IB

Sports, exercise and health science

Fundamentals of biomechanics

Topic 4

Movement analysis

Sub-topics

1. Neuromuscular function

2. Joint and movement type

3. Fundamentals of biomechanics

Unit 4.3	Fundamentals of Biomechanics
Key learning intention (KLI)	To understand and explain the impact biomechanics has on sports performance.
Success criteria	For your chosen sport, assess your technique and suggest any biomechanical alterations you could make, stating how and why this would improve performance.
Resources	P88-104
Key words	Force, speed, velocity, displacement, acceleration, momentum, impulse, vectors, scalars, velocity-time graph, distance-time graph, force-time graph, centre of mass, first class lever, second class lever, third class lever, newton's laws, angular momentum, angular velocity, moment of inertia, projectile motion, Bernoulli principle,

Fundamentals of biomechanics

What is biomechanics?

Biomechanics is the sport science field that applies the laws of mechanics and physics to human performance, (in order to gain a greater understanding of performance in athletic events).

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Nature vs. nurture?

Sub-topics

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discuss and write down ways in which you think elite athletes are successful because of nature or nurture (training).

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What are scalars and vectors?

Sub-topics

1. Neuromuscular function

2. Joint and movement type

3. Fundamentals of biomechanics

A scalar quality has only magnitude.

4 meters	distance
4 meters per second	Speed
4 kg	mass

Fundamentals of biomechanics

What are scalars and vectors?

A scalar quality has only magnitude.

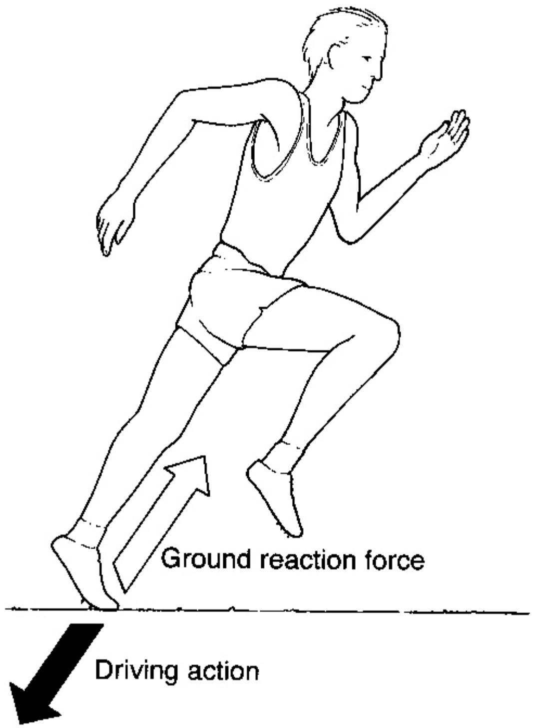
Speed is caulcuated:

distance (m)/ time (seconds)

Fundamentals of biomechanics

What are scalars and vectors?

A vector quality has magnitude and direction.



Force is the mechanical interaction between 2 objects and is measured in newtons.

We also know that Force=Mass x acceleration

Newtons second law

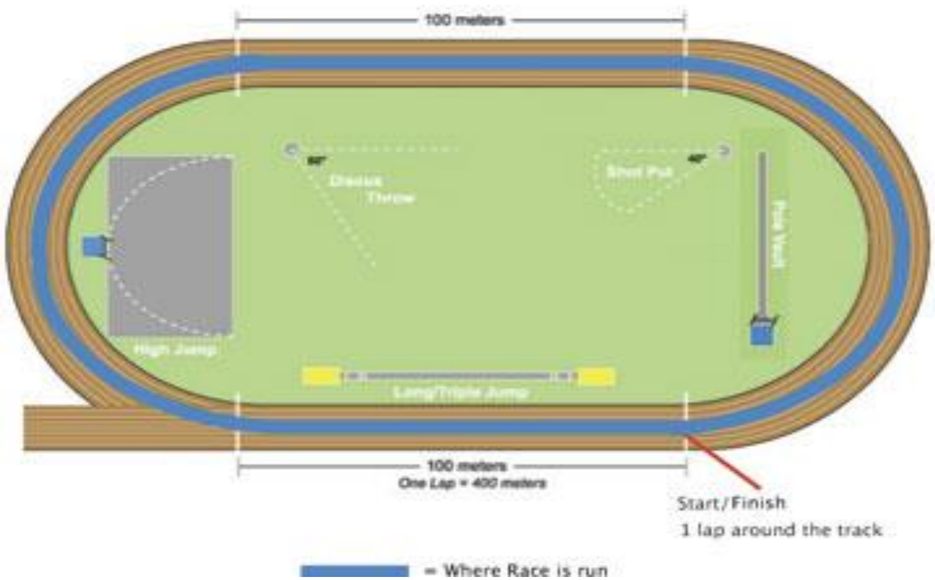
Fundamentals of biomechanics

DISPLACEMENT

A vector quality has magnitude and direction.

Displacement is how far and object has moved in a given direction

400m Dash



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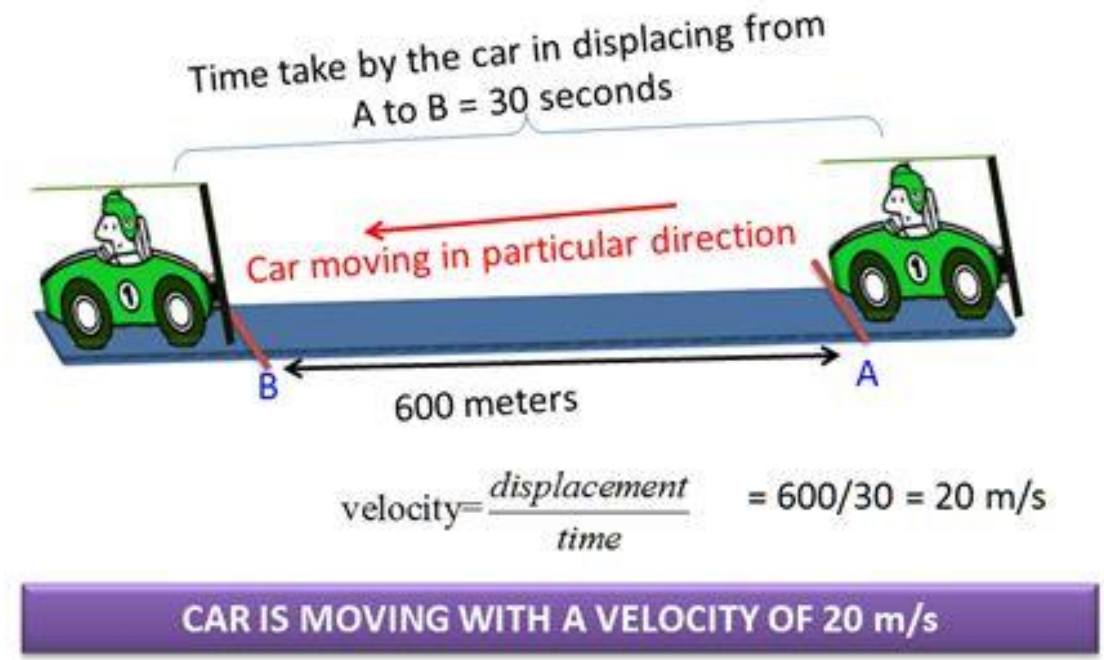
VELOCITY

A vector quality has magnitude and direction.

Velocity= Displacement change / time



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Fundamentals of biomechanics

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ACCELERATION

Sub-topics

1. Neuromuscular function

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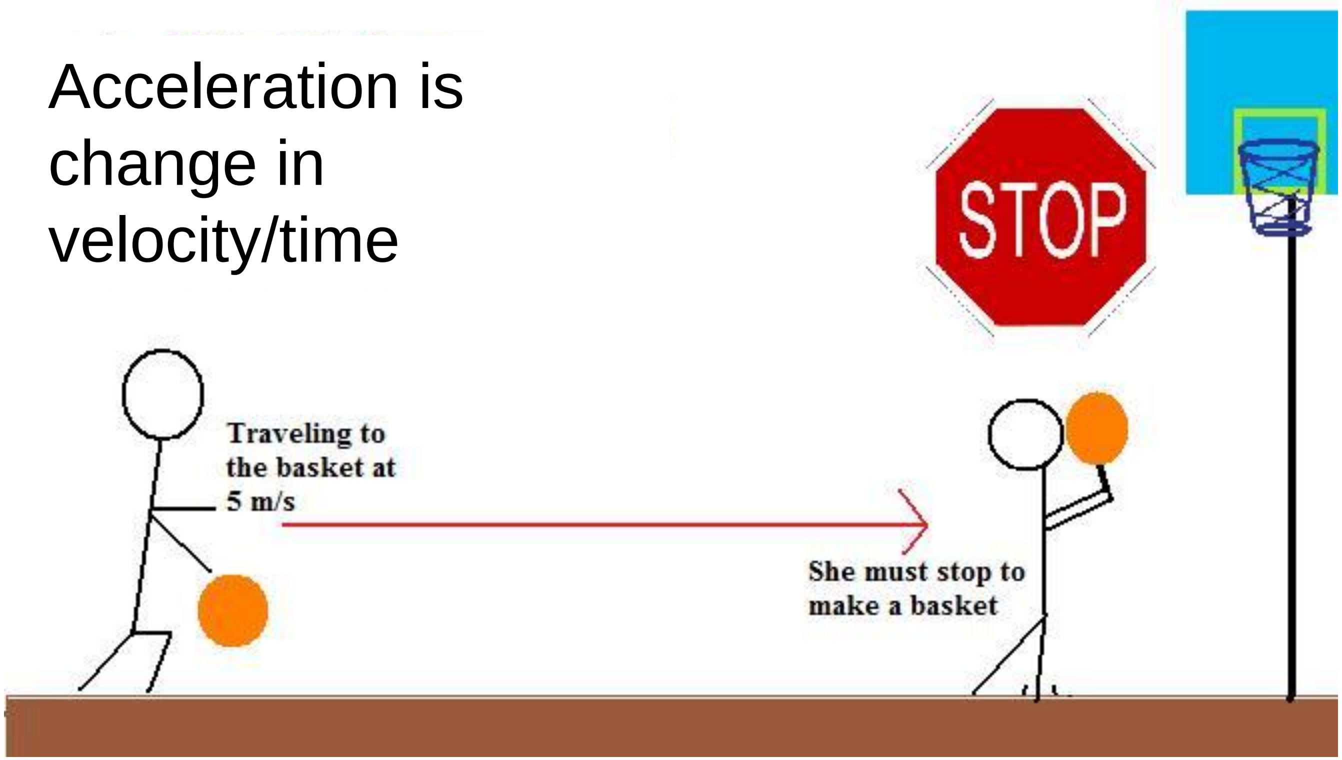
A vector quality has magnitude and direction.

Acceleration is change in velocity/time

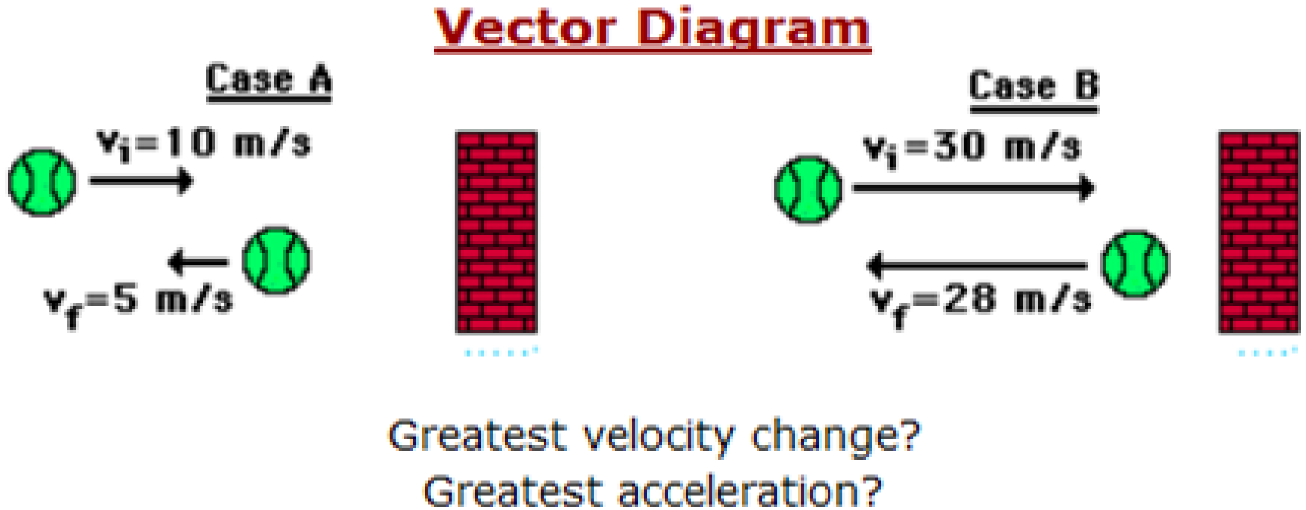


Fundamentals of biomechanics

ACCELERATION

A vector quality has magnitude and direction.

Acceleration is change in velocity/time



- If the direction of 2 vectors is the same, their sizes may be simply combined together.
- If they are different directions, this must be taken into account.

- Scalars can simply be added, subtracted, multiplied and divided.

Practice: A car moved 60 km East and 90 km West. What is the distance and displacement?

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MOMENTUM

Sub-topics

1. Neuromuscular function

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A vector quality has magnitude and direction.

Momentum is the mass of an object x its velocity

Two nfl players approach each other. Just before impact player 1 moves with a velocity of 6m/s and and a mass of 90kg. Player 2 moves with a velocity of 7m/s amd a mass of 80kg. What is the momentum of each before impact?

Fundamentals of biomechanics

IMPULSE

A vector quality has magnitude and direction.

Impulse= force x time

Whenever a force is being applied it always takes time. When a person applies a force over a certain time then we can say that they have applied an **impulse**.

How force and time are combined depends on:

- the physical capabilities of the person applying the force: compare elite athletes to beginners in a task.
- the requirements of the task: compare sprinting verses rowing, speeding something up verses slowing something down

Fundamentals of biomechanics

IMPULSE

A vector quality has magnitude and direction.
Impulse= force x time

- A resultant force causes acceleration and a change in the velocity of the body for as long as it acts.
- A resultant force applied over a longer time therefore produces a bigger change in linear momentum than the same force applied briefly: the change in momentum is equal to the product of the average force and duration.
- Conversely, a small force applied for a long time produces the same change in momentum—the same impulse—as a larger force applied briefly.

Movement analysis

Why are the following variables important in maximizing impulse?

The **impulse** experienced by the object equals the change in **momentum** of the object.

- Strength
- Speed
- flexibility

Sub-topics

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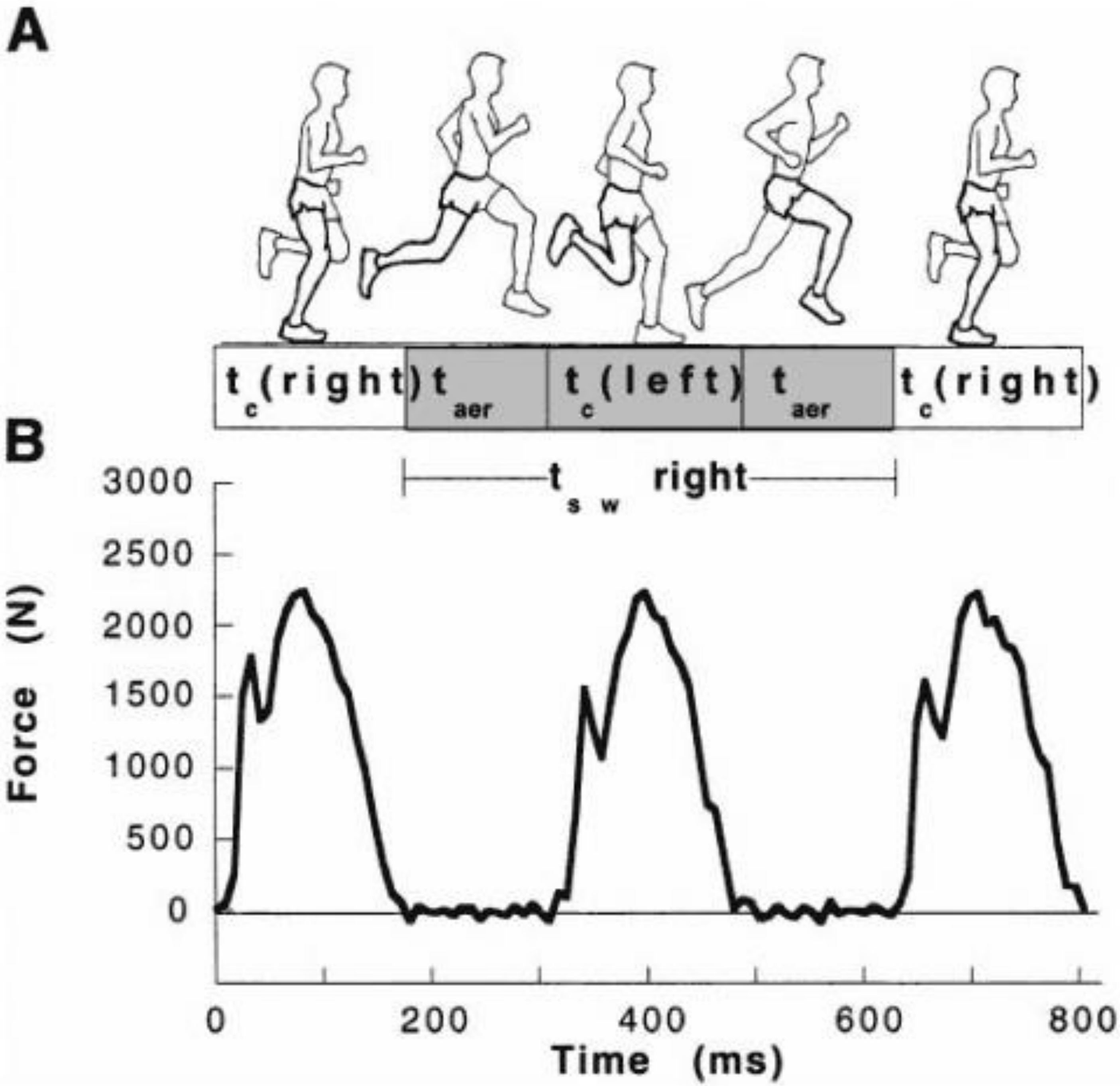
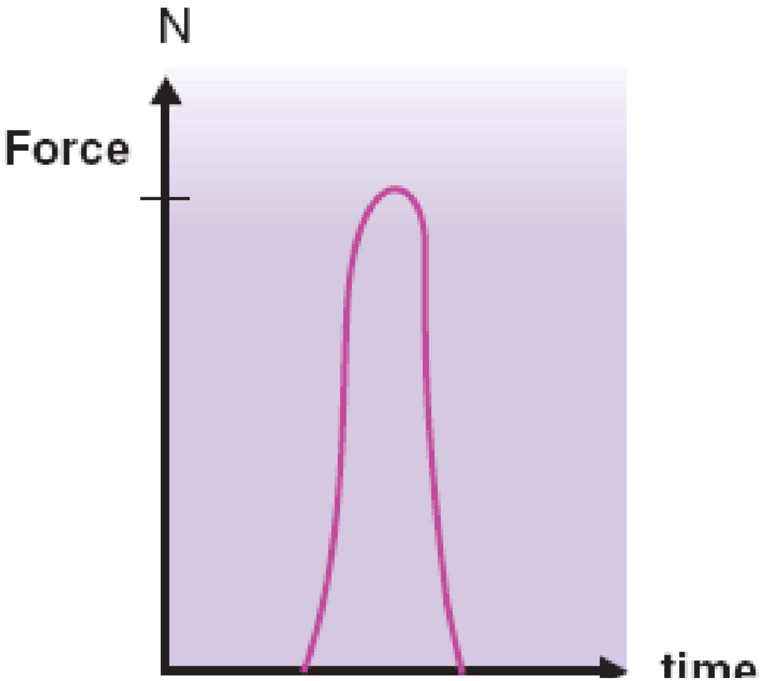
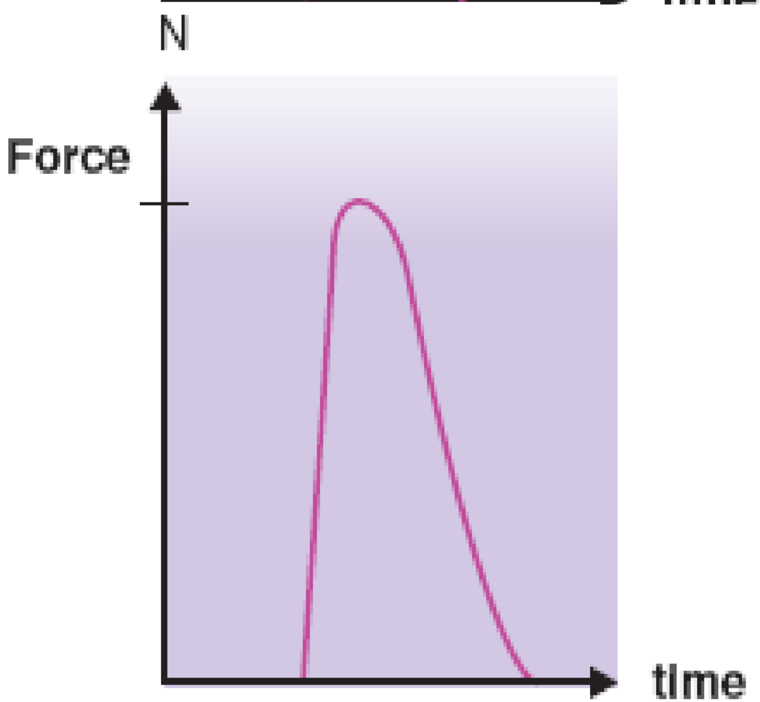






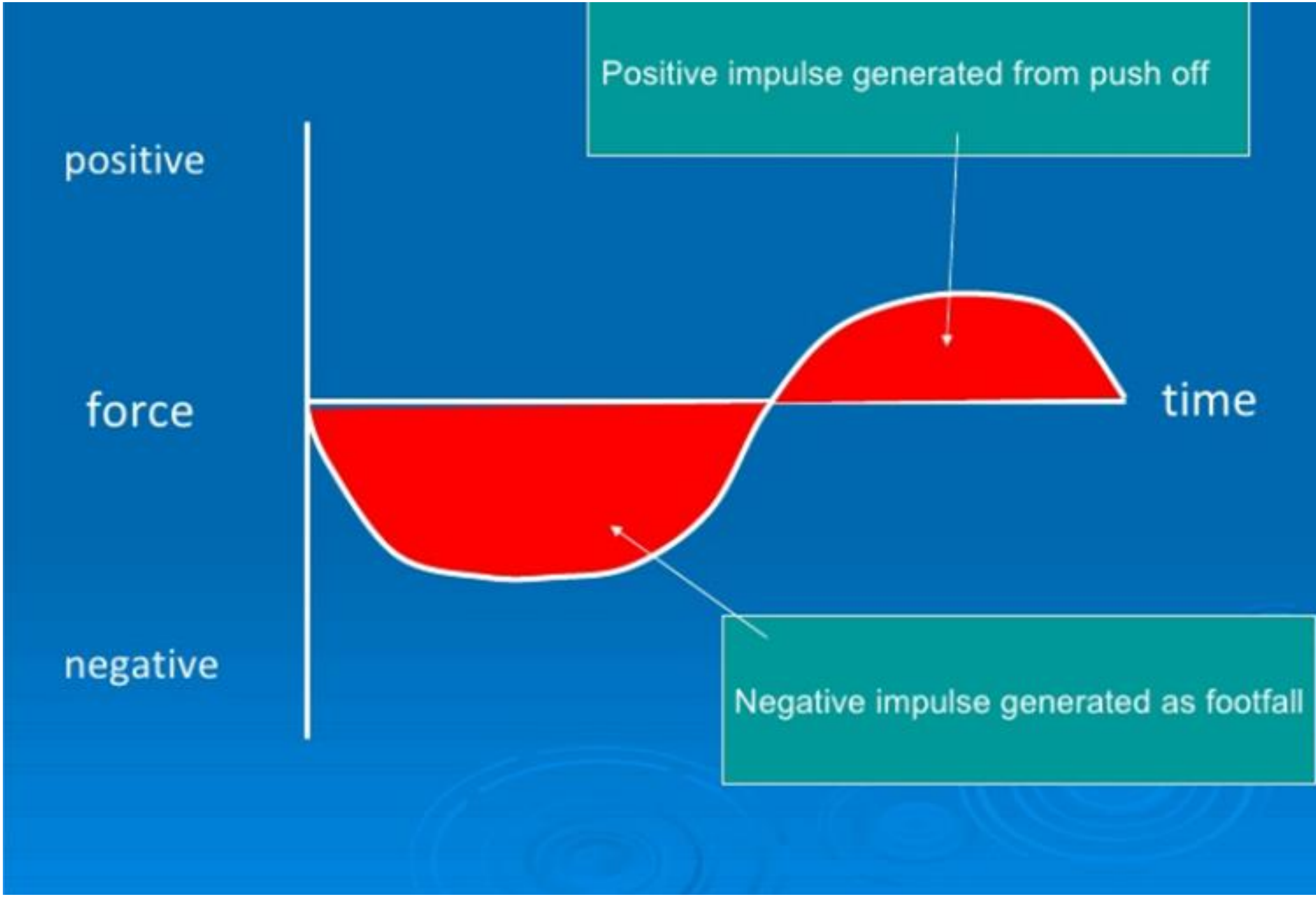
Movement analysis

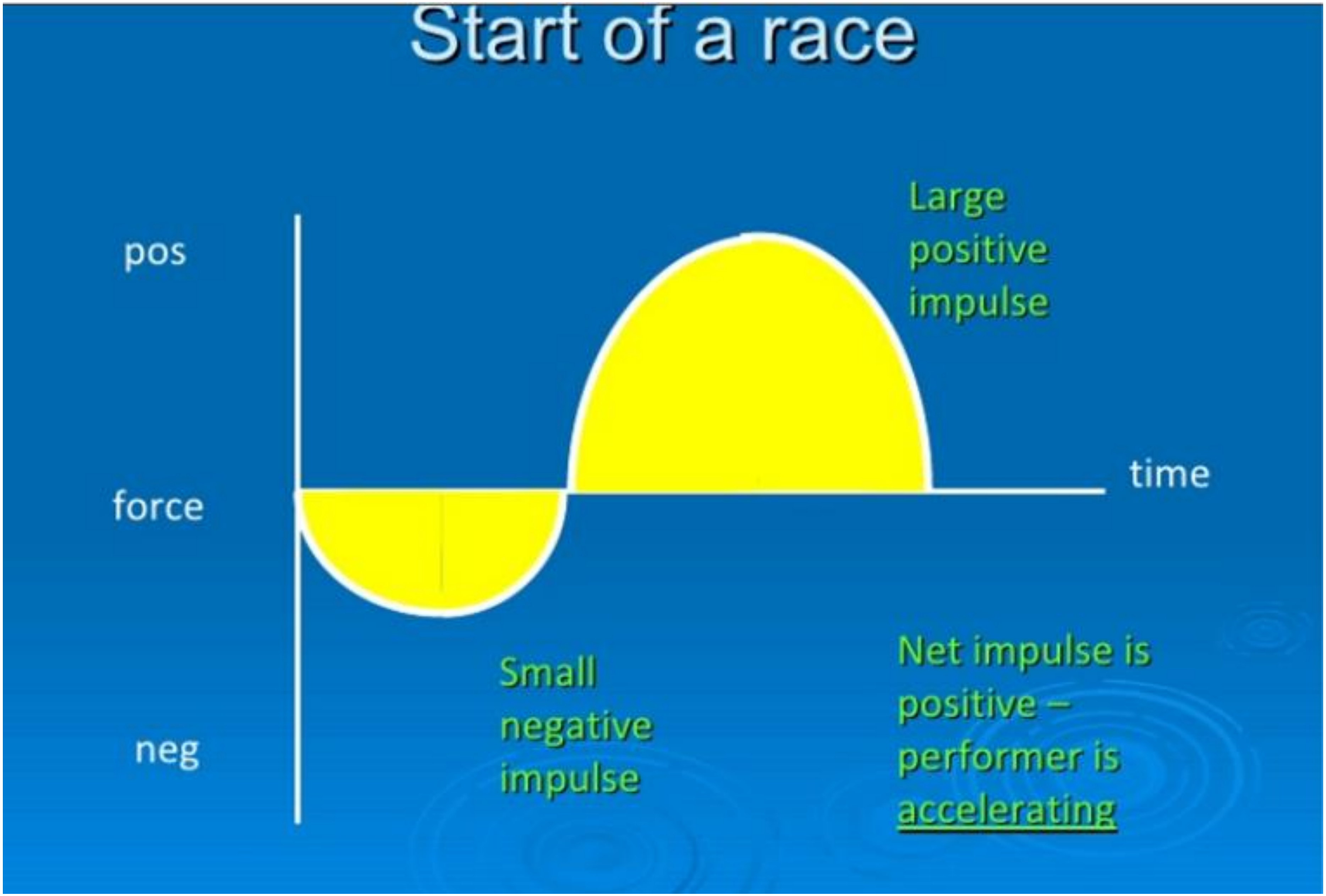
Knowing that the area under the curve equals the impulse that a person has applied, look at the graphs illustrated below and then explain why following through with a bat swing increases the velocity and potential distance that a ball will travel.

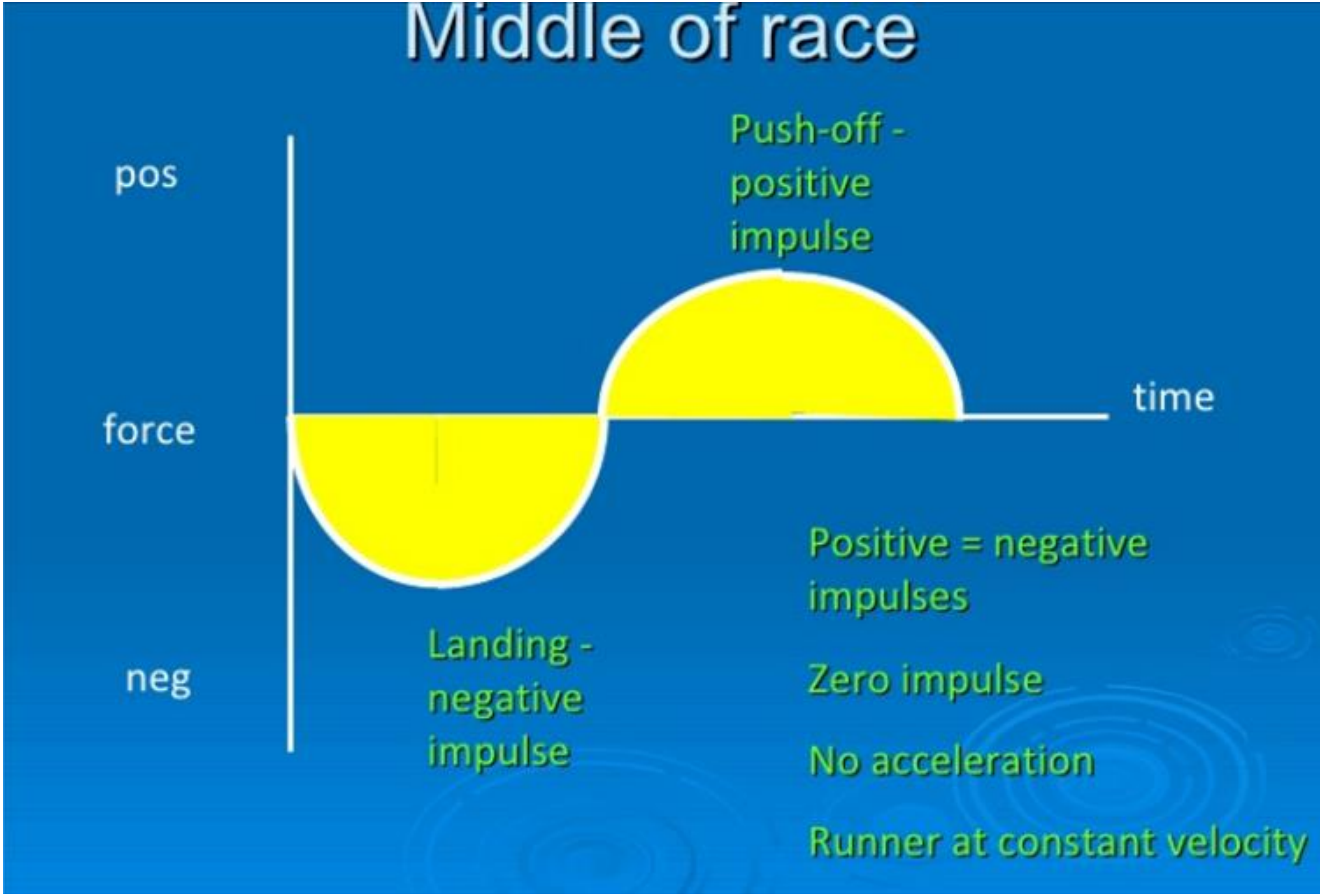
Can you think of other examples in sport?

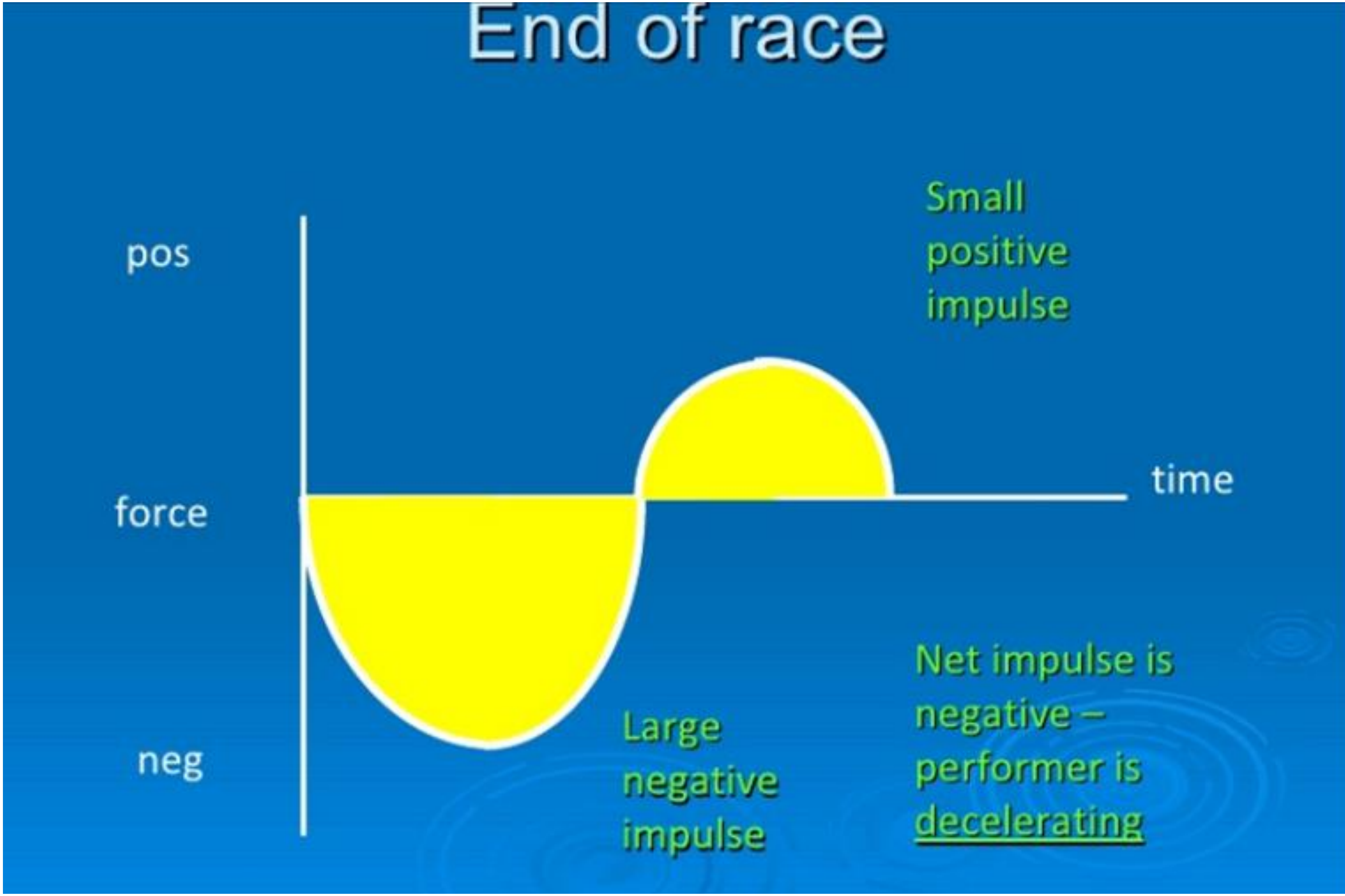
Impulse

- Force is not applied to objects instantaneously
- When we run, our feet are in contact with the ground for a period of time (milliseconds)
- This means ground reaction force is applied over e period of time
- Impulse = force x time
- Impulse is also a change in momentum (mass x velocity)


Positive impulse generated from push off
positive
force
time
negative
Negative impulse generated as footfall


Start of a race
pos
force
neg
Large
positive
impulse
time
Small
negative
impulse
Net impulse is
positive –
performer is
accelerating


Middle of race
pos
force
neg
Push-off - positive impulse
time
Landing - negative impulse
Positive = negative impulses
Zero impulse
No acceleration
Runner at constant velocity


End of race
pos
force
neg
time
Small positive impulse
Large negative impulse
Net impulse is negative – performer is decelerating

Fundamentals of biomechanics

What are scalars and vectors?

A **scalar quantity** has only **magnitude.**

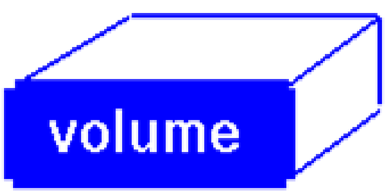
A **vector quantity** has both **magnitude** and **direction.**

Scalar Quantities

length, area, volume
speed
mass, density
pressure
temperature
energy, entropy
work, power

Vector Quantities

displacement, direction
velocity
acceleration
momentum
force
lift , drag , thrust
weight



Velocity time graph

figure 7.6 – start, middle and end of a sprint

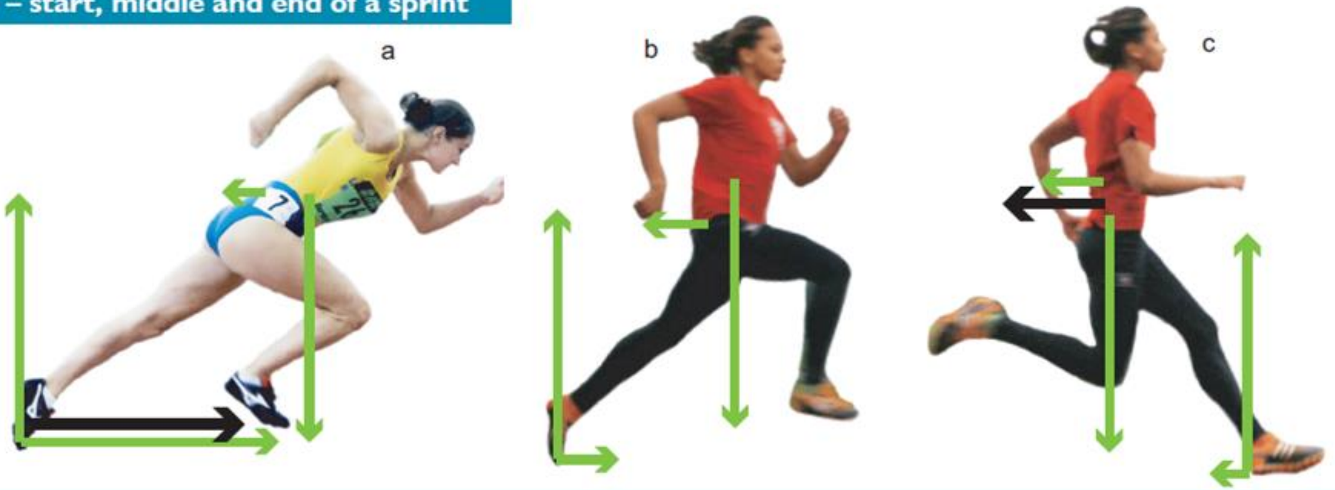
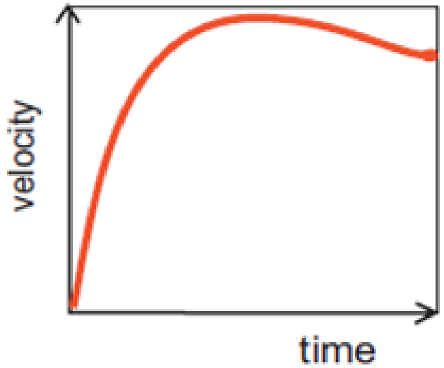


figure 7.5 – velocity time graph



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distance time graph

Topic 4

Movement analysis

Sub-topics

1. Neuromuscular function

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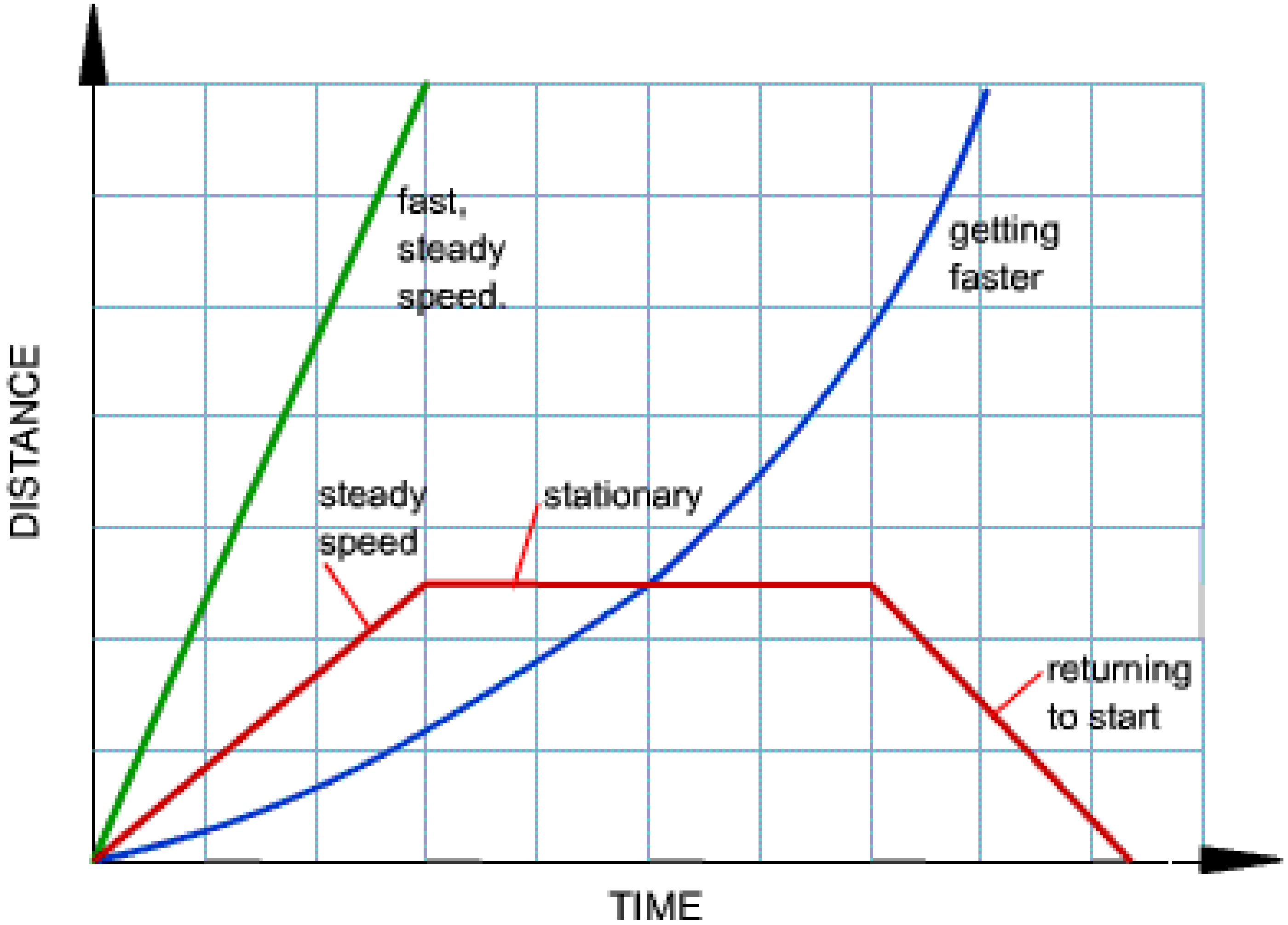

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distance time graph

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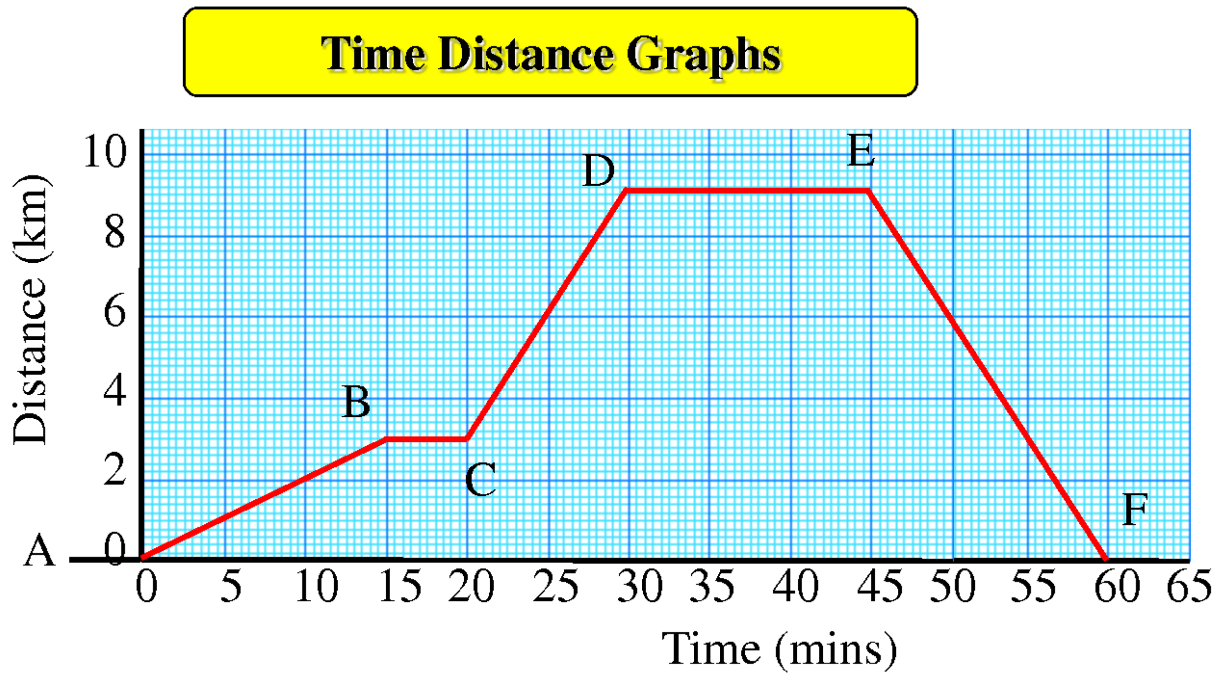
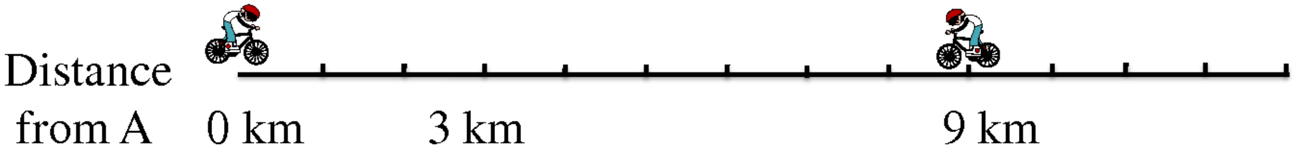
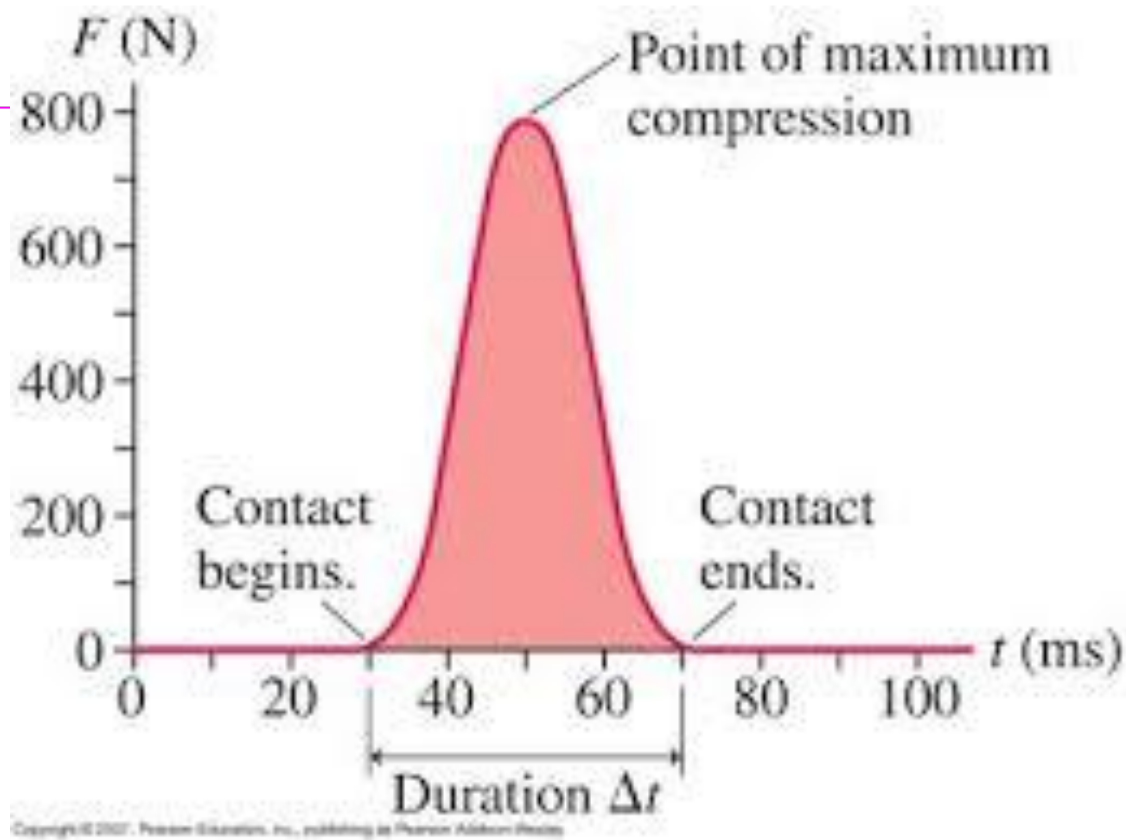




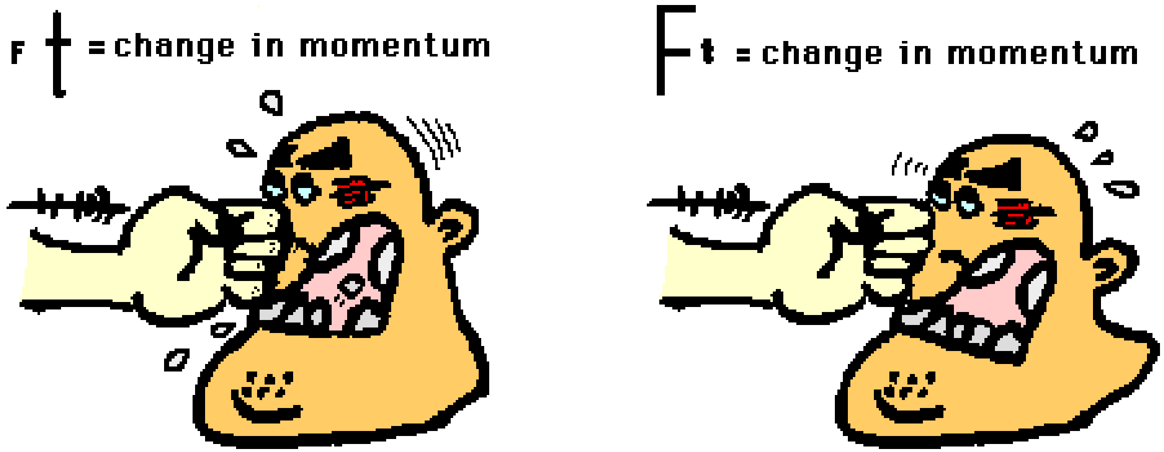
Force time graph



How does change in momentum = Impulse?

In football, the defensive player applies a force for a given amount of time to stop the momentum of the offensive player with the ball.

Force=Mass x acceleration



Riding the punch increases the time of collision and reduces the force of collision.

Combinations of Force and Time Required to Produce 100 units of Impulse

Force	Time	Impulse
100	1	100
50	2	100
25	4	100
10	10	100
4	25	100
2	50	100
1	100	100
0.1	1000	100

Impulse=change in momentum

Jennifer, who has a mass of 50.0 kg, is riding at 35.0 m/s in her red sports car when she must suddenly slam on the brakes to avoid hitting a deer crossing the road. She strikes the air bag, that brings her body to a stop in 0.500 s. What average force does the seat belt exert on her?

F = (mass * velocity change)/time
F = (50 * 35) / 0.500
F = 3500 N

Impulse=change in momentum

If Jennifer had not been wearing her seat belt and not had an air bag, then the windshield would have stopped her head in 0.002 s. What average force would the windshield have exerted on her?

F = (mass * velocity change)/time
F = (50 * 35)/0.002
F = 875 000 N

Bags and padding reduce the force of impact by increasing the time.

Can you think of examples in sport where this is done?

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What is the impulse momentum relationship?	 In football, the defensive player applies a force for a given amount of time to stop the momentum of the offensive player with the ball.

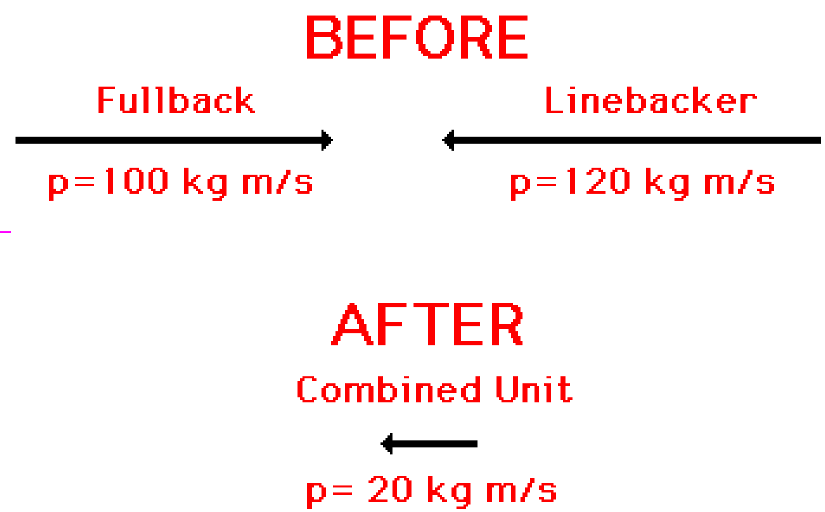
Momentum conservation principle

The law of momentum conservation can be stated as follows.

For a collision occurring between object 1 and object 2 in an isolated system, the total momentum of the two objects before the collision is equal to the total momentum of the two objects after the collision.

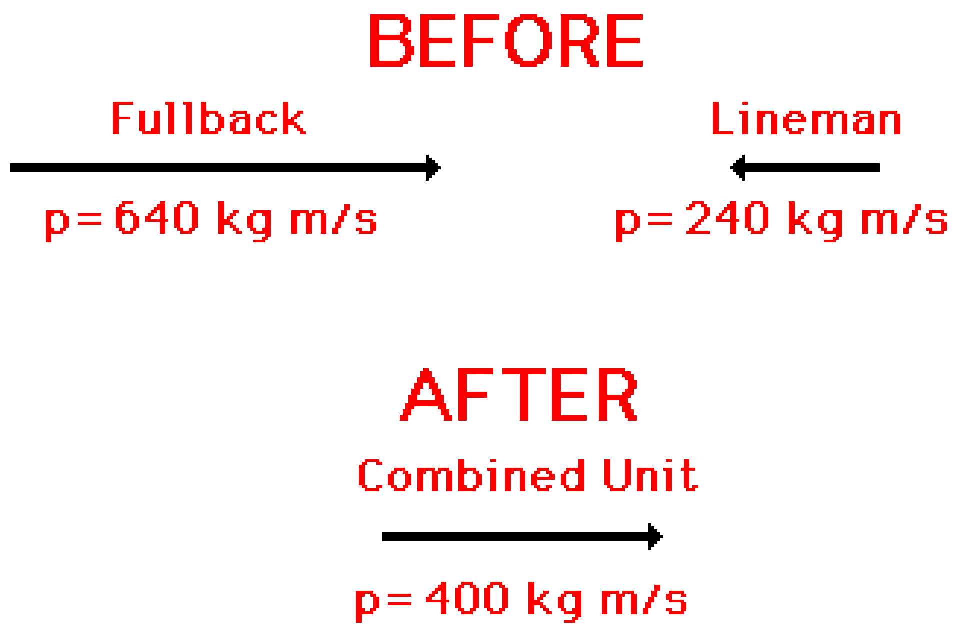
That is, the momentum lost by object 1 is equal to the momentum gained by object 2.

Momentum conservation principle



A 120 kg lineman moving west at 2 m/s tackles an 80 kg football fullback moving east at 8 m/s. After the collision, both players move east at 2 m/s. Draw a vector diagram in which the before- and after-collision momenta of each player is represented by a momentum vector. Label the magnitude of each momentum vector.

Momentum conservation principle



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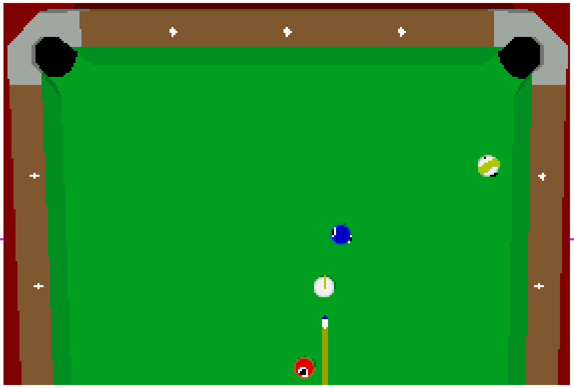
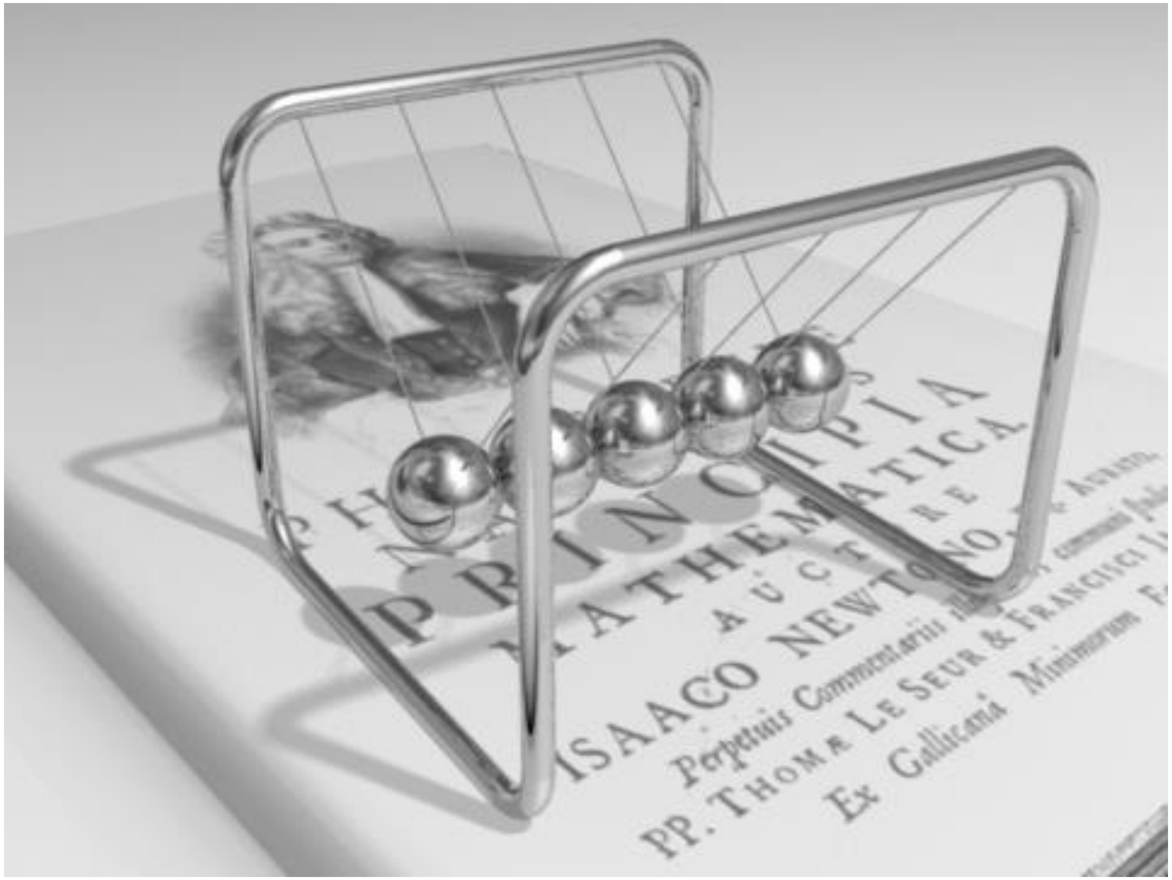


Conservation of momentum

Newtons cradle is a perfect example of this theory.



Force (N)	Time (s)	Impulse (F*t)	Momentum (kg*m/s)	Mass (kg)	Velocity change (m/s)
4000	0.010	40	40	10	-4
400	0.100	-40	-40	10	-4
-20,000	0.10	-200	-200	50	-4
-20,000	0.010	-200	-200	25	-8
-200	1.0	-200	-200	50	-4

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Lesson objectives

Topic 4

Movement analysis

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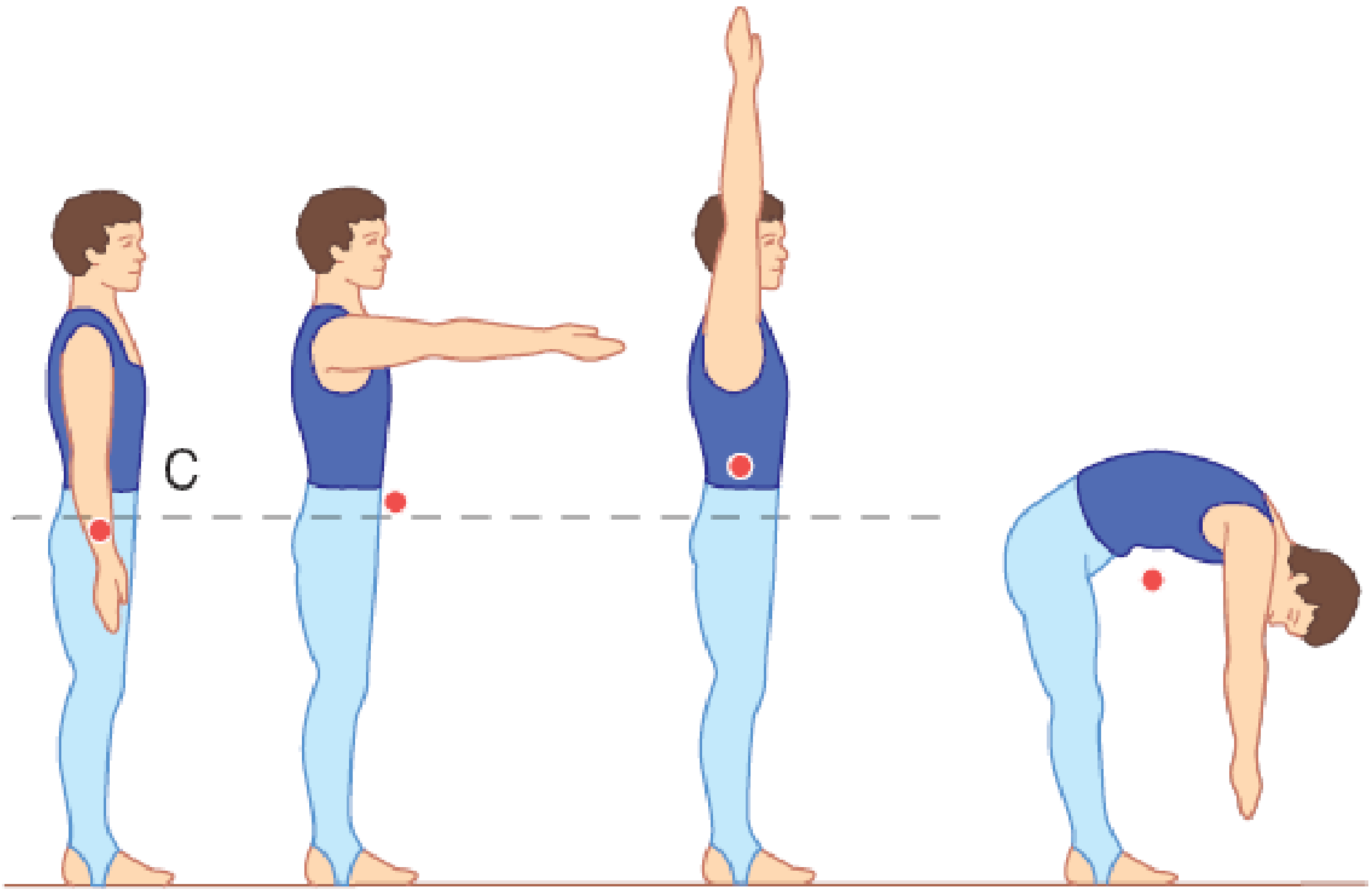
Why do power lifters have short legs and swimmers have long arms?

How does the center of mass affects sports performance?

What is the Center of Mass?

1. The mathematical point around which the mass of a body or object is evenly distributed
2. Point at which the mass and weight of an object are balanced in all directions.
3. It is the axis for all free airborne rotations

How the COM changes



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COM and base of support

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COM for the sprint start

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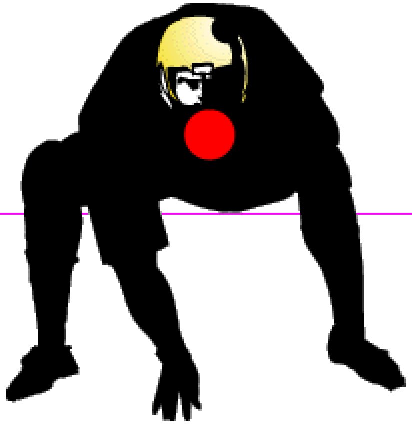
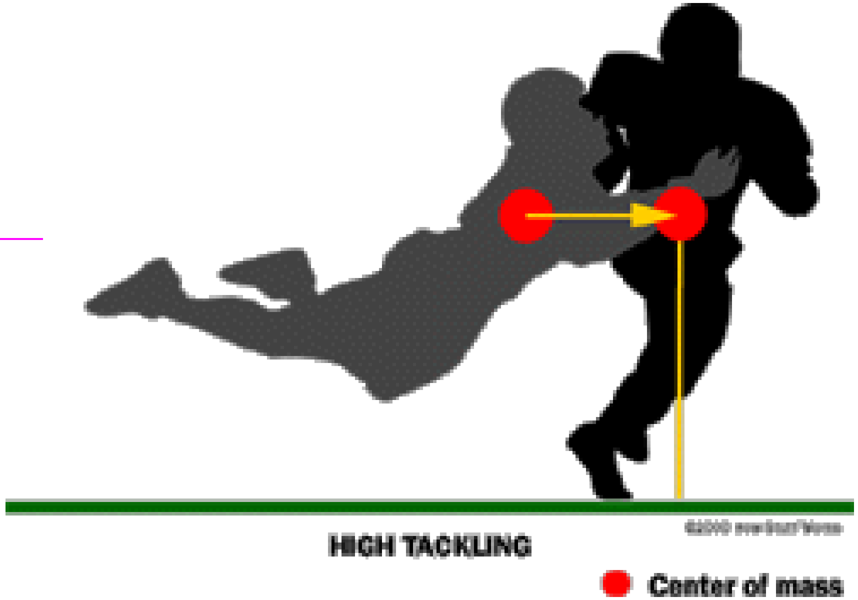
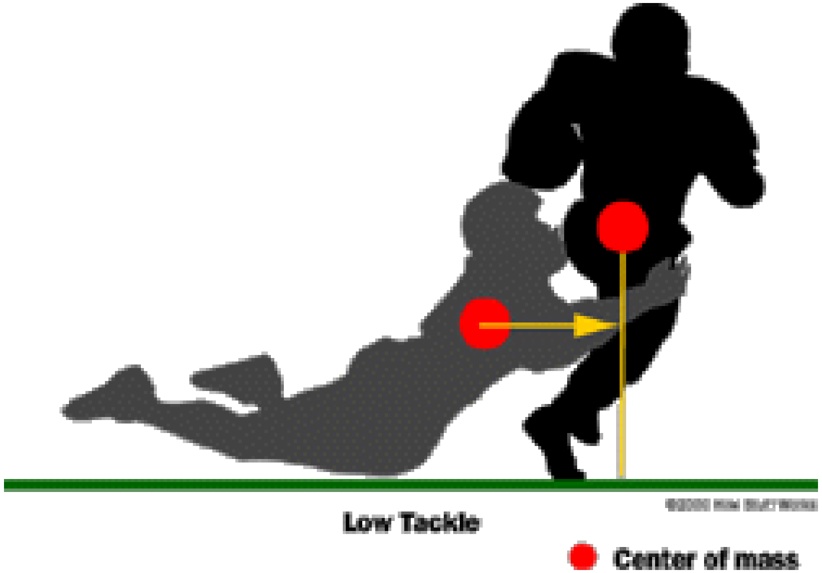
Which tackle is better and why?







Frosbury flop vs scissor

Fosbury Flop:

1. The athlete bends their body like a banana around the bar and their center of mass is below and outside the body/may be below the bar.
2. The jumper using the Fosbury technique will therefore not have to raise their center of mass as high as an athlete performing the scissors when clearing the same height.
3. Using the Fosbury technique the jumper will be able to clear a higher bar compared to using the scissors.

scissors:

1. The upper body is upright and the legs are horizontal to the body – this puts the center of mass above the legs/hips/bar.
2. The distance between the center of mass of the athlete and the greatest height cleared is generally 25–30cm.

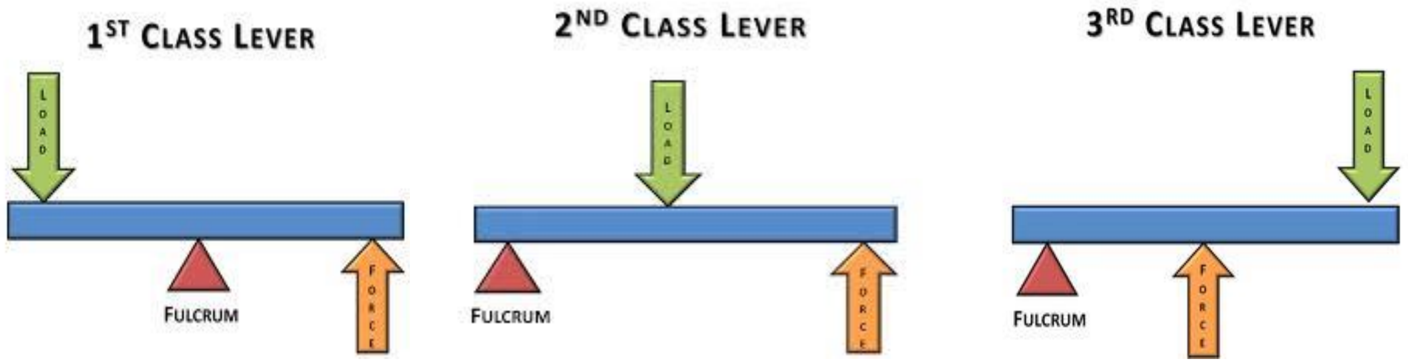
COM

Now think of a examples in sport where the center of mass:

- Changes and benefits your performance
- You change in order to benefit your performance
- Changes and negatively impacts your performance
- Can potentially be outside of your body

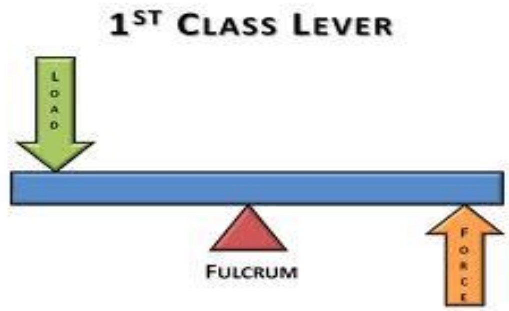
COM

Levers: rigid structures hinged at one point (fulcrum) to which forces are applied to two other points (effort and load)

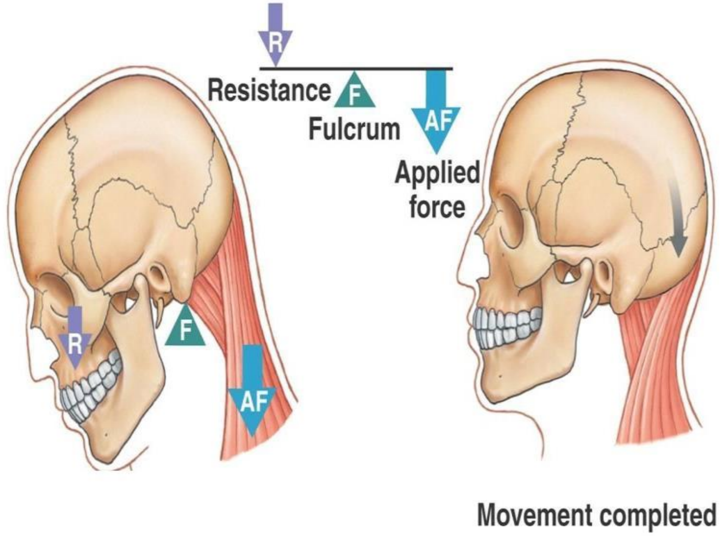


1. First Class Lever:

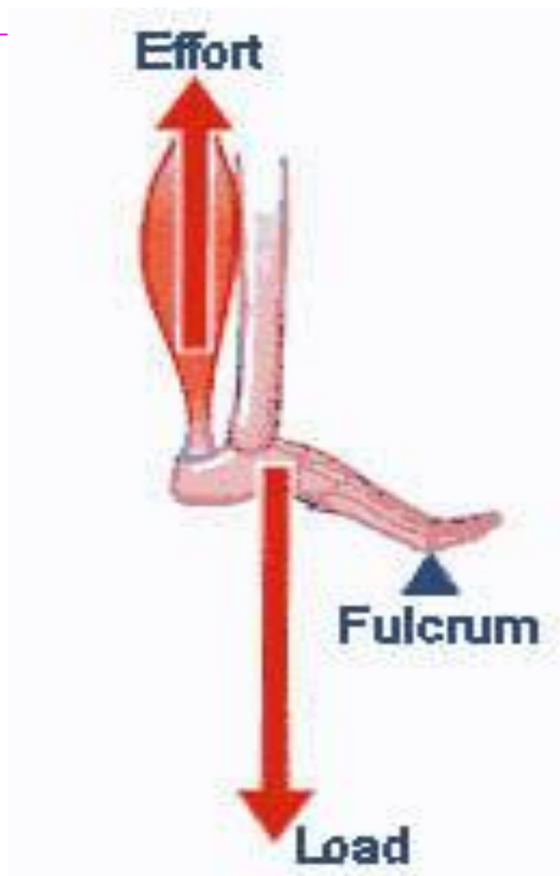
The fulcrum lies between the effort and load.

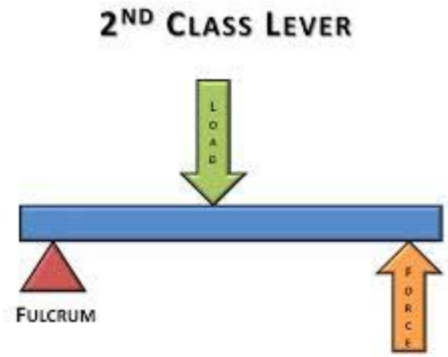


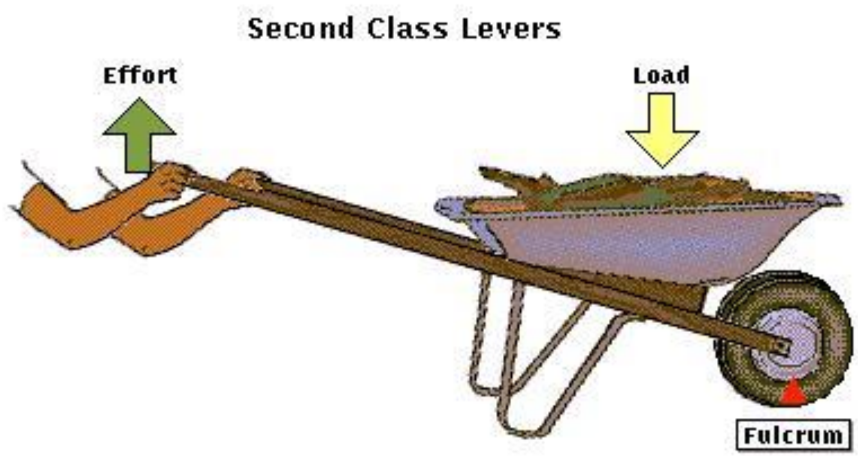
Ex. Neck providing effort force to overcome the resistance force caused by the weight of the head.



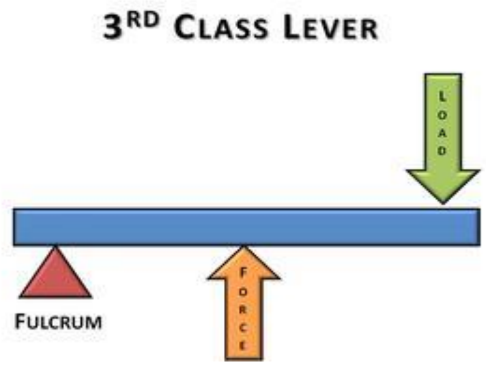
2. <u>Second Class Lever</u>: the fulcrum lies at one end with the effort at the other and the load in the middle.
Ex. Standing heel raise

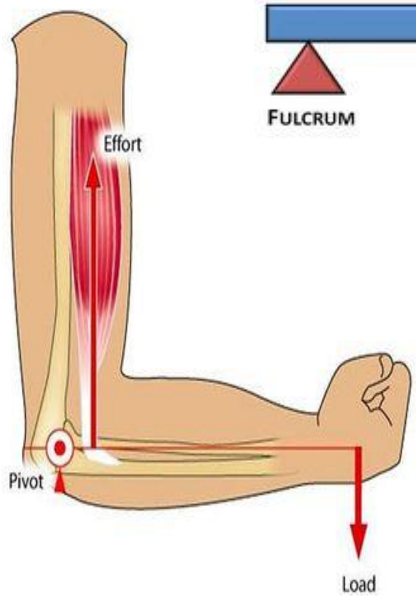






3. <u>Third Class Levers</u>: the effort lies between the load and the fulcrum. Ex. Biceps curl swinging a bat.





COM

Sub-topics

1. Neuromuscular function
2. Joint and movement type
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COM

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COM

Newton's Laws of Motion

"Every object persists in its state of rest or uniform motion in a straight line unless it is compelled to change that state by forces impressed on it."

"Force is equal to the change in momentum (mV) per change in time. For a constant mass, force equals mass times acceleration."

$$F = m\,a$$

"For every action, there is an equal and opposite re-action."

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Newton's first law (The law if Inertia)

Topic 4

Movement analysis

An object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

Sub-topics

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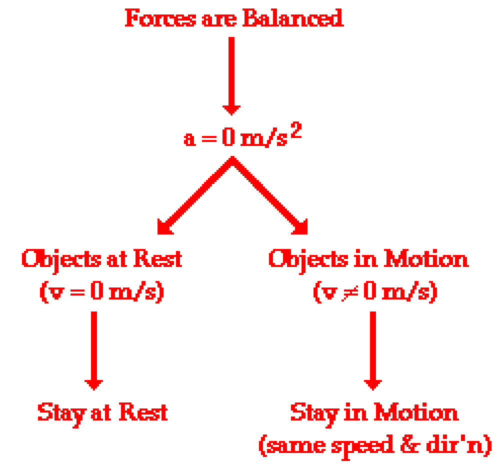
With no outside forces, this object will never move

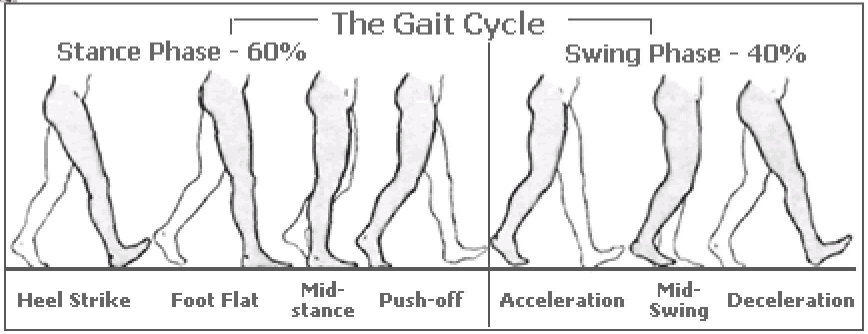


With no outside forces, this object will never stop

Newton's first law (The law if Inertia)

An object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

Inertia is the resistance of any physical object to any change in its state of motion



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Newton's Second law (F=MA)

Topic 4

Movement analysis

The second law states that the acceleration of an object is dependent upon two variables - the net force acting upon the object and the mass of the object.

Sub-topics

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Forces are Unbalanced

There is an acceleration

The acceleration depends directly upon the "net force"

The acceleration depends inversely upon the object's mass.

Force in newtons (N)

Mass in Kilograms (KG)

Acceleration in (m/s^2)

Newton's Second law (F=MA)

The second law states that the acceleration of an object is dependent upon two variables - the net force acting upon the object and the mass of the object.

Determine the accelerations that result when a 12-N net force is applied to a 3-kg shot putt and then to a 6-kg shot putt.

A 3-kg object experiences an acceleration of **4 m/s/s**.

A 6-kg object experiences an acceleration of **2 m/s/s**.

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Sports, exercise and health science

Newton's Second law (F=MA)

Topic 4 Movement analysis

The second law states that the acceleration of an object is dependent upon two variables - the net force acting upon the object and the mass of the object.

Sub-topics

1. Neuromuscular function

2. Joint and movement type

3. Fundamentals of biomechanics

Suppose that a running back is has a total of 1000N of force acting on them, causing them to to accelerate at a rate of 5 m/s^2. Determine the mass of the player.

force (N)= Mass (kg) x acceleration (m/s)

mass= force/acceleration

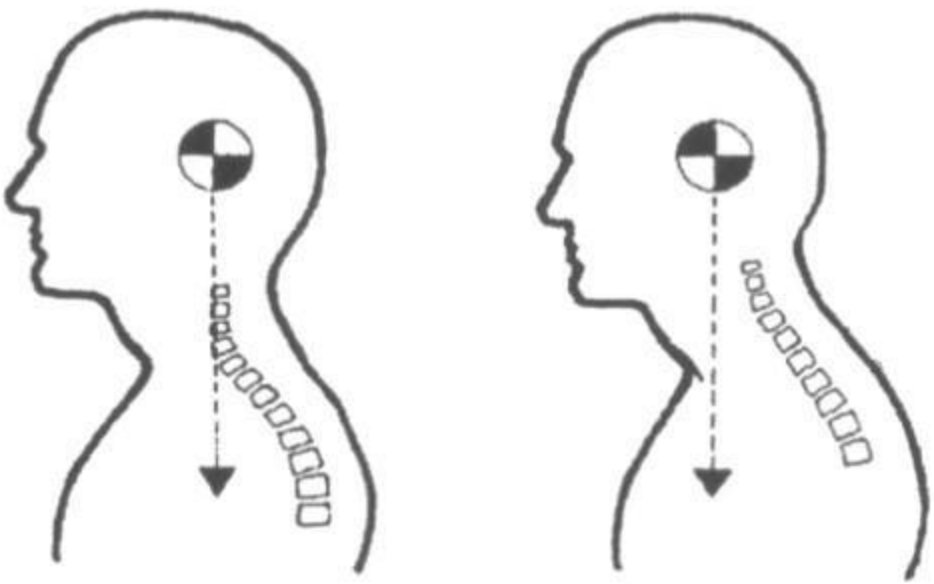
Mass=1000/5

Mass= 200kg

Newton's second Law

Force = Mass x acceleration

Acceleration = Force/Mass



Think about the forces needed to stop your head from coming off during a crash 'whiplash'.

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Newton's Third Law

Topic 4

Movement analysis

For every action, there is an equal and opposite reaction.

Sub-topics

1. Neuromuscular function

2. Joint and movement type

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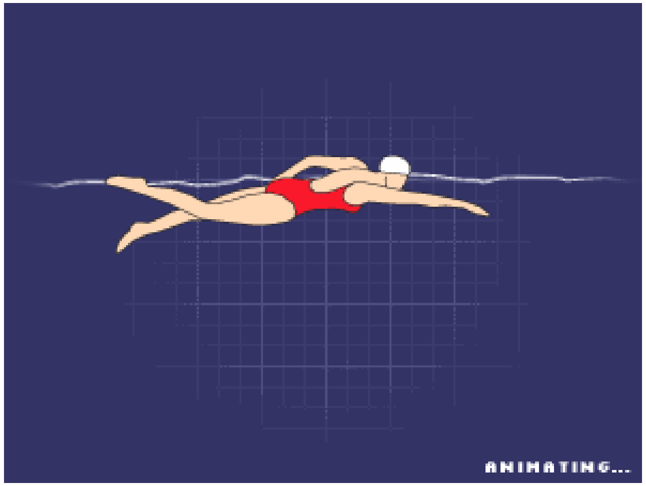
Sports, exercise and health science

Newton's Third Law

Topic 4

Movement analysis

For every action, there is an equal and opposite reaction.



Sub-topics

1. Neuromuscular function
2. Joint and movement type
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Sports, exercise and health science

Topic 4

Movement analysis

Sub-topics

1. Neuromuscular function

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4.3.8. Explain how Newton's laws relate to sporting activities.

Activity	Explanation with example
Newtons First Law	
Newtons second law	
Newtons Third Law	Block start
	The third law states: for every action, there is an equal and opposite reaction. Athletes must push backwards and downwards with large forces on to the blocks. According to Newton's third law, the blocks will push back with the same force, but in the opposite direction (forwards and upwards) (reaction force) As the blocks are connected to the ground (which has a much larger mass than the athlete) the ground will not move backwards, but the athlete will move forwards and upwards out of the blocks.

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Sports, exercise and health science

Topic 4
Movement analysis

Sub-topics

1. Neuromuscular function

2. Joint and movement type

3. Fundamentals of biomechanics

Unit 4.3	Fundamentals of Biomechanics
Key learning intention (KLI)	To understand and explain the impact biomechanics has on sports performance.
Success criteria	For your chosen sport, assess your technique and suggest any biomechanical alterations you could make, stating how and why this would improve performance.

Lesson One - apply the principles of momentum to their own sports

Lesson Two - using the term centre of mass, students can explain why the frosbury flop is a more effective jump than the scissor technique.

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Sports, exercise and health science

State and explain the factors that affect projectile at take-of or release

Topic 4

Movement analysis

Newton's first law states that things that are in motion keep moving without the need for an external force

Sub-topics

1. Neuromuscular function

2. Joint and movement type

3. Fundamentals of biomechanics

Therefore, once a force has been removed the object can no longer be altered

This means that the path of the object is determined at the moment it leaves the hand/racquet etc

State and explain the factors that affect projectile at take-of or release

Gravity, air resistance and lift play a part in how far an object will go

The most important factors are…..

- Projection speed
- Projection angle
- Projection height

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Sports, exercise and health science

State and explain the factors that affect projectile at take-of or release

Topic 4

Movement analysis

Projection height

Sub-topics

1. Neuromuscular function

2. Joint and movement type

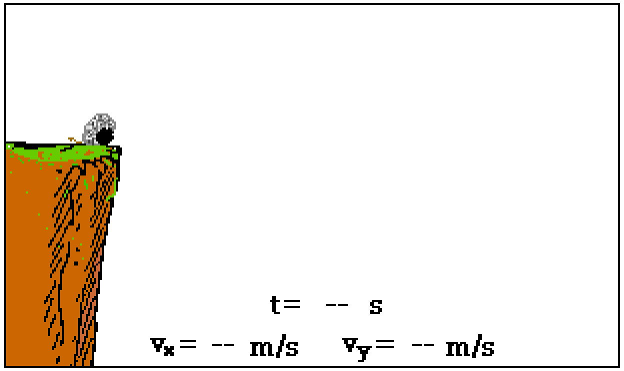
3. Fundamentals of biomechanics

State and explain the factors that affect projectile at take-of or release

Throwing a ball to a friend or shooting a cannon are both examples of projectile motion. **Gravity** is a force that acts upon objects, drawing them towards the center of the Earth at 9.81 m/s^2. Horizontal motion happens when an object is acted upon by an outside force, and it will stay in motion until acted upon by another force, including hitting the ground.

Newton's Third Law of Motion says that an object will stay in motion unless acted on by an outside force, so this means that there is no acceleration in the horizontal direction.

The angle at which something is thrown or shot also affects how far it will travel, because what goes up must come down!



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Sports, exercise and health science

State and explain the factors that affect projectile at take-of or release

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Movement analysis

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Problem: Find the launch angle of a projectile for the longest distance.

- Which angle will launch the projectile the farthest? Why? What happens if the launch angle is smaller? Greater?

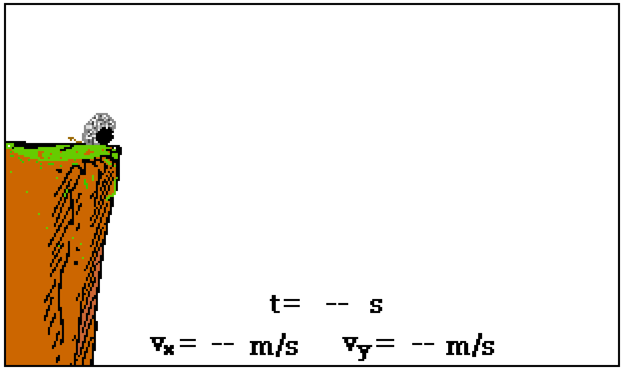
Materials

Marshmallow gun

Marshmallows

Tape measure

Calculator



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Sports, exercise and health science

State and explain the factors that affect projectile at take-of or release

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Movement analysis

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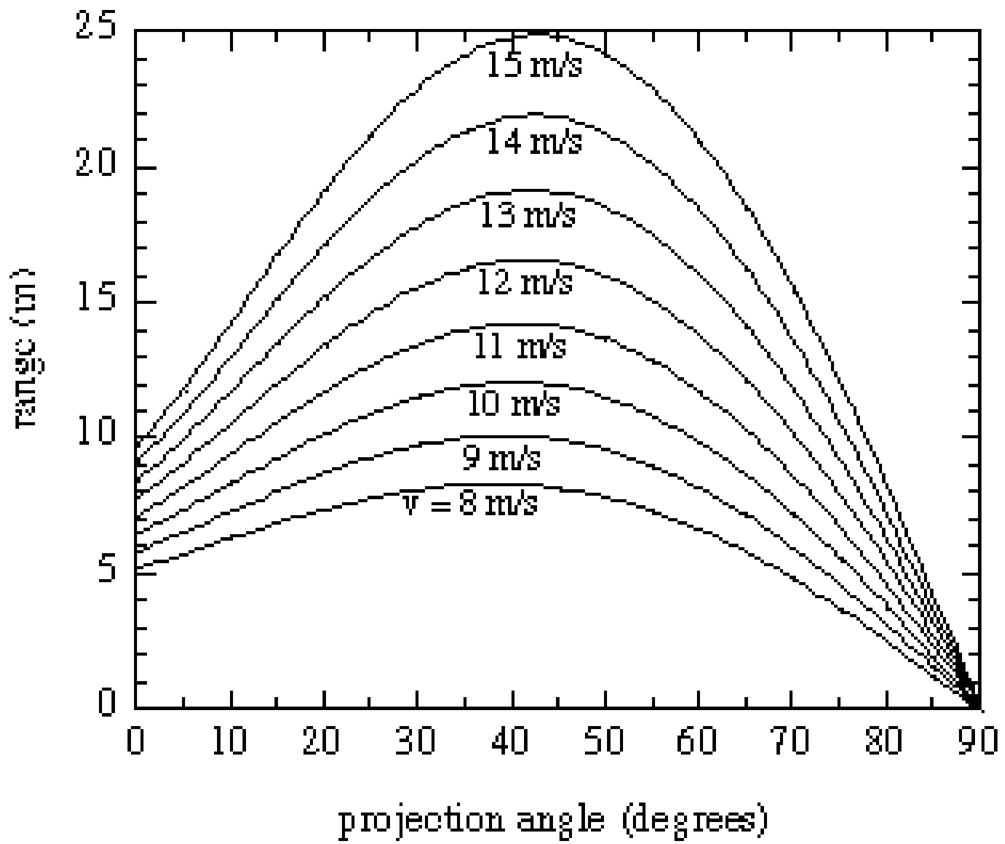
The effect of velocity on distance in throwing the shot putt



As a coach, would you change your shot putters angle to 40 to improve distance???

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State and explain the factors that affect projectile at take-of or release

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Movement analysis

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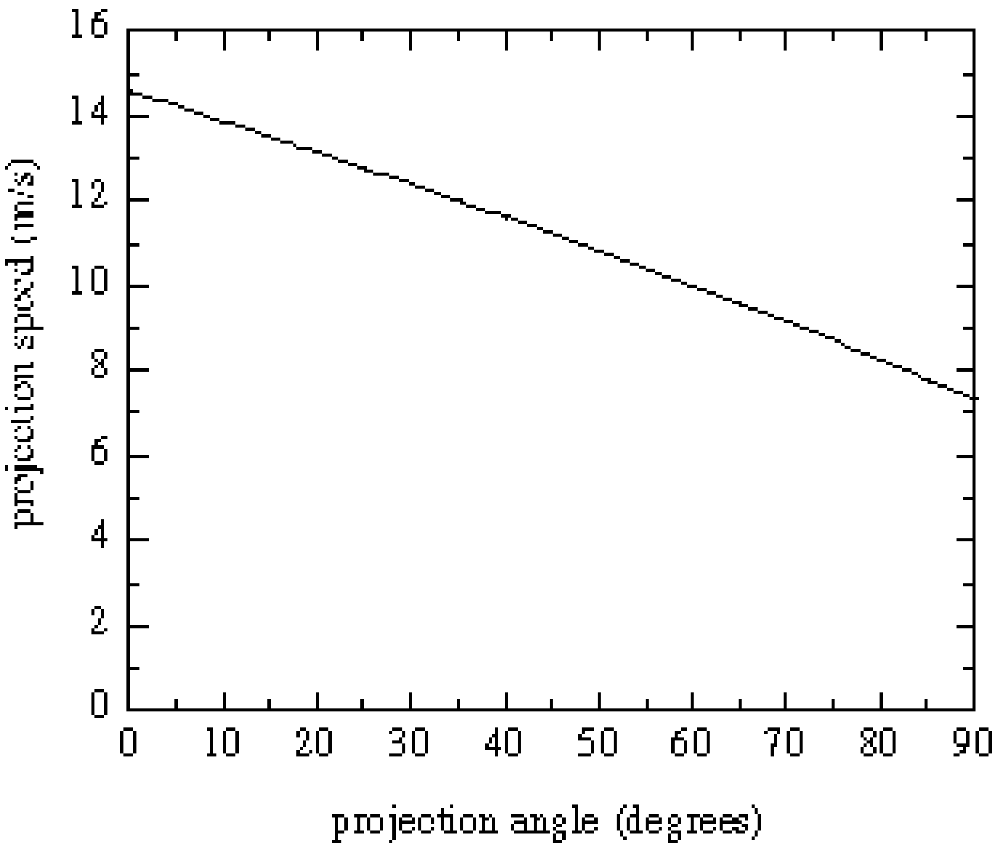
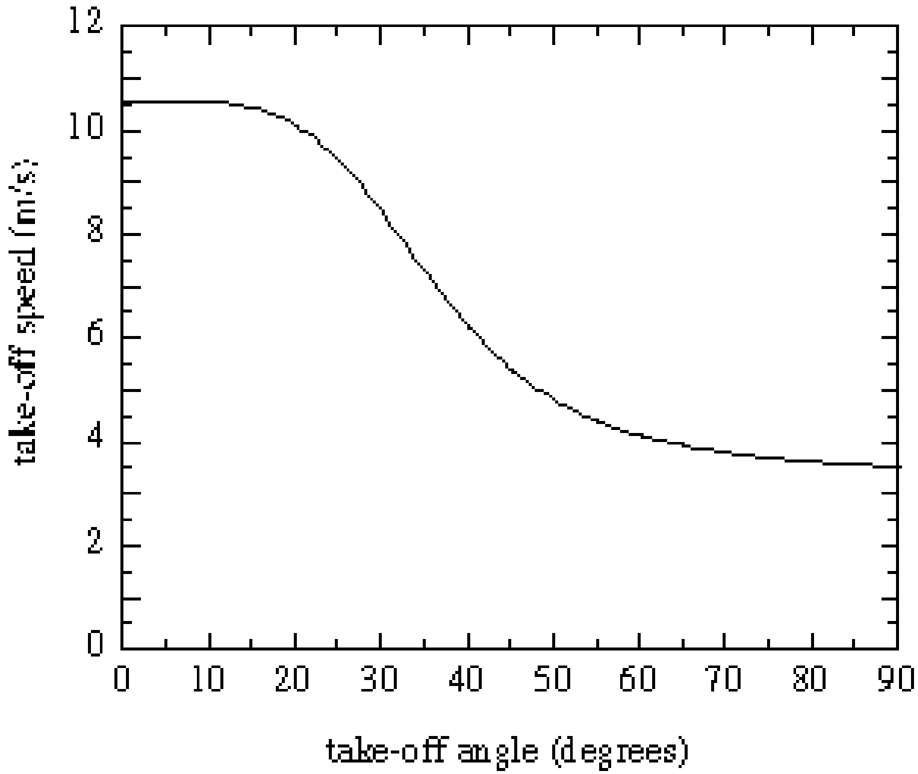
The effect of projection angle on velocity



- The structure of the human body motions production of force in the horizontal direction more than vertical i.e. should press vs bench press
- shot-putter must expend a greater effort during the delivery phase to overcome the weight of the shot, and so less effort is available to accelerate the shot (i.e. produce projection speed).

State and explain the factors that affect projectile at take-of or release

The effect of projection angle on velocity



State and explain the factors that affect projectile at take-of or release

conclusion

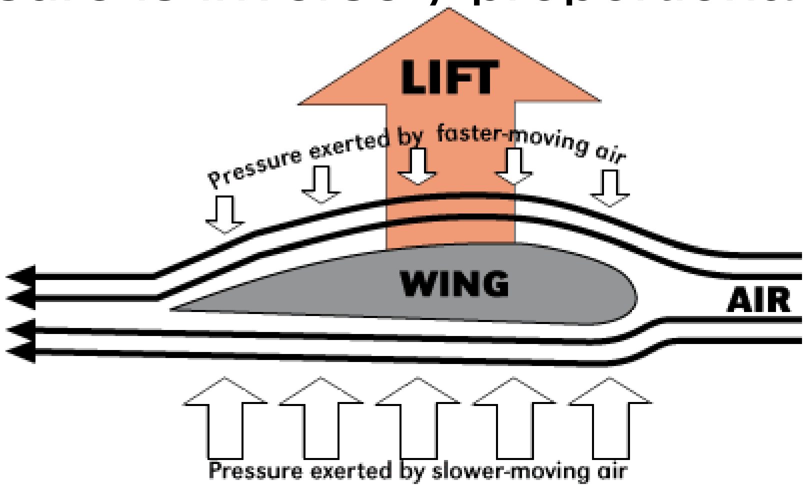
- In the throwing and jumping events, the optimum projection angle is usually considerably less than 45° because the speed an athlete can produce decreases as the projection angle is raised.
- the optimum projection angle is different for every athlete.
- Most athletes find their optimum projection angle relatively quickly through trial-and-error, and achieving a high projection speed is much more important than throwing or jumping at the optimum angle.

The Bernoulli Principle

- The Bernoulli's Principle is a physics principle that an increase in the speed of a fluid/air produces a decrease in pressure and that a decrease in the speed of a fluid/air produces an increase in pressure.

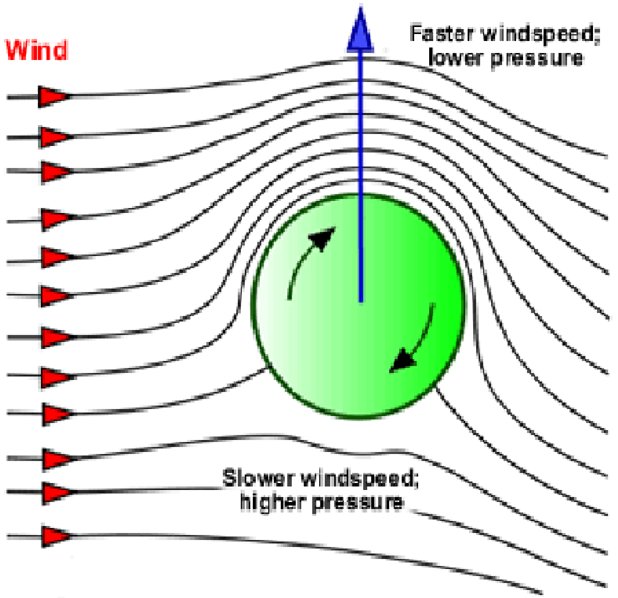
- The principle states that the total energy of a moving fluid remains constant at all times.

- Therefore fluid pressure is inversely proportional to fluid velocity.



The Bernoulli Principle

- The ***<u>Magnus Effect</u>*** describes the flow of air around a rotating sphere (baseball, golf ball, soccer ball).
- On one side of the sphere the velocity will be enhanced. On the opposite side the velocity will be decreased.
- According to Bernoulli's principle, this creates a pressure differential and a force perpendicular to the velocity vector of the sphere. This is the Magnus force. (curveball, etc)



The Bernoulli Principle

- **Dimples** on a **golf ball** create a thin turbulent boundary layer of air that clings to the **ball's** surface.
- This allows the smoothly flowing air to follow the **ball's** surface a little farther around the back side of the **ball**, thereby decreasing the size of the wake.
- This reduces the Magnus force and thus the effects of the Bernoulli Principle causing the ball to fly on a straighter line.

The Bernoulli Principle