PHY 107
Force and Motion 1

Mohammad Murshed
Department of Math and Physics

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OUTLINE

- Force in Newtonian mechanics
- Newton's First Law and Inertial Frame
- Newton's Second Law
- Some particular forces
- Newton's Third Law
- Application/Examples

Force in Newtonian Mechanics

What can cause an object to accelerate?
Force (a push or a pull on the object)
Force will change the velocity of that object.

Newton's First Law and Inertial Frame

If no net force acts on a body ($\overrightarrow{F_{net}} = 0$), the body's velocity cannot change, the body can't accelerate.

There may be multiple forces acting on a body, but if their net force is zero, the body can't accelerate

Inertial Frame: One in which Newton's Laws hold e.g. ground is an inertial frame provided we can ignore Earth's astronomical motions (such as its rotation)

Puck sliding:

Earth's rotation causes an apparent deflection.

(a) (b)
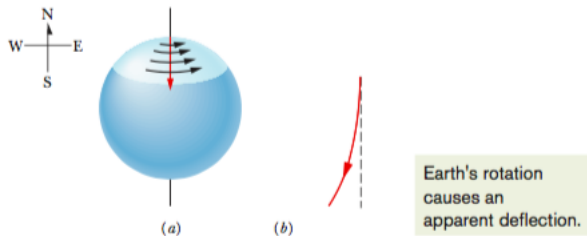
Newton's Second Law

The net force on a body is equal to the product of the body's mass and acceleration.

We draw a free-body diagram in which the only body shown is the one for which we are summing forces
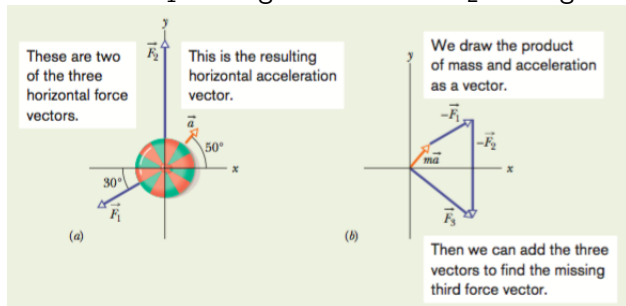
XYZ coordinate system:

$F_{net,x} = ma_x$, $F_{net,y} = ma_y$, $F_{net,z} = ma_z$

Internal force: Total mechanical energy (KE + PE) stays constant e.g. gravitational force, spring force

External forces are capable of changing the total mechanical energy of an object, they are sometimes referred to as nonconservative forces e.g. friction

Newton's Second Law

EXAMPLE A 2 kg cookie tin is accelerated at $3m/s^2$ in the direction shown by $\vec{a}$, over a frictionless horizontal surface. The acceleration is caused by three horizontal forces, only two of which are shown: $\vec{F_1}$ of magnitude 10 and $\vec{F_2}$ of magnitude 20 N.

These are two of the three horizontal force vectors.

This is the resulting horizontal acceleration vector.

We draw the product of mass and acceleration as a vector.

Then we can add the three vectors to find the missing third force vector.

(a)

(b)

Newton's Second Law

$\overrightarrow{F_{net}} = m\overrightarrow{a}$

$\overrightarrow{F_1} + \overrightarrow{F_2} + \overrightarrow{F_3} = m\overrightarrow{a}$

x components:

$\overrightarrow{F_{3,x}} = m\overrightarrow{a_x} - \overrightarrow{F_{1,x}} - \overrightarrow{F_{2,x}}$

$= ma\cos(50) - F_1\cos(-150) - F_2\cos(90)$

y components:

$\overrightarrow{F_{3,y}} = m\overrightarrow{a_y} - \overrightarrow{F_{1,y}} - \overrightarrow{F_{2,y}}$

$= ma\sin(50) - F_1\sin(-150) - F_2\sin(90)$

$\overrightarrow{F_3} = 13\hat{i} - 10\hat{j}$

Some particular forces

Normal Force: When a body presses against a surface, the surface (even a seemingly rigid one) deforms and pushes on the body with a normal force F_N that is perpendicular to the surface.

The normal force is the force on the block from the supporting table.

The gravitational force on the block is due to Earth's downward pull.

Normal force $\vec{F}_N$

Block

$\vec{F}_N$ — Block

$\vec{F}_g$

$\vec{F}_N$

$\vec{F}_g$

The forces balance.

(a)

(b)
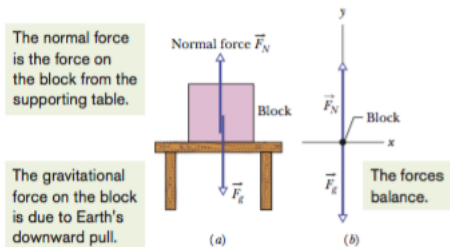
Friction: Motion resisted by a bonding between the body and the surface

Some particular forces

Tension

The forces at the two ends of the cord are equal in magnitude.
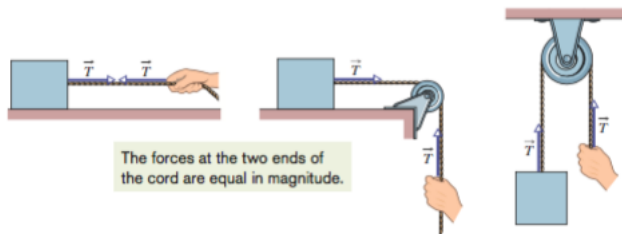
Cord is massless and unstretchable
Massless, frictionless pulley: If the cord wraps halfway around a pulley, the net force on the pulley from the cord has the magnitude 2T.

Newton's Third Law

LAW: When two bodies interact, the forces on the bodies from each other are always equal in magnitude and opposite in direction.
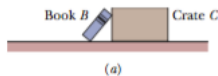
The book and crate are stationary, but the third law would still hold if they were moving and even if they were accelerating.

Application/Examples

Cord accelerates block up a ramp A cord pulls on a box of sea biscuits up along a frictionless plane inclined at $\theta = 30$. The box has mass $m = 5$ kg, and the force from the cord has magnitude $T = 25$ N. What is the box's acceleration component a along the inclined plane?
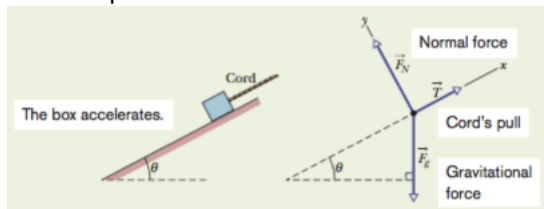
Apply Newton's second law: $\overrightarrow{F_{net}} = m\overrightarrow{a}$

$T - mgsin(\theta) = ma$

Application/Examples

Atwood's Machine Two blocks are connected by a cord (of negligible mass) that passes over a frictionless pulley (also of negligible mass). The arrangement is known as Atwood's machine. One block has mass $m_1 = 1.3$ kg; the other has mass $m_2 = 2.8$ kg .Find (a) the magnitude of the block's acceleration and (b) the tension in the cord
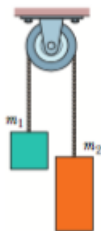
Draw FBD: $m_2g - T = m_2a$

$T - m_1g = m_1a$

Reference

Fundamentals of Physics by Halliday and Resnik