Force

- Force as a Vector
- Real Forces versus Convenience
- The System
- Mass
- Newton's Second Law

Force as a Vector

- Forces are vectors (magnitude and direction)

- Drawn so the vector's tail originates at the object that the force is being exerted on

- It is typical that multiple forces act on an object simultaneously

- In such cases, use vector addition

Demo:

A long rope has a 5 kg mass attached to its centre. Two students pull on either end of the rope to make the mass rise off of the ground. How hard to the students have to pull in order for the rope to become perfectly straight?

Fundamental forces

1) **Gravity**

- the force between masses
- holds planets and stars together, makes things fall, etc…

2) **Electromagnetism**

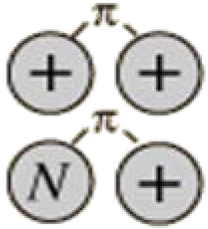
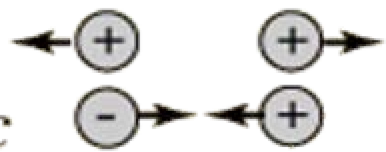
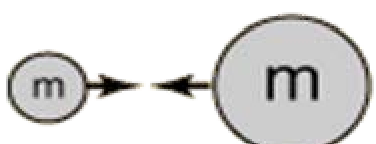
- the force between charges
- responsible for all familiar "everyday" forces (except gravity)

3) **"Weak Nuclear Forces"**

-changes one flavour of quark into another

4) **"Strong Nuclear Forces"**

- holds atomic nuclei together

Force	Diagram	Strength	Range (m)	Particle
Strong	 Force which holds nucleus togeher	1	10^{-15} (diameter of a medium sized nucleus)	π, others mass > 0.1 GeV
Electro-magnetic		$\frac{1}{137}$	Infinite	photon mass = 0 spin = 1
Weak	 neutrino interaction induces beta decay	10^{-5}	10^{-17} (0.1% of the diameter of a proton)	Intermediate vector bosons W^+, W^-, Z_0, mass > 80 GeV spin =1
Gravity		6×10^{-39}	Infinite	graviton ? mass = 0 spin = 2

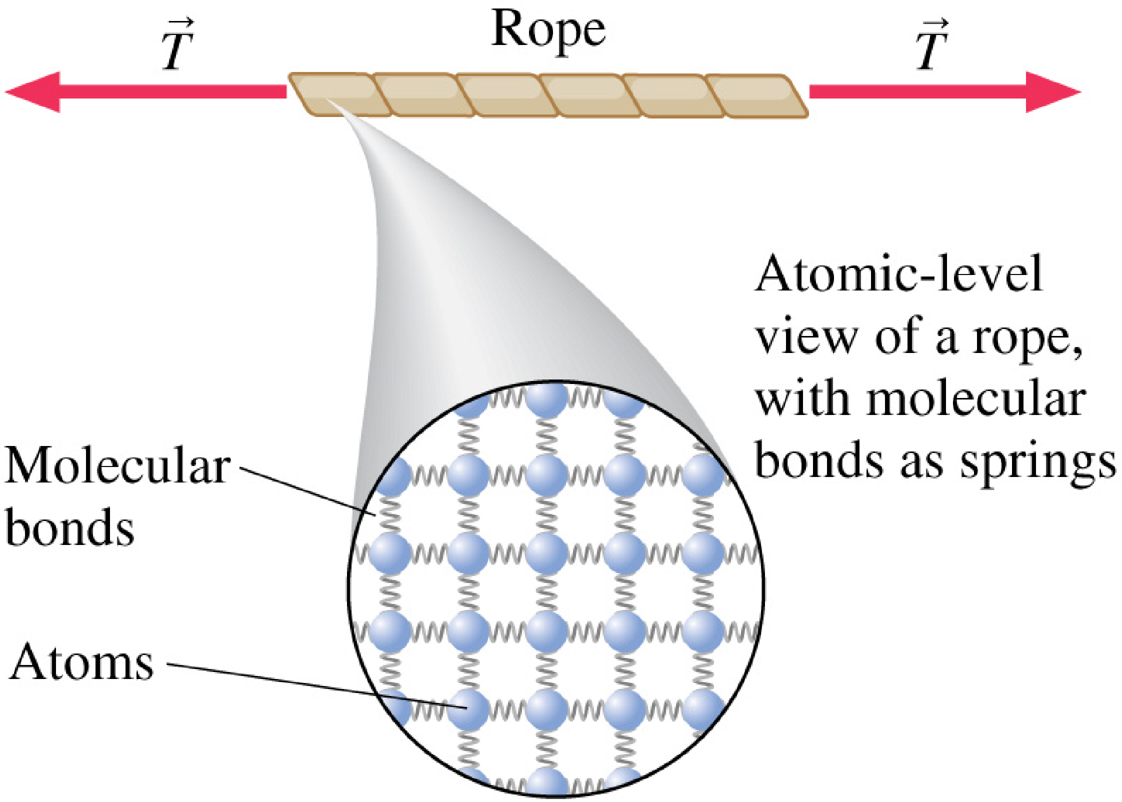
Forces of Convenience

1) **Tension Force** – string, rope, wire…
2) **Spring Force** – elasticity returns an object to its original shape
3) **Normal Force** – not that we're calling other forces abnormal
4) **Friction** – when one surface moves with respect to another
5) **Drag** – air resistance, fluid resistance
6) **Thrust** – what makes a rocket move?

These forces aren't fundamental, but they are a convenient way to visualise the world around us

Tension Force

- Elastic (or inelastic) deformation of molecular bonds
- Really just the electromagnetic force
- Can only pull



Spring Force

- Can push or pull
- Elastic (or inelastic) deformation of molecular bonds
- Really just the electromagnetic force

Normal Force

- Normal means orthogonal (orthogonal means at right angles)
- Results from compression of molecular bonds
- Can only push
- Really just the electromagnetic force

Friction Force

- Acts to reduce the relative motion of two surfaces
- Results from compression of molecular bonds
- Static and Kinetic forms, but still the same concept
- Really just the electromagnetic force
- Can push or pull

Quick Quiz 23:

Friction slows moving objects and keeps stationary objects from moving. Can it cause an object to speed up?

(A) Yes
(B) No

Drag Force

- The friction experienced when moving through a fluid
- You are currently in a fluid

Thrust Force

- Caused by expelled exhaust gasses
- Best understood after learning about momentum

Identifying "the System"

- Very important to correctly identify the system you are considering
- Imagine a closed surface around that object
- All forces in contact with that surface are forces that act on that object
- Remember to count long-range forces as well

Example:

Identify all of the forces that are acting on the box.

A Bit of History

- Aristotle said objects were “naturally” at rest, and needed a continuing push to keep moving. This is still a widely held view, since it is almost impossible to find an object in motion with no net external forces on it.

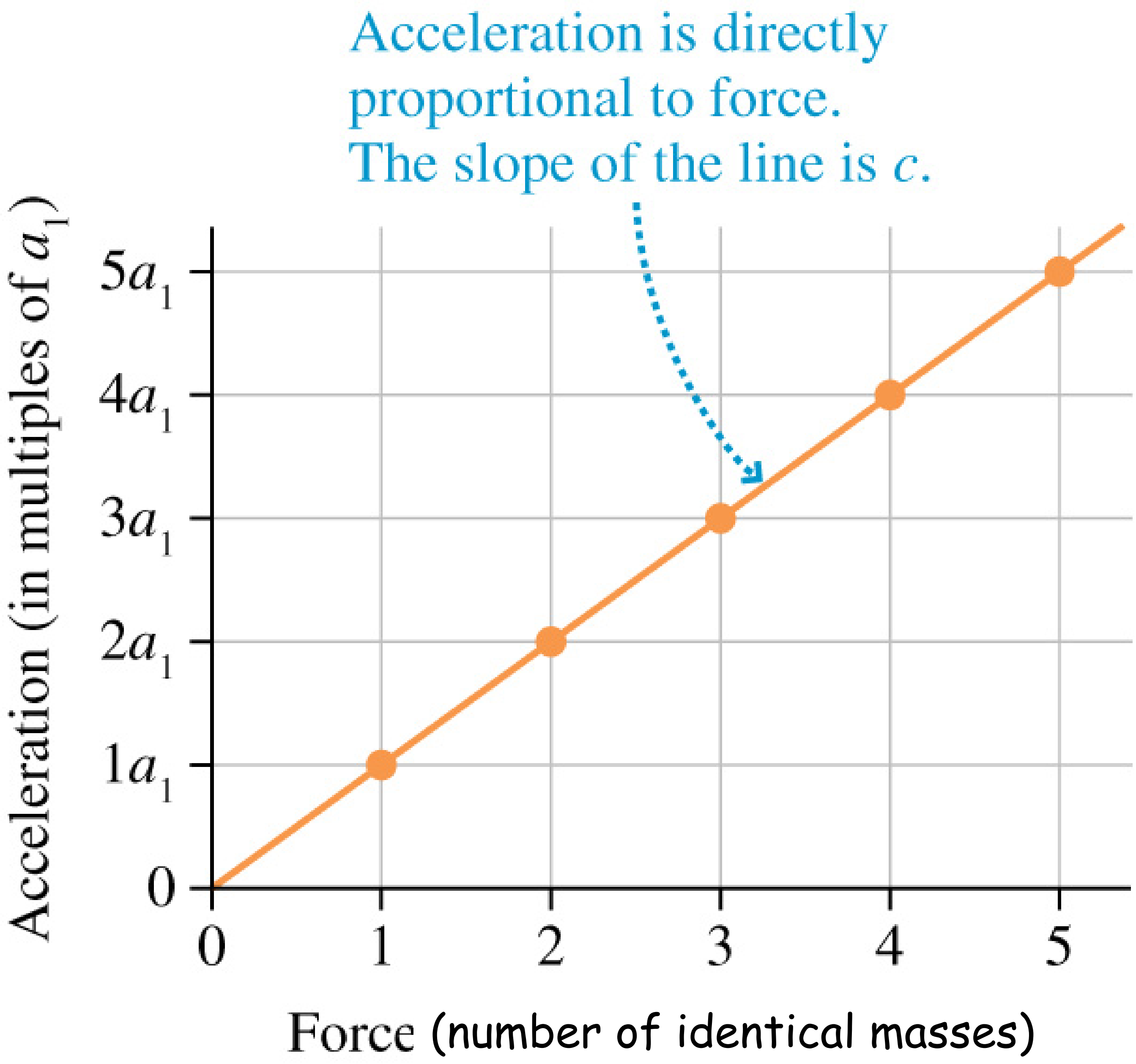
- Galileo held that motion at constant velocity is “natural” and only **changes** in velocity require external causes.

Quick Quiz 24:

A cart is initially motionless. If you pull on it with a constant force, which of the following can not describe the subsequent motion of the cart?

(A) The cart doesn't move
(B) The cart continuously accelerates
(C) The cart moves at a constant velocity
(D) The cart accelerates at first and then moves at a constant velocity

*don't ignore air resistance



Acceleration is directly
proportional to force.
The slope of the line is c.
Acceleration (in multiples of a_1)
$5a_1$
$4a_1$
$3a_1$
$2a_1$
$1a_1$
0
0
1
2
3
4
5
Force (number of identical masses)

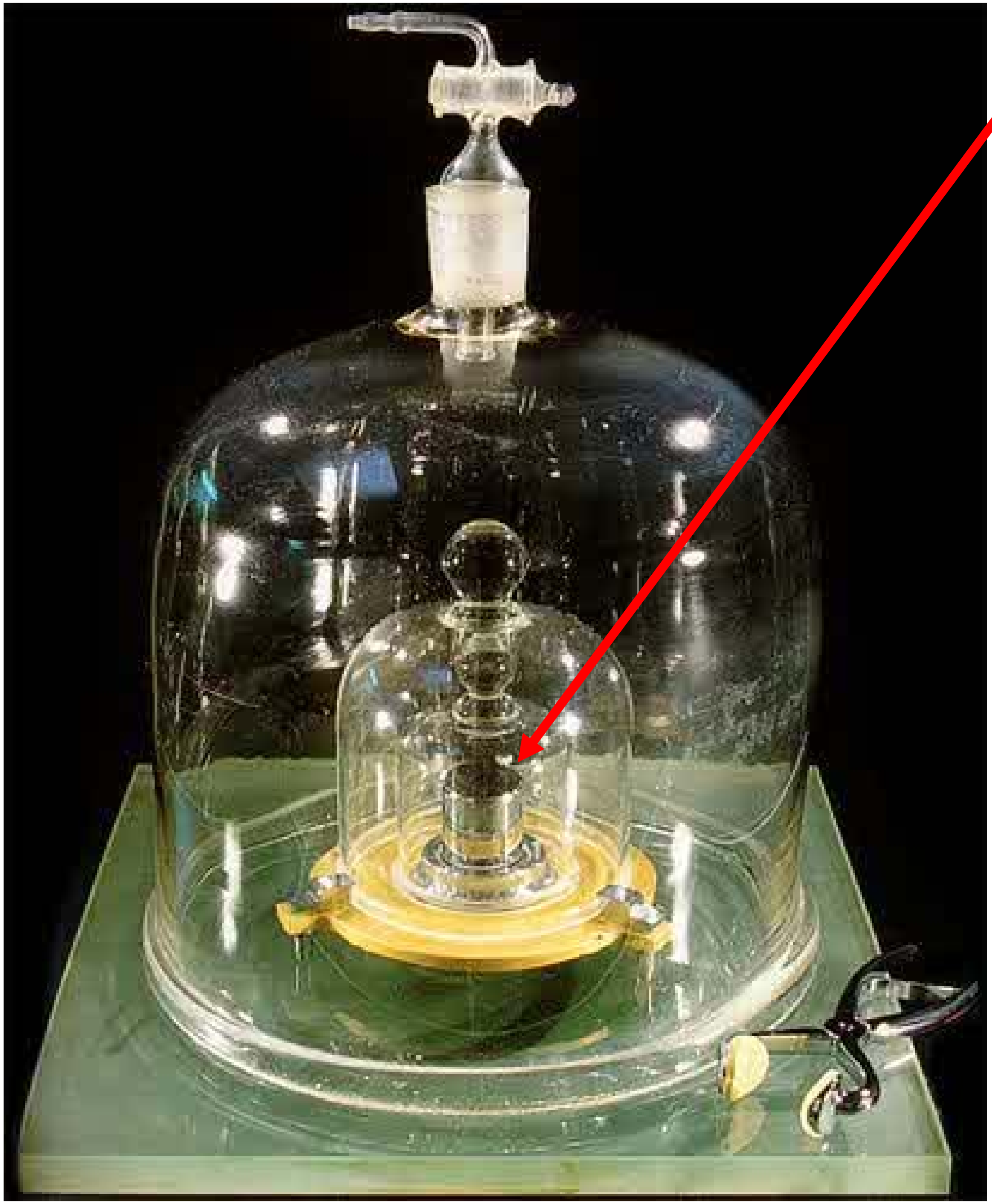
Mass

- The slope of the line on the acceleration versus force graph indicates how reluctant something is to change its motion

- Inertial mass is the word we use to describe the reluctance to changes in motion

- A steep slope indicates that the object has little mass (need less force for a given acceleration)

- A gentle slope indicates that the object has a lot of mass (need more force for a given acceleration)



This is THE kilogram.

This international prototype, made of platinum-iridium, is kept at the BIPM under conditions specified by the 1st CGPM in 1889.

Weight

- Don't confuse mass with weight

- THE kilogram would have a different weight depending on which planet it is on

Newton's Second Law

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

- Forces cause things to change their velocity.
- Their reluctance to change is called inertia.

What do you include in the $\Sigma \mathbf{F}$?

All influences on an object from its surroundings.

Contact Forces where direct contact is required:

examples - support from a wall or table, friction, air resistance, tension in a string …

Non-Contact Forces :

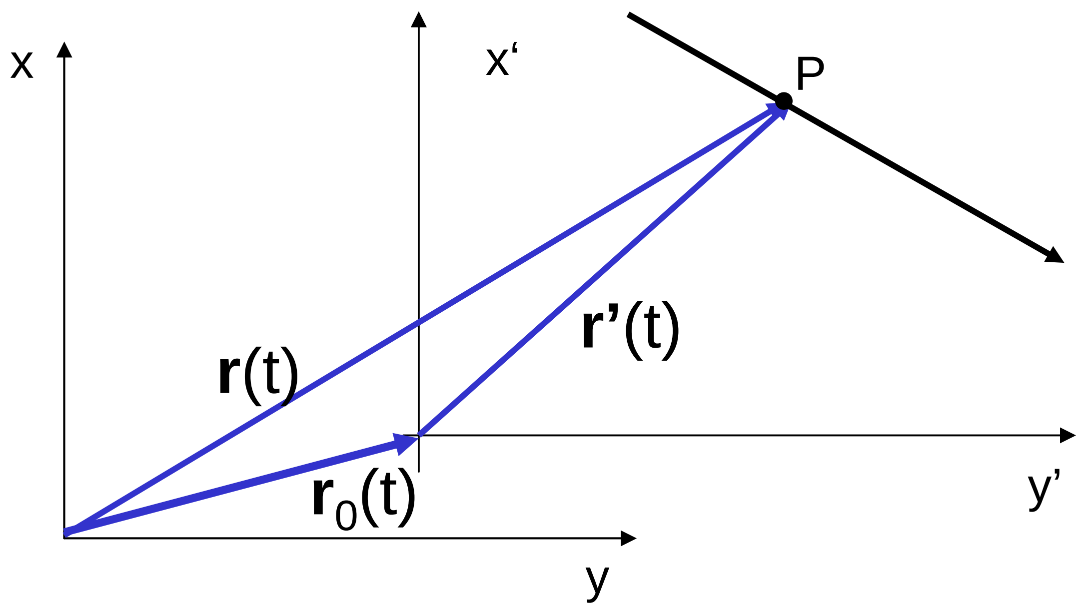
examples - gravity, electromagnetic forces

In the absence of external forces, an object continues in motion with a constant velocity

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

Using Forces:

Observers must be able to agree upon whether or not an object is accelerating.



Observers in different reference frames (x,y) and (x',y') see the same acceleration **a** = **a'** if the reference frames are not accelerating