2.1 Biomechanical Principles
2.2 Levers

Teacher Answer Booklet

Content	Additional Information	Pupil comments – How confident do you feel on this topic?
Newton's three laws of linear motion applied to sporting movements.	First law (inertia), second law (acceleration), third law (action/reaction). Force.	
Definitions, equations and units of example scalars.	Speed, distance.	
Centre of mass.		
Factors affecting stability.	Height of centre of mass, area of base of support, position of line of gravity and body mass.	
Three classes of lever and examples of their use in the body during physical activity and sport.		
Mechanical advantage and mechanical disadvantage of each class of lever.		

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<u>Newton's Three Laws of Motion</u>

Newton's First Law of Motion – **The Law of Inertia**:

This states that 'Unless acted upon by an external force, an object at rest remains at rest, or if in motion, it continues to move in a straight line with constant speed.'

Think about a swimmer stood on the blocks before a race. They will remain stationary on the blocks until there is an act of force. What provides this force?

The swimmers legs will provide this force as they push against the blocks.

As they dive through the air they will begin at a constant pace, before the **resistance of the water** slows them down.

Now think about the sport of badminton.

Using Newton's First Law explain how the shuttlecock travels through the air following a smash shot.

Following the smash shot the shuttlecock will accelerate and then remain at a constant speed. The force which changes this is air resistance, which will act against the shuttlecock and slow it down. The force of air resistance will eventually bring the shuttlecock to a stop.

What about a long jumper as they prepare to begin their run up? Using Newton's First Law, as well as your knowledge of the **neuromuscular system,** analyse how the jumper is able to begin their movement.

The long jumper will be in a stationary position at the start of their run up, until an external force acts upon them.

This external force will come from the muscles in their legs pushing against the track so that acceleration begins.

Newton's Second Law of Motion – **The Law of Acceleration**:

This states that 'a force upon an object causes it to accelerate according to the formula **force = mass x acceleration**'.

Think back to the swimmer on the blocks. Their mass will remain constant, therefore the force exerted by their muscles will define the size of acceleration produced.

Now think about a 100m sprinter. Using Newton's Second Law, explain how a 100m sprinter starts a race.

The sprinters leg muscles (gastrocnemius/quadriceps) will push against the starting blocks. As each runners' mass will remain constant, the force that they push against the starting blocks will determine the speed of acceleration.

Imagine that the 100m sprinter accelerated out of the blocks at 8.5 m/s and that they weighed 80kg. What force (in newtons) will be applied?

force = mass x acceleration. 8.5m/s x 80kg = 680N

Put your knowledge of the first two laws together for this next question.

A tennis player is preparing to serve the ball. Using Newton's First and Second Law of motion, explain how the serve will take place.

Newton's First Law of Motion is The Law of Inertia. This states that 'Unless acted upon by an external force, an object at rest remains at rest, or if in motion, it continues to move in a straight line with constant speed.' Therefore the tennis player will remain stationary until the force of their muscles act in order to serve the ball.

The force of the acceleration of the ball will be defined by the force of the tennis players muscles, alongside their mass.

Newton's Third Law of Motion – **The Law of Action/Reaction**

This states that 'for every action (force) there is an equal and opposite reaction'.

Once again, consider the swimmer standing on the blocks at the start of the race. In order to generate force they push back as hard as possible into the block. As a result the block pushes back the same amount of force against the swimmer, allowing them to dive into the water.

As the swimmer enters the water they will then begin to swim. As they draw back their hand in the water, an action has taken place. The reaction in this case is the water creating a reaction and pushing the swimmer forwards.

Now think about a 100m runner at the start of the race. Using Newton's Third law of Motion, explain how they will generate acceleration from the start line?

As the sprinter uses their leg muscles to push against the starting blocks, there will be an equal reactive force from the blocks through the sprinter. Therefore the greater the force that they exert against the blocks, the greater the speed of acceleration.

What about a tennis player producing a forehand shot. Using Newton's Third Law of Motion, explain how they will produce a powerful shot.

As the tennis player puts force into their forehand shot, they have produced a powerful action. This action in turn creates a reaction in the ball. This reaction will be the ball travelling at a great speed.

Using the table below, explain how the Laws of Motion can be applied to a sport of your choice.

Newton's Law	**Application in the sport of Long Jump**
Law of Inertia	'Unless acted upon by an external force, an object at rest remains at rest, or if in motion, it continues to move in a straight line with constant speed.' The long jumper will be running at a constant speed but when they reach the board a more powerful external force (the leg muscles) push against the board in order to the jumper to lift up into the air.
Law of Acceleration	This states that 'a force upon an object causes it to accelerate according to the formula **force = mass x acceleration**'. The long jumper will begin in a stationary position. Their leg muscles will provide the force necessary in order to begin accelerating towards the long jump pit.
Law of Action/Reaction	For every action (force) there is an equal and opposite reaction. Once the jumper reaches the board they will stamp down hard with a great force. This is the 'action'. As a result an equal and opposite force will come from the board through their body, causing them to jump up into the air. This is the reactive force.

<u>Scalars & Equations</u>

A scalar is used when 'measurements are described in size or magnitude, without direction being taken into account'.

The scalars that you need to be able to work out include **speed, distance and mass.**

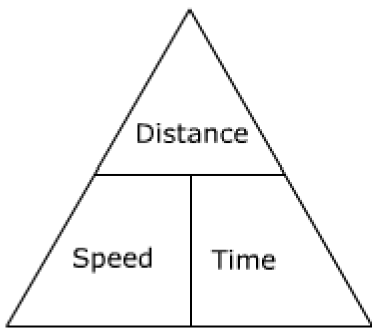
Working out Speed, Distance and Time:

The triangle on the right helps to remember how to work out each measurement.

Distance = Speed x Time

Speed = Distance ÷ Time

Time = Distance ÷ Speed



For example, if a sprinter covered 15km in 60 minutes, the following equation would be used to work out their speed.

The question was in km and minutes – so this is included within the answer

15 (distance) ÷ 60 (time) = 0.25

Therefore the runner is moving at a speed of 0.25km per minute.

Make sure you use the correct units

What about a sprinter who covers 100m in 12 seconds? Work out what speed they were travelling at.

100/12 = 8.33 metres/sec

Now imagine a formula one driver has travelled at a speed of 150 miles per hour for 25 minutes. What distance have they covered?

25 minutes is 5/12 of an hour. 5/12 as a decimal is 0.416

150 x 0.416 = 62.4 miles covered

What about a formula one driver travels at a speed of 180 km per hour for 1 hour?

Again think carefully about the units required in your answer

180 x 1 – 180km covered

The table below shows the distance covered of a player during a basketball match. Calculate the player's average speed during each quarter.

	Distance	**Time**	**Average Speed (m/minute)**
1st Quarter	2014m	10 minutes	201.4
2nd Quarter	875m	10 minutes	87.5
3rd Quarter	1035m	10 minutes	103.5
4th Quarter	1187m	10 minutes	118.7

Practical task

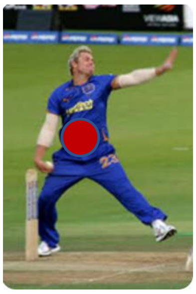
Time yourself to run the distances in the table below, before working out your average speed.

	Distance	Time (seconds)	Average Speed (m/second)
100m		Individual Pupil Work	
200m			
400m			
800m			

Centre of Mass

The centre of mass can be defined as **'the point of balance'.** It can differ from person to person depending on their height, weight, muscle mass and body shape. The centre of mass also changes as we move, particularly as we take part in sport.

The red circle shows the centre of mass in each of the performers below.



Highlight the centre of mass in the two images below.

Factors Affecting Stability:

There are four factors that affect stability.

1. **The Height of the Centre of Mass** – Lowering the centre of mass will increase stability
2. **Area of Base of Support** – The more contact points a performer has, the more stable they will become
3. **Position of the Line of Gravity** – This should be central over the base of support
4. **Mass of the Performer** – The greater the mass, the more stable a performer will become

A prop forward has been told that their scrummaging position is unstable. Explain two ways that they can increase their stability in the scrum.

1. The rugby player can lower the height of the centre of mass by getting lower at the beginning of the scrum
2. The rugby player can increase their mass through weight training over several months

A volleyball player has been told that they are unstable whilst playing a set shot. Explain two ways that they can increase their stability whilst playing this shot.

1. The volleyball player can make sure that they are playing this shot whilst both of their feet are on the ground (rather than one foot in the air)
2. The volleyball player should consider the 'position of the line of gravity'. They should line up their whole body in a straight line underneath the ball.

Lever Systems:

What do you think of when you hear the word 'lever'?

Something that generates movement. A system that includes a pivot.

How do you think parts of your body can be referred to as levers?

Joints allow movement to take place and muscles can produce the force required to move parts of the body, acting as a lever.

Every lever has 3 components. Use the words below to fill in the gaps.

Fulcrum – The axis around which the lever rotates

Load – The force of the thing that you want to move

Effort – The force that is applied by the user of the lever system

force	axis	move	force	lever	rotates

Think about a darts player throwing a dart. What would be the….

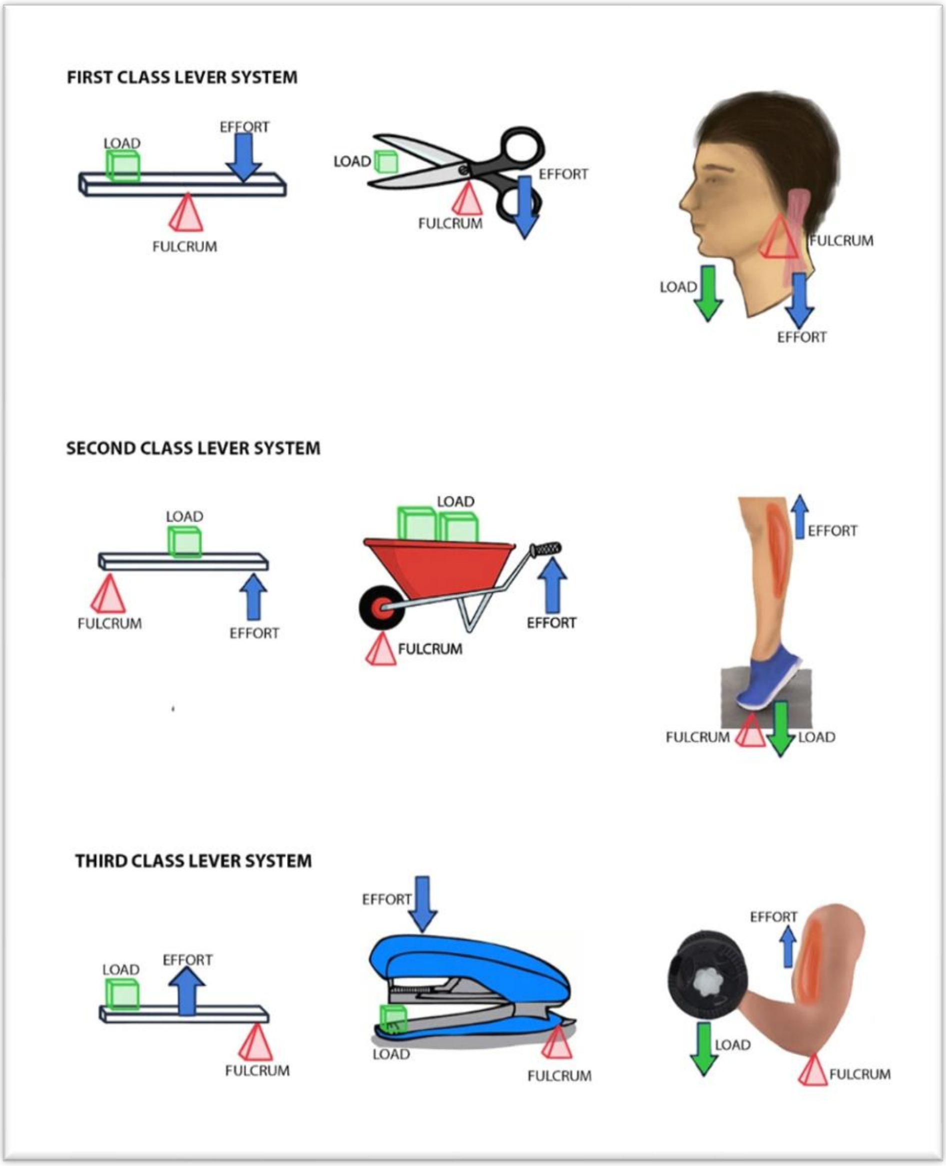
Fulcrum: Elbow

Load: Dart

Effort: Tricep

Different Classes of Lever:

Levers are classified as either **First Class, Second Class** or **Third Class** according to the placement of the fulcrum, load and effort.



1st class = **fulcrum** in the middle

2nd class = **load** in the middle

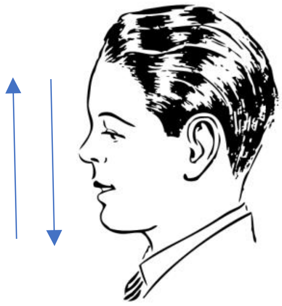
3rd class = **effort** in the middle

To remember what is in the middle you simply need to think **FLE**. Think 'FLY LITTLE ELF' to remember this.

First Class Levers: Load – Fulcrum - Effort

In this lever system the fulcrum sits in the middle, between the load and the effort.

For the pictures shown, fill in the table below.



Exercise/Activity	Load	Fulcrum	Effort
Tricep dips	Water	Top of the Oar	Biceps
Rowing	Body Weight Through the Hands	Elbow	Triceps
Nodding	The weight of the head through the chin	The joint at the top of the neck	The muscles at the bottom of the neck

Can you think of any other first class lever systems?

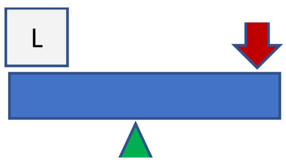
See-Saw:

Load – The person in the air

Fulcrum – The base (middle)

Effort – The person pushing off the floor

This diagram is **very important** – if asked to draw a lever system in an exam, this is what you will need to present.



Second Class Levers: Fulcrum – Load - Effort

In this lever system, the load sits between the fulcrum and the effort. For the pictures shown, fill in the table below.

Exercise/object	Fulcrum	Load	Effort
Calf raises	Balls of Feet	Weight going through the centre of the feet	Gastrocnemius
Wheelbarrow	Wheel	Contents	Person Pushing

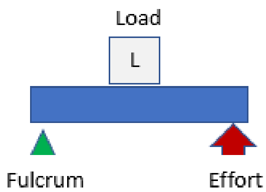
Can you think of any other second class lever systems?

Stapler:

Fulcrum – The back of the stapler

Load – The item being stapled (in the middle of the stapler

Effort – The top of the stapler



Third Class Levers: Fulcrum – Effort - Load

In this lever system, the effort is applied between the fulcrum and the load.

For the pictures shown, fill in the table below.

Exercise/Activity	Fulcrum	Effort	Load
Bicep curl	Elbow	Bicep	Dumbbell
Kicking a football	Knee	Quadricep	Ball
Digging	Right hand at the top of the spade	Left hand in the middle	Soil at bottom of spade

Can you think of any other third class lever systems?

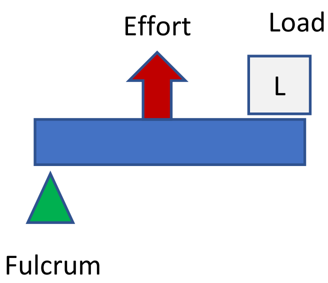
Tweezers:

Fulcrum – End of tweezers

Load – Item being lifted

Effort – Middle of tweezers

Hint – you must know the difference between each lever system and the location of the fulcrum, effort and load



<u>Advantages/Disadvantages of lever systems:</u>

Lever Systems can be seen to have a **mechanical advantage** or a **mechanical disadvantage.**

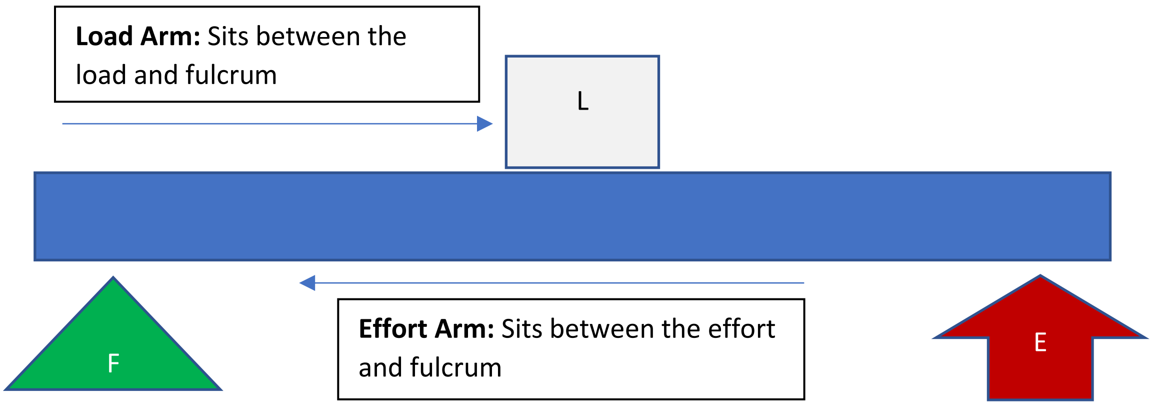
Mechanical Advantage = Effort Arm ÷ Resistance Arm.

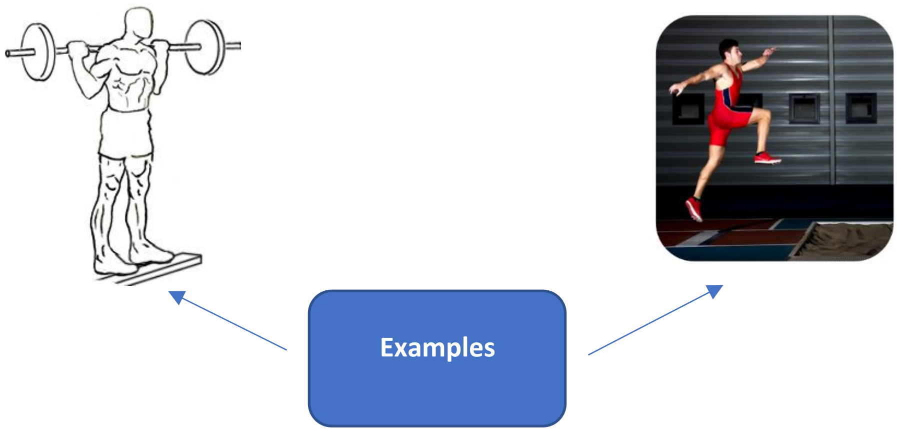
This is when a large load can be lifted with relatively little effort. It is usually due to the effort arm being longer than the .

Mechanical Disadvantage:

This is when it takes a lot of effort to lift a relatively small load.

A **Second Class Lever System** will always have a mechanical advantage due to the **effort arm being longer than the load arm.**

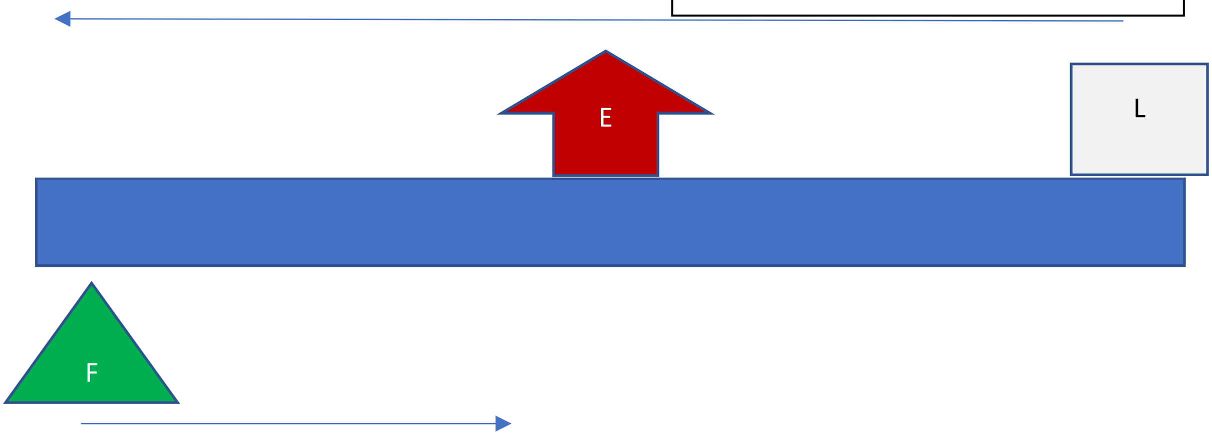




A **Third Class Lever System** will always have a mechanical disadvantage due to the **load arm being longer than the load arm.**

Load Arm:

Sits between the load and fulcrum



Effort Arm:

Sits between the effort and fulcrum

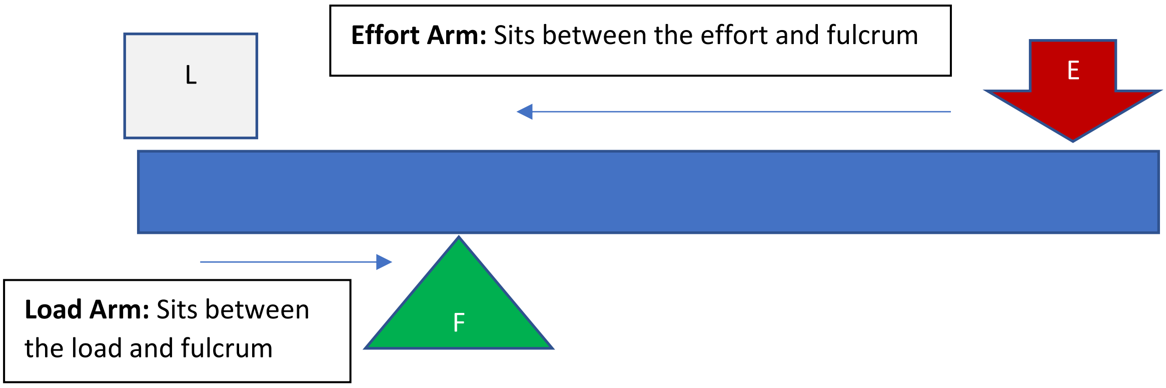
Examples

A mechanical disadvantage has the benefit of producing fast movements

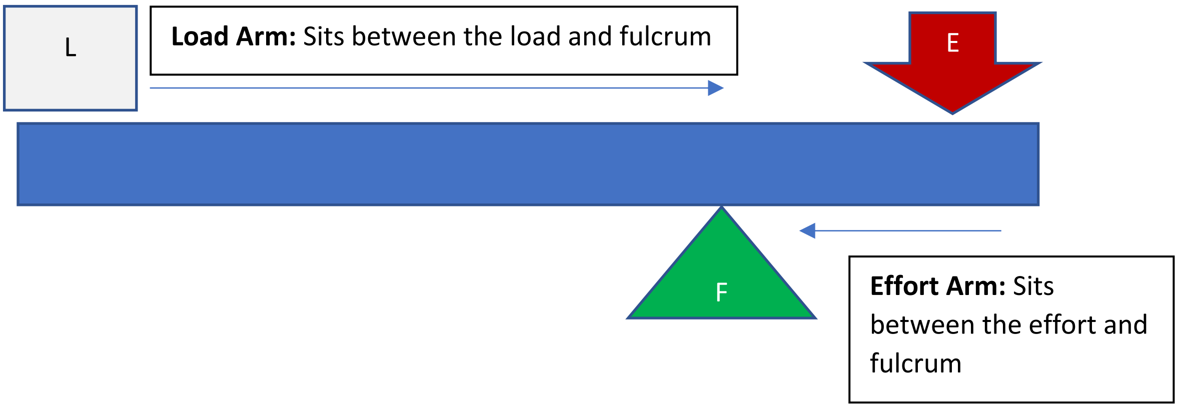
A **First Class Lever System** may have a mechanical advantage or a mechanical disadvantage depending on the length of the effort arm in relation to the resistance arm.

Remember Mechanical Advantage = Effort Arm ÷ Resistance Arm

In the following example the effort arm is longer than the load arm, producing a mechanical advantage.



In the following example the load arm is longer than the effort arm, producing a mechanical disadvantage.



Class of lever	Advantage	Disadvantage
First Class	**Mechanical Advantage -** if the length of the effort arm is greater than the length of the load arm	**Mechanical Disadvantage -** if the length of the load arm is greater than the length of the effort arm
Second Class	**Mechanical Advantage –** A large load can be lifted with relatively little effort	Slower Movement
Third Class	Fast Movement	**Mechanical Disadvantage –** A large effort is needed to lift a relatively small load

What **movement action** is shown through a tricep dip?

Extension.

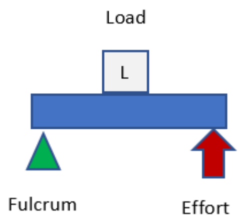
How do you know that a tricep dip is a first class lever system?

The fulcrum is in the middle.

What is the fulcrum when a tricep dip is performed?

The elbow.

Draw the lever system that operates at the ankle joint, labelling the fulcrum, effort and load.



Analyse the lever system being used at the ankle.

The second class lever system at the ankle shows a mechanical advantage. This is because a heavy load can be lifted with relatively little effort.

A bicep curl is an example of which type of lever system?

Third class

Give one advantage and one disadvantage of the lever system used when performing a bicep curl.

Advantage = Fast Movement

Disadvantage = Mechanical Disadvantage - A large effort is needed to lift a relatively small load

Key Terms:

Inertia – The resistance an object has to a change in its state of motion

Newton's First Law (Inertia) – A force is required to change the state of motion

Newton's Second Law (Acceleration) – The magnitude and direction of the force determines the magnitude and direction of the acceleration

Newton's Third Law (Action/Reaction) – For every action there is an equal and opposite reaction

Fulcrum – The point around which the lever rotates

Load – The force of the thing that you want to move

Effort – The force that is applied by the user of the lever system

Mechanical Advantage – A large load can be lifted with relatively little effort. Effort Arm ÷ Resistance Arm

Mechanical Disadvantage – Cannot lift as heavy a load with the same amount of effort