Force

Action that an object does that causes another object to change its velocity, state, size, shape, direction

Forces are **Invisible**, but we see their **effects**

Commented [SD1]: Moon orbit earth, things fall, you move

We measure forces with **Newtons (N)** according to the **SI system**

Newton

The amount of force exerted on an object with a mass of **1kg**, that produces an acceleration of **1m/s^2**

That means, when you push an object **(force)** that weighs the same as a standard kilogram, you will give that object an acceleration of a

TYPES OF FORCES

- **APPLIED FORCE (F_{app})**

When you push something, you **apply force to that object**

- **GRAVITATIONAL FORCE ($F_{grav} = mg$)**

When you are somewhere above the earth and you go down, there is a gravitational force applied to you

It can be calculated through **Fg = mass x gravitational acceleration** which equals 9.81 m/s^2 for earth

Of course, we know acceleration is a vector quantity, which means that you are not going on the x or y axis but going in a vector (xΔ, yΔ) so that equation gets you the **magnitude** of the gravitational force acting on you, which is called **weight**

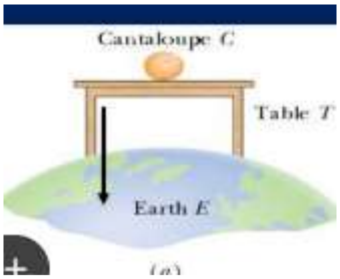
so your **weight** will be different depending on the gravity

so if you weighed 6 newtons on Earth, you would weigh 1 newton on the moon because it has 1/6 the gravitational acceleration

so, if you want to get the weight you multiply your mass by the gravity

and if you want your mass, you divide your weight by gravity

the direction of gravity force is vertically downwards



- **NORMAL FORCE (F_{norm} = N)**

When you are standing on something that makes you not fall, that support force between the two bodies in contact is called **normal force**

This is the force that thing exerts on you to keep you from falling through

The direction of the normal force is Always perpendicular to the thing supporting you

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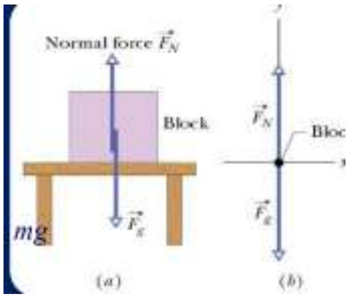


$N - F_g = ma_y$

This equation represents Newton's second law, **force = mass x acceleration**

It's saying that the difference between the normal force that's pushing against the gravitational force equals the mass of the object times its acceleration

Newton's 2nd law states that the acceleration of an object has a positive correlation with the total force **(aka sum of all forces, in our case it's the normal force + gravitational force on the opposite side making it a minus)** and it has a negative correlation with the mass of the object

So when you're pushing harder, the force increases, the acceleration increases

But if the thing gets heavier, the acceleration decreases

$N - M_g = ma_y$

It is saying the same thing as the first one but instead of the difference between normal force and **gravitational force**, it is now **weight** represented as **M_g** or **gravitational mass**

$N = m_g$

It represents a special case of Newton's first law of motion, which says when something is resting, it will tend to stay resting, and something in motion will tend to stay in motion unless an external force interferes

In our case, when an object is in equilibrium on a horizontal surface (not accelerating), the normal force and the weight are going to be the same, so the downward force of gravity and the upward force by the surface are in a state of equilibrium, so the net force is 0 and the object remains at rest

All these equations touch Newton's third law of motion

For every action, there is an opposite reaction

- FRICTION FORCE ($F_{frict} = F_f$)

When you are moving across a surface or trying to move across a surface, the surface exerts a force on you called **friction force**

The magnitude of the friction force equals that of the applied force

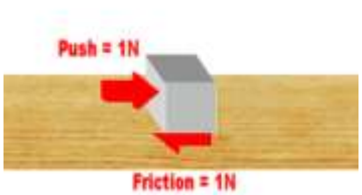
And it’s usually in the opposite direction to the applied force

- AIR RESISTANCE FORCE (F_{air})

When you are traveling through the air, air exerts a force on you, that force is a special type of friction force called **air resistance force**

It’s observed to be in the opposite direction and the force will usually be neglected due to its negligible magnitude (usually minimal)

But it will be most noticeable when an object is traveling at high speeds



- TENSION FORCE (F_{tens} = T)

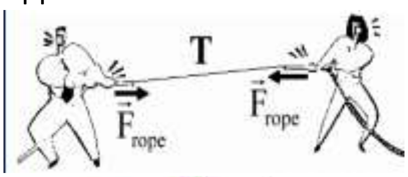
It’s the force that is transmitted through a flexible object like a rope, it happens when the rope is acted upon by 2 forces in opposite directions

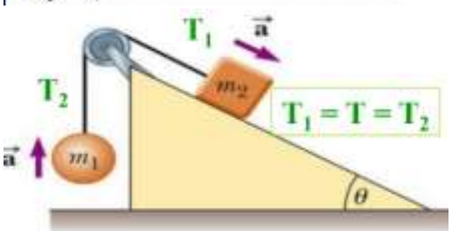
It is directed along the length of the wire and away from the object

$|F_{on\ A}| = T = |F_{on\ B}|$

We can say that the force that the tension is equal in all parts of the rope so the force that A feels is the force that B is exerting and vice versa

Working with newtons third law of motion “every action has an opposite reaction”





- SPRING FORCE ($F_{spring} = F_a$)

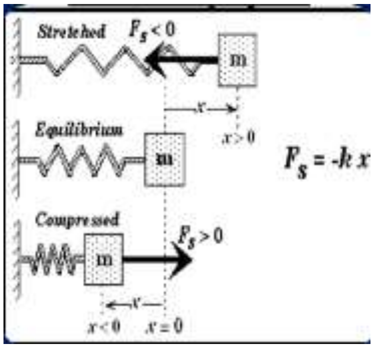
It’s the force that’s exerted by a compressed or a stretched spring upon any object attached to it
that force’s goal is to restore the object to its equilibrium state

Its maginitude is relative to the amount of stretch/compression on the string

It’s represented by **hooke’s law**
it states that **the force exerted by the spring** equals **the negative of the spring constant (k)** multiplied with the **displacement to the equilibrium position (x)**
so it states that

$\mathbf{F_{spring} = -kx}$

The spring constant is a measure of the stiffness of the spring, the higher it is, the more stiff the spring is, it's measured using **N/m** according to the **SI System**



As you can see, **there is no one force acting on an object**

For example, you are pushed off a plane and started gliding and you fell on a spring
there is an applied force, then the gravitational force started affecting you, then the air produced a force to slow you down, and then you fell on a spring and compressed it, making the spring exert a spring force on you

this is called a **force system**, a collection of forces acting at a specified location, it has many types

- Coplanar system **when the forces are in a plane (aka x, y)**
- Non-Coplanar system **where the forces are in 3D (aka x, y, z)**
- Parallel system **where they are parallel**
- Collinear system **where the line of action of all forces act along the same line**
- Concurrent system **when all forces pass or intersect through a single point called concurrency point**

- Non-Concurrent system **when forces do not intersect at a point, parallel forces are an example of this**

All these systems can combine with each other and we get

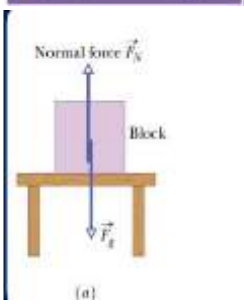
- Coplanar concurrent system **is a system where it's 2d and forces intersect in a point**
- Coplanar non-concurrent system **is a system where it's 2d and forces do not intersect in a point**
- Non-Coplanar concurrent system **is a system where it's 3d and forces intersect in a point**

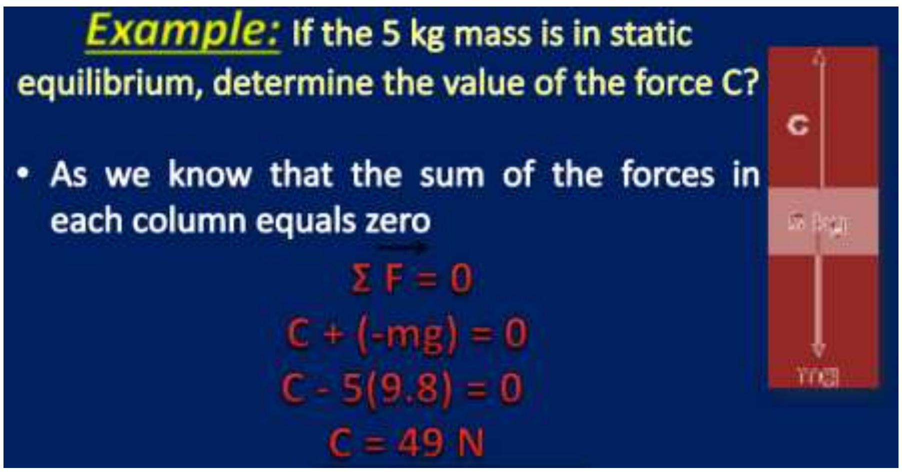
When **the forces** acting on a **resting** object, are **balanced**, then the object is in a state of **static equilibrium**

For example, when an object is resting on a table with a velocity of 0, that's because the gravitational force and the normal force are at balance, causing a **static equilibrium**, it's like a tug-of-war game where both teams aren't moving because they are on the same strength

We can conclude that the vector sum of forces equals 0

$$\sum \vec{F} = 0$$





Dynamic Equilibrium

Imagine moving in a void with no forces acting on your speed or direction (**uniform motion**), so dynamic equilibrium is when forces are balanced but you're not resting but moving at a constant speed in the same direction

So the forces acting on your motion are 0, but ur moving, how?

$$\sum \vec{F} = 0$$

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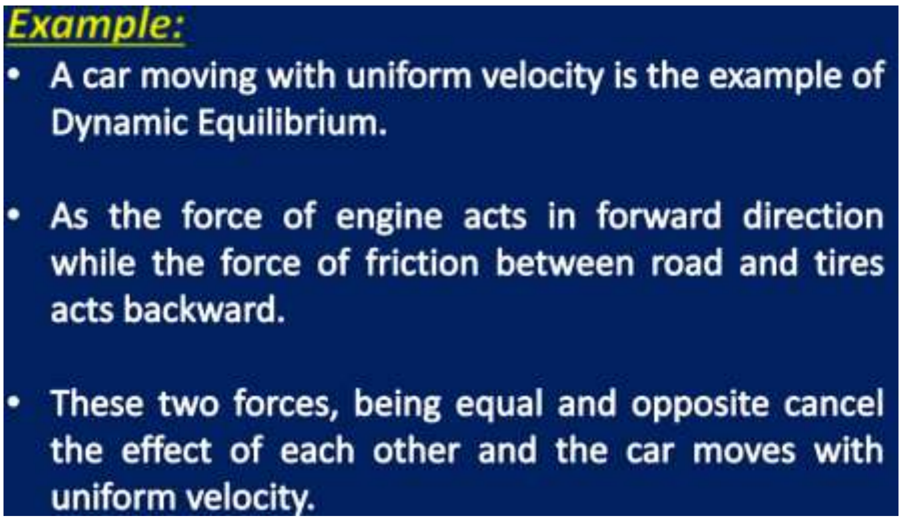
Well, according to newton’s first law, an object in motion will stay in motion and vice versa, as you can see in our example, no applied forces made you accelerate to movement, ur acceleration is 0 but ur just moving at a constant speed, just that

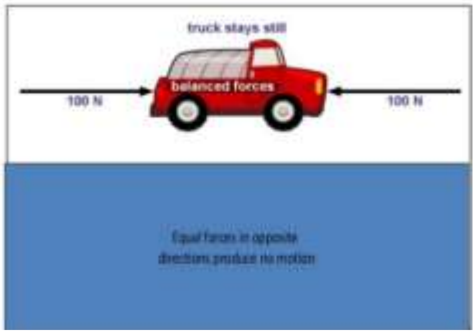
in these examples, there is uniform motion, same speed and same direction, but no acceleration because forces are balanced



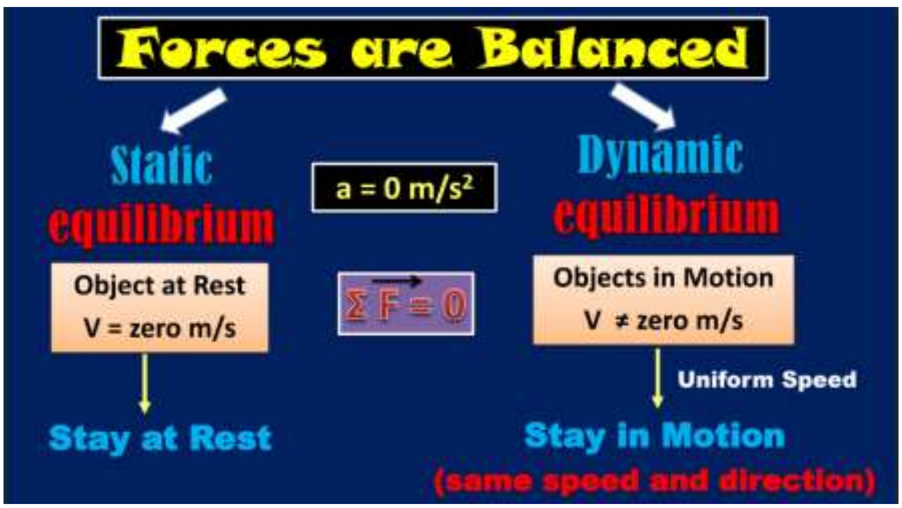
We have

Balanced forces

When forces are equal in size and direction, they cancel eachother

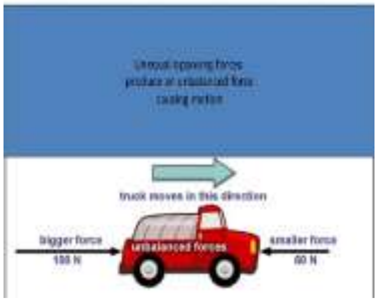


The object's acceleration will be 0, and it will not change its velocity/state



Unbalanced forces

When one force is greater than the other, it will cause the object to have an acceleration, so the velocity and direction or the motion state will change depending on the greater force



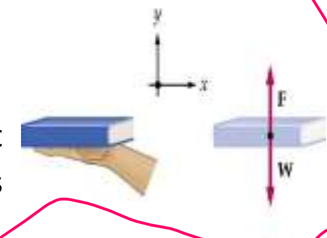
FORCE/FREE BODY DIAGRAMS

When we are designing structures and large stuff, we need to know if it's going to bend or crack or fall under forces

like air, gravity, etc
we use free body diagrams to see and visualize the forces acting on objects

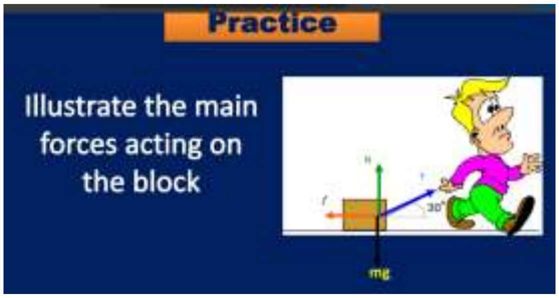
Free-body diagram is a diagram used to represent the relative magnitude and direction of all forces acting on an object in a given situation

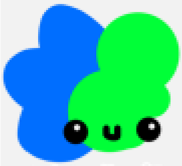
So here we have a book on some idiot's hand, the arrow direction represents the direction, the size represents the magnitude, so the book is being acted on by gravity and normal force



(a) Physical picture
(b) Free-body diagram

A point proticle is an idealized object that has mass but no extent in space, it's zero dimensional





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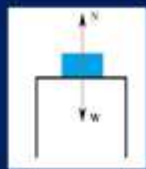
Exercises

Example 1 : A book on a table

There are two forces acting on a book at rest on a table:

1) The weight **W** exerted by the earth on the book
2) The normal force **N** exerted by the table on the book.



Example 2 : A suspended block

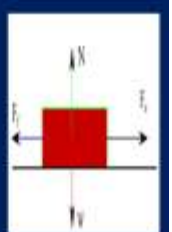
There are two forces acting on the suspended block at rest:

1) The weight **W** exerted by the earth on the block
2) The tension force **T** exerted by the string (or rope) on the block.

Example 3 : A block on a floor with an acting force F_a to pull the block

The block is being pulled and therefore a force of friction acts on the block.
So there are four forces acting on the block.

1) The weight **W** exerted by the earth on the block
2) The normal force **N** exerted by floor on the block.
3) The acting force F_a to pull the block.
4) The force of friction F_f exerted by floor on the block in the direction opposite the motion due to F_a



Example 4 : A falling object

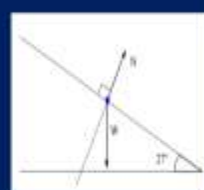
There is only one force action on the falling object.

1) The weight W exerted by the earth on the falling object

Example 5 : An box on an incline plane (with no frictions)

We assume that the inclined plane is frictionless; two forces act on the box:

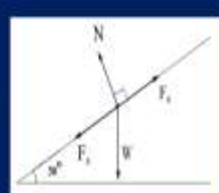
1) The weight W exerted by the earth on the box.
2) The normal force N exerted by the inclined plane on the box. N is normal to the inclined plane



Example 6 : An box on an incline plane with an acting force and friction considered.

A force F_a pulls the box upward and frictions are not negligible.
Four forces act on the box:

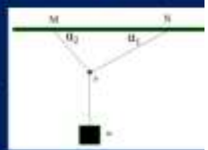
1) The weight W exerted by the earth on the box.
2) The normal force N exerted by the inclined plane on the box. N is normal to the inclined plane.
3) The acting force F_a.
4) The force of friction F_s exerted by the inclined plane on the box in the direction opposite the motion due to F_a.



Example 7 : A block suspended to the ceiling using three strings.

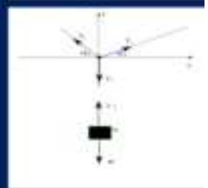
A) free body diagram for the block; two forces (lower part of figure below)

1) The weight **W** exerted by the earth on the box.
2) The tension force T'_3 exerted by the string on the block.



B) free body diagram of point P; three forces (upper part of figure below)

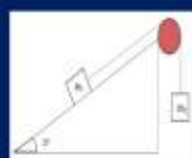
1) Tension T_1
2) Tension T_2
3) Tension T_3



Example 8 : An box on an incline plane with an acting force and friction considered.

A) free body diagram for block m_1 (left of figure below)

1) The weight W_1 exerted by the earth on the box.
2) The normal force **N**
3) The force of friction F_f
4) The tension force **T** exerted by the string on the block m_1.



B) free body diagram of block m_2 (right of figure below)

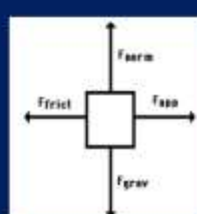
1) The weight of the block W_2
2) Tension **T '**.

Force pairs between objects are equal and opposite, even if objects are of different mass.

Example 9 : A rightward force is applied to a book in order to move it across a desk at constant velocity(a rightward acceleration).

The free-body diagram depicts four forces acting upon the object.

1) The weight **W** exerted by the earth on the box.
2) The normal force **N**
3) The force of friction F_f
4) The applied force



Netwon's third law

As we learnt in normal forces or tension forces

Every action has an opposite reaction with the same magnitude but opposite direction

For example, tension force is $|F_{on\ A}| = T = |F_{on\ B}|$
so the tension A is fealing is the same as B is feeling because netwon's third law

Action-reaction force pairs

When ever two object interact, they exert a force on each other, so according to newton's 3rd law, action-reaction force pairs are forces that are equal in size and opposite in direction

Aspects of a 'Newton's 3rd law pair of forces"

- The forces act on different bodies
- Same type (gravity = gravity , etc)
- Equal in magnitude
- Opposite in direction

Newtonian pairs are action-reaction pairs that follow newton's third law, for example

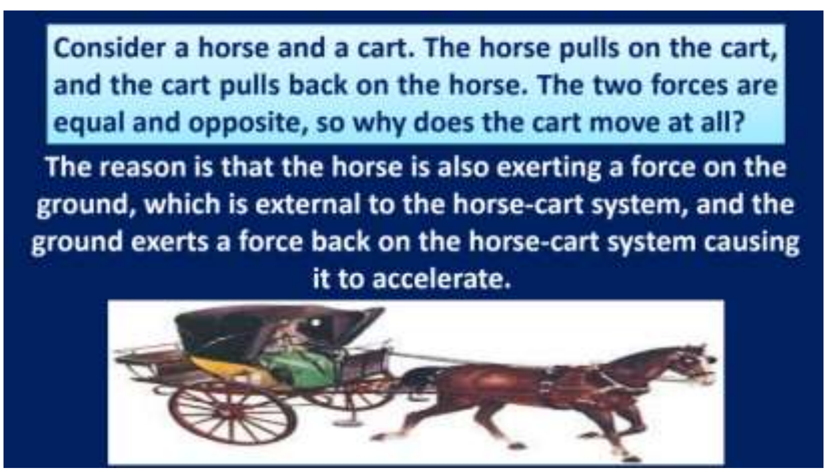
- The pull of the Earth on the book and the pull of the book on the Earth (gravitational forces)

- the push of the book on the table and the push of the table on the book (contact forces).

You would realize in newtonian pairs, if a force vanishes, the other one vanishes too

But if they are opposites, why don't they cancel each other? **Well**.

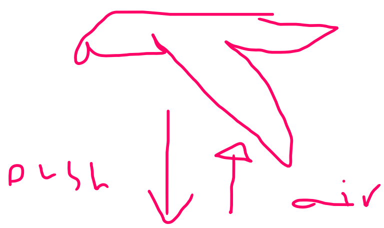
from this example, we can see that the two forces are equal, so the car should stop, but plus those pairs, there is a friction force

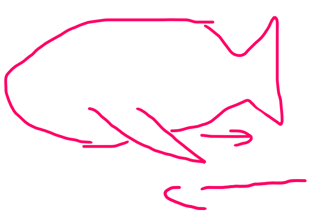


Other examples of Newton's 3rd law in nature

1. A fish uses its fins to push water backwards. But a push on the water will only serve to accelerate the water. Since forces result from mutual interactions, the water must also be pushing the fish forwards, propelling the fish through the water.

2. A bird flies by use of its wings. The wings of a bird push air downwards. Since forces result from mutual interactions, the air must also be pushing the bird upwards.





Imagine your dad telling you to drive the nail into a block , to accelerate the nail to drive into the block, the hammer would need to exert a net force on the nail

Newton's 3rd law says that as the nail gets an acceleration boost, the hammer itself is slowed down and stopped by the force it exereted

The applied force from the hammer on the nail got hit back with an applied force from the nail on the hammer