Mechanisms

Mechanisms

A mechanism is a collection of **moving parts** that **work together** to perform a job.

For example, a pair of scissors is a mechanism.

Can you think of any other mechanisms?

A mechanism is a collection of moving parts, such as gears, levers, pulleys, cams and chains, that work together to perform a job.

Mechanisms make life easier and more comfortable

Mechanisms transmit energy in the form of movement..

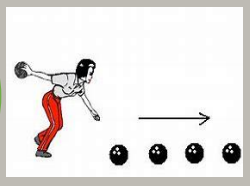
Input	***Control***	***Output***
Force/movement is put into a mechanism	**Mechanism converts /transmits the input force and movement**	**Force/ movement to satisfy the need**

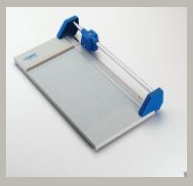
Movement/Motion

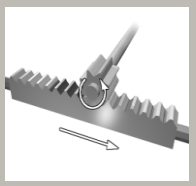
There are 4 basic types of movement (motion):

Linear

Moves in a straight line

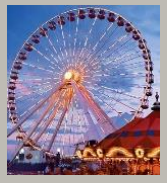






Rotary

Moves round & round






Reciprocating

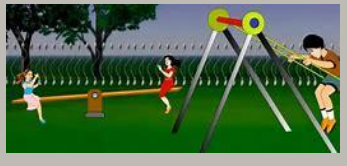
Moves forwards & backwards





Oscillating

Moves on an arc






Name: Date: CWK/HWK

Mechanisms

Core 1.5 — 1

1. What is a mechanism? _____

_____

2 Name the 4 basic types of motion:

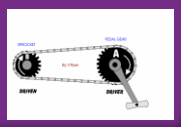
a)_____ b) _____ c) _____ d) _____

Write the type of motion/movement, or use arrows in the boxes below, for input and output:

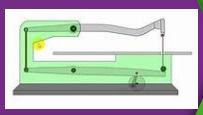
3.

Input Movement	Mechanism	Output Movement
	Bevelled gears, transfer the motion through 90° 	

4.

Input Movement	Mechanism	Output Movement
	Chain & Sprocket, attached to the wheel 	

5.

Input Movement	Mechanism	Output Movement
	Crank, and parallel Arm System 	

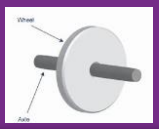
6.

Input Movement	Mechanism	Output Movement
	Rack & Pinion on a pillar drill, to move table up/ down 	

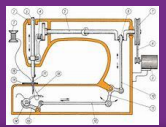
7.

Input Movement	Mechanism	Output Movement
	Worm wheel on a guitar, attached to tuning peg 	

8.

Input Movement	Mechanism	Output Movement
	Wheel and axle 	

9.

Input Movement	Mechanism	Output Movement
	Crank and cam, attached to a motor. 	

10. Why do you think humans invented mechanisms?

_____

Total: _____

20

Mechanisms

Core 1.5 — 2a

Levers

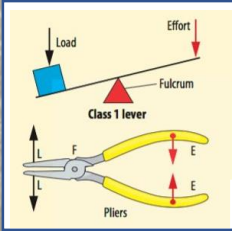
LEVER: A fixed rigid beam requiring a fulcrum, load and effort to provide mechanical advantage (make a task easier to do).

FORCE: A push or a pull upon an object that, when unopposed, will change the object's motion

Levers are classed by the position of the fulcrum (PIVOT), load and effort.
The **load** is the object you are trying to move.
The **effort** is the force applied to move the load.
The **fulcrum** (or **pivot**) is the point where the load is pivoted.

There are 3 classes of lever: 1st Class, 2nd class and 3rd class

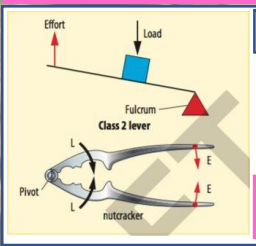
In a class 1 lever, the FULCRUM is in between the load and the effort:



Reason for mechanical advantage:
A large input movement can produce a small output movement, but with greater force.

Eg. Seesaw, scissors, crowbar

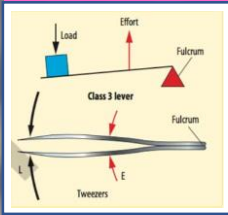
In a class 2 lever, the LOAD is in the middle:



Reason for mechanical advantage:
A large input movement can produce a smaller output movement with greater force.

Eg. Bottle opener, nutcrackers wheelbarrow

In a class 3 lever, the EFFORT is in the middle:



Reason for mechanical advantage:
The force applied by the user is greater than the output force

Eg. Human arm, tweezers, fishing rod

Calculating the Efficiency

This is the relationship between the input force and input movement and the output force and output movement.
You may be asked to work out the efficiency of a particular mechanism
Eg a lever
You need to know the MA and the VR to calculate the efficiency:

Efficiency = MA / VR x 100 = ??%

The higher the number the more efficient the mechanism.
So if the MA = 6 and the VR = 8

Efficiency = 6 / 8 x 100 = 75%

Mechanical Advantage.

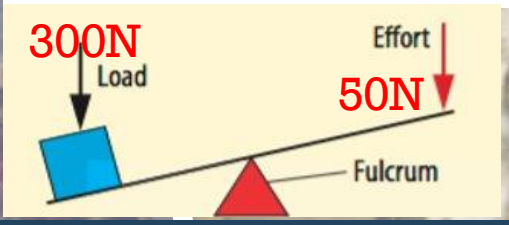
Mechanical advantage (MA) allows a large force to be exerted with a small amount of effort.
It is calculated by comparing the weight of the load and the effort required to move it. (The larger the number the greater the advantage).

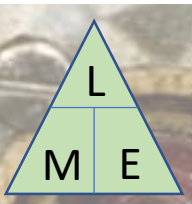
MA = Load / effort

Example: 50N effort is needed to lift a 300N load, so what is the mechanical advantage?

MA = 300 / 50 = 6

MA = 6

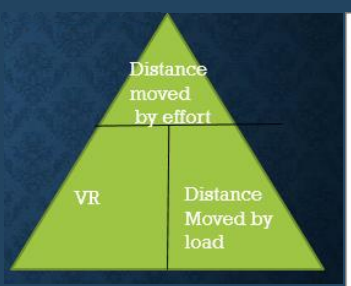


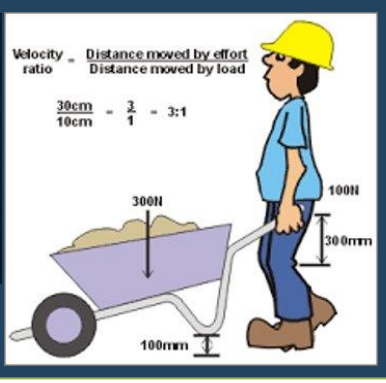


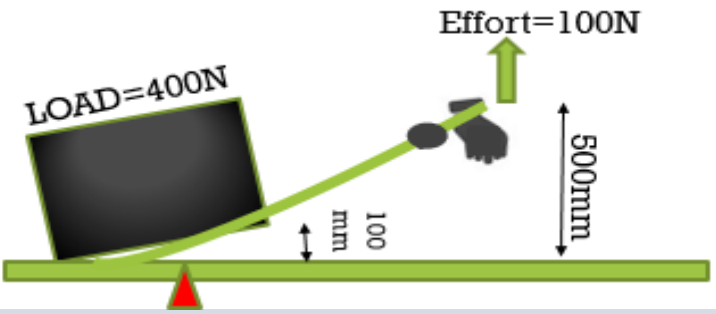
Calculating the Velocity ratio

This is the ratio of the distance the effort has to move compared to the load.

VR = Distance moved by effort / Distance moved by load







MA = Load / effort= 400÷100 = 4

VR = Distance moved by effort / Distance moved by load =500÷100 = 5

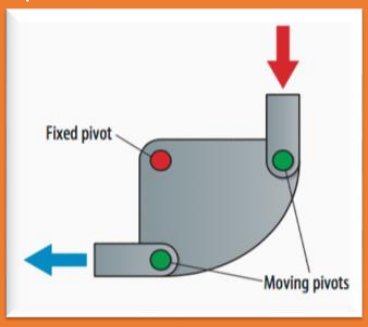
E= 4÷5 x 100 %= 0.8 x 100 % = 80% efficient

Linkages

Linkages can be used to change:
- **The direction of motion**
- **The type of motion**
- **The size of a force**

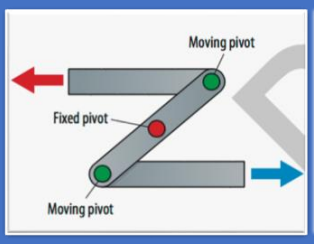
Bell crank

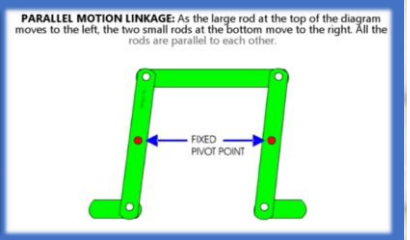
This is a class 1 lever that transmits the motion through 90 degrees to allow an input force to be transmitted around a corner.
Example:
Brakes on a bike.



Reverse motion linkages

This is also a class 1 lever but it reverses the motion of the input such as on car windscreen wipers.

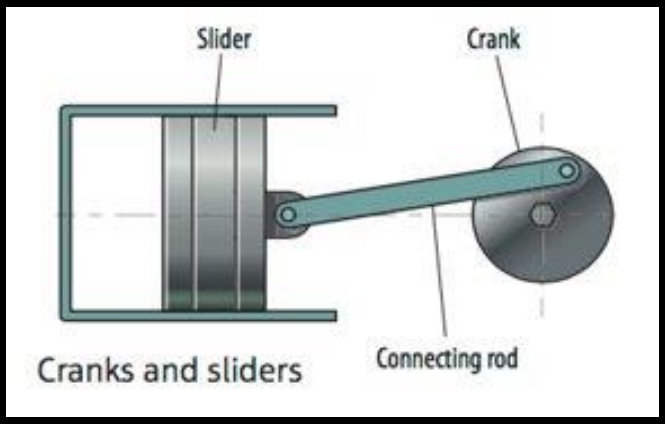


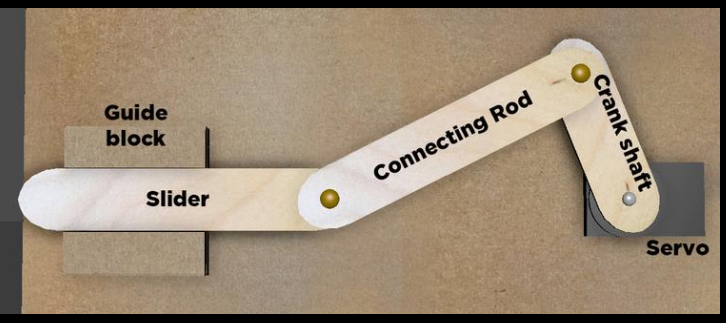


Crank, Link & Sliders

These mechanisms convert the rotary motion in a crank to reciprocating motion in a slider.

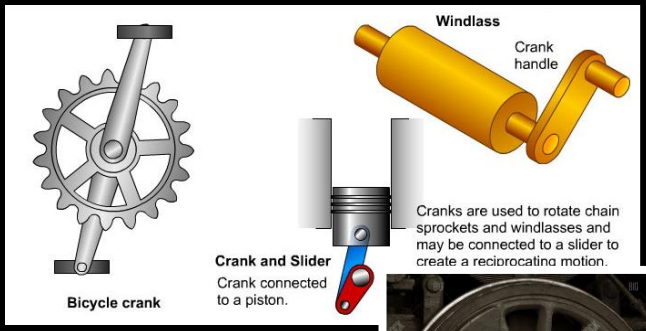
The distance the slider moves depends on the size of the crank arm. The crank arm can be used as the driving force, such as in the crank shaft and pistons of a car or to compress air in the cylinder of a compressor.

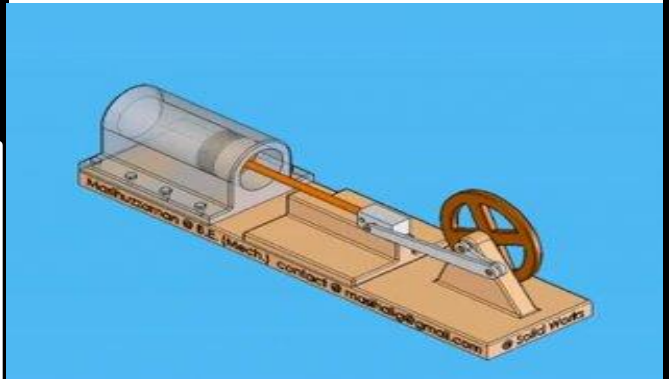




The slider can also operate as the driver and turn the crank, for example in steam engines, where the wheels are driven by the pressure of the steam pushing the slider.

The distance moved by the slider is twice the radius of movement of the crank arm.





Name: Date: CWK/HWK

Mechanisms

Core 1.5 — 2a & 2b

Levers & Linkages

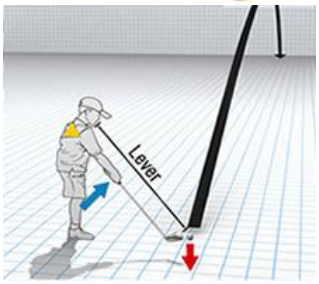
1. a) What class of lever are these nutcrackers? _____

b) On the picture, label the fulcrum. load and effort.

c) Name another product of this class of lever

_____

(5 marks)

2. 

a) Label the fulcrum (F), load (L) and effort (E) on the diagram of the golfer.

a) Name this class of lever _____

(4 marks)

3. What is a lever? _____

_____

(1 mark)

4. a) What is the purpose of a linkage?

_____

a) Name a product that uses a linkage.

_____

(2 marks)

Cranks & Sliders

5. Describe how the crank and slider mechanism works.

_____

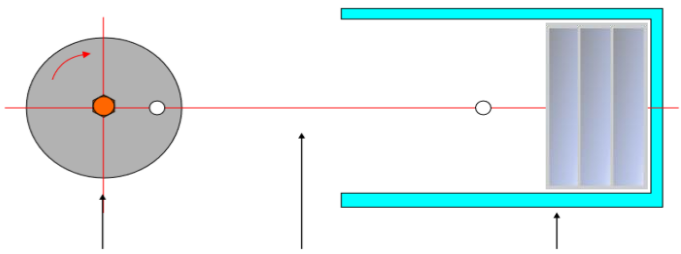
_____

_____

(2 marks)

6. Complete the drawing of the crank and slider mechanism shown below, by adding the connecting rod and slider, and showing where it attaches to the crank and the slider. Label the parts.

(3 marks)



TOTAL: / 17

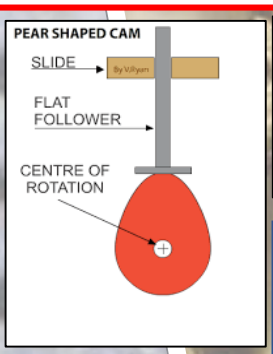
Mechanisms

Cams

Key terms

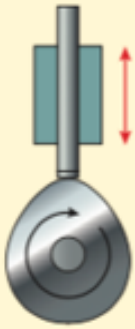
CAM: a mechanism for converting rotary motion into reciprocating or oscillating motion.
FOLLOWER: a device that follows the movement of a cam profile to provide a desired output in a connecting part.

The cam shaft rotates continually, turning the cam. The follower is a rod that rests on the edge of the turning cam. The follower is free to move up and down, but is prevented from moving from side to side by a slide or guide, so the follower can only do three things:
Rise (move up)
Fall (move down) or
Dwell (remain stationary)

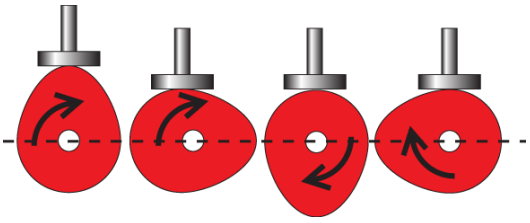


A cam mechanism has three parts:
- **cam,**
- **slide and**
- **follower.**

Pear shaped cam

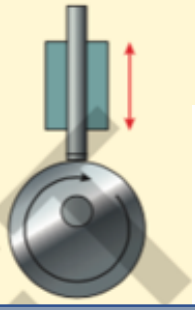


The effect of the shape :
- **Motion-less (dwells) for about half the cycle**
- **During the second half it rises and falls**

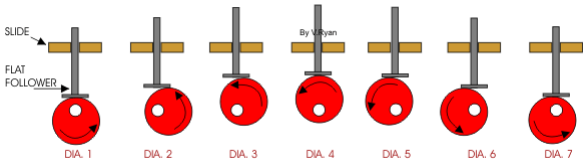


Used for opening and closing valves in a car engine

Eccentric (circular) cam

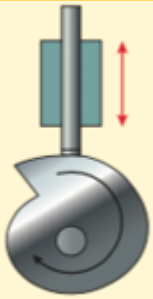


The effect of the cam:
- **Circular to give a smooth continuous movement as the follower rises and falls.**

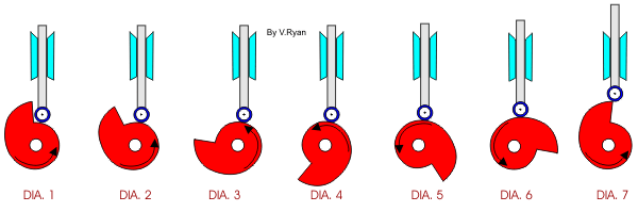


Used in fuel pumps and steam engines

Drop or snail cam



The effect of the shape:
Gives a slow rise with a spiral cross – section, and then a sudden fall.



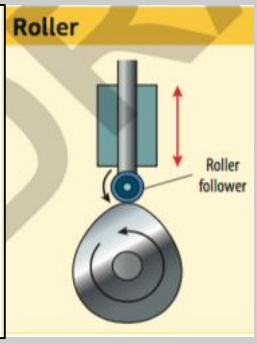
Used in mechanical hammers and punches.

Followers

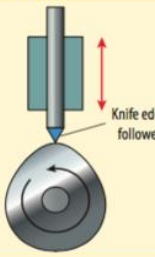
You need to be aware of the following followers.

Roller

- Used when higher speeds are required, such as in engines
- Rolling motion reduces friction so it will wear better
- Has separate parts in the roller mechanism and contends with forces pushing them to the side



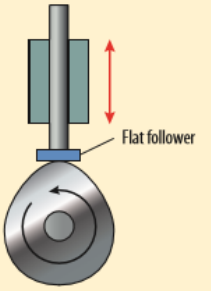
Knife edge



- Used when accuracy is required, such as in an embroidery machine, as the cam's profile is followed closely
- Suffers from a rapid rate of wear and contends with forces pushing them to the side

Flat

- Used when higher load bearing capabilities are required, such as in a steam engine
- Has reduced forces pushing it, but suffers from increased friction
- The larger surface area means it could rotate, but has larger load carrying abilities



Name: Date: CWK/HWK

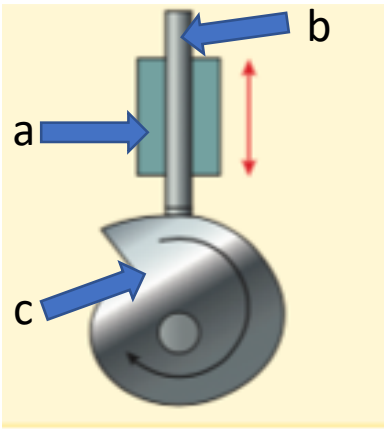
Mechanisms

Core 1.5 3

Cams

Answer all of the following questions:

1. i) State which type of cam is shown in the diagram below: _____



Name the 3 main parts:

a) _____

b) _____

c) _____

ii) Name a machine where you might find this type of cam:

_____ (5marks)

2. In which type of cam does the follower "dwell" for half a rotation?

_____ (1 mark)

3. True or False? : Cam mechanisms are used to change a rotary input into a reciprocating output. _____ (1 mark)

4. Which cam can only work one way? _____ (1 mark)

5. What is the job of the slide in a cam mechanism? _____ (1 mark)

6. True or false? : cam mechanisms transmit an input force through a lever, to move a large load. _____ (1 mark)

7. Name an advantage of a flat follower over a knife follower. _____

_____ (1 mark)

8. Why are roller followers used in car engines? _____

_____ (1 mark)

9. Name an advantage of a roller follower over a flat follower. _____

_____ (1 mark)

10. Which cam shape would you use in a mechanical toy depicting a caterpillar?

_____ (1 mark)

Total: ____ / 14

Mechanisms

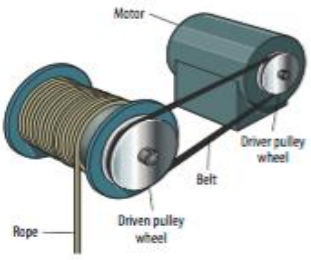
Pulleys & Belts

Pulleys

A simple pulley mechanism has a rimmed wheel and cable, which sits inside the rimmed wheel. There is no mechanical advantage, but it makes things easier to hoist/lift.

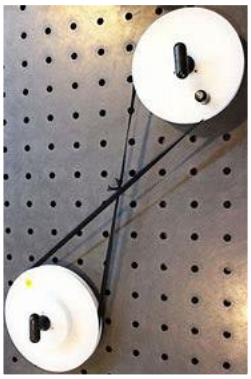
Using 2 or more pulleys (block & tackle system) halves the required input force to lift a load.

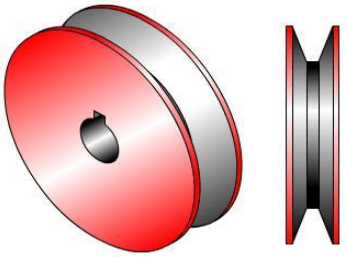
Belt & Pulley Systems

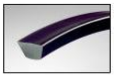


A belt & pulley system consists of two pulley wheels each on a shaft, connected by a belt. This transmits rotary motion and force from the input, or driver shaft, to the output, or driven shaft.

Used in car engines and washing machines, vacuum-cleaners, pillar drills, wood lathes.

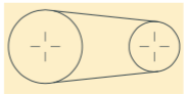


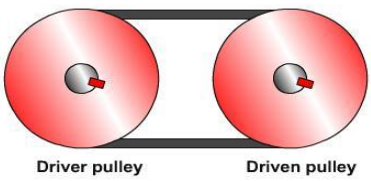




Some pulleys have V shaped grooves.

A vee-belt connects two pulleys and transfers motion and torque from the driver pulley to the driven pulley.





V shaped belts

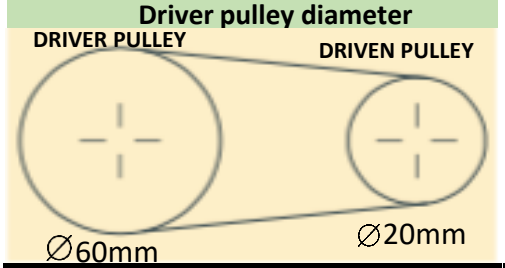
V belts are shaped to increase the force that can be transferred. The V shape increases the gripping area by having sloping sides. This increases efficiency by reducing any slipping and it also tightens the drive surface as it runs, as it wedges into the pulley wheel.

If the driver pulley is bigger than the driven pulley, the driven pulley will rotate faster.

When the driver pulley is smaller than the driven pulley, the driven pulley will rotate slower.

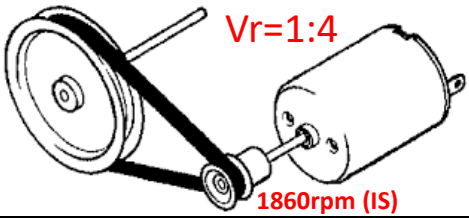
Calculating the velocity ratio (VR).

VR = Driven pulley diameter / Driver pulley diameter



Calculating the output speed.

OP= Input Speed (IS) / VR



Using different sized wheels changes the speed and torque (force of rotation).

VR = 20 / 60 = 0.3333

OP= 1860 / 0.25 = 1:4 (a quarter)

So the output speed is 7440rpm (essentially 1860 / 0.25).

Name: Date: CWK/HWK

Mechanisms

Core 1.5 4

Pulleys & Belts

1. **What is a pulley?** _____ [1]

2. **What is the formula for calculating the Velocity Ratio (VR) between 2 pulleys?** [1]

3. **Name a product in which you may find a belt & pulley system.** _____ [1]

4. **What is the formula for calculating the OUTPUT SPEED (OS) of a pulley system?** [1]

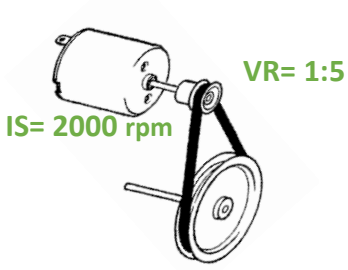
5. **Why do you think pulley wheels have V-shaped grooves?**

_____

_____

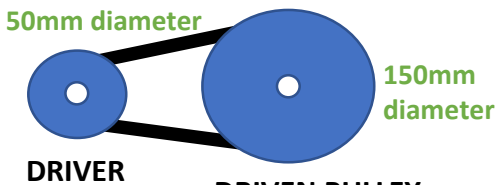
_____ [1]

6.Find the OUTPUT SPEED of this pulley system. Show all of your working out, including the formula.



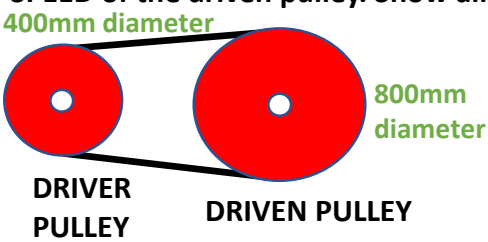
[3]

7. What is the velocity ratio of the pulley system shown below? Show all of your working out, including the formula.



[3]

8. The driver pulley in this system below is rotating at a speed of 360 rpm. Calculate the OUTPUT SPEED of the driven pulley. Show all of your working out, including the formula.



[3]

Total : / 14

Mechanisms

Core 1.5 | 5a

Key Term

GEAR: a toothed wheel fixed to a shaft that connects (meshes) with other gears to change the speed or direction of rotation of a driving mechanism

Gears:
Gear Trains , Velocity Ratios

Gears can be found in many machines…in workshops, factories, and at home .

They are often an important part of a machine or mechanical devices.

In a car, the gears help drivers increase or decrease speed, as they changes the gears with a gear stick.

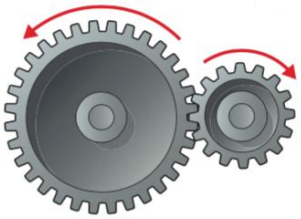
Simple Gear Trains

A simple gear train is when two spur gears are meshed (to prevent slipping) and fixed on parallel shafts.

Simple gear trains reverse the driver gear's direction of the rotation and the driven gear will turn in the opposite direction.

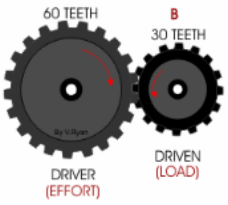
When the gears are different sizes (with more or fewer teeth) speeds can be increased or decreased.

The amount of change in speed is called the velocity ratio.



In examinations one of the first questions will probably for you to work out the '*gear ratio*' (sometimes called *velocity ratio*). As a guide - always assume that the larger gear revolves one revolution. The number of rotations of the second gear has then to be worked out.

1A.



Work out the Velocity Ratio (Gear Ratio);

$$\frac{\text{Distance moved by Effort}}{\text{Distance moved by Load}} = \frac{60\text{T (GEAR A)}}{30\text{T (GEAR B)}}$$

$$= \frac{1}{2} = \frac{\text{Input movement}}{\text{Output movement}}$$

$$= \frac{\text{Driver}}{1} : \frac{\text{Driven}}{2}$$

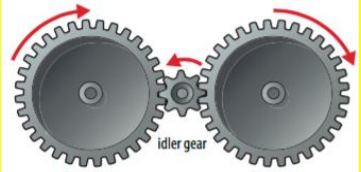
Idler gears

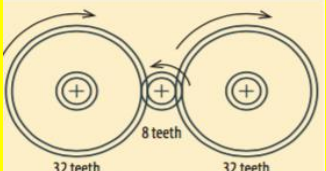
In a simple gear train of two meshed spur gears, the driver gear and the driven gear rotate in opposite directions.

The driver and driven gears rotate in the same direction.

The idler gear does not have any impact on the output speed, so size doesn't matter.

The velocity ratio is still based on the driver and driven gears.



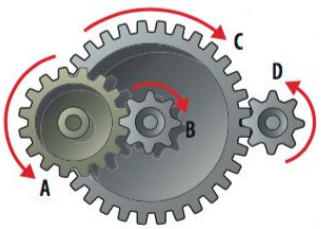


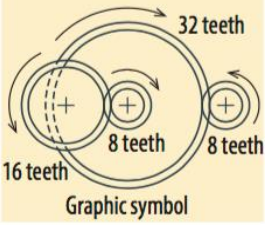
Compound Gear Trains

With simple gear trains, the speed change is limited to the number of teeth on the two gears

For larger speed changes, several pairs of meshing gears can be combined for a higher velocity ratio.

A compound gear train has more than one gear on a shaft .





Calculating Velocity ratio of a compound Gear system.

Total VR = [VR of gear train 1 (A to B)] **X** [VR of gear train 2 (C to D)]

VR = distance moved by effort / distance moved by load

VR train 1 = 8 / 16 = 1 / 2 – 1:2

VR train 2 = 8 / 32 = 1 / 4 – 1:4

Total VR = 1:2 x 1:4 = 1:8 = 8

So for every one rotation of the driver gear, the driven gear will rotate 8 times.

Changing Speed

Gears are used to change the speed of a mechanism:

To make the output speed faster , the input (driver) gear must be bigger than the output (driven gear). To make it go slower, the driver gear must be bigger than the driven gear.

Faster: Driver Gear (20 teeth) → Driven Gear (10 teeth)

Slower: Driver Gear (10 teeth) → Driven Gear (10 teeth)

Calculating Gear Ratios

The larger gear always equals 1. The smaller gear is calculated by dividing the number of teeth on the larger gear, by the number of teeth on the smaller gear.

Driver Gear =1 (20 teeth) → Driven Gear (10 teeth)

Gear ratio= 20/10 (=2)

Gear Ratio = 1:2

Calculating output speed of a gear system

$$\text{Output speed} = \frac{\text{input speed}}{\text{gear ratio}}$$

So if a driver gear is rotating at 100 rpm is connected to a gear ratio of 1:18.

Name: Date: CWK/HWK

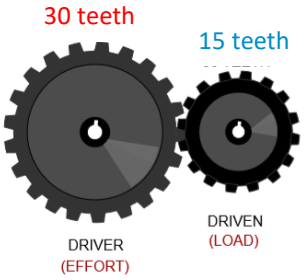
Mechanisms

Core 1.5 — 5a

Gears

Exam style questions. Remember to show all your working out.

1. Calculate the Gear Ratio / Velocity Ratio

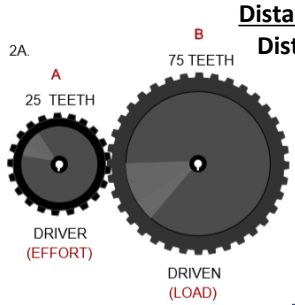


Distance moved by EFFORT = __
Distance moved by LOAD

VR = Driver : Driven
1 :

[3]

2. Calculate the Gear Ratio / Velocity Ratio



Distance moved by EFFORT = __
Distance moved by LOAD

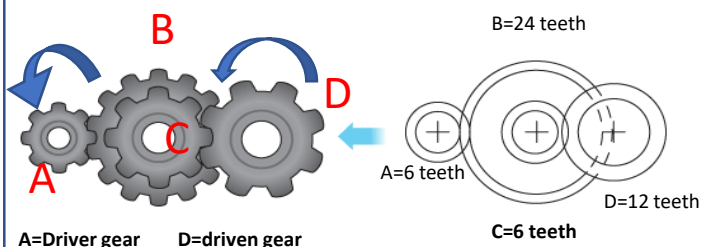
VR = Driver : Driven
:

[3]

3. The diagram below shows a compound gear train.

1. Which direction is gear B moving? Clockwise or anticlockwise? _____
2. Calculate the VR

VR1 (A-B) = VR2 (C-D) =

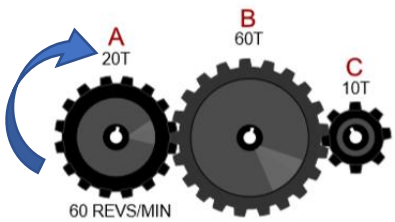


VR =

A=Driver gear D=driven gear

[4]

4.The diagram shows a gear train composed of 3 gears. Gear A revolves at 60rpm. Find out the speed output of gears B and C , in terms of rpm. (you will need to work out the ratio of gears A and B, to find the output speed of gear B. When you have worked that out, work on gears B and C).



Speed of Gear B

_____ teeth on gear B =
teeth on gear A

60 rpm = _____rpm for gear B

Speed of Gear C

_____ teeth on gear B =
teeth on gear C

60 rpm = _____rpm for gear C

GEAR A	GEAR B	GEAR C
20 teeth	60 teeth	10 teeth
60 rpm		

[8]

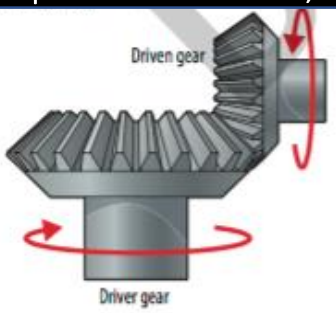
Total: / 18

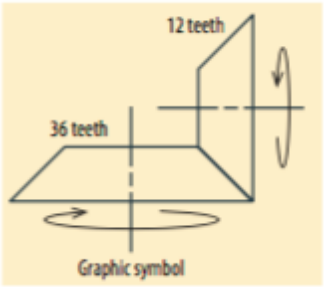
Mechanisms

Core 1.5 — 5b

Gears:
Bevelled Gears and Rack & Pinion

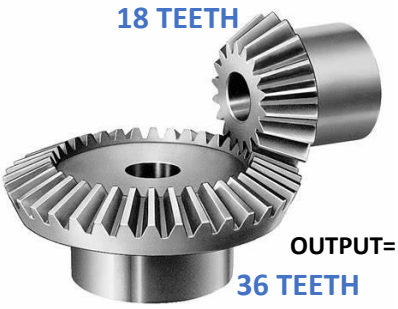
Examples of use: hand drills, helicopters, can openers. Lawn mowers, metal lathes, whisks





Bevel Gears

These are special gears with sloping sides, that can rotate movement through 90 degrees.
These beveled gears can vary in size to achieve different gear ratio and output speeds.
This example has a gear ratio of 1:2.
If the two gears are the same size they are called *mitre gears.* Input and output speeds will be the same.



Rack and Pinion Gears

This system uses a gear wheel and a rack to change rotary motion to linear motion or vice versa.
The rack's movement is determined by the number of teeth on the pinion gear and the number of teeth per metre (TPM) on the rack.

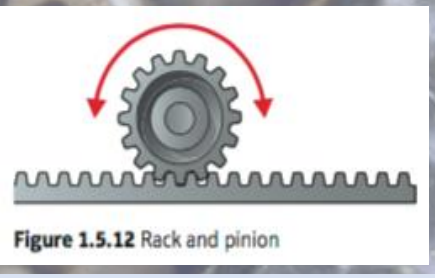
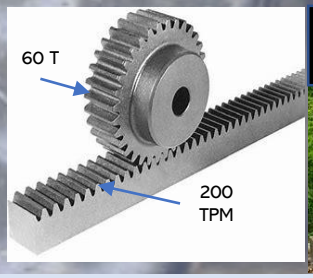
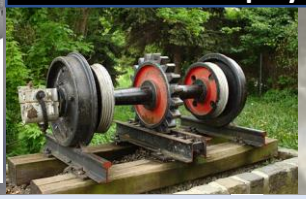
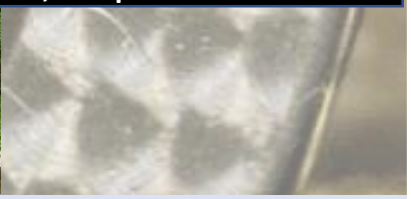


Figure 1.5.12 Rack and pinion



Examples of use: pillar drills, car steering system, CD players, computers.

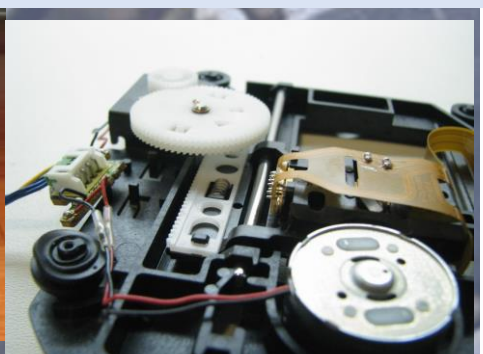




Calculating the output movement of a rack and pinion:

Movement = Number of teeth on pinion (60) / number of teeth on rack per metre. (200) X 1000mm = 3/10 = 300

So for every one rotation of the pinion the rack will move 300mm.



Name: Date: CWK/HWK

Mechanisms

Core 1.5 6

Gears: Bevelled Gears

1. What do you think is the purpose of the bevelled gears in this LEGO buggy?

_____

_____

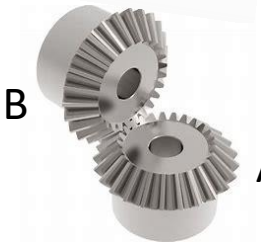
_____ **[1]**

2. The large gear (driver) in this hand drill has 64 teeth. The pinions have 8 teeth. What is the gear ratio?

: **[1]**

3. In this manual whisk, the driven gear has 39 teeth. The crank handle turns the driver gear. If the gear ratio is 1:3, how many teeth does each driver gear have?

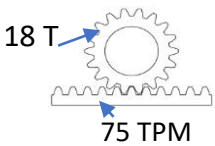
_____ **[1]**



4. These are mitre bevel gears. Gear A is the driven gear. It has 14 teeth. It has an output speed of 3200 rpm. What is the output speed of Gear B?

_____ **[1]**

Gears: Rack & Pinion



5. The pinion of this pillar drill has 18 teeth. The rack has 75 teeth in one metre. How far will the rack move for one single rotation of the pinion?

_____ = x 1M = ____M **[1]**

6. The Snowdon Mountain Railway is a narrow gauge rack and pinion mountain railway in Wales. It is a tourist railway that travels for 4.7 miles from Llanberis to the summit of Snowdon. It is the only public rack and pinion railway in the United Kingdom. The railway track has 10 TPM. The pinions on either end of each axle, have 25T. How far will the train move along the rack for each rotation of the pinion? Answer in metres.

_____ = x 1M = ____M **[1]**

Total: / 6