Forces

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Changes in acceleration require a force. All influences on a particle from its surroundings are forces exerted on the particle. There are four fundamental forces.

Four fundamental forces

Type	Attribute	Strength	Range	Gauge Particle	Propagation Speed
gravity	mass	1	∞	graviton	c
weak	weak charge	10^{25}	10^{-18}	vector bosons	varies
electromagnetic	charge	10^{36}	∞	photon	c
strong color	color charge	10^{38}	10^{-15}	gluon	c

Gravity

Gravity is a attractive long range force between any two objects with mass. Weight is the force of gravity exerted on a particle. Note that weight is the same as mass.

$$\vec{F_g} = -\frac{GMm}{r^2}$$
$$|\vec{F_g}| = mg$$

Electromagnetism

Electromagnetic forces are responsible for the structure of atoms and molecules, chemical and biological processes, repulsion between objects in contact, and light. The repulsion is what causes objects to not intersect when they collide.

$$\vec{F_E} = \frac{kQq}{r^2}$$
$$\vec{F_B} = q\vec{v} \times \vec{B}$$

Types of Forces

Normal

Normal forces are always perpendicular to the contact surface. The normal force is a passive force which means that it gets as big as it needs to be to hold a object in place. We have to calculate it based off the situation a object is in. A normal force is a type of electromagnetic force because it is caused by the interaction between atom.

Friction

Friction acts when a object is in contact and in motion. It opposes the direction of motion and is parallel to the contact surface. There exists two kinds: kinetic friction and static friction

Static motion is friction that happens when there is no relative motion. Static friction prevents sliding. There is a maximum static friction and the static friction force will be as big as it needs to be while under the maximum static friction to prevent the object from moving relative to the surface. Kinetic friction happens when an object is moving.

$$\begin{aligned} f_{s,max} &= \mu_s N \\ f_s &\leq \mu_s N \\ f_k &= \mu_k N \end{aligned}$$

Coefficient of friction is a approximation of friction depending on smoothness and temperature. Usually static friction is greater than kinetic friction.

Spring

The spring force is a restoring force that depends on how much a spring is stretched or compressed from its natural length.

$$F_s = -kd$$

Tension

Tension is a pulling force that points away from the object. An ideal rope has the same tension across the entire rope and ideal pulleys change the direction of the tension but not the magnitude. In the real world, none of these exists so the tension on a rope will be non-uniform and a pulley will change the magnitude of the tension.

When a pulley is stationary, the tension will only change directions, but if the pulley can be moved, there will be two tension forces acting on the pulley.

Drag

Drag or air resistance of a object in a fluid is the friction between an object and the fluid.

Buoyancy

Buoyant forces is a upward force equal to the mass of the displaced fluid.

Free Body Diagrams

For free body diagrams, we pick one single objects and identify all external forces which act directly on that body. Then we set up a coordinate system and draw the object as either a rough sketch or a point at the center of mass. Every force is drawn as vector starting at the object and in the direction of the force. The direction of acceleration should be indicated but not as a vector on the body because it is not a force.

Passive Forces

A passive force can only be calculated as a response to other forces. They will depend on the load it has to support and the acceleration they have to provide. They are often limited.

Equilibrium

A system whose motion or state is not changing is said to be in equilibrium. A object at rest or moving at a constant velocity is said to be in translational equilibrium. When objects are in equilibrium, the sum of all forces is zero.

Tips for forces problems

- identify known and unknowns
- draw free body diagrams for each objects
- relate forces in action reaction pairs
- analyze constraints of motion.
- use Newton's second law
- determine if there are any free variables