Core Technical Principles
Mechanical devices

A: Types of movement

There are four basic types of motion in mechanical systems

Linear motion: movement in a straight line, such as on a paper trimmer

Reciprocating motion: movement backwards and forwards, or up and down in a straight line, such as the movement of a needle on a sewing machine

Rotary motion: movement round in a circle, such as a wheel turning

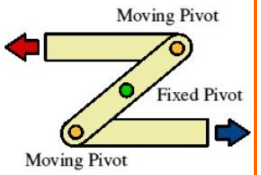
Oscillating motion: movement swinging from side to side, such as a swing or the pendulum on a clock

B: Linkages

Levers can be connected together to form linkages. Linkages are widely used in mechanisms to transfer force and can also change the direction of movement.

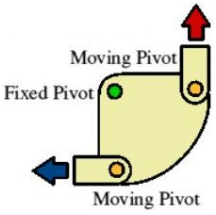
Simple linkage

- Uses two fixed pivots
- The input and output motions of the linkage are in the same direction. The motion of the link arm is in the opposite direction



Bell crank

- Changes the direction of a force through 90°
- The magnitude of the output force can be changed by moving the fixed pivot
- If the fixed pivot is closer to the output lever the output force is greater than the input



C: Changing magnitude and direction of force

Levers

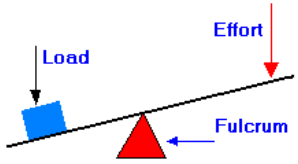
A lever changes an input movement and force (effort) into an output movement and force (load). A lever moves around a fixed point called a pivot. Scissors and pliers consist of two lever that pivot around one point.

There are three basic types or orders of lever. The order of lever depends upon the position of the load (L), effort (E) and fulcrum.

- The **load** is the object to be moved
- The **effort** is the force to be applied to move the load
- The **fulcrum** is the point where the load is pivoted

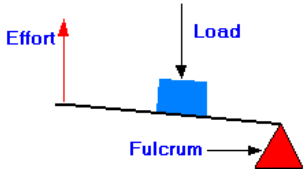
First order lever

A first order lever has the fulcrum between the effort and the load. If the fulcrum is moved closer to the load less effort is needed to move it (although the load does not move as far).



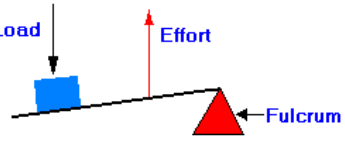
Second order lever

A second order lever has the fulcrum at one end of the lever and the effort is at the other end. The closer together the pivot and the load are, the easier it is to lift.



Third order lever

A third order lever has the effort in between the load and the pivot. Moving the effort and pivot further apart makes it easier to move or lift the load.



This is a mnemonic to remember the 3 orders of levers: FLE– 1-2-3. The F, L, and E stand for the part of the lever system that is in the middle of the lever. So, the fulcrum is in the middle of the 1st order lever, the load is in the middle of the 2nd order lever, and the effort is in the middle of the 3rd order lever system.

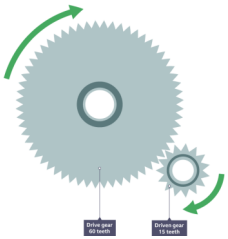
F 1 Fulcrum in the middle – 1st order
L 2 Load in the middle – 2nd order
E 3 Effort in the middle – 3rd order

D: Gear trains

Gears are toothed wheels that interlock. They transfer motion from one part of a machine to another.

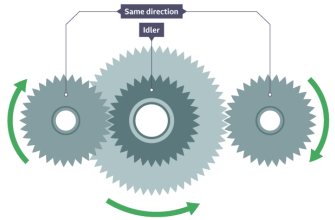
Gear trains transmit or change rotary motion. A gear train is where two or more gears are linked together. They can be used to change the direction of motion or change the magnitude of the input force.

Smaller gears with fewer teeth turn faster than larger gears with more teeth. This difference in speed is called the gear ratio.



Gear ratio = number of teeth on driven gear ÷ number of teeth on the drive gear for example:
Gear ratio=20÷10 = 2/1 or 2:1

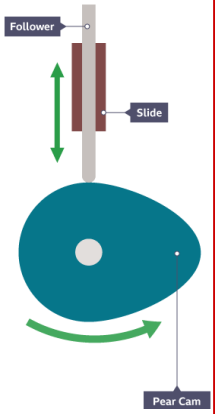
If the drive gear and the driven gear are separated by another gear, called the idler, they will move in the same direction.



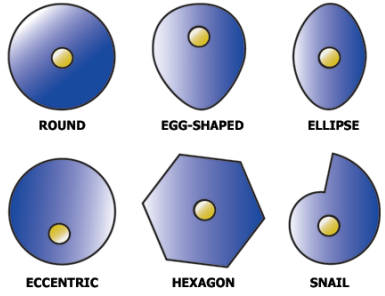
E: Cams and followers

A cam mechanism has three parts: a **cam**, a **slide** and a **follower**. When the cam rotates, the follower moves up and down in a reciprocating motion. The pattern the follower moves up and down in, varies depending on the shape of the cam; it can do three things:

- go up (rise)
- go down (fall)
- Stay still (dwell)



Cams come in many different shapes to create different combinations of rise, fall and dwell.

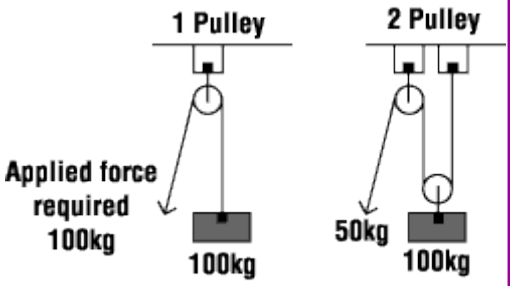


Core Technical Principles
Mechanical devices

F: Pulleys and belts

A simple pulley is made up of a wheel with a grooved outer edge and a cable, rope or belt that sits in this groove. Pulleys make lifting a load easier.

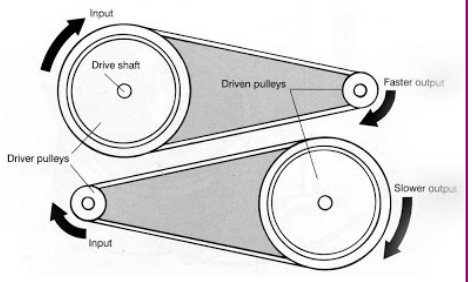
One pulley on its own changes the direction of the force required. The same amount of force is needed, but pulling down might be easier than lifting something up.



Using two or more pulleys together can change the magnitude of the force too - they can make things feel a lot lighter than they actually are. For example, one fixed pulley and one moving pulley (a block and tackle) will mean you only need half the force to pull a load. (shown above)

A **belt drive** transfers movement from one rotating shaft to another.

Belt drives are used in pillar drills and in products such as washing machines.



In a pillar drill, a flexible belt joins two separate pulley wheels and links the motor to the drill shaft. The belt can be put in different positions to make the drill turn faster or slower. This works in a similar way to gears - if the wheels are of different sizes, the smaller wheel will spin faster.

The diameter of the wheels can be used to calculate the velocity ratio - how fast the driven wheel will spin relative to the driver wheel.

velocity ratio = $\frac{\text{diameter of the driven pulley wheel}}{\text{diameter of the driver pulley wheel}}$

G: Key words

- Linear motion: movement in a straight line
- Reciprocating motion: movement backwards and forwards or up and down in a straight line
- Oscillating motion: movement swinging from side to side
- Rotary motion: movement round in a circle
- Mechanism: a device that changes an input motion into a different output motion
- Lever: a mechanism that moves around a fixed point (pivot)
- Linkages: mechanisms that transfer force and can change the direction of moevement
- Cam: a mechanism with a cam, slide and follower. When the cam rotates the follower moves up and down
- Follower: a rod that rests on the edge of the turning cam
- Gear train: a mechanism fro transmitting rotary motion and torque
- Torque: the turning force that causes rotation

H: Video and web-links

- GCSE bitesize: https://www.bbc.com/bitesize/guides/zbt26yc/revision/1

Revision Checklist	
I can describe the four types of movement	
I understand what levers and linkages are and what they do	
I can identify the different orders of lever	
I understand how one type of motion can be converted to another using mechanisms	
I understand how diagrams and symbols are used to represent mechanisms	
I know that mechanisms can change the magnitude and direction of forces	

Test yourself

1. Explain what is means by the terms rise, fall and dwell in a cam mechanism.
2. Describe reciprocating motion and give an example of where it can be found.
3. State an example of a second order lever.
4. A pillar drill operates using a belt drive mechanism. The driver wheel has a diameter of 32mm and the driven wheel has a diameter of 128mm. Calculate the velocity ratio.
5. A gear train contains two gears. The driver gear has 10 teeth and the driven gear has 50 teeth. Calculate the gear ratio of this gear train.