The Physics of Ice Skating:

History, Motion, Momentum, and More

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Abstract

This paper investigates the physics that allow the motions and moves of figure skating to exist. Starting with its origin in Finland the paper explores how ice skating change from a form of transportation to an artistic sport. It covers the main principles that allow skating including friction and inertia. It then covers the more advanced topics that allow what is now considered as figure skating. Angular momentum and projectile motion allow throws and spins. When you understand conservation of momentum you can work to maximize your number of spins and your velocity. This paper will explain how figure skating is possible through multiple physical principles. Without understanding the principles of physics it can be difficult to fully understand and appreciate the beautiful moves in skating. Information from this paper comes from multiple sources that can be found in the works cited page.

The Physics of Ice Skating

From its humble origins in southern Finland over three thousand years ago, ice skating has revolutionized how people spend their leisure time. Ice skating is a sport where people wear skates with metal blades that allow them to glide over ice. It is a riveting pastime that can be explained by the concepts of physics.

Forces and friction are responsible for creating the motion of skating. A skater propels himself forward by pushing off the ice with a force perpendicular to the skate blade. Since the friction of the blade with the ice is almost zero, this is the only way he can propel himself forward. Friction is the force that resists when two objects slide against each other, lessening their energy of motion. Friction arises because the molecules on both surfaces bond with each other, and resist when the surfaces try to move away and break the bonds. The more rough and jagged something is, the more easily more of its molecules will come into contact with molecules on the surface it touches, which causes a greater force of friction. Due to the smoothness of ice there is minimal friction. This allows the gliding motion of skating.

The need for a small coefficient of friction is why skate blades are thin. The reduced surface area creates less friction which allows a skater to glide on ice. The weak friction allow explains why figure skates have toe picks on their blades. Toe picks are jagged teeth near the toes on blades. They used to pushing off the ice to make jumps. In order to reach the force needed to launch into the air one must be able to push off the ice; however, you need friction for the foot to grip to reach this force. The toe picks have a high coefficient of friction are vital for jumping.

Newton's third law explains the ability to move on ice. This law states that every action has an equal and opposite reaction. When skating there a two forces. One force is the force a skater exerts down and behind into the ground by digging their skate in the ice; the other force is the equal and opposite force of the ground “pushing back” at the skater. This force back is up and forward which propels a skater forward.

The law of inertia explains why people glide when they skate. The law of inertia states that an object in motion will stay in motion unless it is acted upon by an outside force. Similarly, an object at rest with stay at rest unless acted upon by an outside force. Gliding is when a skater can maintain velocity without moving and exerting a force on the ice. Due to the smoothness of ice, friction is very weak. While skating friction is the main outside force that stops one’s motion. When pairing a weak the outside force of friction with Newton’s first law the phenomenon of gliding on ice makes sense. The reason why we stop moving when we stop pushing on the ground but glide on ice is the strength of outside forces, particularly friction. However friction still exists on ice and though it takes a while to slow down, you will eventually stop gliding.

The principles of center of mass explain how a skater stays balanced while skating. Center of mass is the point where mass is equally distributed, this means that if a force was applied to the point the object would move without rotating. The mass is also balanced around this point. In order for a figure skater to maintain balance they must keep their center of mass above their feet, or their base of support. This explains that why figure skaters keep their feet underneath them when skating and jumping.

When skaters perform jump or throws they become a projectile and follow the rules of projectile motion. In projectile motion the projectile follows the path of a parabola. The horizontal and vertical velocity are independent of each other. The horizontal velocity is constant while the vertical velocity changes due to gravity. These principles explain how figure skaters can complete throws and catches. This occurs when a skater tosses their partner into the air for a spin and then catches them. If horizontal velocity was not constant during projectile motion, the skater would be unable to skate alongside and catch their partner. Even though one is in air and the other is skating, due to projectile motion they have the same horizontal velocity and are able to move as one.

Angular momentum allows figure skaters to spin on the ice. Angular momentum is an object's resistance to change in rotational momentum. Angular momentum follows similar principles of linear momentum like how objects in motion tend to stay in motion unless acted upon by a force. Additionally, angular momentum is conserved if no forces act upon. Due to the fact there is minimal friction angular momentum is conserved when skating. The conservation of angular momentum allows figure skaters to spin quickly. Angular momentum is represented by the formula $L = mvr$. Angular momentum is first generated by skating on a curve. Next to begin spinning the skaters brings her in arms to decrease her radius. Due to the fact momentum must be conserved velocity must increase to balance out the decreased radius, mass is constant and can never change.

Angular momentum can also be expressed as $L = I\omega$ where I is the moment of inertia and ω is angular velocity. Figure skaters aim to spin fast and use physics to help them. Due to the conservation of momentum, they aim to have a high moment of inertia and then decrease their inertia to increase their angular velocity, momentum is conserved and inertia and velocity are inversely related. Moment of inertia varies depending on the shape of the object. When a skater has their arms to the side they resemble a cylinder and $I = 1/2mv^2$. However, when they extend their arms parallel to their body their inertia is calculated by adding the formulas of a cylinder and a thin rod. This changes inertia to $I = 1/2mv^2 + 1/12ml^2$. This yield a higher number and ultimately more angular momentum. After they start to spin they can bring their arms to their side to lessen the inertia and increase the angular velocity.

In conclusion, the principles of physics are all around us and are responsible for the sport of figure skating. Without the small coefficient of friction skating and gliding would not be possible. Friction also dictates jumping. Projectile motion allows throws and angular momentum allows spins.

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