UNIT VIII BIOMECHANICS & SPORTS

Overview

- Newton's Law of Motion & its application in sports.
- Types of Levers and their application in Sports.
- Equilibrium – Dynamic and Static and Centre of Gravity and its application in sports
- Friction and Sports
- Projectile in Sports

LEARNING OUTCOMES

Students will able to

- Understand Newton's Law of Motion and its application in sports
- recognize the concept of Equilibrium and its application in sports.
- Classify lever and its application in sports.
- know about the Centre of Gravity and will be able to apply it in sports
- define Friction and application in sports.
- understand the concept of Projectile in sports.

THE IMPOSSIBLE KICK

Roberto Carlos' goal in 1997 defied physics and still impresses scientists today. When the famous free-kick happened, physicists from all around the world were baffled by the images. That goal was the catalyst for many studies and analyses about aerodynamics and the ball's curve that day at the Stade de Gerland in Lyon.

One of the most famous studies was conducted by four French scientists -- Guillaume Dupeux, Anne Le Goff, David Quere, and Christophe Clanet -- and published in the New Journal of Physics in September 2010. In this study, the physicists conduct a

series of experiments and analysis, resulting in an equation that explains the ball's trajectory and all the forces in action at that precise moment.

This is what they wrote.

"The case of soccer, where is twice as small as L, is worth commenting on. The ball trajectory can deviate significantly from a circle, provided the shot is long enough. Then the trajectory becomes surprising and somehow unpredictable for a goalkeeper,"

"This is the way we interpret a famous goal by the Brazilian player Roberto Carlos against France in 1997. This free kick was shot from a distance of approximately 35 metres, that is, comparable to the distance for which we expect this kind of unexpected trajectory. Provided that the shot is powerful enough, another characteristic of Roberto Carlos' abilities, the ball trajectory brutally bends towards the net, at a velocity still large enough to surprise the keeper."

Dupeux, Le Goff, Quere, and Clanet conclude that if the correct calculations were made, and the distances and forces were repeated, the famous goal could be replicated by another player. This, however, is impossible, in the opinion of one of Brazil's most influential physicists. He describes Roberto Carlos' masterpiece as a *"football miracle."*

"Although physics explains perfectly the ball's trajectory, the conditions at that moment, such as the power of the kick, the point of impact of Roberto Carlos' foot on the ball, and the distance to the goal, were so rare that we can call that a miracle," says professor Luis Fernando Fontanari of Sao Roberto Carlos Physics Institute, a branch of the University of Sao Paulo -- the most respected university in the country.

Fontanari is one of the editors of "Physics of Life Reviews" and "Theory in Biosciences," two of the most important scientific journals in the world. He adds that if the ball hadn't stopped in the net, it would have continued in the air, drawing an incredible spiral trajectory, as the image above shows.

"I don't believe we will see something like that happening again," Fontanari said.

Israeli scientist Erez Garty also theorized about Roberto Carlos' kick. In a YouTube video, he gave a lesson for "physics dummies," which explains the magic. The transcript is as follows[1]:

In 1997, in a game between France and Brazil, a young Brazilian player named 'Roberto Carlos set up a 35-meter free-kick. Carlos attempted the seemingly impossible with no direct line to the goal. His kick sent the ball flying wide of the players, but before going out of bounds, it hooked to the left and soared into the goal. According to Newton's first law of motion, an object will move in the same direction and velocity until a force is applied. When Carlos kicked the ball, he gave it direction and velocity, but what force made the ball swerve and score one of the most magnificent goals in its history?

The trick was in the spin. Carlos placed his kick at the lower right corner of the ball, sending it high and to the right and rotating around its axis. The ball started its flight in a direct route, with air flowing on both sides and slowing it down. On one side, the air moved in the opposite direction to the ball's spin, causing increased pressure, while on the other, the air moved in the same direction as the spin, creating an area of lower pressure.

That difference made the ball curve towards the lower pressure zone. This phenomenon is called the Magnus effect. This type of kick, often referred to as a banana kick, is attempted regularly, and it is one of the elements that makes the beautiful game beautiful. But curving the ball with the precision needed to bend around the wall and back into the goal is difficult. Too high, and it soars over the goal. Too low, and it hits the ground before curving. Too wide, and it never reaches the goal.

Not wide enough, and the defenders intercept it. Too slow, and it hooks too early, or not at all. Too fast, and it hooks too late. The same physics make it possible to score another impossible goal, an unassisted corner kick.

The Magnus effect was first documented by Sir Isaac Newton after noticing it while playing a game of tennis back in 1670. It also applies to golf balls, frisbees, and

baseballs. In every case, the same thing happens. The ball's spin creates a pressure differential in the surrounding airflow that curves it in the direction of the spin.

And here's a question. Could you theoretically kick a ball hard enough to make it boomerang all the way around back to you? Sadly, no. Even if the ball didn't disintegrate on impact, or hit any obstacles, as the air slowed it, the angle of its deflection would increase, causing it to spiral into smaller and smaller circles until finally stopping. And to get that spiral, you'd have to make the ball spin over 15 times faster than Carlos's immortal kick.

So, think again[2]

Introduction

Biomechanics is the science of movement of a living body, including how muscles, bones, tendons, and ligaments work together to produce movement. Biomechanics is part of the larger field of kinesiology, explicitly focusing on movement mechanics. It is both a primary and applied science, encompassing research and practical use of its findings.

Biomechanics includes the structure of bones and muscles and the movement they can produce, as well as the mechanics of blood circulation, renal function, and other body functions. The American Society of Biomechanics says biomechanics represents the broad interplay between mechanics and biological systems.

Biomechanics studies not only the human body but also animals and even extends to plants and the mechanical workings of cells. ***For example, the biomechanics of the squat includes considering the position and/or movement of the feet, hips, knees, back, shoulders, and arms.***

The biomechanical principle of motion relates to linear motion, velocity, speed, acceleration, and momentum. Motion is a movement that results from a force. In any physical activity, there are multiple forces and motions occurring. This could include angular motion around a joint or the motion of the whole body in various directions. The motion or movements of the body are often caused by forces produced by our muscles, but this is not always the case. For example, if an opposition player pushes you to the ground, the force has come from them and not your muscles.

Motion can be linear, angular, or general. The type of motion is determined by the direction of movement. The only type of motion you are asked to understand is linear motion. However, to properly apply velocity, speed, acceleration, and

momentum, the other types of motion should also be defined. Angular motion is motion in a circular movement around a central point. Essentially every movement of your body at a joint is angular. The general motion is a combination of linear and angular motion, such as completing the 400m sprint. It, therefore, becomes important to know about the laws of motion for a better understanding of motion and its application in physical education and Sports.

8.1 Newton's Laws of Motion and their Application in Sports

Sir Isaac Newton (1642-1727) was one of the greatest scientists and mathematicians that ever lived. Newton came up with three general rules about the movement of objects, which are now known as Newton's Three Laws of Motion.

8.1.1 NEWTON'S FIRST LAW OF MOTION (LAW OF INERTIA)

According to the first law, a body will remain at rest or continue to move at a constant velocity unless acted upon by an external (resultant) force. Inertia is the resistance of any object to any change in its motion, including a change in direction—objectives to keep moving in a straight line at a constant speed.

Application in Sports

- If you slide a hockey puck on ice, eventually, it will stop because of friction on the ice. It will also stop if it meets something like a player's stick or a goalpost.[3]

A skater gliding on ice will continue gliding with the same speed and in the same direction unless an external force acts upon the skater.[4]

That unbalanced force is the player's foot, head, friction, gravity, and the net during a soccer game. A soccer player uses the body's muscles to create a force to move the leg and kick the ball from rest to motion until another player or the net stops or changes the ball's motion. [5]

When a ball is thrown and is in mid-air, the only force acting upon it is the force of gravity. If the force of gravity did not exist, the ball would keep traveling at a constant speed until it was affected by an object or another person touched it. If this ball were thrown upwards, it would end up traveling into space!

8.1.2 NEWTON'S SECOND LAW OF MOTION (LAW OF MOMENTUM)

As per the law, the rate of change of momentum is proportional to the resultant force and takes place in the direction of the resultant force. When a net force acts on an object, the acceleration of the object it produces is directly proportional

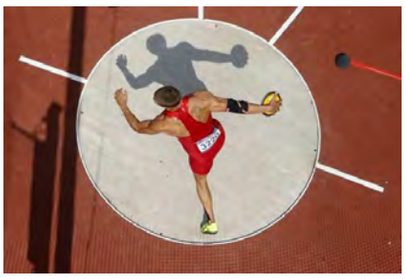
to the magnitude of the net force, is in the same direction as the net force and inversely proportional to the mass of the object. The more mass the thing has, the more net force has to be used to move it.

In general, if you use the same force to push a truck and push a car, the car will have more acceleration than the truck because the car has less mass.

Application in Sports

As in Shot-put, a player who applies more force and tosses the shot-put at the correct angle has a greater displacement of shot-put, whereas a player who exerts less force has a lesser displacement of shot put.[6]

In a Discuss throw, if we want to determine the force acting on a discuss (2kg), if it is accelerated at 20 m/ second sq.



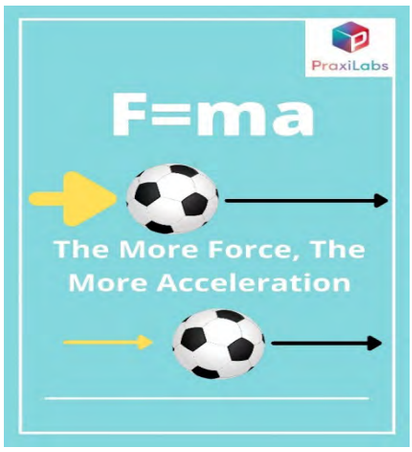
F = m*a

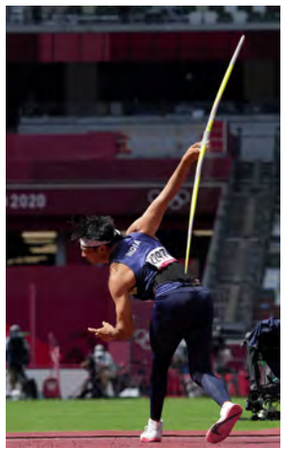
F = 2*20

F = 40 Newton[7]

When a ball is thrown, kicked, or struck with an implement, it tends to travel in the direction of the line of action of the applied force. The greater the amount of force applied, the greater the speed the ball has. If a player improves leg strength through training while maintaining the same body mass, they will have an increased ability to accelerate the body using the legs, resulting in better agility and speed.[8]

- In soccer, a team will require more force to kick the ball high and faster. This law of motion is fundamental in soccer, so you can calculate the force needed to give a pass or kick the ball to the net without missing.[9]



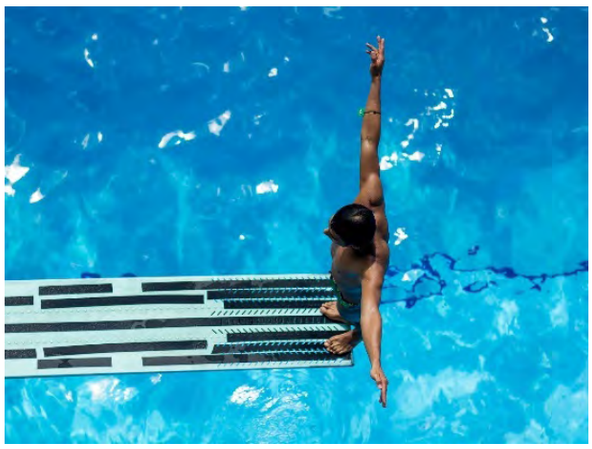


8.1.3 NEWTON'S THIRD LAW (LAW OF REACTION)

According to this law, there is an equal and opposite reaction for every action, and this reaction acts with the same Momentum and the opposite velocity for every action. It states that whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first object. When you walk on a floor, the floor pushes you along. No force can act alone.

Application in Sports

- In Swimming, a diver needs to push down on the springboard when he/she dives off a diving board. The springboard pushes back the force on you for proper projecting into the air during the performance.[10]



- When you jump off a small rowing boat into the water, you will push yourself forward towards the water. The same force used to go ahead will make the boat move backward.[11]

- During a soccer match, we need to kick the ball for passing, shooting, or clearing the ball. While kicking the soccer ball, we will feel the force of the kickback on our leg. we won't feel the force as much because our legs have more mass than the soccer ball.[12]

- During any type of motion, if we need to jump, our legs apply force to the ground, and the ground applies equal and opposite reaction force (ground reaction force) that propels us into the air.[13]

Do you know?

When we take a vertical jump, thee knee experiences mean peak loadings of 2.4 - 4.6 × body weight at the patellofemoral joint, 6.9 - 9.0 × body weight at the tibiofemoral joint, 0.3 -1.4 × body weight at anterior tibial shear and 1.0 - 3.1 × body weight at posterior tibial shear. The hip experiences a mean peak loading of 5.5 - 8.4 × body weight and the ankle 8.9 - 10.0 × body weight.[5]

Extension Activity

During your physical education period under the guidance of a physical education teacher, perform motor actions like running, jumping, and throwing. Try to identify, which law of motion defines the activity you performed and give remarks.

Motor action	Law	Remarks

I. Tick the correct options.

1. According to Newton's Second Law of Motion, the greater the movement of an object, the
   a. The longer distance will it travel
   b. Stronger will it resist the external forces
   c. Speedier it will cover the given distance
   d. More stable will it remain in its motion.
2. Newton's First Law of Motion is known as the

a. Law of Reaction

b. Law of Inertia

c. Law of Effect

d. Law of Momentum

3. Newton's Second Law of Motion is also known as

a. Law of Reaction

b. Law of Inertia

c. Resultant Force

d. Law of Effect

4. Acceleration due to an external force acting on a moving object is technically defined as the change in that object's

a. Location

b. Direction

c. Velocity

d. Movement

II. Answer the following questions briefly.

1. List Newton's Laws of Motion.

2. Elucidate Newton's Law of Inertia.

III. Answer the following questions in 150-200 words.

1. With the help of suitable examples, discuss the application of Newton's Laws of Motion in sports.

2. How can Newton's second law and third law of motion be applied in sports?

8.2 Levers

The lever is a type of machine. It is the human body's mechanism for movement, and although it may be viewed as a part of the skeletal system, the role of the muscles in supplying the necessary force for lever action should be kept in mind. The bony levers will be less stationary until they are moved by the muscles, which are motionless until the nervous system stimulates them.

All lever systems are made up of four components:

- the load
- the fulcrum
- the effort
- the lever.

The load is the object requiring moving, the effort is the muscular force we use to move the object, the fulcrum is the joint around which the movement occurs, and the bones of the skeleton are the levers. If asked to sketch a diagram of a lever system, you would need to include all four parts.

Lever systems have standard symbols that are used to represent each part.

You will need to know these standard symbols.

◆ Load	
◆ Fulcrum	
◆ Effort	
◆ Lever	

Definition of a Lever

A lever is "a rigid bar used to overcome resistance when a force is applied.

"A rigid piece transmits and modifies force or motion when forces are applied at two points, and it turns about a third."

The Fulcrum

- It is the point at which the lever rotates or turns and identifies the lever class by its position in relation to the other two parts. In human movement, the fulcrum is the joint that dictates the kind of action.

The Force/Effort Arm

- It is the point at which the force is applied.

The Load/Resistance Arm

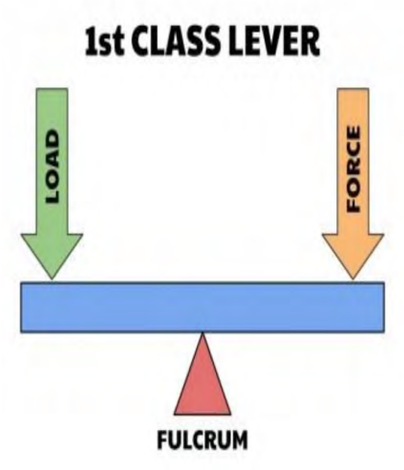
- It is the point where the load or resistance is located.

8.2.1 TYPES OF LEVERS

There are three types/classes of levers:

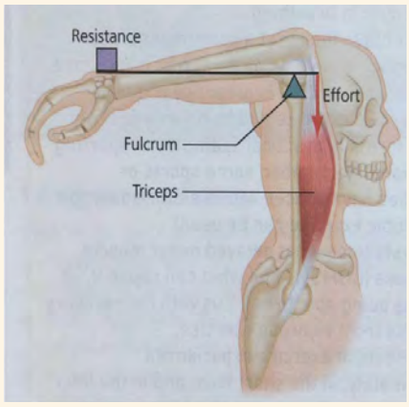
- First-Class Lever
- Second Class Lever
- Third Class Lever

First-Class Lever: A first lever has the fulcrum between the force and the resistance. This class fulcrum may be moved about along the lever, thereby changing the relative lengths of the force arm and the resistance arm. If the fulcrum is placed close to the resistance, the force arm is length, and hand and less force need to be applied to move the resistance, but force must be applied through a long distance to lift the resistance a short distance. Conversely, a shortened force arm requires more excellent force application, but there is a gain in speed and range of motion at the resistance end.

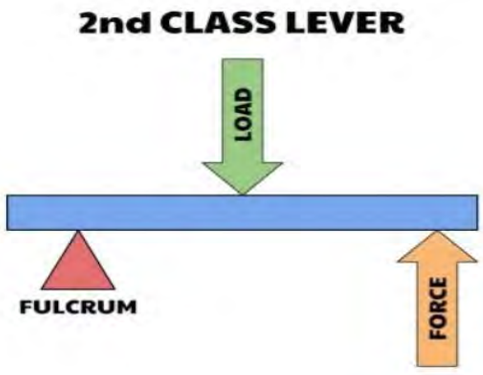


First-Class Lever

Examples of 1st class lever

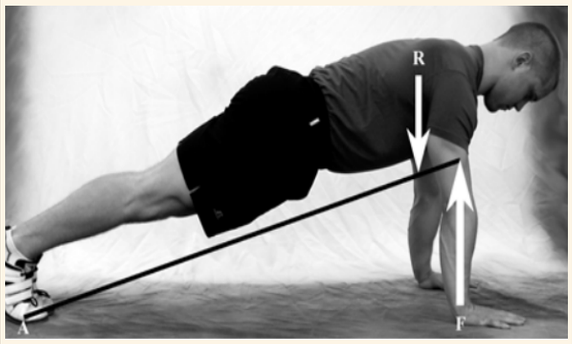
	
Triceps causing Extension at the elbow Example: When throwing a ball: ◆ Fulcrum = Elbow ◆ Effort = Triceps ◆ Load = Arm/ball	V- sit-up position. Example: When doing V-sit-up – Fulcrum = Hip joint Effort = Abdomen Load = Leg/Lower body

➤ **Second Class Lever:** A second class lever has the load resistance between the fulcrum and the force. In this class of levers, movement of the fulcrum will increase or decrease both the force arm and the resistance arm. The force arm is always the longer of the two, and therefore the force needed to lift resisting weight will always be less than the weight.

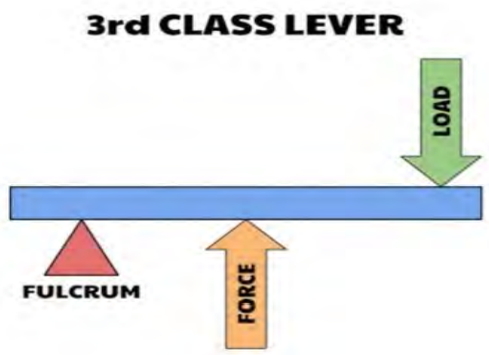


Second Class Lever

Examples of 2nd class lever

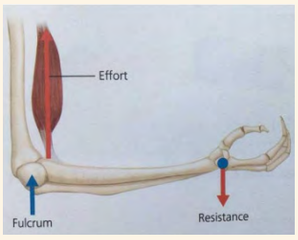
	
The foot acting as a whole is a second-class lever when the fulcrum is the ball of the foot, and the body weight is lifted to the toes by force at the heel. Example: When throwing a ball: Fulcrum = Ankle joint Effort = Gastrocnemius Load = Ankle joint	*Straight Push-ups.* Example: When doing V-sit-up – Fulcrum = Ball of the foot Effort = Arm Muscle contraction. Load = Body weight

- **Third Class Lever:** A third-class lever has the force between the fulcrum and the resistance. In this class of lever, the force arm is always shorter than the resistance arm, and so a large amount of force must be applied, but the resistance is moved through a much longer range of motion than the force application. In the human body, the most common class of lever is the thread. His is particularly important in the movements of the limps because the desired results are often those of speed or range of motion, albeit at the expense of force.



Third Class Lever

Examples of 3rd class lever

	
Bicep causing flexion at the elbow Example: When throwing a ball: Fulcrum = Elbow joint Effort = Biceps Load = Arm/Weight	**Sit-ups** Example: When doing Sit-ups Fulcrum = Hip joint Effort = Abdomen Load = Upper body

8.2.3 APPLICATION IN SPORTS

The human leverage system is built for speed & range of movement at the expense of force. Short force arms & long resistance arms require great muscular strength to move like biceps & triceps attachments biceps force arm is 1 to 2 inches triceps force arm less than 1 inch. Human leverage for sports skills requires several levers; throwing a ball involves levers at the shoulder, elbow & wrist joints. The longer the lever, the more effective it is in imparting velocity. A tennis player can hit a tennis ball harder with a straight-arm drive than with a bent elbow because the lever is longer & moves at a faster speed. Long levers produce more linear force and thus better performance in some sports such as baseball, hockey, golf, field hockey, etc. For quickness, it is desirable to have a short lever arm baseball catcher brings his hand back to his ear to secure a quick throw sprinter shortens his knee lever through flexion that almost catches his spikes in his gluteal muscles. A few examples of lever application in sports are:

1. **Cricket bat (2nd class) -** *The fulcrum is the top of the handle, the load is the bat's body, and the force is closer to the neck of the handle.*
2. **Kicking - Lower limb (3rd class) -** *The fulcrum at the knee joint, force at tibial tuberosity, (attachment of the quadriceps) load is the foot.*
3. **Jumping - Plantar flexion of the foot (2nd class) -** *The load is at the toes, the fulcrum is at the heel, and force is your weight which is anterior to your heel.*
4. **Looking up/down or side-to-side (1st class) -** *Your head is balanced on your atlantooccipital joint, which pivots, similarly to a see-saw.*

Do you know?

Levers can be found either internally in the form of extremity bones (limbs) or externally in the form of sports implements such as rackets, bats, hockey sticks, and so on. It should be clear that the bar referred to in the definition can be of any shape.

Extension Activity

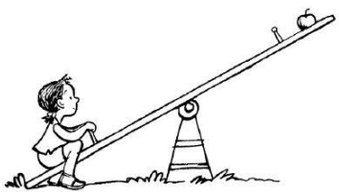
Classification of Levers

Use the information we have just gone through to complete your table

Class	Middle Component	Line drawing	Sporting example/ movement in the body
First			
Second			
Third			

I. Tick the correct options.

1. The three basic components of a lever are
   a. Mass, weight & velocity.
   b. Force, Fulcrum & Load
   c. Fulcrum, Resistance & Effort
   d. Both b and c.

2.  What type of lever is depicted in the picture?

a. 1st Class lever

b. 2nd Class lever

c. 3rd Class lever

d. None of the above

3. Push up is an example of which lever?

a. Law of Reaction

b. Law of Inertia

c. Resultant Force

d. Law of Effect

4. In the human body, the most common class of lever.....

a. 1st Class lever

b. 2nd Class lever

c. 3rd Class lever

d. None of the above

II. Answer the following questions briefly.

1. Define Lever.

2. Draw 3 types of levers used in sports.

III. Answer the following questions in 150-200 words.

1. With the help of suitable examples, discuss the application of 1st class lever in sports.

2. What do you mean by lever? Explain with the help of diagrams.

8.3 Equilibrium (Stability/ Balance)

When we say something is stable or balanced, we generally mean that it is not easily upset; that is to say, it takes some effort to topple it. By contrast, of course, an unstable object is easily upset.

Equilibrium or stability is necessary for performing skills. Naturally, the centre of gravity (CG) shifts with each change in posture. In the standing posture, the centre of gravity, while somewhat different for males than females, is located near the centre of the upper pelvic region. It shifts with each new posture assumed by the body. A significant part of any skill is the continual adjustment of body segments to

counteract this change in position and control the centre of gravity.

Equilibrium is defined as a state of balance or a stable situation, where opposite forces cancel each other out and where no changes are occurring.

8.3.1 TYPES OF EQUILIBRIUM

With respect to the state of a body, equilibrium may be divided into two categories:

1. Static equilibrium.
2. Dynamic equilibrium.

Static Equilibrium

For a body or an object to be in static equilibrium it must not be moving or rotating. All the force and torques acting on the body or object must add up to zero.

For an object or body to be in a static or static equilibrium, where it is completely motionless it must meet 3 conditions:

1. The sum of all the vertical forces acting on the body must be zero
2. The sum of all the horizontal forces acting on the body must be zero.
3. The sum of all torques must be zero.

Static equilibrium can be defined as a state when a body is at rest or completely motionless.

Static equilibrium is the balance of the body during rest or stationary position.

8.3.2 FACTORS INCREASING EQUILIBRIUM

- The centre of gravity falls within the base of support
  - Decrease instability when the centre of gravity becomes near the edge of the base
- Larger base
- Greater weight
- Lower centre of gravity
- When anticipating an oncoming force
  - Place centre of gravity near the side of the base of support expected to receive force

- Extending the base of support in direction of expected force

➤ Greater friction between body and surfaces it contacts

➤ Rotation about an axis

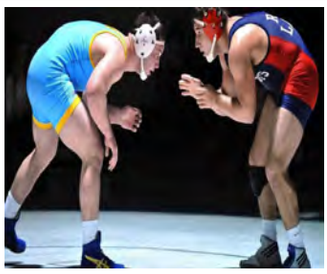
- Moving cycle is easier to balance than a stationary cycle

➤ Kinaesthetic physiological functions

- Vestibular system, vision, touch, and kinaesthetic awareness

Examples: Stance maintained by the batsmen in cricket, on the starting block by the sprinter, wide stance maintained by the wrestler, etc.


17


18


19

Dynamic equilibrium

Dynamic Equilibrium can be defined as a state when all the applied and inertial forces applied to a moving body are in balance, resulting in movement with unchanging speed or direction. To control the equilibrium and achieve balance, stability needs to be maximized.

When the body or an object is moving with a constant velocity - that is with no change in speed or direction it is said to be in dynamic equilibrium.

Dynamic equilibrium or dynamic stability is a balance of the body during movement.

Example: Body position maintained by a sprinter while running on the track, Cyclist while cycling, dribbling of the football by a soccer player etc.

20


21


22

Guiding Principles to Determine the Degree of Stability

1. **Broader the base, the greater the stability:** Broadening the base of support helps an athlete to achieve greater stability. eg., *while standing spreading the feet in the direction of movement provide stability. Where a stance is required, using both hands and feet creates the widest base.*

2. **Body weight is directly proportional to stability:** The athlete or an object which weighs more will have greater stability. *eg., it is difficult to move a heavier person than a lighter one, Combative sports like, judo, wrestling, taekwondo, and boxing are played according to the bodyweight principle.*

3. **Lower the Centre of gravity, higher the stability:** When a player does an activity that needs stability, the player usually lowers their centre of gravity by bending. *eg., when a player bends his knees while running, he can stop sooner and more efficiently. Similarly, a wrestler half sits to maintain his stability. Even a shot-put thrower bends his knees in the end so that he may avoid a foul.*

4. **The nearer the centre of gravity to the centre of the base of support the more will be the stability:** If the centre of gravity extends beyond the base of support, balance is lost. Keeping the body's weight centred over the base will support and help maintain stability. *eg., when a gymnast walks on a balance beam one requires a small base of support. During the performance, if the balance is lost the gymnast raises the arm or legs on the opposite sides to shift the centre of gravity back towards the base of support.*

5. **Direction of acting force:** During a competition, if the direction of an acting/ applied force is known, stability can be increased by moving the line of gravity as close as possible to the edge of the base where the force is expected. *eg., when in a judo match the judoka shifts his foot in the line of direction of the force applied by the opponent to use the force of the opponent as a counterforce to throw him down.*

8.3.3 CENTRE OF GRAVITY

The Centre of gravity is the point at which all the weight or mass of a body may be considered to be concentrated.

The centre of gravity of an individual standing in the anatomic position marks the intersection of three primary planes and axes.

The human body's flexibility and its fluidity creates problems in accurately locating

the centre of gravity because, while the mass centre can be determined for any given, momentarily fixed stance, any significant movement is accompanied by a shift in the location of the centre of gravity. It means that the mass centre is constantly moving in many sports skills.

Locating the centre of mass of a rigid object is not difficult and is even easier if the object is of uniform density and asymmetrical shape; in this case, the centre of gravity is at the exact centre of the object. An object suspended from this point is in rotational equilibrium.

The ability to balance, whether stationary or moving, is key to success in most sports and physical activities. The stability of an athlete depends on her/his COG. It is exactly in the middle of the body around which it can rotate freely in any direction and where the weight of the body is centred.

Examples:

(a) For wrestlers in snatch and jerk, the widening of legs and lowering of body to maintain the stability, makes COG come down.

(b) During running, the runner's centre of gravity is in the lower region of the pelvis and in front of his body, because his upper body is leaning forwards. Having the centre of gravity lower and in front of his lower body is advantageous for acceleration.

23

Importance and Application of centre of gravity in Sports

(a) Helps the athlete to move

(b) Stops the moving object

(c) Helps the athlete to accelerate

(d) Helps the athlete in throwing objects.

(e) Helps the athlete to lift the object.

(f) Helps the athlete to pull the object

Example of Centre of Gravity

To get better results and to be strong, the position of the centre of gravity is quite important in many sports, few examples are given below:

- In the game of basketball and volleyball, high defence players spread their legs to lower the centre of gravity towards the base to occupy a better position against the offensive player.
- Starting in short sprints in track events is another example of the use the of centre of gravity. As we need to take an instant start in sprints, we take our body weight on our hands in the "Set" position. So, that we can start immediately while balancing our weight. *(Initially, the centre of gravity of the body falls on the edge of the baseline of hands. If the centre of gravity falls behind the line, then there will be delay in starting because it will require a greater force to go ahead).*
- In combative sports like wrestling, a wrestler falls on the mat with arms, knees, and legs spread on the mat to get a proper balanced position, (This position, makes it difficult for the opposite player to move him.

24


25

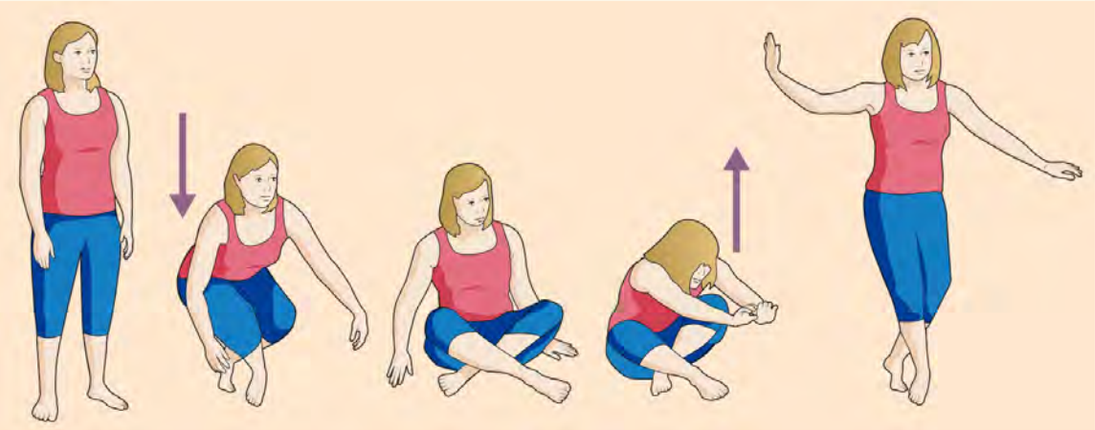
Do you know?

In our daily routine, we maintain different body positions and movements. Balance, equilibrium, and stability are the major factors that help us to do all these activities. Normally in an adult man the COG in a standing position will be at 56.18 % of the height from the ground, and it will be at 55.14 % in adult women.

Extension Activity

Try this simple sitting test for yourself:

1. Stand in comfortable clothes on your bare feet, with clear space around you.
2. Without using any type of support, lower yourself to a sitting position on the floor. This should be a controlled movement; you should not be concerned about the speed of the movement.
3. Now stand back up, without using your hands, knees, forearms, or the sides of your legs for support, and without loss of balance.



Scoring

4. The two basic movements in the sitting-rising test – lowering to the floor and standing back up – are each scored on a scale of 1 to 5, with one point subtracted each time a hand or knee is used for support and 0.5 points subtracted for loss of balance. The maximum score achievable is 1. 26

I. Tick the correct options.

1. When the sum of force acting upon the object and sum of the movement acting upon the body is both equal to zero then the body is said to be in
   a. Equilibrium
   b. Static equilibrium
   c. Dynamic equilibrium
   d. Zero force
2. The position of the centre of gravity changes depending upon the
   a. position of force

b. position of the body

c. position of the intersection of force

d. position of stability

3. Centre of gravity is the average location of an object's

a. weight

b. force

c. balance

d. velocity

II. Answer the following questions briefly.

1. What do you understand by equilibrium? What are the types of equilibrium?

2. Give suitable examples of the type of equilibrium applied to sports / games.

3. Define the centre of gravity.

III. Answer the following questions in 150-200 words.

1. Why do wrestlers spread their arms, knees, and legs on the mat when they fall?

2. Discuss the importance of the centre of gravity in sports with suitable examples.

8.4 Friction & Sports

Friction is a force that opposes the motion between two surfaces that are in touch. Friction always works in the direction opposite from the direction the object is moving or trying to move. Friction also produces heat. For example, if you rub your hands together quickly, they get warmer. We can also say that frictional force is a contact force that acts in the opposite direction to the motion of an object. This force can cause objects in motion to come to rest, as they act in the opposite direction to their motion. For example, if you roll a ball on a surface, it would come to rest after a short while.

8.4.1 TYPES OF FRICTION

Static friction:

It occurs when the force applied to an object does not cause the thing to move. Because of static friction, you must use extra force to start the motion of stationary objects. eg., if you try to push a heavy object with less force than the force of static friction between the object and the floor, the object will not move. To make the object move, you need to exert more force than the force of static friction. Once the object is moving, there is no longer any static friction.


27

Kinetic friction

It occurs when force is applied to an object and the object moves. It includes three different types of friction:

(a) **Sliding friction:** Pushing an object across a surface. This is when two bodies are in contact and one body moves on the surface of the other body by sliding on it or rubbing over the surface. Example – skating on ice, planting a pole in the pole vault event and skiing or sliding weight.


28

(b) **Rolling friction:** It occurs between wheels and a surface. When two bodies are in contact and one body rolls over the other, it is referred to as rolling friction. eg., when a hockey or cricket ball is hit it begins to move ahead and roll on the ground. After sometimes it stops rolling due to the friction force, this type of friction is often seen in sports. eg., Roller skates and skateboards


29

Fluid friction

It opposes the motion of objects traveling through the fluid (gas, air, and water).

For example:

- When you ride a bike, fluid friction occurs between you and the air.
- Cyclist often wears streamlined helmets and specially designed clothing to reduce fluid friction.
- Paragliding vs hang gliding when an athlete glides on air.

30

Things that affect friction

- Applying a lubricant between two surfaces. (Motor oil, grease, and wax)
- Friction can be reduced by rolling rather than pushing an object
- Friction increases as surfaces are made rougher.
- Friction increases when the force between two objects is increased
- In general, smooth surfaces produce less friction than uneven surfaces.

8.4.2 METHODS OF REDUCING FRICTION

- **Polishing:** If we polish and rub the surface to reduce its unevenness and make it smooth, the force of friction can be reduced. eg., shining a cricket ball increase the swing of the ball.
- **Lubricating:** A common way to reduce the force of friction is by applying a lubricate such as Motor oil, grease, wax etc. eg., the most widely used lubricants in practical mechanical systems like bearings or gears.
- **Wheels and Ball bearing use:** It is easier to roll an object than to slide it by using wheels and ball bearings as we convert sliding friction into rolling friction. This reduces friction between the two contact surfaces and helps us to save energy and time. eg., in roller skates, both wheels and balls contribute to reducing friction.

- **Streamlining:** Friction due to air is reduced by streamlining the shape of the body. eg., the Javelin, boats, ships, and vehicles, are made with a sharp point to reduce friction.

8.4.3 ADVANTAGES AND DISADVANTAGES OF FRICTION IN THE FIELD OF SPORTS

Advantages

Friction is essential in the field of sports. Without appropriate friction, we will not be able to grip any sports equipment effectively. The advantages of friction in various sports can be explained as follows:

- **Athletics:** In Athletics, the shoes (spikes) are designed to increase friction so that better speed can be generated. The shoes used for short-distance running events have spikes in the front potion only. Whereas the long-distance runner uses completely different shoes.
- **Badminton:** The grip in badminton plays a major role in performing a shot perfectly during a match. That is why a good grip in rackets, will increase the friction with the hand, helping the shot to count and preventing the racket from slipping.
- **Basketball:** Friction between the shoes and the court helps players to maintain control of movement. They wipe their shoes often to get more friction for better movement control.
- **Cricket:** The cricket players, essentially the fielders wear shoes that have spikes. The helps them increase the friction with the ground and hence, helps the cricketer during the run-up for balling, running between the wickets, and preventing from slipping
- **Cycling:** The friction between the tires and the surface prevents cyclists from slipping and skidding. The friction between the brakes and the wheel help cyclists slow down their bikes.
- **Football:** In Football, a footballer kicks and catches the ball. Friction helps him/her to run, change and maintain his/her position on the ground. Better friction helps him/her to tackle the opponent correctly.
- **Gymnastics:** It is due to friction that a gymnast is able to perform actions on the Horizontal bar. In fact, he uses lime powder on his hands to increase the friction between his palm and the bar

- **Javelin:** Friction between the hand and javelin allows the thrower to grip the javelin and friction between shoes and track helps them to generate a perfect ground reaction force for throwing the javelin in the right direction. Without friction, the javelin would just fall out of their hands.
- **Running:** Friction between the shoes and the track enables an athlete to run fast, deaccelerate, stop and change direction. If friction is low, the athlete would slip and even fall.
- **Soccer:** In soccer also number and size of spikes between a striker to a defensive player are different, this technical difference is based on the type of friction required by the players.
- **Weightlifting:** In weightlifting, the weightlifters needs more friction between their feet and the floor to prevent slipping while lifting heavy weights, for which they use specially designed shoes.

The friction force is also required for pulling and pushing which is common in all sports activities. Hence, we can say that friction is necessary to give the best performance all forms of games and sports.

Disadvantages

The disadvantages of friction are as follows:

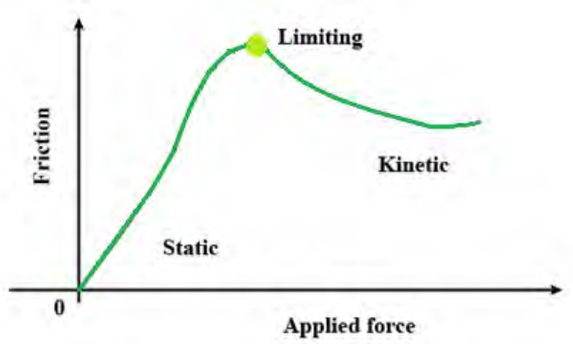
- **Bicycling:** During cycle racing the tires get heated up due to friction. Due to more heat, tires may burst and it may lead to serious accidents.
- **Weightlifting and Gymnastics:** In weightlifting and gymnastics, the skin in the palm gets damaged due to friction and the athlete even may slip while performing the lift. Hence, gymnasts and weight lifters are advised to use powder on their palms and wear special shoes to maintain appropriate friction
- **Pole-Vault:** During Pole-Vault, a vaulter may lose grip on the pole if less friction is there between palms and pole. Hence, pole vaunters are advised to use adhesive on the palm to increase friction and perform correctly.
- **Friction makes movements difficult:** Any time you want to move an object, friction can make the job more difficult, as movement is directly affected by mass and force applied and also on the surface condition.
- **Excess friction means extra energy:** in other words, more friction means more force to overcome it and more force means more energy. Thus, energy is wasted due to friction.

- **Friction can cause injuries:** if a player slides/falls across the ground. In fact, friction can lead to critical injuries.
- **Wear and tear:** sporting equipment occurs with time because of friction. If, there were no friction, they would last forever.

Consequently, it can be said that it is friction can be is advantageous or disadvantageous depending on the use, time, and place of using it. To some extent, some force of friction is required in various sports. The requirement may differ or vary from sport to sport.

Do you know?

Do you know? Recently one more friction type has been recognized which is known as Limiting Friction. Limiting friction is the force that comes into play when one body is just on the verge of moving over the surface of another body. (Limiting friction occurs when the moving force and the force opposing the motion are equal; any addition to the moving force will cause slipping. The limiting frictional force is proportional to the normal reaction between the contacting surfaces and is independent of the area of contact.)



31

Extension Activity

Below are images of four sports where you find friction is prominent. Using the image provided and your knowledge to identify the type of friction in each image and complete the table below:

Sport/activity	Equipment	Type of Friction	Effect on performance
Golf – shoes			

Bobsleigh skeleton – sled			
Gymnastics – mag chalk			
Mountain bike riding – tyres			

I. Tick the correct option.

1. The Friction force acts in a/an _____direction to the direction of motion of an object.
   a. opposite
   b. same
   c. downwards
   d. diagonal
2. Among the following sports, in which does friction plays the least important role?
   a. Car Race
   b. Football
   c. Hockey
   d. Ice Skating
3. Friction is a –
   a. Magnetic Force
   b. Non-contact Force

c. Contact Force

d. Couple Force

4. Cyclist often wears streamlined helmets and specially designed clothing to reduce Calibration

a. Fluid Friction

b. Rolling Friction

c. Sliding Friction

d. None of the above

II. Answer the following questions briefly.

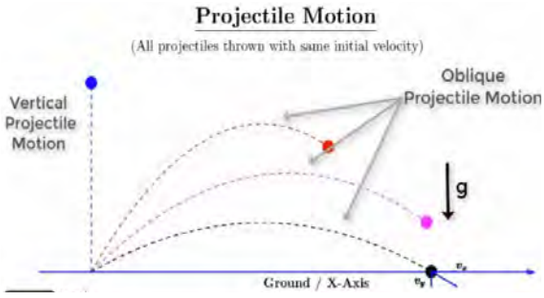
1. Define Friction.
2. What is Air Resistance?
3. What do you mean by 'Friction is a necessary evil'?

III. Answer the following questions in 150-200 words.

1. Discuss various types of friction.
2. Is friction advantageous or disadvantageous in games and sports?
3. Write down the methods of reducing friction and explain any two with suitable example.

8.5 Projectile in Sports

A projectile is a force that acts under the influence of gravity and air resistance. A projectile would travel in a continuous straight line if gravity were not present. A projectile is any object which once projected or dropped continuously in motion by its inertia and is influenced only by the downward force of gravity. A projectile is an object upon which the only force acting is gravity. Projectiles travel with a parabolic trajectory due to the influence of gravity.



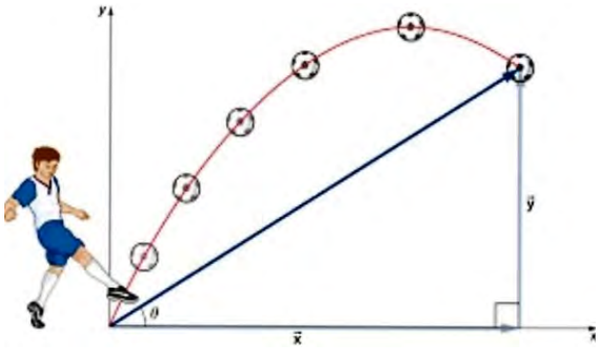
Defining Projectiles

A projectile is an object upon which the only force acting is gravity. There are a variety of examples of projectiles. An object dropped from rest is a projectile (provided that the influence of air resistance is negligible). An object that is thrown vertically upward is also a projectile (provided that the influence of air resistance is negligible). And an object which is thrown upward at an angle to the horizontal is also a projectile (provided that the influence of air resistance is negligible). A projectile is any object that once projected or dropped continues in motion by its own inertia and is influenced only by the downward force of gravity.

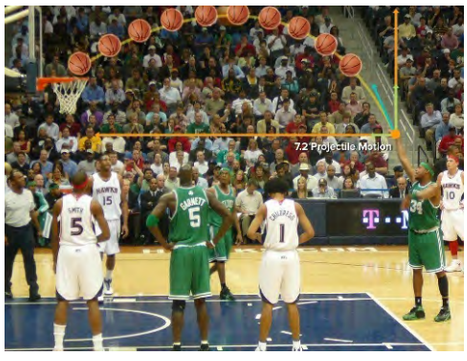
In simple words, an object in flight after being thrown a project is called projectile motion.

Examples from sports involve projectile motion:

- *Objects acting as projectiles: basketball, football, shot-put, hammer, discus, javelin, golf ball, volleyball, tennis ball, etc*
- *The body acts as a projectile in high jump, long jump, gymnastics, diving, figure skating, ski jumping etc.*



33



34

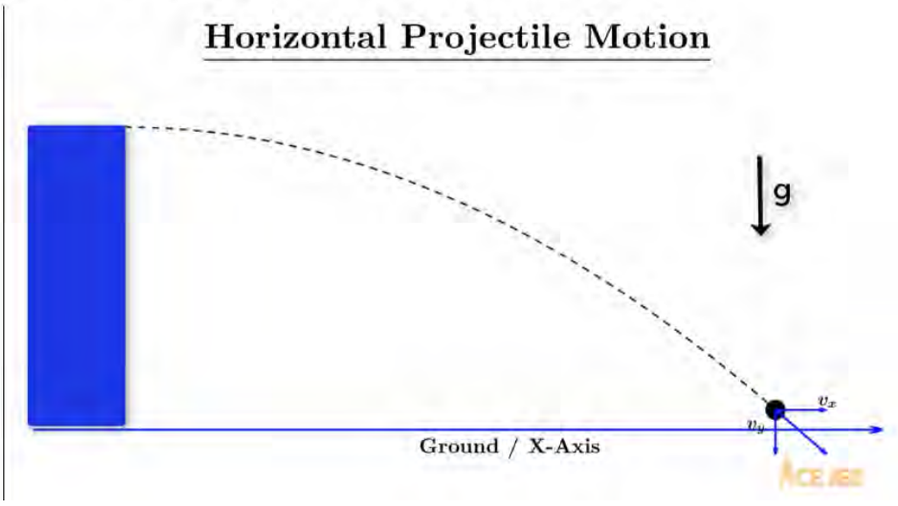
The motion of a projectile is due to two separates simultaneously occurring components of motion

(a) One along the horizontal direction

(b) Other along the vertical direction

- With constant acceleration due to force of gravity

Horizontal Projectile Motion



35

8.5.1 FACTORS AFFECTING PROJECTILE TRAJECTORY/ FLIGHT PATH

a. Gravity

b. Air resistance

c. Speed of release

d. Angle of release

e. Height of release

f. Spin

(a) **Gravity-** Gravity is the force exerted by the earth on any object towards the centre of the body, and it is directly proportional to the mass of the body. Without gravity, the body will travel in a straight line after being thrown.

(b) **Air Resistance-** Several vital factors bring air resistance into play

- ***Surface area:*** The larger the surface area, the more air resistance will affect the object. Example: Basketball compared to a golf ball.
- ***Speed:*** As speed increases, so does air resistance. Example: The Space shuttle.
- ***Surface of the object:*** If the surface is rough, then air resistance will be greater.

Example: Swinging ball in cricket.

- **Mass:** The smaller the mass (lighter the object), the more air resistance will affect it. Example: Movement of the shuttle in badminton.

(c) **Speed of release:** This refers to how fast the object is released (thrown or hit). The muscle force largely determines a projectile speed of release. Generally, the greater the release rate, the greater the distance gained. Example: Speed of release in throwing events like javelin, discus, etc.

(d) **Angle of release/ projection angle:** This refers to the pitch at which the object is thrown or hit into the air. In sporting situations, the angle of release varies according to the activity. A basketball angle above 45 degrees is required in activities such as shooting. In activities such as tennis, a lower, around 3-to-15-degree grade is required.

(e) **Height of release:** This refers to how high above the ground an object is released. Increasing the height of release improves the horizontal distance an object can be projected. For a given speed and angle of release, the greater the height of release, the greater the distance gained. Example: Height of release in throwing events like javelin, Hammer throw, etc.

(f) **Spin:** Spin happens as a ball moving through the air will move in the direction of at least air pressure. This helps the projectile maintain its course and can cause it to change height or direction. When applying force to a projectile below, above, or the side of the centre of gravity, you will impart spin to the projectile. Example: principle of spin in basketball shooting.

8.5.2 APPLICATION OF PROJECTILE IN SPORTS

There are many instances where projectile motion is applicable, whether it is in daily life, sports, or technological advancements. Here are some of the applications of projectile motion given below:

Sports

Projectile motion is very common in sports since most sports involve the motion of a projectile (usually a ball). By using physics, we are able to determine the optimal angle of a ball's flight in order to maximize speed or distance.

Baseball

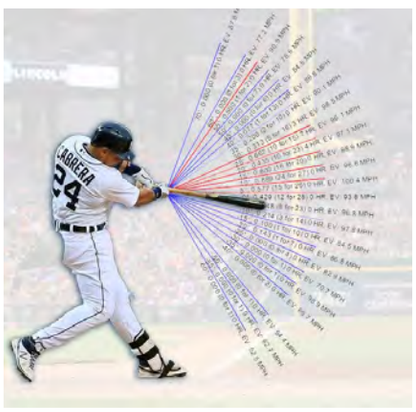
Pitching analysis

Projectile motion is applicable in both throwing and hitting. A thrown ball undergoes projectile motion when it is mid-air since the only force that affects the ball is the acceleration due to gravity. A variety of factors will go into the trajectory of a pitch, including a pitcher's height, arm angle, and the spin being applied to the ball.

36

Hitting analysis

In terms of hitting, advanced analytics like to use "launch angle" as a good indicator of the optimal angle that a ball should be hit. Launch angle is the angle at which a ball exits the bat as soon as they connect with each other. The best launch angles, which allow for line drives and home runs, are calculated to be around 10–30 degrees North of East, relative to the bat. This allows for the most optimal ball flight, usually necessary to hit the ball over 325 to 400 feet over the fence.



37

Basketball

Another example of projectile motion in sports is basketball. For a basketball shot to enter the hoop, the basketball must be shot at a certain angle with a certain amount of force. The optimal angle of a shot will vary depending on the height from which the ball is shot and the player's distance from the hoop. According to Professor John

Fontanella, the ideal angles from the free-throw line will vary from 48.7 degrees to 52.2 degrees, with shorter players.

38

Did you Know

There are four main types of spin used in sports, Top Spin- is where you hit over the ball. Topspin creates a downward force on the ball, causing the ball to drop, Back Spin- this is where you hit under the ball, Backspin creates an upward force that lifts the ball, causing the ball to rise, Clockwise Spin-this is we are you hit the ball on the left side of the centre of gravity. It causes the ball to swing to the right and Anticlockwise- this is where you hit the ball on the right side to the centre of gravity. It causes the ball to swing to the left.

Extension Activity

Identify Projectile in Sports: Make groups in your class and during your physical education period select 5 sports and try to apply the projectile principal in them and write down your observation in the table below:

S.No.	Sports	Activity/Skill	Observation

I. Tick the correct option.

1. Factors that bring air resistance into play
   a. Larger the surface area
   b. Rough surface
   c. Smaller the mass
   d. All of the above
2. The motion of a projectile is due to two separates simultaneously occurring components of motion and they are
   a. One along the vertical
   b. One along the horizontal
   c. both a and b
   d. none of above
3. According to Professor John Fontanella, the ideal angles from the free-throw line will vary from _____ to ___with shorter players.
   a. 48.7 degrees to 52.2 degrees,
   b. 45.6 degrees and 50.2 degrees,
   c. No specific degree
   d. Any degree

II. Answer the following questions briefly.

1. Define Projectile.
2. What is Air Resistance? list any four factors.

III. Answer the following questions in 150-200 words.

1. With suitable example explain different types of projectiles in sports.
2. Discuss various Factors affecting projectile motion.
3. Is projectile advantageous in games and sports? Justify.

IV. Read the given situations and write which of Newton's Laws of Motion applies to it.

S.no.	Sports situation	Law of motion
1.	When a ball is thrown, kicked, or struck with an implement, it tends to travel in the direction of the line of action of the applied force. The greater the amount of force applied, the greater the speed the ball has.	
2.	A skater gliding on ice will continue gliding with the same speed and in the same direction unless an external force acts upon the skater.	
3.	The force applied to the ball is matched with an equal and opposite force applied to the racket.	
4.	When a white ball (the cue ball) hit a yellow or green ball in billiards.	
5.	The force applied to the arrow in archery to hit the target.	

V. ART INTEGRATION – IDENTIFY, PERFORM AND MAKE CARDS

We do different types of activities in our daily life routine; in the same way, newton's law of motion applies to those activities. In your classroom, make groups and select different games for different groups. Identify three fundament skills from those games, perform them and identify which newton's law of motion relates to that skill. Make activity cum learning cards and write the following details in the table given below:

S.No.	Game	fundament skill	Name the Law of Motion	Remarks

VI. SPORTS INTEGRATED

39

Sports science is a fascinating topic on its own, and most physical sports require

having a basic understanding of scientific concepts. Consider the amount of physics involved with a sport like a golf – a golfer must understand the concept of a trajectory and how this can be affected by a multitude of factors (wind speed and direction, for instance). From tennis to basketball, angles, arches, mass, the center of gravity, angle of contact/release, etc, are all involved with these types of sports!

Based on this students can make a project individually or in a group on different sports and games where these laws and principle is applied with practical example and presented in their classes.

VII. Case Study

During her gymnastics practice, Zoya was finding it difficult to maintain her balance on the balancing beam. Her coach tried to explain to her about basic principles of equilibrium.

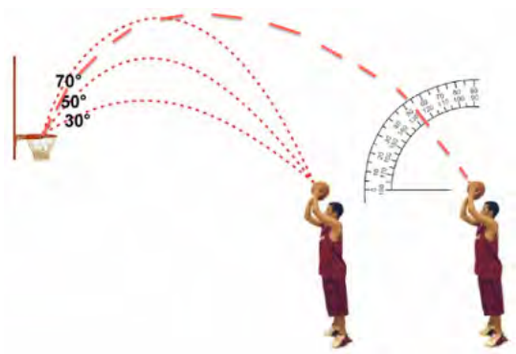
According to the principles of equilibrium Centre of gravity plays a very important role.

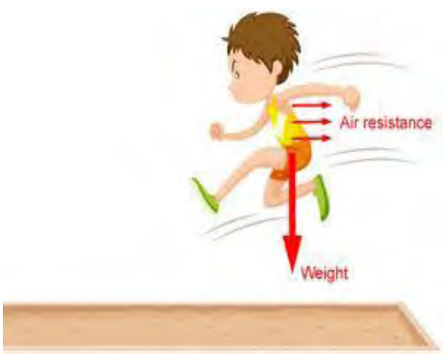
(a) _____ C.G helps in increasing stability.

(b) _____ base more stability.

(c) There are two types of equilibrium namely _____ and _____.

2.





While explaining how to release basketball at a correct angle to successfully score points the basketball coach showed students this picture.

Basketball players wanted to know more about projectiles therefore the coach explained to them the factors affecting flight of an object.

(a) An object covers less distance when the projected path is at _____ degrees.

(b) If the initial velocity is low the object will cover _____ distance.

(c) If the weight of the object is more the impact of gravity will be _____.

References:

1. Dhananjay Shaw (2000), Mechanical Basis of Biomechanics, Sports Publication, Delhi, p.10.
2. Dhananjay Shaw (1998), Biomechanics and Kinesiology of Human Motion, 4th ed, Khel Sahitya Kendra, Delhi, p.120.
3. James. G. Hay. (1985). The Biomechanics of Sports Techniques, 3rd ed. Prentice/ Hall International, Inc. New Jersey. p.2.
4. Susan. J.Hall. (2004), Basic Biomechanics, 4th ed. McGraw-Hill, New York, P.3

Suggested Readings

1. Dhananjay Shaw (2000), Mechanical Basis of Biomechanics, Sports Publication, Delhi,
2. Lutlegen, & Nancy, H. (1997). Kinesiology: Scientific Basis of Human Motion. Mc Graw Hill.
3. Physical Education and Yoge (373). (n.d.). Retrieved 11 25, 2020, from National School of
4. Thompson, & Floyd. (2017). Manual of Structural Kinesiology. Mc Graw Hil.

Foot Note

1. https://www.espn.in/football/club/brazil-bra/205/blog/post/3138037/roberto-carlos-brazil-free-kick-in-1997-the-physics-behind-impossible-strike
2. https://www.youtube.com/watch?v=m57cimnJ7fc
3. https://www.wsj.com/articles/the-death-of-the-slap-shot-in-the-nhl-1511547355
4. https://www.rmotoday.com/local-sports/olympic-speed-skating-hopeful-howe-impresses-with-national-championships-gold-4525417
5. https://www.gftskills.com/the-proper-way-to-kick-a-soccer-ball/
6. https://www.espn.in/fantasy/baseball/story/_/id/27239743/fantasy-baseball-daily-notes-pitcher-hitter-rankings-tuesday
7. https://www.tutorialspoint.com/shot_put/shot_put_rotational_style.htm
8. https://co.pinterest.com/juanestebanruiz110/discus-throw/

9. https://viewpress.photoshelter.com/image/I0000G.2zfTUlZIY
10. https://blog.praxilabs.com/2021/02/24/applications-of-newtons-laws-of-motion-in-daily-life/
11. https://www.rediff.com/sports/report/first-throw-perfect-but-need-to-improve-neeraj-shivpal-olympics-javelin/20210804.htm
12. https://www.liveabout.com/dives-in-springboard-and-platform-diving-1100076
13. https://olympics.com/en/featured-news/rowing-at-tokyo-2020-how-did-indian-rowers-fare-at-the-olympics
14. https://www.dailymail.co.uk/sport/football/article-3226944/England-2-0-Switzerland
15. http://theexercisers.com/how-to-increase-vertical-jump/average-vertical-jump/
16. https://cpb-ap-se2.wpmucdn.com/learn.stleonards.vic.edu.au/dist/7/166/files/2012/12/Unit-3-Ch-5-Nelson.pdf
17. https://www.sportskeeda.com/slideshow/5-basic-wrestling-techniques-for-beginners
18. https://www.rediff.com/cricket/report/slide-show-1-figure-out-sachin-tendulkar-glorious-career-facts-records-test-odis-retirement-cricket/20131010.htm
19. https://en.wikipedia.org/wiki/Biomechanics_of_sprint_running
20. ttps://cycling.today/20-million-indoor-velodrome-to-be-built-in-u-s/
21. https://www.hihstore.com/?category_id=2289336
22. https://pdhpe.net/the-body-in-motion/how-do-biomechanical-principles-influence-movement/balance-and-stability/centre-of-gravity/
23. https://www.active.com/volleyball/articles/volleyball-101-position-breakdown/
24. https://olympics.com/en/featured-news/what-how-greco-roman-wrestling-style-rules-scoring-techniques-olympics
25. https://cpb-ap-se2.wpmucdn.com/learn.stleonards.vic.edu.au/dist/7/166/files/2012/12/Unit-3-Ch-5-Nelson.pdf
26. https://endlessreference.com
27. https://theathleticbuild.com/weighted-sled-workouts/
28. https://olympics.com/en/featured-news/everything-you-need-know-roller-speed-
29. https://blog.manawa.com/en/outdoor-activities/paragliding/paragliding-vs-hang-gliding-which-one-is-really-dominating-the-skies/
30. https://www.geeksforgeeks.org/limiting-friction/
31. https://acejee.com/blog/types-of-projectile-motion/
32. https://psc.bibimohanan.com/2020/12/malayalam-gk-questions-kerala-psc.html
33. https://app.emaze.com/@AZIZCWCQ#/1
34. https://acejee.com/blog/types-of-projectile-motion/
35. https://www.thenewstribune.com/sports/mlb/tacoma-rainiers/article257599333.html
36. https://www.greatlakesbatco.com/single-post/2018/03/13/attack-angle-vs-launch-angle
37. https://www.pinterest.com/pin/715650197007266762/
38. https://theithacan.org/sports/golf-team-uses-simulator-to-train-during-winter-months/