Exercise & Sports Biomechanics
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Lecture 27
Forces in motion

[Let us continue this section with another type of force called friction].

What is friction?

It is the force that resists or opposes the motion of one body on another body. It acts parallel to the two surfaces in the direction opposing that of the motion. So, friction occurs when two surfaces are in contact.

Friction is the force that opposes motion between the two surfaces in contact. Friction is an important force in every sport and human movement. When force is applied to an object, the resistive force of friction acts in the opposite direction, parallel to the surface. The standard friction equation for determining the resistive force of friction when trying to slide two solid objects together can be written as $F_r = \mu N$

where Fr is the resistive force of friction, n is the perpendicular force pushing the two objects together, whereas mu is the coefficient of friction for the two surfaces. This coefficient of friction is different for different surfaces. So, we feel different friction with different surface types.

Friction is a force between two surfaces that are sliding or trying to slide across one another. For example, when you try to push a box along the floor, the friction always works in the direction opposite to the direction the object is moving or trying to move. It always slows a moving object down. In sports, friction can be both beneficial and detrimental, depending on the situation.

[Let us discuss **the beneficial aspect of friction**. Let us take the example of traction]:

The friction between the shoes and the ground allows athletes to grip the surface and generate force for running, jumping, and changing direction. This is crucial in sports like track and field, basketball, and soccer. Traction is what keeps athletes grounded and agile. Simply, it is the friction between the shoes and the ground that allows athletes to grip the surface and generate force for running, jumping, and changing direction. Imagine trying to run on ice; it slips and slides every way.

This is the right traction with which you can grip the surface nicely in sports like track and field, basketball, and soccer. The traction is crucial. It allows sprinters to launch off the starting block, basketball players to pivot and cut sharply, and footballers to change directions with precision. Without it, they would struggle to perform at their best.

Another example would be the ball spin. So, friction between a ball and a surface, or the implements like a tennis racket or a golf club can cause the ball to spin. This spin can affect the ball's trajectory and bounce, adding complexity and strategy to sports like tennis, baseball, and golf. Have you ever wondered why some balls curve like magic? Imagine you are playing tennis.

When you hit the ball with a racket, the friction between the strings and the ball makes it spin. This spin changes the way the ball flies through the air and bounces on the court. In baseball pitching, the pitcher uses spin to throw curveballs, sliders, and fastballs. The spin affects the air pressure around the ball, making it move in unpredictable ways. And in golf, a well-executed spin can make your ball roll closer to the pole. A backspin can stop it quickly, while a sidespin can make it curve around obstacles.

In sports like skiing and snowboarding, the friction between the skis and snow allows athletes to control their movement and make turns.

Let us talk about the **detrimental friction now**:

We can understand this by taking some examples like resistance. So, the friction can slow down an athlete's movement, such as in swimming or cycling. This is why athletes in this sport often wear streamlined clothing to reduce friction with the air or water. Wear and tear. The friction can cause wear and tear on equipment such as shoes, tires, and even the playing surface itself. Heat: friction can generate heat, which can be uncomfortable or even cause blisters in some sports.

Friction is governed by certain laws, which state that it depends on the normal load or the normal forces, is independent of the area of contact between the surfaces, and depends on the nature of the surfaces in contact.

For example, runners depend on friction to prevent slipping at the start and every propulsive step in order to prevent slipping. A goalkeeper in football requires friction between the ball and fingers in order to catch the ball. In track and field, sprinters use shoes with spikes to increase friction with the track surface, allowing for better acceleration. In basketball, the grip of the basketball on the player's hands and the friction between the shoes and the court are essential for dribbling, shooting, and changing directions. Cyclists wear aerodynamic clothing and adopt a streamlined posture to minimize friction with the air, allowing them to go faster.

In tennis, the friction between the tennis ball and the racket strings, as well as the friction between the ball and the court surface, affects the ball's spin and mass. In general, the magnitude of friction depends on the following factors. The type of material of which the contacting bodies are made. The relative roughness or smoothness of the contacting surfaces. And the presence of lubricants, dust, or moisture. The normal perpendicular force presses the two surfaces together.

Mostly, friction is of three types. The **static friction**, we also call it starting friction. The fluid friction and the kinetic friction. **Kinetic friction** can also be known as **dynamic friction**, and it has two components: **sliding** friction as well as **rolling friction.**

In static friction, suppose an object lies motionless on a surface, and a force is applied to displace it. However, the object continues to remain stationary. The reason is that the surface exerts a reaction force in the direction opposite to the applied force. This force is known as the **frictional force** because the object remains immovable. The phenomenon of resisting its motion is known as **static friction.**

The static friction force always occurs at the contact between the object and the surface. Essentially, it takes place between two surfaces in contact. When the applied force is large enough to move the object, the static friction disappears, and the kinetic friction comes into action. Static friction is responsible for keeping an object at rest. Here are a few examples: a book lying on a table, a car parked on a hill, a towel hanging from a rack.

A person is walking on a floor. Talking about the characteristics of static friction, here are some facts and properties of static friction: it depends on the contact forces, it depends on the responsive forces, and it basically reaches a maximum value before kinetic friction takes over. Talking about the laws of static friction. So, it obeys the laws like it is proportional to the normal forces. It is equal and opposite to the applied force.

It depends on the surface roughness and is independent of the area of contact between the two surfaces. The static friction always varies when the surface changes, like it acts differently when the surface is a stable surface or a plane surface, and it changes when the surface is a kind of inclined plane, and it definitely changes when the object is moving in a circular path. So, when it is on a plane surface or a stable surface, the static friction can be expressed mathematically as $F_s = \mu_s mg$, where mu is the coefficient of friction as talked about earlier, and mg is nothing but the weight of that particular object. While on the inclined plane, the static friction depends on the angle of inclination.

As the angle increases, the friction basically decreases, and if the angle is less, you can see the static friction is more. In the circular path, it depends on the coefficient of friction, which depends on $\mu_s = v^2/gR$, where v square is nothing but the velocity of the motion, and g is the gravitational constant. In circular motion, the coefficient of friction depends on $\mu_s = v^2/gR$, where v square is nothing but the square of the velocity of the object which is moving, g is the gravitational force, and r is nothing but the radius at which the circular motion is taking place.

Fluid friction: it takes place when a body moves in air or water. Skiing, cycling, athletics. These are the events which are greatly affected by fluid friction. There are many examples of fluid friction in daily life. Here are some of them: a person swimming in water, a plane flying through air, the flow of honey when it spreads over bread, the flow of water when it is sucked through a straw, the motion of coffee when it is stirred, and a ship sailing on water. Remember one thing: fluid means the medium which allows anything to flow. So, it could be water as well as air. These are the factors which affect fluid friction. The first one is viscosity.

The fluid with higher viscosity offers more resistance than the one with lower viscosity. As the temperature increases, the viscosity of liquids decreases whereas the viscosity of gases increases. With increasing pressure, the viscosity of liquids increases except water, and the viscosity of gas is unaffected. And viscosity ultimately affects friction.

Laws of fluid friction:

There are some laws like and it is different for different fluids, independent of the load and pressure. It reduces with the increase in temperature. It depends on the velocity of the flow and is proportional to the surface area of contact.

The third one is **kinetic friction**:

When an object moves over a surface experiences resistance to its motion. This resistance is known as kinetic friction. Also known as dynamic friction, the frictional force is in the direction opposite to the object's motion. Kinetic friction occurs when two surfaces are in relative motion to each other. It takes place at the point of contact between the two surfaces, and the kinetic energy gets converted into heat.

Kinetic friction can be of two types: The sliding friction and the rolling friction.

Sliding friction is the type of friction where the object slides over the surface. In this type of friction, the object slides over the surface. For example, a vehicle skidding on the road after applying brakes. An ice skater or a skier coming to a stop. A box being pushed on a floor. The generation of heat due to the rubbing of hands.

Rolling friction - In this type of friction, the object rolls over the surface. For example, a soccer ball coming to a stop after being kicked. A golf ball coming to a stop after rolling over the greens. A roller skater coming to a stop and a roller coaster slowing down before coming to a stop. So, like other types of friction, kinetic friction is also governed by certain laws, such as acting in the direction opposite to the object's motion and being proportional to the normal force. It is independent of the area of contact between the surfaces and is independent of the sliding speed as long as the speed is not too high.

Athletes and coaches often try to optimize friction for their specific sports and situations. This can involve choosing the right equipment, as different shoes, tires, or other equipment can have different levels of friction. Modifying the surfaces. The condition of the playing surface can affect friction. So, groundkeepers may adjust the moisture level or grooming of the surface.

Using the technique that reduces friction, Swimmers, for example, try to minimize their body surface area in contact with the water to reduce drag. In order to remove the confusion between friction and gravity, this table could help you out.

[So, we can see in the table that the gravitational force is basically between two objects with masses or between the Earth and that particular object. On the other hand, the frictional force is between two surfaces in relative motion].

The gravitational force always acts along the line joining the two bodies. On the other hand, the frictional force always acts against the direction of motion. The gravitational force cannot be increased or decreased. On the other hand, the frictional force can be increased or decreased. And both of them depend on the mass. They depend on the weight as well.

The **gravitational force** is a non-contact force. On the other hand, the frictional force is a contact force. Gravitational force is generally a weaker force. On the other hand, the frictional force is a bit stronger force.

There are different ways to express them mathematically. The other type of force which we are talking about in this particular section is **centripetal and centrifugal** forces. The centripetal and centrifugal forces play a significant role in many sports, particularly those involving curves, spin, or circular motion.

Centripetal force, in particular, is the force which is directed towards the center, while centrifugal force is the apparent force and is directed outwards. Speaking separately, the centripetal force is the force that keeps an object moving in a curved path rather than flying off in a straight line. It acts inward towards the center of the circular motion. It is often provided by friction, tension, or muscular forces. It is at a right angle to the object's motion and causes the object to change its direction. Here are a few examples, applications, and uses of centripetal forces in everyday life. The force experienced by a car when it makes a turn on a circular road.

The Earth's gravitational force keeps satellites in orbit and causes centripetal motion. The Earth's gravity is responsible for keeping objects on the surface. The tension force on a string swirling a bucket of water and the force experienced by a roller coaster in an amusement park when going around a loop.

In sports, when a cyclist or a runner takes a turn, the friction between the tires or the shoes and the ground provides the necessary centripetal force to prevent slipping outward.

The skaters lean into the turns to create centripetal forces that counteract the tendency to move in a straight line. The cars rely on their tire grip and banking on the track to generate centripetal force and stay on the curve. A gymnast swinging on a high bar uses grip force and muscular tension to provide centripetal force, keeping their body in motion around the bar. The centripetal force can be measured using the concept of mass and inertia. The object moves in a circle of constant radius.

The centripetal force is always directed towards the center. The centripetal force can be measured by using the concept of mass and inertia. You can see here the centripetal force can be expressed as $F_c = MV^2/R$. Where m is the mass of an object, v square is the velocity with which the object is moving, and r is the radius of the circle. The object moves in a circle of constant radius.

The centripetal force is always directed towards the center. In this case, the force and the displacement vectors are at a right angle. Therefore, the work done by the centripetal force is zero. Now let us talk about the centrifugal force. The centrifugal force is an apparent force experienced by an object going around a curve or circular path.

[Let us talk about the second part, which is the **centrifugal force**].

Centrifugal force is an apparent force experienced by an object moving around a curve or circular path. It is an outward force felt by the object in its frame of reference and directed away from the center of curvature. It is opposite to the centripetal force. This is a pseudo force experienced in a rotating frame of reference.

It appears to push an object outward due to inertia, but it is not a real force acting on the object. In reality, an object wants to continue in a straight line due to Newton's first law, which is inertia, and the centripetal force prevents this. Here are some examples of centrifugal force in real life. When the wheels of a vehicle rotate on a dirty, wet road, they scatter mud around them due to the centrifugal force. A bucket of water rotating in a vertical plane does not spill water because it is pinned to the bottom by centrifugal force. I am very sure that everyone of us must have tried this experiment at home. The children sitting on a merry-go-round experience an outward pull as it rotates about its vertical axis. Have a look at certain examples in sports. So, the athlete feels a strong outward force while spinning before release, which is the apparent centrifugal force due to their own inertia.

So, in motorcycle racing, when taking a sharp turn, riders lean into the curve to counteract the outward tendency. During a high-speed turn in skiing, the skier must balance the outward force with body position to maintain control. So, in the case of a roller coaster in a loop and banked curve, the rider feels an outward force. This is actually the reaction to the centripetal acceleration keeping them on the path. [So, to avoid confusion between centripetal and centrifugal force, this table would definitely help you out].

There are some differences between centripetal and centrifugal forces. The centripetal force is directed towards the center of the curvature of the curved path. In contrast, the centrifugal force is directed away from the center. The centripetal force is real to an observer in an inertial frame of reference, whereas the centrifugal force is virtual.

Also known as the pseudo force, the centrifugal force is observed by an observer in a non-inertial frame, i.e. the stationary frame. In order to balance these two forces, athletes constantly manage centripetal and centrifugal forces by doing various adjustments like body position, obviously by leaning into the turn, adjusting angles, by adjusting the grip and the friction, like the shoes, tires, surface, etc., by adjusting the speed and the angular momentum, by slowing down the speed, and by adjusting the speed and the angular momentum. They slow down the speed, reducing the required centripetal force. Thank you.

[See you in the next video].