Inclined plane

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The **inclined plane** is one of the original six simple machines; as the name suggests, it is a flat surface whose endpoints are at different heights. By moving an object up an inclined plane rather than completely vertical, the amount of force required is reduced, at the expense of increasing the distance the object must travel. The mechanical advantage of an inclined plane is the ratio of the length of the sloped surface to the height it spans; this may also be expressed as the cosecant of the angle between the plane and the horizontal. Note that due to the conservation of energy, the same amount of mechanical energy is required to lift a given object by a given distance, except for losses from friction, but the inclined plane allows the same work to be done with a smaller force exerted over a greater distance.

Inclined plane

Roman soldiers constructed an inclined plane out of earth to lay siege to the Masada during the First Jewish-Roman War in 73 CE.

Classification	Simple machine
Industry	Construction

Contents

Ramps, chutes and slides

An inclined plane is a simple machine that does not move. Many devices based on the principles of the inclined plane allow expending less force to achieve a task. Ramps enable accessing heights that would be too difficult to scale vertically. Ramps allow heavy objects to ascend to, and descend safely from, a high-level bridge. Portable ramps allow easy loading and unloading of high-decked trucks. Siege ramps gave ancient armies the ability to walk up bringing heavy equipment to the tops of high walls. Chutes and slides allow fragile objects, including humans, to be safely lowered from a vertical rise by countering gravitational force with the normal force provided by a stiff surface at an angle to the gravitational vector. Airplane rescue slides allow people to quickly reach the ground safely, without the danger of jumping from a height. The addition of the normal force and gravity vectors causes the sliding object to move parallel to surface of the slide, so a slide can be used to move objects through a distribution system from one area to another. Hoppers and funnels are formed by planes shaped into an inverted pyramid or cone shape to concentrate granular or fluid material at the apex.

Eliminating friction from a slide increases the maximum speed at which an object can move down the slide, while the acceleration of the moving object can be controlled to any degree by varying the angle of the slide. Because of this, slides are one of the most common and popular forms of entertainment. A well-polished slide can allow a human to move at a high speed with no effort, even experience near free-fall acceleration, yet arrive on the ground safely because the angle of slide can be varied along its length to end up parallel to the ground, so the forward motion of the slider can be slowly arrested by friction. The metal slide is a popular piece of playground equipment, and towering water slides employ liquid lubrication to reduce friction even further. Wheeled cars of rollercoasters roll down inclined tracks to achieve high speeds. In the sports of luge, bobsled, sledding, and skiing, participants accelerate to extremely high speeds utilizing only the inclined plane, whether a mountain slope provided by nature, or a chute lined with near-frictionless ice. Mountains are another example of an inclined plane.

Blades, wedges, and foils

The blade is a compound inclined plane, consisting of two inclined planes placed so that the planes meet at one edge. The edge where the two planes meet is pushed into a solid or fluid substance and overcomes the resistance of materials to separate by transferring the force exerted against the material into two opposing forces normal to the faces of the blade. First known to be used by humans in the knife to separate animal tissue, the blade allowed humans to separate meat, fibers, and other plant and animal materials, with much less force than it would take to tear them by simply pulling them apart. Blades can separate solid material, as with plows that separate soil particles, scissors and shears to cut flexible materials, axes to separate wood fibers, and chisels and planes to remove precise portions of wood.

Wedges, saws and chisels can separate thick and hard materials, such as wood, including solid stone and hard metals, with much less force, less waste of material, and more precision, than crushing. Saws have many chisel-like "teeth" along their cutting surface to transfer linear or circular motion to counteract the normal force of the surface to be cut. Crushing, the overcoming of material bonds by transferring momentum to a material through the normal force of another, harder, object was the only way to cut through a hard material before saws, and the materials to make them, were developed.

Drills produce circular holes in solids by rotating a chisel around its center, with the edge is sharpened at opposing angles on either side of the rotation axis, so as to cut in the direction of rotation. Twist drills provide one or more heliacally twisted chisels formed out of grooves cut along the side of the bit, to help evacuate cuttings from the drill hole, by using the same inclined plane principle as the archimedean screw. The water screw, though most likely preexisting Archimedes, has been used since ancient times to pump water, and is now also used to move granulated and ground materials, such as wheat, coal, and meat. Screws also join pieces of wood or metal together, by using a helical plane, usually formed by cutting a helical groove into a rod, so that the rod can force itself into the material when it is rotated.

The ancient water wheel uses inclined planes mounted around a rotating wheel to transform the momentum of moving water into a torque that can turn a shaft and do work. Sails extract the momentum of moving air to drive a vehicle, and windmills extend the principle to move a balanced set of sails around a shaft to perform work. Although known for thousands of years, these devices for extracting work from a moving fluid were always limited in efficiency by the drag-inducing vortices caused when a fluid is separated. Foils are specialized blades, shaped to allow the most efficient movement of fluid over their surfaces, to minimize the turbulence caused by these vortices. Rotating vortices dissipate the momentum of the fluid as heat, reducing the amount of energy available to do useful work.

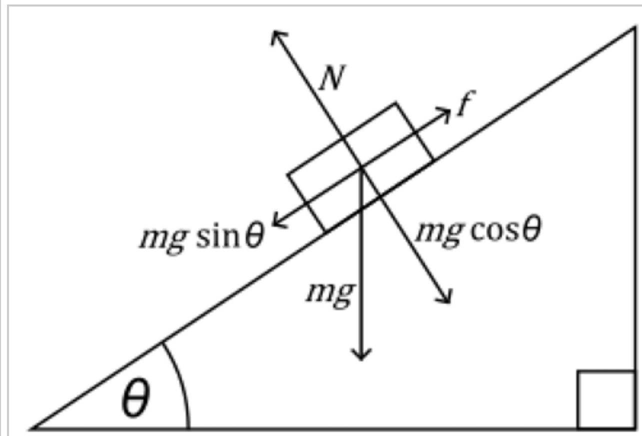
Foils have many different designs, depending on the viscosity, velocity, and pressure of the fluid they will operate in, and their intended purpose. Aircraft wings and helicopter rotors counteract gravity by redirecting momentum generated from lateral movement, as with fixed-wing aircraft, or from rotating airfoils around a shaft, as with helicopters, so that separated air flows over the top of the foil faster than it flows over the bottom. This difference in velocity causes the pressure to decrease on the top surface, generating a lifting force, through what is known as Bernoulli's Principle. The resulting decrease in pressure across the upper surface provides up to 65% of the lift of the airfoil. The same principle in reverse allows an automotive spoiler to keep a car firmly in contact with the road.

Airplane and marine propellers use the same principle to drive vehicles though a fluid along the direction of the torque applied to the propeller shaft. Nautical propellers are often called screws. Rotating impeller blades increase the pressure difference between the inlet and outlet of a pump to force fluids through pipes. Turbines capture momentum from fast-moving fluid at high efficiency to a torque vector along the direction of the turbine's axis of rotation, while compressors use rotational motion to increase the pressure in a fast-moving fluid. Rotary fans move air, and can harness the reaction force of the moving air to drive a limo. .

Calculation of forces acting on an object on an inclined plane

To calculate the forces on an object placed on an inclined plane, consider the three forces acting on it.

1. The normal force (*N*) exerted on the body by the plane due to the force of gravity i.e. mg cos θ
2. the force due to gravity (*mg*, acting vertically downwards) and
3. the frictional force (*f*) acting parallel to the plane.



Key:
N = Normal force that is perpendicular to the plane
m = Mass of object
g = Acceleration due to gravity
θ (theta) = Angle of elevation of the plane, measured from the horizontal
f = frictional force of the inclined plane

We can decompose the gravitational force into two vectors, one perpendicular to the plane and one parallel to the plane. Since there is no movement perpendicular to the plane, the component of the gravitational force in this direction ($mg \cos \theta$) must be equal and opposite to normal force exerted by the plane, *N*. If the remaining component of the gravitational force parallel to the surface ($mg \sin \theta$) is greater than the static frictional force f_s – then the body will slide down the inclined plane with acceleration ($g \sin \theta - f_k/m$), where f_k is the kinetic friction force – otherwise it will remain stationary.

When the slope angle (θ) is zero, $\sin \theta$ is also zero so the body does not move.

The MA or Mechanical advantage(ratio of load to effort) of the inclined plane equals to length of the plane over the height of the plane, in an ideal case where efficiency is 100%.

See also

- Frictionless plane
- grade (slope)

External links

- An interactive simulation of Physics inclined plane (http://www.phy.hk/wiki/englishhtm/Incline.htm)

Categories: Simple machines