BIOMECHANICAL PRINCIPLES

Recap – Setting the scene

Area of Study 1 looks at how movement skills can be improved. The first part of this area of study looked at;

- How skill and movement can be classified.
- Understanding the characteristics different learners exhibit and the teaching/coaching implications for each learner.
- The direct and constraints based approaches that can be used when working with different learners.
- Qualitative movement analysis process.

To further understand how movement skills are produced the study of biomechanical principles, derived from quantitative movement analysis (in addition to qualitative) is vital in improving the efficiency and quality of movement.

Biomechanics is the field of sports science that applies the laws of mechanics and physics to human performance in order to gain a greater understanding of performance in physical activity. It is the study of forces and the effect of those forces on and within the human body.

The field of biomechanics has helped define;

- Movement techniques (Sprinters technique, kicking technique)
- Equipment design (F1 car, Golf club design)
- Causes of injury (Overuse, or poor technique)
- Improving movement of people with disability.

However, what do we need to focus on in our VCAA study design with regards to Biomechanics?

Our focus is on how Biomechanical principles can be used to improve movement skills in sport and physical activity.

KEY KNOWLEDGE

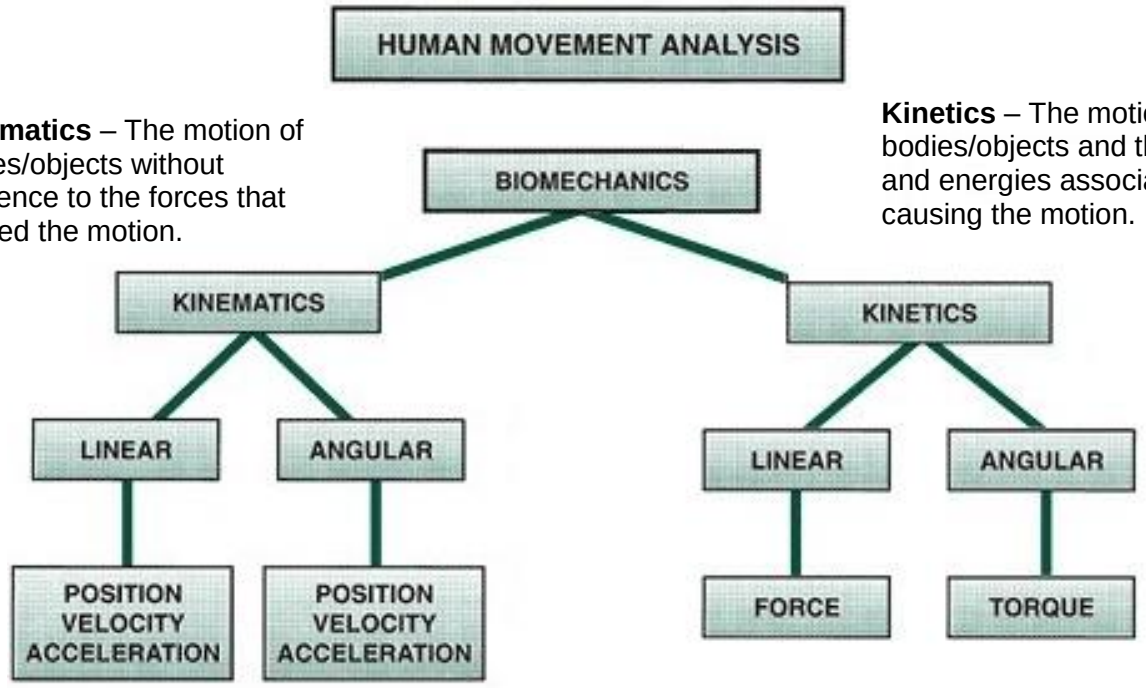
- Angular and linear kinetic concepts of human movement: Newton's three laws of motion, inertia, mass, force, momentum and impulse
- Angular and linear kinematic concepts of human movement: distance, displacement, speed, velocity, acceleration and projectile motion (height, angle and speed of release)
- Equilibrium and human movement: levers (force, axis, resistance and the mechanical advantage of anatomical levers), stability and balance (centre of gravity, base of support and line of gravity).

KEY SKILLS

- Perform a qualitative analysis of a movement skill using video and systematic observation to analyse and improve a variety of movement skills

- Analyse, interpret and apply graphical, visual and physical representations of biomechanical principles to improve movement skills in a coaching context

http://www.vcaa.vic.edu.au/Documents/vce/physicaledu/PhysicalEducationSD_2017.pdf



Kinematics – The motion of bodies/objects without reference to the forces that caused the motion.

Kinetics – The motion of bodies/objects and the forces and energies associated with causing the motion.

m. Distance
n. Displacement
o. Speed

j. Angular Distance
k. Angular Displacement
l. Angular Speed

e. Inertia
f. Mass
g. Momentum
h. Impulse
i. Newton's 3 laws of motion

a. Moment of Inertia
b. Torque
c. Angular momentum
d. Newton's laws of angular motion

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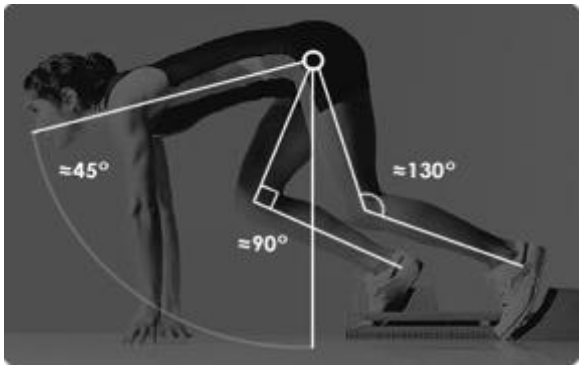
UNDERTAKING A BIOMECHANICAL (QUALITATIVE VS QUANTITATIVE) ANALYSIS

Qualitative assessment is primarily used to provide feedback to a performer, however, a quantitative biomechanical analysis can provide data that supplements these assessments and answers questions. Therefore, both are equally important.

A sprinter – Receiving qualitative and quantitative assessment



Qualitative assessment
Slow out of the block's as your weight was not far enough forward in the blocks.

Quantitative assessment
Your 90degree angle of your front leg allowed you to remain balanced and led to your 2.2second split time over the first 10m.

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PLANNING A QUANTITATIVE BIOMECHANICAL ANALYSIS

The steps of planning a quantitative biomechanical assessment mirror that of a qualitative assessment;

Preparation

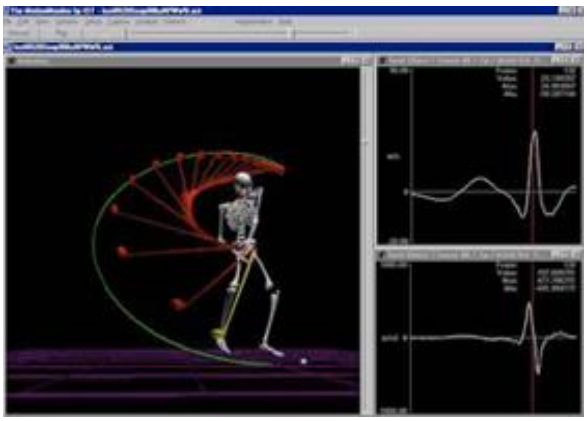
- What question needs answering? E.g How can the speed of a fast bowler be increased?
- Determine the best perspective to observe the movement. e.g side on, single player, whole court?
- How many movements will be observed? This can help determine if error is consistent or random.
- Characteristics of the performer? Skill level, age gender, development level.
- Other factors? Clothing, lighting, what setting (competition, training)

This leads to what equipment will be used to capture the data:

- Digital video recording. Can also be used to provide immediate qualitative assessment with the athlete
- Other biomechanical specific equipment

Opteolectronic motion sensors:

Use cameras that project light onto reflective targets to generate an image on the computer that can be analysed.



http://sydney.edu.au/health-sciences/research/biomechanics/biomechanics.jpg

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Goinometry:

A device that is used to measure joint angles in a static position. Electro-goinometers can also be used to measure dynamic movements.

http://teamawesome34.weebly.com/uploads/1/4/3/2/14326766/8685766.jpg?0

Other devices that are used;

- Light gates – To measure speed and velocity.
- Force plates – To measure ground reaction forces
- Electromyography – Electrical activity within a muscle, shown on a EMG machine.
- Other phone and ipad apps – Dartfish, Ubersense.

SUMMARISING THE STUDY OF BIOMECHANICS

1. What does the term Biomechanics refer to?

   Biomechanics are the mechanical principles that govern human movement.

2. Explain the benefits to athletes and coaches of having an understanding of biomechanical principles.

   By understanding biomechanical principles athletes can receive both qualitative and quantitative feedback from coaches that helps refine movement patterns to increase the efficiency of movements and ultimately improve the overall performance outcomes.

3. Compare and contrast the two terms which describe the two main branches of biomechanics.

   Both terms are biomechanical terms to describe motion and the causes of motion. Kinematic principles describe motion without consideration of the forces that caused it, whereas kinetic concepts look at the forces that act on an object causing motion.

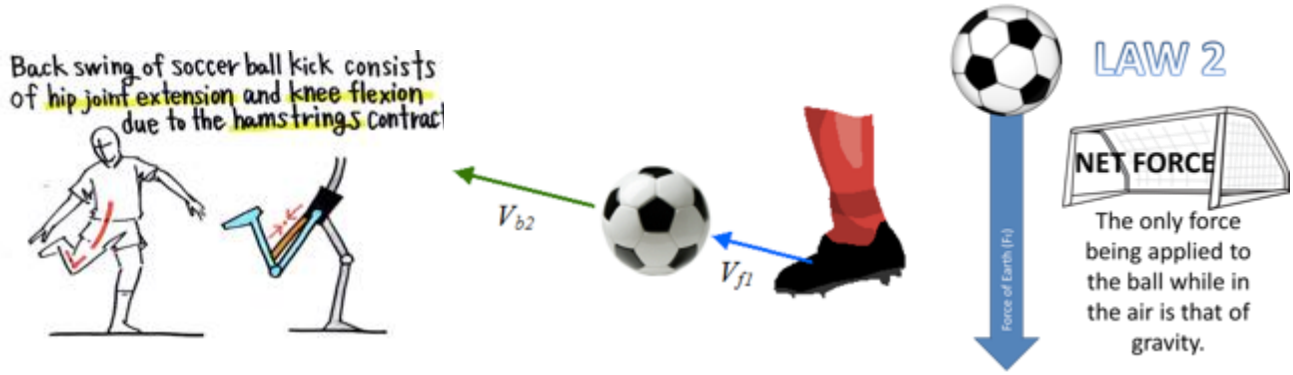
4. Evaluate the similarities and differences between qualitative and quantitative assessment of movement.

   - Both forms of assessment can be used to provide feedback to an athlete to help improve the efficiency and quality of movement.
   - Qualitative assessment uses observation, whereas quantitative assessment relies on data such as speed, distance, force.
   - Both assessment can be completed from video footage.
   - Quantitative assessment utilises specialised equipment to collect data measurements where qualitative just relies upon video/live observation.
   - Qualitative assessment more associated with junior sport, whereas quantitative will be more associated with use with elite athletes.
   - Qualitative assessment can be given instantaneously, whereas quantitative assessment requires calculation in a laboratory.

FORCES

A **Force** is defined as a push or pull.

This description summarises some of the most common forces within a sporting situation;
A muscle attached to one bone pulls another bone closer producing muscular force to allow an individual to push the ball with force. Once it goes into the air gravity will apply a pull force through gravity to bring the ball back to the earth.



Forces **can affect an object** in 2 ways:

- Change the shape of the object (stretch, squash, twist)

- Move the object (start from rest, speed up, slow down, change direction)

The unit of force is the Newton (N) which is the amount of force required to accelerate 1 kg of mass at 1m/s squared. (kg m/s squared)

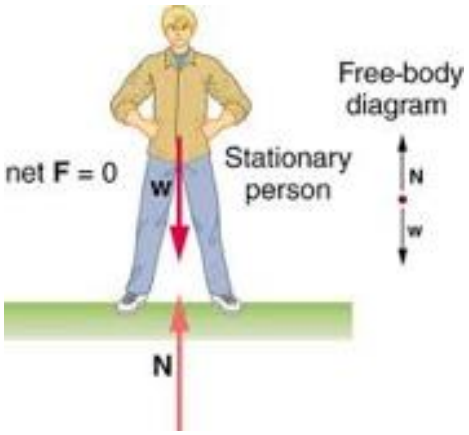
For a change in movement to occur there must be a resultant force acting on a body/object greater than 0 N.

When the forces are acting in opposite directions, but are not equal, we say that the net force is greater than 0 N. There is a resultant force. If the forces are equal and acting in the same direction there will also be a resultant force.

PAIRS OF FORCES

- Forces acting on a human body when standing will have a resultant net force of 0 N because the weight force and ground reaction forces are equal in size and opposite in direction = no movement occurs.

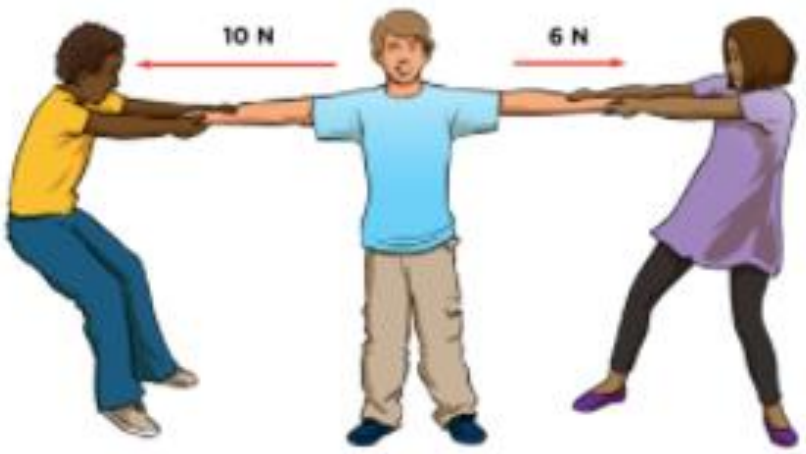
- Note: Forces are drawn as arrows in the direction that the force is being applied.



- Forces acting in the same direction; The net force will be the sum of both forces;

Overall F applied =
7N + 10N = 17N

- Forces acting in different directions will result in an overall net force of the difference in the direction of the greater force. In this example the net force is 4N left.



TYPES OF FORCE

FRICTION

Friction occurs when two surfaces come in contact with one another.

Forces always act in the opposite direction to the motion of the object. Friction resists movement when the object and surface are in contact.

To start an object moving you must apply a force that is greater than the maximum static friction value.

APPLIED EXAMPLE

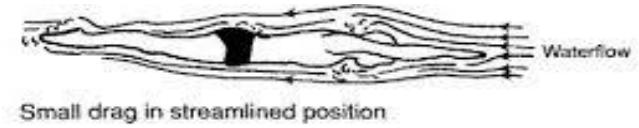
(a) Identify 3 circumstances where a performer tries to increase friction. Explain how this is achieved in each example.

Increasing Friction	**Decreasing Friction**
Studs in a football boot – This helps to increase the friction between the grass and the boot to allow the player to stay balanced and apply force to the ball.	Smooth surface shoes ten pen bowling – This allows the bowler to slide due to decreased friction between the shoe and the floor when bowling the ball. This is important so the knee does not take all of the force when bowling the ball.
Chalk on a gym bar – This helps to increase the friction between the bar and the hands to allow the player to remain a strong grip and exert force to the bar.	French Open clay surface – The smooth clay surface has decreased friction allowing the tennis player to slow momentum gradually when sliding into shots, reducing risk of knee injuries.
Tyres on a motor race car – The grooves in the tyres apply friction to the road surface and allow the car to grip to the road so the car can take the bend at the fastest possible speed.	Ice hockey – The ice has no friction which allows the puck to slide quickly along the surface.

AIR AND WATER RESISTANCE

Drag forces oppose the direction of motion of a body as it moves through air or water.

Affected by cross sectional area (surface area) of a body, speed (drag increases linearly with speed) and air density.



Small drag in streamlined position

Large drag in unstreamlined position

Can you think of any other sports where drag is important?

WEIGHT OR MASS

Many people use the term weight incorrectly in everyday language. For example, a relative may say to you "My weight increased by 2 kgs over the holiday period as I ate too much food." What is wrong with this statement?

The **mass** of an object is the amount of matter in the object. It tells you how many particles you have. Mass is measured in kilograms (kg) and is independent of where you measure it. A wooden block with a mass of 10 kg on Earth also has a mass of 10 kg on the Moon.

However, an object's **weight** can change as it depends on the mass of the object and also the strength of the gravitational force acting on it. Weight is measured in newtons (N) as it is the gravitational force of attraction exerted on an object by the Earth

Weight = Mass x Gravity

GRAVITATIONAL FORCE

Gravitational forces exist between any two objects with mass and they are forces of attraction (pull).

On earth the gravitational force that causes objects to fall towards the center of the earth.

The acceleration due to gravity is is equal to 9.8 m/sec squared.

Acceleration = F / M

INERTIA

The tendency of the body to resist a change in its state of motion (whether at rest or moving) with a constant velocity.

If the force that is applied to an object is not greater than the inertia of an object there will be no change in its motion. Eg: a person may apply a force to a car but the car will not shift if the force is not greater than the inertia of the car.

The relationship between mass and inetia: The amount of inertia an object has is directly related to its mass – the greater the mass, the greater the inertia.

STUDENT QUESTION 2
Explain why Sumo wrestling is considered one of the greatest sporting examples of strength by referring to the principle of inertia.

MOMENTUM

- The term momentum describes the quantity of motion a particular body of mass has.
- It is a combination of mass and velocity: mass (measured in kilograms) multiplied by velocity (measured in metres travelled per second).
- Momentum = Mass x Velocity (p = m x v)
- The greater an objects mass, the greater the momentum (Eg: When comparing a cricket ball and tennis ball with the same velocity – which would have the greatest momentum?)
- The greater an objects velocity, the greater the momentum (Eg: When comparing a cricket ball hit in a full attacking drive and a cricket ball hit in a forward defense – which would have the greatest momentum?)
- The greater momentum an object has, the harder it is to stop.

STUDENT QUESTION 3
Watch the 'Cheese rolling' video and describe why injuries are as common by referring to principles of momentum.

SUMMATION OF MOMENTUM

- When trying to create maximum force or velocity of movement it is important that all body parts involved are coordinated from movement start to movement end.
- Sequence body parts from those closest to the center of gravity to those further away.
- Lager body parts start movement (larger mass, slower velocity), momentum is conserved and passed on to smaller body parts which finish movement with greater speed (smaller mass, greater velocity, fine motor control).
- Eg – Golf Swing: Momentum generated in the lower body is transferred to the hips and trunk, then to shoulders and elbows and finally to wrist.

Smaller, faster body parts, are all involved in the movement

Large body parts initiate the movement and provide a base of support

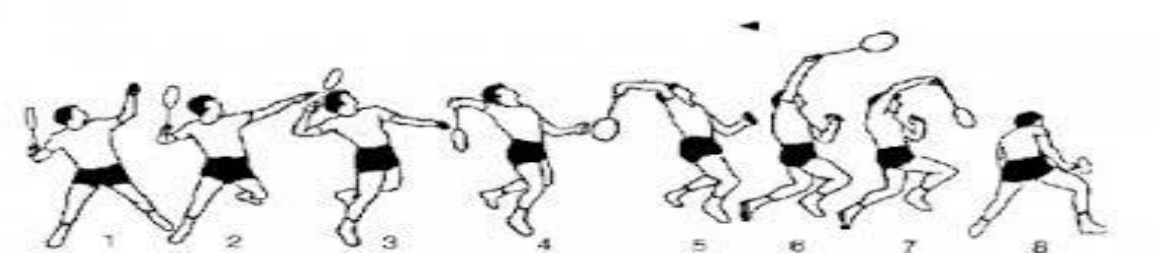
- Use the large muscles of the thighs and trunk first. These body parts have a large mass but move slower.
- Each body part is then sequentially accelerated, transferring momentum from the large and slow body parts to the lighter faster moving body parts.
- Each body part is stabilised before the momentum is transferred.
- By using as many body parts as possible, the time over which the force is applied is maximized.
- Follow through is important so that the last body part doesn't slow down before the ball is released, kicked or hit.

Summation of momentum applies to timing and coordination of movement between body parts, not just to use larger muscles to produce maximal force. An example of this is a basketball free throw.

APPLIED EXAMPLE

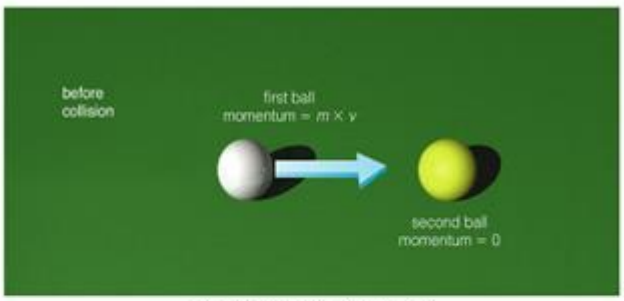
Explain what is happening with this badminton overhead smash using the principle of summation of momentum.

The Badminton player uses the muscles of the lower body to generate the force to get into the air, transferring this through the hips which rotate in picture 2 and 3. The upper body accepts this momentum as the hips drag the upper trunk towards the shuttle, the shoulder extends through picture 4, with this momentum then passed to the elbow, wrist to hit the shuttle.

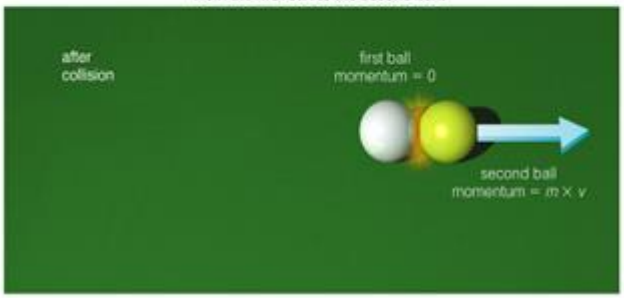


CONSERVATION OF MOMENTUM

- The total momentum before a collision is equal to the total momentum after a collision
- If the mass of the white ball is .1 kg and its velocity is .5 m/s – what is its momentum?
- What will be the momentum of the yellow ball after impact if the white ball's momentum is now zero?
- N.B. Conservation of momentum is important when considering 'Summation of Momentum' as it allows momentum to be passed from one body part to the next.



The collision transfers momentum from the first ball to the second ball.



IMPULSE

Impulse is equal to the change in momentum of an object.

There is an impulse-momentum relationship that can be described by the formula:

Impulse = force x time

The increasing impulse can be used to <u>increase</u> momentum.

- The greater the impulse, the greater the momentum generated.
  For this to occur, the force (via a combination of mass and acceleration) should be applied over the longest period of time. The term 'time' in this formula refers to the length of time force is applied to an object.

- This relationship can be used by generating a large force over a short period of time – e.g striking sports.

- Alternatively, a smaller force can be applied over a greater period of time to create a similar momentum.

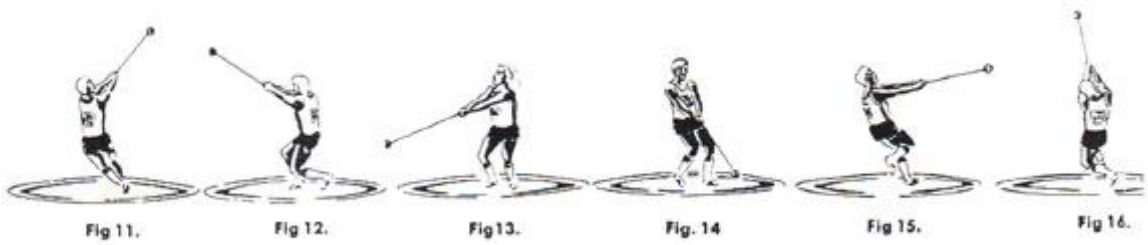
Increased contact time, but lower force compared to hit.

Decreased contact time, but greater force compared to push on left.

A hammer thrower applies a force of 30N for 1 second doing 1 turn and 30N for 3 seconds doing 4 turns. What is the difference in impulse?

I (1 turn) = 30 x 1 = 30 Ns
I (4 turns) = 30 x 3 = 90 Ns

So we can see that three times more impulse is generated by doing three turns as opposed to four turns. The force is applied to the hammer for longer increasing impulse.



The increasing impulse can also be used to <u>decrease</u> momentum.

- If the force is exerted in the opposite direction of the object's original momentum, the object's momentum will decrease.
- If we can increase the time over which the force is applied/absorbed (decrease momentum slowly) you can decrease impact force.
- EG: Egg Toss Competition: In order to reduce the amount of force on the egg so it doesn't break when you catch it, you move your hands in the same direction as the egg as you catch it. This action increases the amount of time you apply force on the egg and the amount of force acting on the egg to change its momentum is reduced so the egg will not break.

Impulse =	**Force**	**x**	**Time**
(Same change in impulse/momentum)	(Decreased Force Component)		(Increase Time Component)

APPLIED EXAMPLE

By referring to the principles of impulse and momentum, explain the importance of gymnastics mats for performers landing from the rings, bar and vault.

The absorbent gymnastics mats allows an impulse to be applied over an extended period of time reducing the force, whilst still having the same change in momentum (as if a harder surface was used).

NEWTON'S LAW'S OF MOTION

NEWTONS FIRST LAW – THE LAW OF INERTIA

Inertia is the resistance of a body to change its state of motion. In the human body the muscles provide the force to change the motion of the body from rest and also to slow the body when it is moving.

Newton's first law states that:

An object will stay at rest or continue to travel in the same direction at a constant velocity unless acted on by an unbalanced force.

In other words, objects will not move from their state of being unless forces acting on them become unbalanced. This can be referred to as a body having uniform motion.

To shift from a state of uniform motion, a force must be applied to disrupt the balance and hence accelerate an object. The higher the mass of a body, the greater the inertia and therefore more force is required to overcome this inertia. This is true both for objects that are static and those that are moving.

APPLIED EXAMPLE

Identify all of the external forces that will be applied to the golf ball from the time it sits on the tee to the time it comes to rest on the fairway.

Forces acting on the golf ball –

Force applied by the golf club to overcome inertia and produce movement

Eg: If the mass of the ball is .046kg and the acceleration is 140000 m/s squared what is the force applied to the ball?

F = M x A F = .046 x 140000 F = 6440 N

Force experienced because of drag force – opposes the direction of motion, slowing the ball down (Greater the speed, cross sectional area and air density the greater the drag force).

Force experienced because of gravitational forces – causes the ball to fall downwards towards the centre of the earth (acceleration due to gravity is 9.8 m/s squared) giving the ball its parabolic flight path.

Forces experienced because of friction – opposes the motion of the ball when it comes into contact with the ground surface.

NEWTONS SECOND LAW – THE LAW OF ACCELERATION

This law of acceleration allows us to calculate force and acceleration.

Newton's second law states:

A force applied to an object will produce a change in motion (acceleration) in the direction of the force that is directly proportional to the force.

F= m x a

Application of Newton's Second Law:

F = m x a

If you increase mass, force will increase:

10 N = 2 kg x 5 m/s2 or 25 N = 5 kg x 5 m/s2

a = F/m

If you increase force, acceleration will increase:

1m/s2 = 5 N / 5 kg or 5m/s2 = 25 N / 5 kg

If you increase mass, acceleration will decrease:

10m/s2 = 20 N / 2 kg or 4m/s2 = 20 N / 5 kg

STUDENT QUESTION 4 – Anna Meres vs Porsche Boxter
Referring to the video and Newton's second law, explain how it is possible for Anna Meres to have greater acceleration over 80m.

NEWTONS THIRD LAW – THE LAW OF ACCELERATION

Newton's third law states:

For every action there is an equal and opposite reaction.

When two objects come into contact, they exert forces on each other that are equal in size but opposite in direction.

It is important to recognise that even though two forces are equal in size and opposite in direction, they don't cancel each other out.

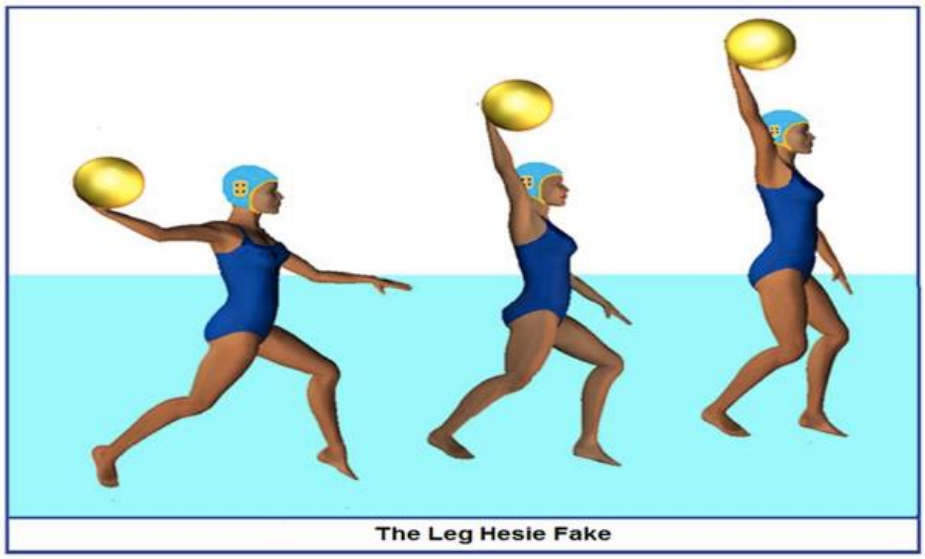
In sporting situations it is sometimes difficult to see the reaction force. The forces are acting on different objects, so the effect of each force will be different.

Example of a reaction force that <u>can be seen:</u>

Waterpolo set shot.

APPLIED EXAMPLE

How is the force produced to lift the body out of the water to shoot for goal in water polo?



http://www.waterpoloplanet.com/HTML_Jim_pages/images/js22_shot_doctor_jim_clip_image012.jpg

The player pushes the ball into the water which exerts an equal force back towards the roof, combined with the player driving their eggbeater kick down, generates an equal force pushing the player out of the water.

Example of a reaction force that cannot be seen:

ReacTime False Start Detection System

APPLIED EXAMPLE

By referring to Newton's Third Law explain how the ReacTime False Start Detection System would work?

The system has a force plate built into the block. As the athlete pushes back into the block to obtain an equal and opposite reaction of pushing them forward down the track, the time from the gun to the exerted force is recorded – reaction time. If this time is faster than the accepted time of non anticipation then the start will be deemed legal.

NEWTON'S LAW'S OF MOTION – SUMMARY

Newton's First Law	Newton's Second Law	Newton's Third Law
		
Law of inertia	F = ma	Action and reaction

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STUDENT QUESTION 5 – NEWTON'S LAWS
Compare and contrast the skateboard Ollie with the Basketball/tennis ball collision by referring to inertia and Newton's laws.

NEWTON'S ANGULAR LAWS OF MOTION

The below table illustrates the corresponding terms for linear and angular motion.

LINEAR		ROTATIONAL	
x	position	**θ**	angle
v	velocity	**ω**	angular velocity
a	acceleration	**α**	angular acceleration
m	mass	**I**	moment of inertia
F	force	**T**	torque
L	momentum	**H**	angular momentum

NEWTON'S FIRST LAW OF ANGULAR MOTION

- <u>The angular momentum of a body remains constant unless acted upon by an external torque.</u>
- Angular momentum(L) = moment of inertia (I) X angular velocity(w)
- Moment of Inertia is a bodies tendency to resist change in rotary motion.
- I = mass X radius^2 (NB. It is extremely important where the mass is distributed in relation to the axis that it rotates around).
- To increase Moment of Inertia – distribute mass further away from the axis.
- To decrease Moment of Inertia – distribute mass closer to the axis.