driver gear}} \checkmark \\ &= \frac{90}{25} \checkmark \\ &= 3.6 : 1 \checkmark\end{aligned}$$

- 4.4 Calculate the **mechanical advantage** in the gear systems below by using...

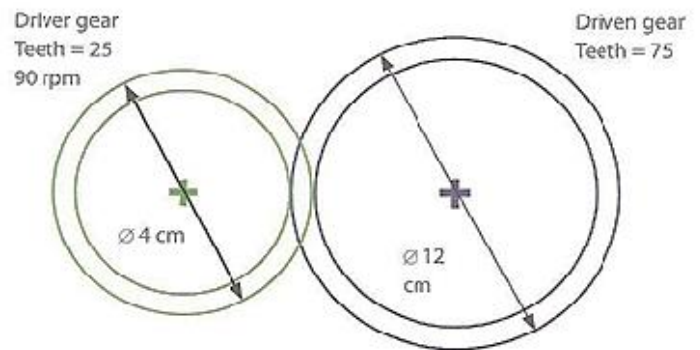
- 4.4.1 Tooth ratio (4)

$$\begin{aligned}\text{MA} &= \frac{\# \text{ of teeth of the DRIVEN gear}}{\# \text{ of teeth of the DRIVER gear}} \checkmark \\ &= \frac{45 \text{ Teeth}}{15 \text{ Teeth}} \checkmark \\ &= 3 : 1 \checkmark \\ \text{MA} &= 3 \checkmark\end{aligned}$$



- 4.4.2 Gear wheel diameters (4)

$$\begin{aligned}\text{MA} &= \frac{\varnothing \text{ of the DRIVEN gear}}{\varnothing \text{ of the DRIVER gear}} \checkmark \\ &= \frac{12 \text{ cm}}{4 \text{ cm}} \checkmark \\ &= 3 : 1 \checkmark \\ \text{MA} &= 3 \checkmark\end{aligned}$$



- 4.4.3 Calculate the velocity ratio in revolutions per minute (rpm) at gear C if gear A rotates at 60 rpm. (5)

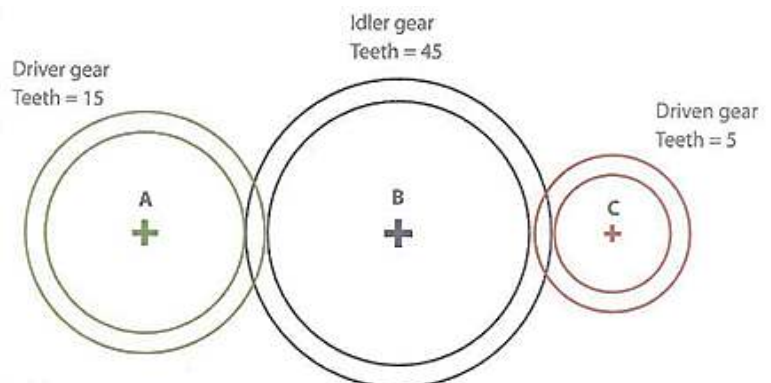
$$\frac{\text{rpm of driver}}{\text{rpm of driven}} = \frac{\text{number of teeth of driven gear}}{\text{number of teeth of driver gear}} \checkmark$$

$$\frac{60 \text{ rpm}}{\text{rpm of driven}} = \frac{5}{15} \checkmark$$

$$\frac{60 \text{ rpm}}{\text{rpm of driven}} = \frac{1}{3} \checkmark$$

$$\frac{60 \text{ rpm}}{1} \times 3 = \text{rpm of driven} \checkmark$$

$$\text{rpm of driven} = 180 \text{ rpm} \checkmark$$



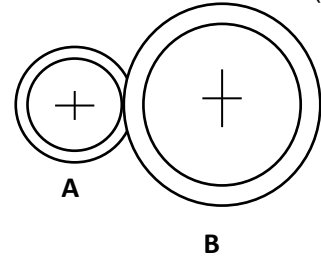
MEMORANDUM

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SOURCES: PLATINUM, VIA AFRIKA, SASOL INZALO

4.4.4 If the diameter of the driver/input gear (A) is 10 cm and diameter the driven/output gear (B) is 5 cm, calculate the gear ratio. (3)

$$\begin{aligned}\text{Gear ratio} &= \frac{\text{Diameter of the output/driven gear B}}{\text{Diameter of the input/driver gear A}} \quad \checkmark \\ &= \frac{10}{5} \quad \checkmark \\ &= 2 : 1 \quad \checkmark\end{aligned}$$



4.4.5 From the calculation in 4.4.4 indicate the magnitude of the output force in comparison to the input force. (1)

Mechanical advantage of 2 implies that the magnitude of the output force will be 2 times greater than the magnitude of the input force. ✓

## REPRESENT GEAR SYSTEMS GRAPHICALLY

### RULES OF DRAWING

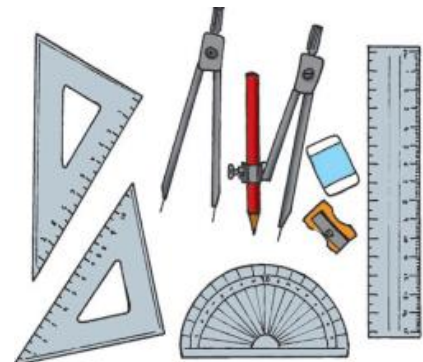
- Design engineers have to draw the gear system of a machine very clearly and accurately.
- **Keep the following in mind when drawing gears of the same size:**
- **Two meshed gears rotate in opposite directions.** Use arrows to show the direction of rotation.
- An **idler gear causes the driver gear and the driven gear to rotate in the same direction**, but it does not affect the velocity ratio of a gear system.
- **The gear with the most teeth in a gear train will rotate the slowest.**

### DRAWING TOOLS AND EQUIPMENT

To draw gears for working drawings you need appropriate drawing equipment:

- ➔ a pencil,
- ➔ sharpener,
- ➔ eraser,
- ➔ ruler,
- ➔ set squares and
- ➔ a pair of compasses.

**A basic set of mathematical instruments should contain these items.**



## DRAWING GEARS

- Because it would take too long to draw all the teeth of a gear, **one gear is represented as two circles.**
- **One circle** is drawn **slightly larger than the other**. Drawing two spur gears with a pair of compasses
- The teeth of gears are represented with two circles drawn inside one another.

## STEPS TO FOLLOW WHEN DRAWING GEARS:

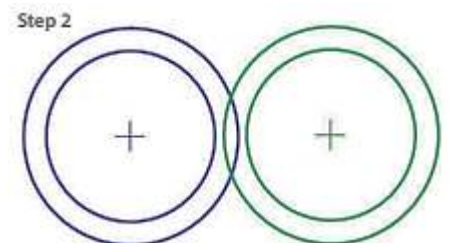
### STEP 1:

- Start by drawing a horizontal centre line for both gears.
- Draw a vertical centre line for the driver gear on the marks the centre of the driver gear wheel.
- Use a pair of compasses to draw one circle according specifications e.g., 50 mm diameter.
- Draw another circle 10 mm smaller than the first circle diameter inside the previous circle.
- Mark the centre of the gear with a cross.



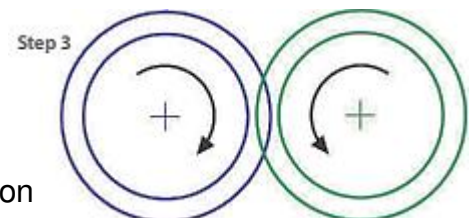
### STEP 2:

- Draw a second gear meshing with the first gear.
- The two outer circles must overlap slightly to show where the gears are meshing.



### STEP 3:

- Label the first gear the driver gear.
- Label the second gear the driven gear.
- Draw a directional arrow on both gears to show the direction of rotation.

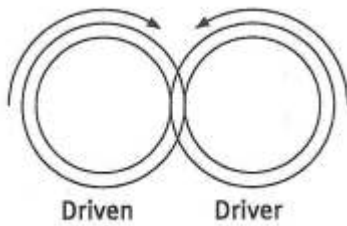


Driver = 25 t    Driven = 25 t

- Write the number of teeth /  $\varnothing$  (diameter) of gears under the gears.  
E.g., 25 teeth / 25 mm

#### 4.5 Represent the the following gears graphically

##### 4.5.1 The driven gear rotating in the **opposite direction** to the driver (counter rotation).

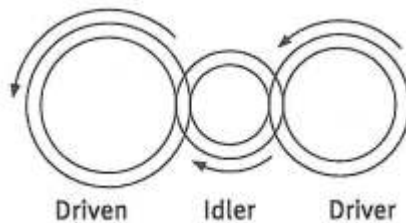


**PLEASE NOTE:**

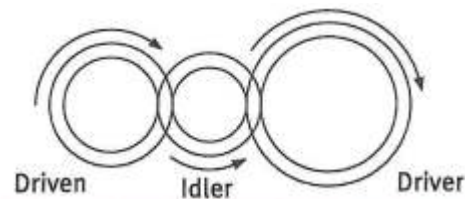
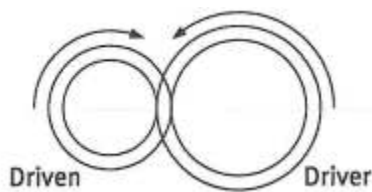
if no measurements of the different gears were given to the learners → the size of the gears will differ from one another.

You could give a measurement e.g., 55 mm and 45 mm to order to determine whether learners can measure accurately.

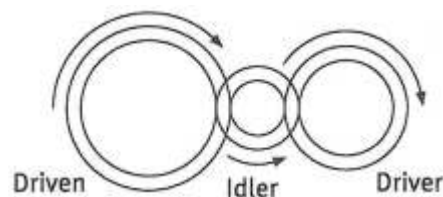
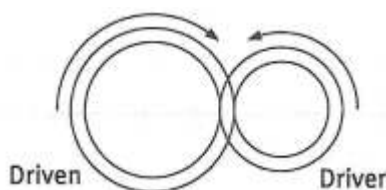
##### 4.5.2 The driven gear rotating in the **same direction** to the driver (include an idler gear).



##### 4.5.3 The driven gear rotating **faster** than the driver (with and without an idler).

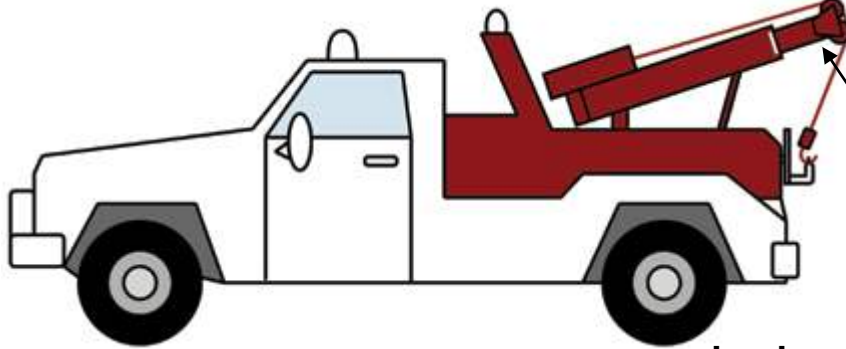


##### 4.5.4 The driven gear rotating **slower** than the driver (with and without an idler).



4.6 Read the following information and follow the instructions.

→ Study the tow truck on the below.



This **mechanism** is a **winch**.  
It is used to **pull broken-down cars** onto the back of a tow truck.

### PROBLEM / SCENARIO

- A tow in company has a **problem with their winch**.
- The company using this winch has found that it is **not powerful enough to pull large vehicles**.
- The company asked you to **improve the winch with a gear system**.
- They want the winch to pull large vehicles that are three times as heavy as ordinary cars.

### KEEP THE FOLLOWING IN MIND

Gear systems have two important uses:

- A gear system can **give a mechanical advantage**.
  - In this case, a **small driver gear** is used to turn a **larger driven gear**.
  - The **output** of the system → turns more **slowly**, but with **greater turning force**.
- Gears can also give a **speed advantage**.
  - In this case, a **large driver gear** will turn a **smaller driven gear**.
  - The **driven gear turns faster** than the driver gear, but with **less turning force**.

4.6.1 Write a design brief that summarise the problem that needs to be solved, as well as the purpose of the proposed solution.

The gear system should include the following:

- A **mechanical advantage** with **force multiplication of three times**.
- An **increase in output velocity of four times**.

I am going to design a gear system for the winch of a tow truck to allow it to pull a vehicle which is up to three times the weight of ordinary cars.

4.6.2 Write a list of THREE specifications for the new winch / gear solution.

**Remember: Specifications are lists of things that your solution must do, and some things that it must not do.**

POSSIBLE SOLUTIONS TO IMPROVE THE WINCH WITH A STRONGER GEAR SYSTEM

- The winch must be able to pull vehicles that are up to three times as heavy as an ordinary car.
- The gear systems should not change the direction of rotation.
- The cable of the winch must be strong enough not to break when it pulls the weight of three cars.

4.6.3 Describe how you are going to improve this winch.

- I am going to add a gear system to the winch that gives a mechanical advantage, but that does not change the direction of rotation.

4.6.4. How will you know that the winch can pull vehicles that are up to three times heavier than an ordinary car?

- The driven gear will be three times the size of the driver gear. / The mechanical advantage of the gear system should be 3.

## WEEK 5

### DRAW GEAR SYSTEMS IN 2D

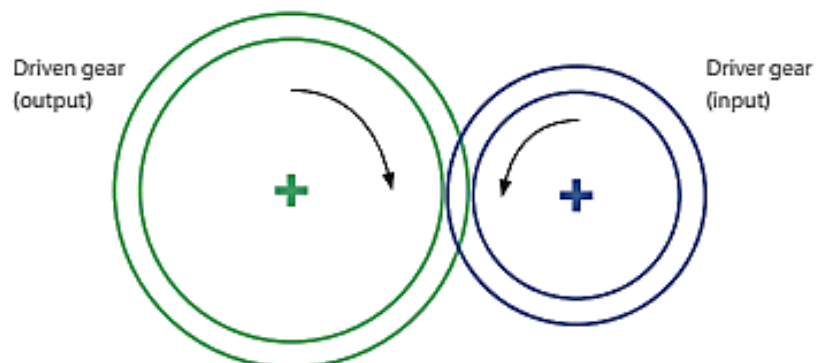
5.1 When an input gear drives a larger output gear, there is a decrease in the rotation rate of the driven gear.

This means the system will slow down, but there will be an increase in force. Therefore, the driven gear will rotate with greater force, giving a mechanical advantage of more than 1 ( $MA > 1$ ).

5.1.1 Revise the steps on how to draw gears in 2D and draw a gear system that provides and output force four times greater than the input force ( $MA = 4$ )

**Indicate the DRIVER & DRIVEN gears as well as the measurements of the gear train.**

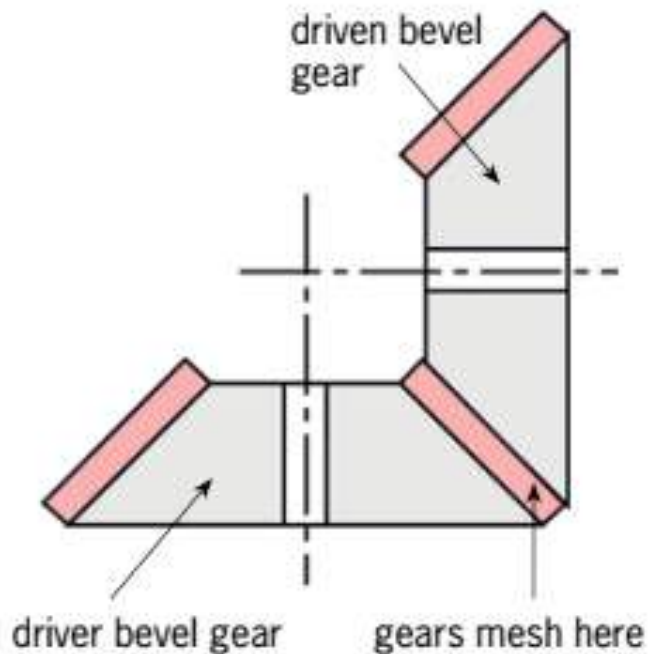
POSSIBLE ANSWER



5.2 You learnt how bevel gears were used on a hand drill. Bevel gears are used when we want to change the output direction.

5.2.1 Draw the bevel gear below.

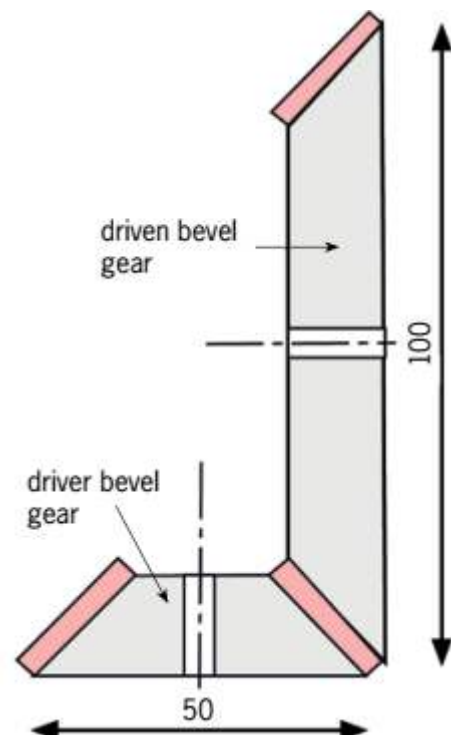
This gear will rotate at the **same speed**, but the **direction of rotation is turned with  $90^\circ$** .



5.2.2 Now you have to draw a bevel gear that will double the rotation rate on a driven axle at  $90^\circ$  to the driver axle.

Indicate the DRIVER & DRIVEN gears as well as the dimensions of the gear system.

**POSSIBLE ANSWER**



# SYSTEM ANALYSIS – BICYCLE GEAR SYSTEM

- The **gears on a bicycle** can be seen as a **system**.
- Bicycle gears **change the input energy** from the cyclist's legs **into an output motion of the back wheel**.
- The gears are an important part of how the bicycle do this work. Some **modern bicycles have multiple gears** that make it easier to go up steep hills and allow us to ride faster

## ANALYSIS OF A BICYCLE GEAR SYSTEM

- **COGS:** toothed discs on a bicycle are toothed discs called cogs.
- The **front cog** is attached to a **pedal crank**. This **input unit** is called the **master or driver cog**.
- The **back cog drives** the **back wheel** of the bicycle. This **output unit** is called the **slave or driven cog**.
- The **CHAIN WHEEL** connects the **cogs with a chain**, making them **turn in the same direction**. A larger cog will have more teeth.
- The **higher the tooth ratio** between the **back and the front cog**, the **higher the output force** will be.
- **DERAILLEUR/ GEAR SHIFTER** is a **device (lever and cable)** that **moves the chain to a different-sized gear on the back wheel to change the speed and the turning force of the bicycle wheel**.

### Key words

- **cogs** – a set of gear wheels found either at the bicycle's pedal or at the axle of the back wheel
- **pedal crank** – the lever joining the pedal to the front cog
- **master or driver cog** – the input mechanism driving the bicycle and operated by the pedal crank
- **slave or driven cog** – the output mechanism being rotated by a chain linking to the driver cog
- **chain wheel** – the chain linking the front and back cogs, to transfer rotational force
- **derailleur** – a mechanism that moves the chain from one gear to another to increase the speed or turning force of the bicycle wheel

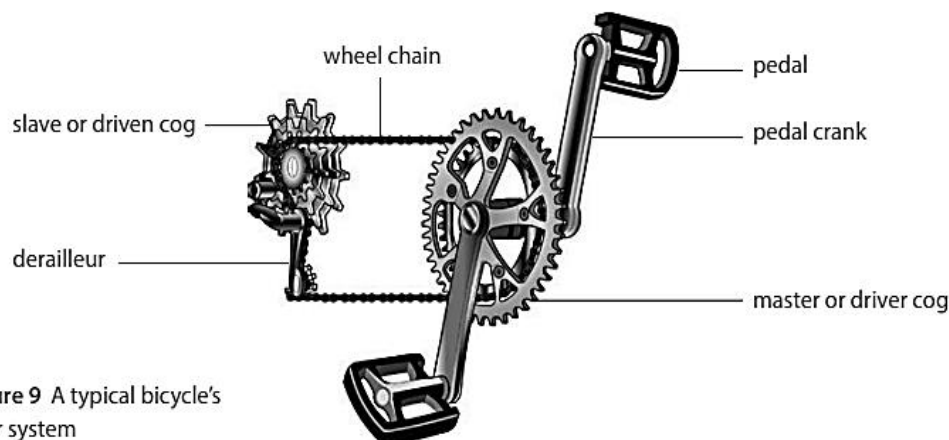


Figure 9 A typical bicycle's gear system

- On a **ten-speed bicycle**, for example, there are **five gear wheels** on the **rear cog** and **two on the pedal crank fixed to the front wheel**. This gives the cyclist ten possible gear combinations to choose from, depending on the conditions

## USING A BICYCLE GEAR SYSTEM TO GO UP OR DOWN A HILL

### UP A HILL

- To obtain **force multiplication**, the correct gear combination must be selected.
- There should be a **small input gear** that drives **a larger output gear** there is an **increase in force**.
- Even though this will cause **movement to slow down**, **output force will increase**.



### DOWN A HILL

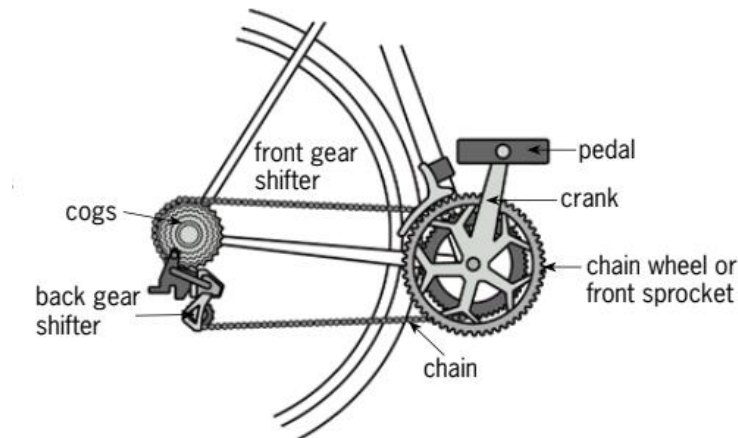
- A gear combination where a **large input gear** wheel (with more teeth) **drives a smaller output gear** wheel (with fewer teeth).
- **Force usually decreases**, but there is a **multiplication of speed**.



## ADVANTAGES OF USING A CHAIN DRIVE RATHER THAN SPUR GEARS

- **Chain drives** can **easily and cheaply connect gears** that are far away from each other.
- A **chain can be adjusted easily** if the distance between the axles of the two gears changes.
- With **spur gears**, the **axles need to be aligned precisely**, so that the gears mesh well but without too much resistance.
- With a **chain drive**, the **axles do not have to be aligned precisely because the chain can bend sideways a little**.

### 5.3 Answer the following questions on bicycle gear systems



5.3.1 What do you call the large gear wheels at the front that are turned by the pedals?

Chain wheels or front sprockets

5.3.2 What do you call the group of gears that turn the back wheel? (1)

Cogs

5.3.3 What connects the front gears to the back gears? (1)

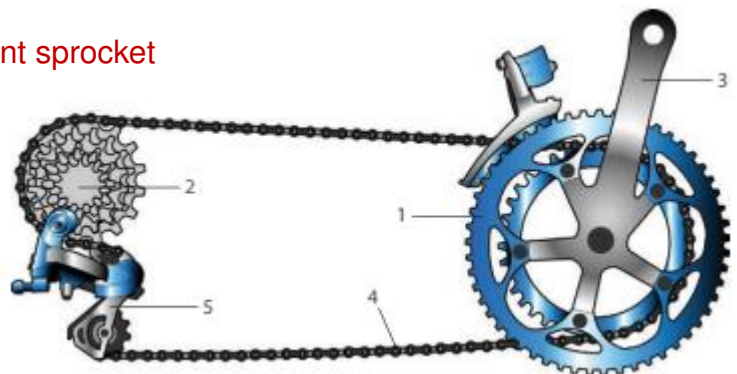
A chain

5.3.4 What do you call the mechanism that changes the gears? (1)

A gear shifter or a derailleur

5.4.1 Look at illustration of a bicycle's gear system. Identify the different components labelled 1 to 4. (4)

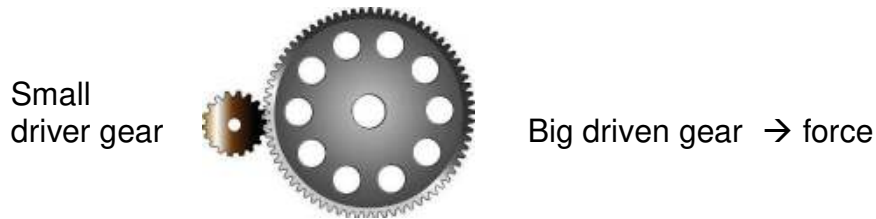
1. Master / driver cog / chain wheel / front sprocket
2. Slave / cogs
3. Pedal crank
4. Chain



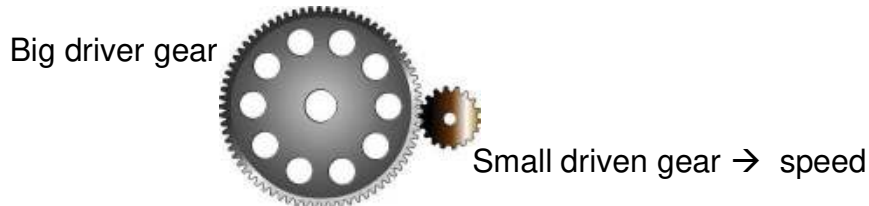
5.4.2 Describe the function of the mechanism labelled 5 on the diagram. (2)

- **DERAILLEUR/ GEAR SHIFTER** is a device (lever and cable) that moves the chain to a different-sized gear on the back wheel to change the speed and the turning force of the bicycle wheel.

5.4.3 Sketch a bicycle's gear system combination that will be used when going up a hill.(5)



5.4.4 Sketch a bicycle's gear system combination that will be used when going down a hill.  
(5)



5.5 Indicate whether the following statements are TRUE / FALSE (4)

5.5.1 A driver gear can also be called slave gear.

**FALSE**

5.5.2 A master gear can also be called a driver gear.

**TRUE**

5.5.3 To travel fast on a bicycle you must have the chain on a small driver gear and a large driven gear.

**FALSE**

5.5.4 To use less effort going up a hill you must place the chain on a small driver gear and a large driven gear.

**TRUE**

## WEEK 6: SYSTEM DIAGRAMS

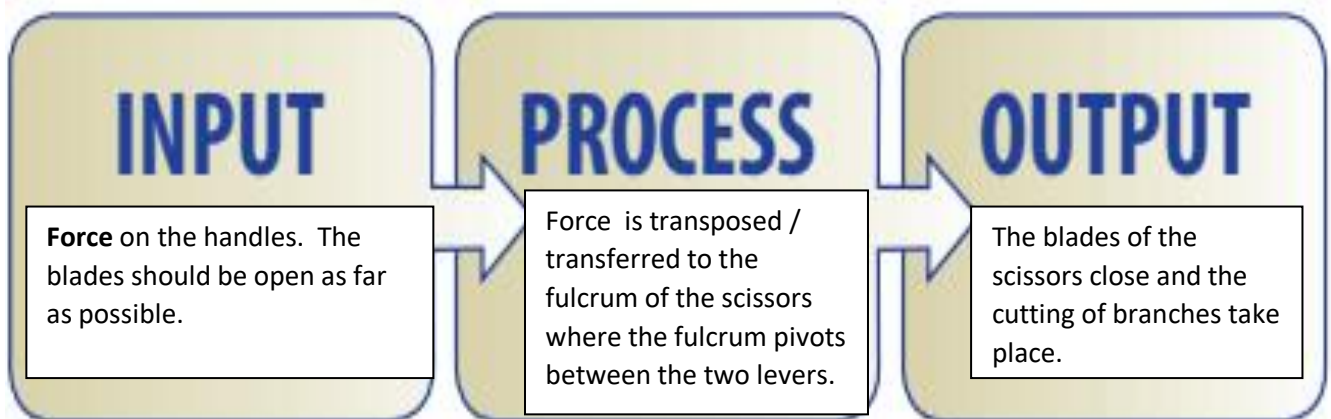
- A systems diagram divides a system into different stages.

These different stages are classified as **input, process and output**.

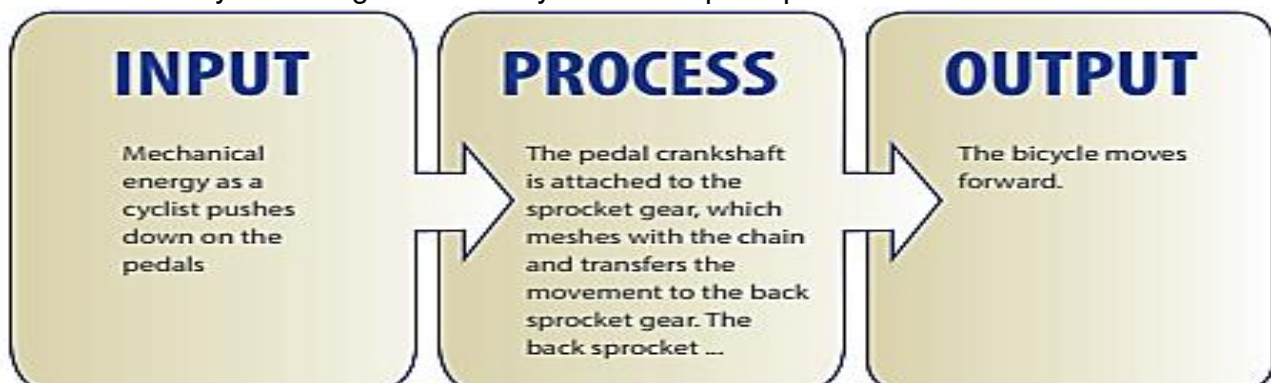
- Arrows** are used to join the different stages in the process.

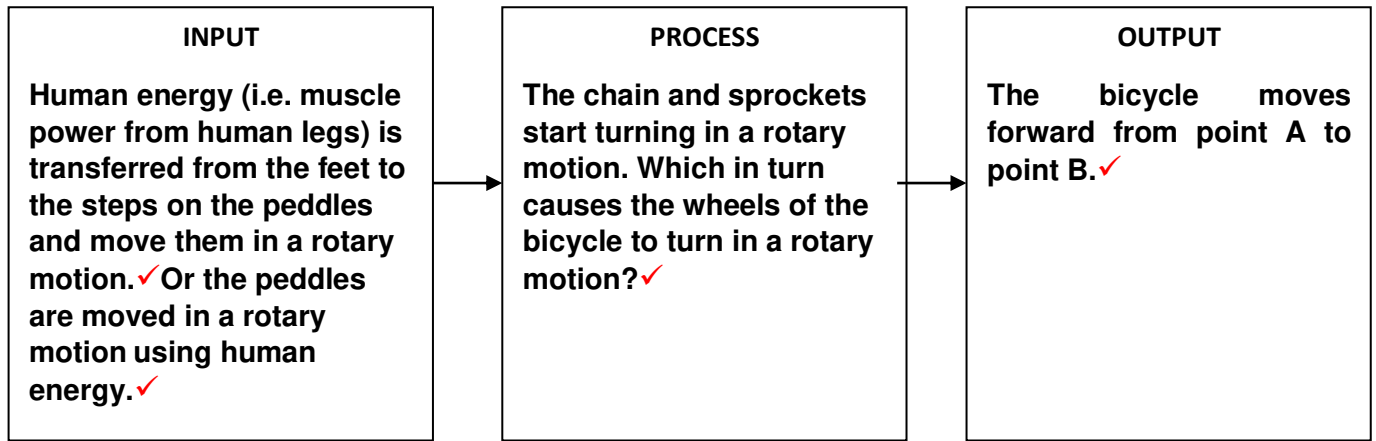


- When a machine is analysed with a systems diagram, it shows **how an input of energy is changed by the movement of mechanisms to make a machine do work**.
- The system diagram for a pair of **pruning scissors / secateurs** that is used for cutting branches will look like the diagram below.
- The mechanism is used to work according to a specific system if it has to produce maximum mechanical advantage.



6.1 Draw a system diagram of a bicycle in the space provided.

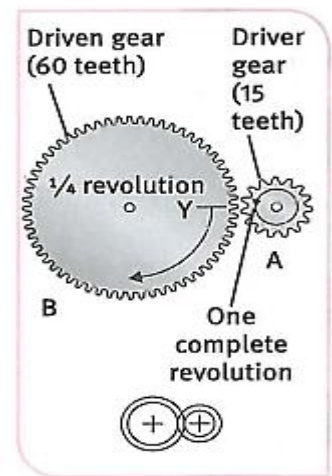




## 6.2 Draw a Systems Diagram for a gear system with a mechanical advantage of 4:1.

Use the following equation to work out how to get a 4:1 gear ratio:

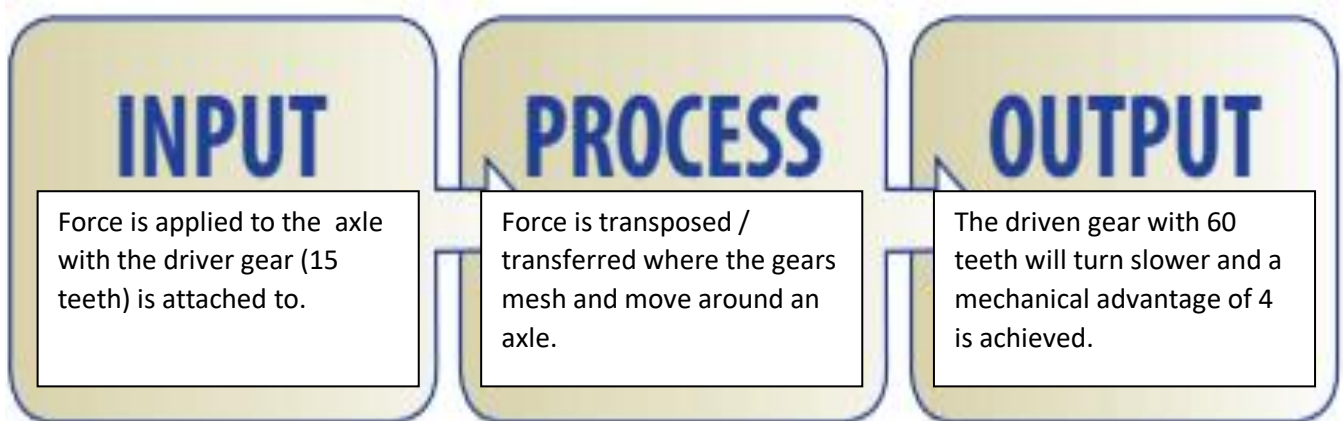
$$\text{Gear ratio} = \frac{\text{Number of teeth of driven gear}}{\text{Number of teeth of the driver gear}}$$



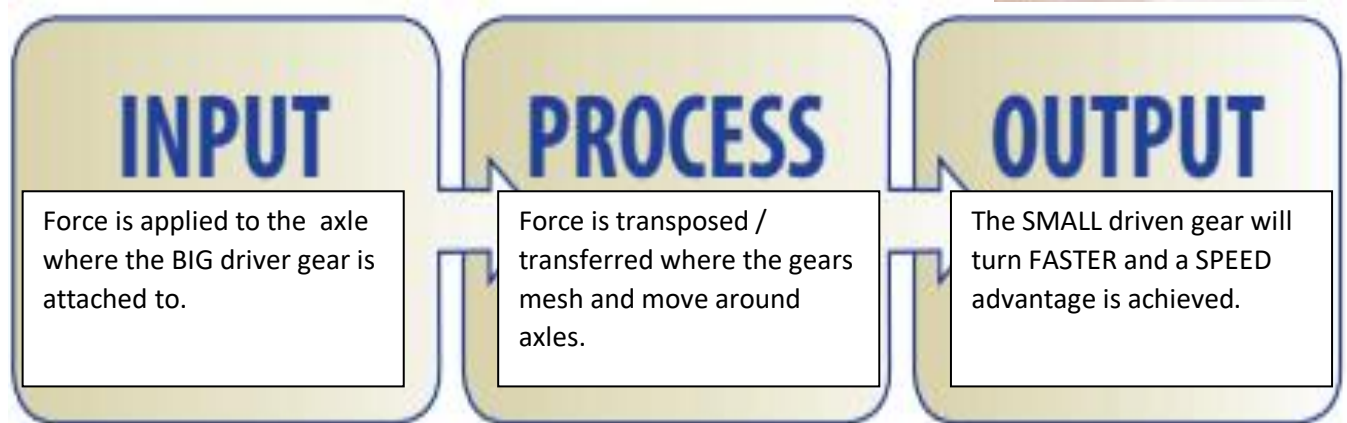
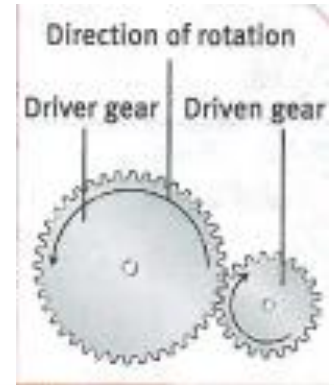
$$MA = \frac{\text{DRIVEN}}{\text{DRIVER}}$$

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

$$MA = 4$$



- 6.3 Draw a system diagram for a gear train with the driven gear rotating faster than the driver.



## WEEKS 7 – 10: PAT (FORMAL ASSESSMENT)

**INVESTIGATION SKILLS = 30 MARKS**

**DESIGN SKILLS = 40 MARKS**

**TOTAL = 70**