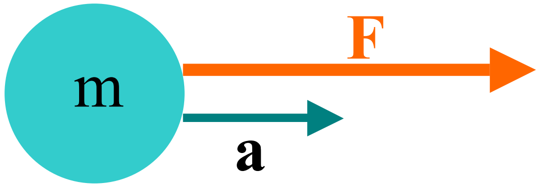
Recap.

- Newton's 1st and 2nd laws relate the net force to the resultant acceleration of an object.



$$\vec{a} = \frac{\vec{F}}{m}$$

- Weight and mass are not the same!
- Weight is a gravitational force exerted on a body of mass 'm' : $W = m \cdot g$
- Mass is an inherent property of a body related to its quantity of matter. Mass is also a measure of its resistance "inertia" to change in motion.
- The weight of an object may vary, depending on 'g' varying, but its mass is constant.

Weight

Example: A body of mass 100 kg on the moon weighs:

W = m . g = 100 x 9.8 / 6 = 163 N

(Compared with 980 N on Earth)

Note: In English (imperial) system, weight (W) is measured in **lbs** (pounds) – which is also a **force**.

1 lbs = 4.45 N so, W = 163 N = 36.6 lbs only!

A mass of 1 kg therefore weighs 9.8 N or 2.2 lbs near Earth's surface.

Newton's Laws Continued… Chapter 4

Questions:

- What is the origin of a force?
- How can we identify a force?
- What happens when a force arises?

Example: If we **push** on an object – how does it **react**? Does it push back? If so, how does the push back affect us?

Newton's 3rd law of motion helps us identify and quantify the **external forces** acting on an object (at rest or in motion).

Experiment: Pushing hands…

Results:

1. **In order to enable a force there has to be an interaction between two objects.**
2. **The interacting objects appears to push back on you!**
3. **The harder you push, the harder the push back!**

Newton's 3rd law

Embodies the idea that forces are caused by interactions of two (or more) objects – each exerts a force on the other…

Newton's 3rd Law:

In Newton's words: **"To every action there is always opposed an equal reaction."**

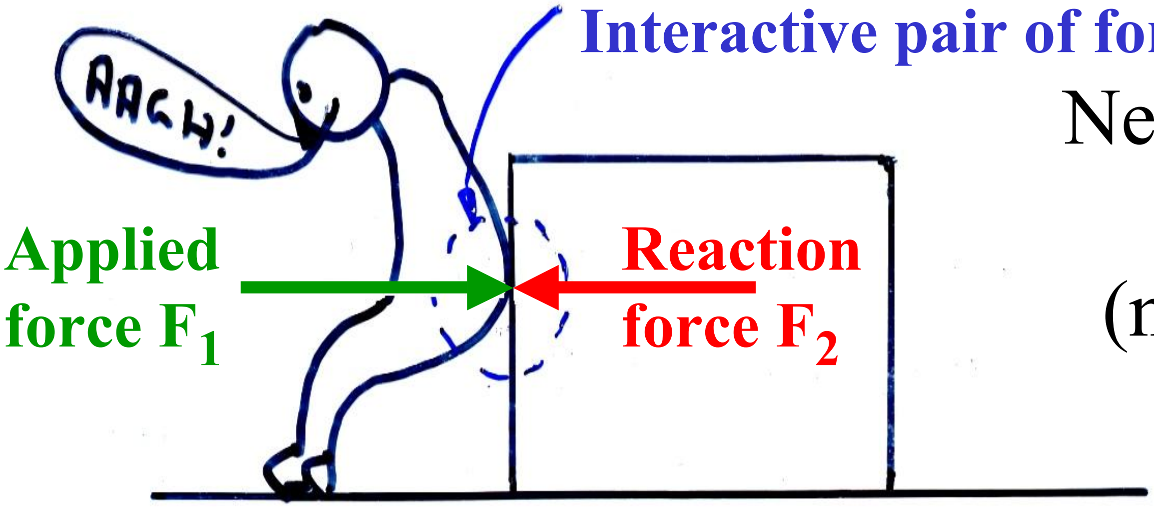
③ **The interaction of two bodies always occurs by way of a force and an equal–magnitude, oppositely directed counterforce (reaction).**

Or we could simply say:

"If an object 1 exerts a force 'F' on object 2, then object 2 will exert a counterforce '-F' on object 1."

- There is **no such thing as a single force**-there is only **interaction**!
- **Forces** always occur in **pairs** and are always **directed oppositely.**
- These **paired forces** always act on **two different objects** – never the same one.

Example 1: If you push a lab bench, the **applied force is on the bench**, but the **reaction force produced by the bench is on you**.



Newton's 3rd law states:

$$F_2 = -F_1$$

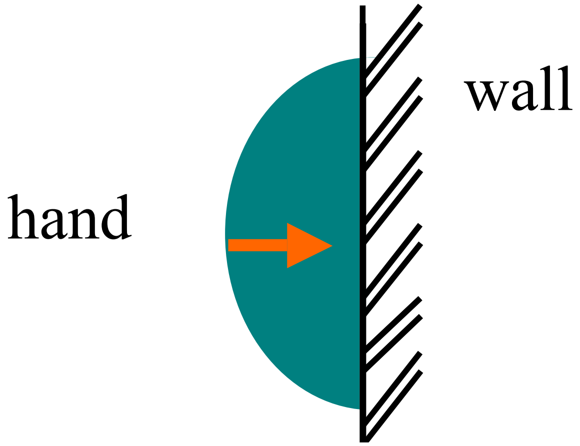
(negative sign denotes opposite direction)

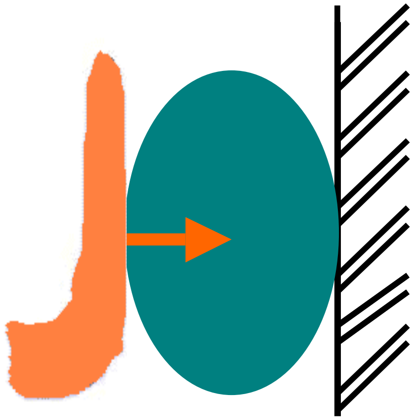
The force F1 that you apply will enable you to move the bench (if it is large enough to overcome friction).

The force F2 acts on you…and if you push too hard you may be pushed over (if reaction force exceeds friction of your feet on ground).

Example 2: (Two interacting force pairs)

What happens if we press a balloon against a wall?



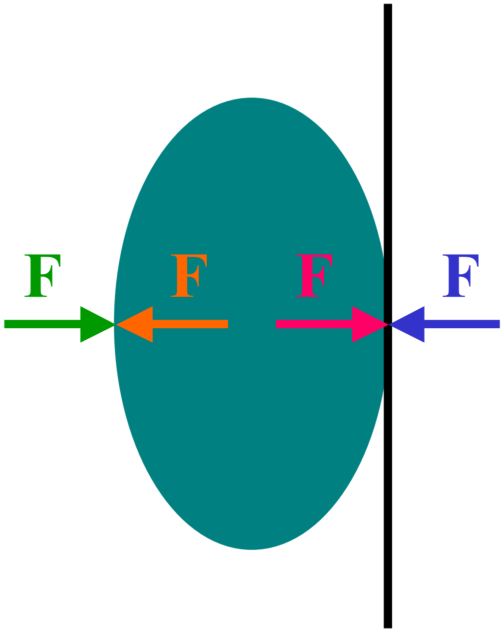


Does it … Go flat on the side next to the wall?... or stay symmetrically shaped?

Answer: It stays **symmetrically shaped**, but why?

Reasoning: To be symmetric both the **wall** and the **hand** must push **equally** on the balloon.

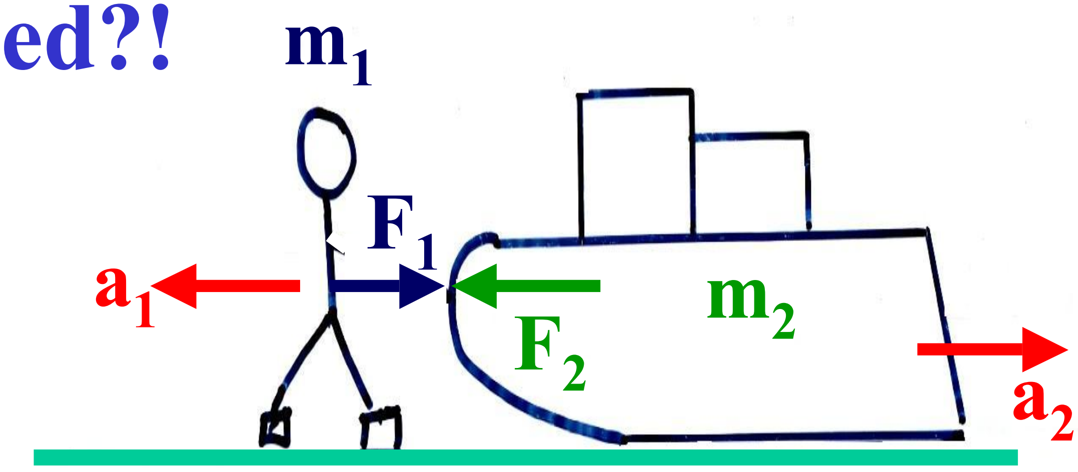
1. **Hand pushes on balloon with force 'F'.**
2. **Balloon pushes on hand with equal and opposite force '-F'.**
3. **Balloon acts as an extension of hand and transmits hand force 'F' to wall.**
4. **Wall reacts with equal and opposite force on balloon.**



Thus balloon is **squashed** from **both sides** by **F** & **F**.

Still not convinced?!

Consider what happens if you try to push a loaded sled on ice…



According to Newton's 3rd law as you push the sled, it will push back equally on you.

If no friction, then **Newton's 2nd** law gives:

$F_1 = m_2 a_2$ and $F_2 = m_1 a_1$ but $F_2 = -F_1$…

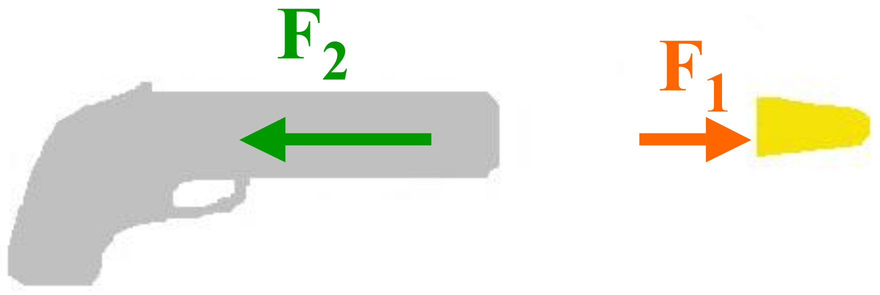
So: $m_1\, a_1 = -m_2\, a_2$ or.. $a_1 = -\left(\dfrac{m_2}{m_1}\right) a_2$

Thus both objects will accelerate in opposite directions with values inversely proportional to their masses.

Example:

- If ratio of masses is 10:1, then the induced accelerations (and hence velocities as a = Δv / t) will be in same ratio.
- Thus depending upon how hard you push, you could be pushed back with a high velocity!
- This effect is often called "recoil".

Common example is firing a gun...



Large F_1 accelerates bullet ($F_1 = m_1\ a_1$) to a high velocity.

small mass **large accel'n**

Recoil F_2 ($= -F_1$) accelerates gun backwards.

Qu: How to reduce the impact of recoil?
Answer: Make the gun heavy, so that 'a' is lower.

$$F_2 = m_{gun}\ a_{gun} = -F_1$$

Trick: Hold gun **rigid with body** (so body and gun are effectively on large mass).

- reduces recoil and improves your aim...

Reaction Force:

- This is also how **rockets** work in the **atmosphere** and in **outer space**.
- Like firing a **continuous series of bullets** out of the back and moving **forward** on the **recoil**.
- **Note:** We will consider this again when we discuss conservation of momentum and impulse in chapter 7.
- **Conservation of momentum** allows us to determine velocity changes **without** a detailed **knowledge** of the **forces** involved.

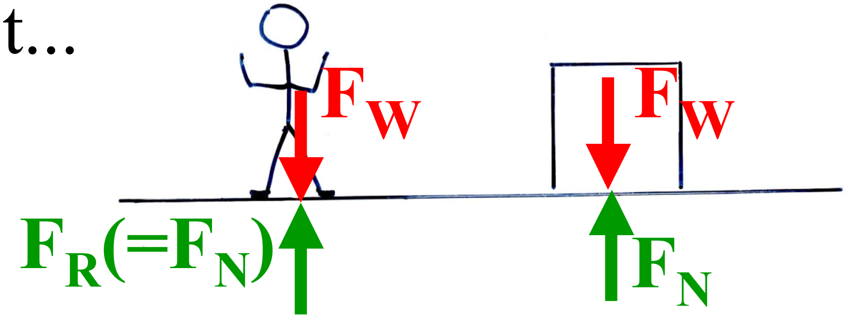
Summary:

- Now we know it all ?!
- **Newton's 1st and 2nd laws tell us how the forces change the motion.**
- **Newton's 3rd law says where force pairs come from - interaction with objects.**
- Note: In general **2nd and 3rd laws** are needed to define the forces.

Forces Involved With Everyday Life

- We need to know **all** the **external** forces in order to find the **net force** on an object...

Free-body diagram:



- The weight of a person or object is supported by an equal and opposite **reaction force $F_R = F_W$**.
- In many cases F_R is normal (ie. perpendicular) to the surface and is called **Normal Force 'F_N'**.
- In general, F_R at some angle to vertical…and vector components:

  F_N = Weight (F_W)

  F_F = Friction - to stop sliding