Forces

Stage 1 physics

Physics

- Aristotle said a bunch of stuff that was wrong. Galileo and Newton fixed things up, sort of. Then Einstein said they were wrong. Then we sort of fitted it together except we don't quite understand; small things, big things, hot things, cold things, fast things, heavy things, dark things or turbulence. But we sort of have time sussed.

Onward

- On or near the surface of the earth at “normal” speeds and temperatures, “normal” things can be described using Newtonian Mechanics
- Thus we will start our study looking at normal stuff in everyday situations – except there is no friction and everything is considered a point (has no dimensions), but otherwise perfectly normal
- Who am I kidding – you chose physics – nothing is normal

Force changes motion

- You are racing through Gotham city in the Batmobile. Keeping your foot on the accelerator, you tear around a tight corner between two buildings.
- Suddenly you find your shoulder pressing against the side of the car – a force
- But where does that force come from? Your speed has not changed

Newton's First Law (N1L)

- In our universe, everything 'wants' to go in a straight line
  - 'linear'
- Properties are conserved in a straight line;
  - Energy
  - Momentum
- Any object that is not moving in a straight line is moving under the influence of a force

Big think

- Earth moves around the sun, which moves around a black hole

Inertia

- a property of matter by which it remains at rest or in uniform motion in the same straight line unless acted upon by some external force (*Merriam Webster Dictionary)*

Newton's Second Law (N2L)

- You have seen it many times as

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

- To calculate the motion of objects we use it as

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

- But Newton actually said

$$\frac{\Delta\vec{p}}{\Delta t} = \vec{a}$$

$\vec{p}$

Momentum

- Momentum is a linear property of all moving objects
- Even light, which has no mass, displays momentum
- For a 'normal' object $\vec{p} = m\vec{v}$

Momentum vs Inertia?

Momentum is a calculatable / measurable quantity

Inertia is a concept (without an equation)

Quick discussion

- Newton was actually 400 years ahead of his time
- Newton proposed that light was a particle, this was rejected by other physicists at the time, however, the important point is that Newton was not looking for ways to describe 'massless' particles
- But … light is massless and light has momentum, so, hundreds of years before the debate on the nature of light even got close to being settled, Newton's law allowed for its inclusion in motion calculations

Newton's Third Law (N3L)

- The one that is most regularly presented incorrectly

- A good way to remember it is as the "sore bottom law"
- When you sit on a seat for long enough you get a sore bottom
  - Is your bottom pushing down on the seat?
  - Is the seat pushing up on your bottom?
  - Is the "push" the same in each direction?

That's N3L

- Whenever something is pushed, the push back must be the same

Gravity

- Everything with mass attracts other things with mass
- Gravity works over enormous distances

Newton's Universal Law of Gravitation

$$F = \frac{Gm_1m_2}{r^2}$$

Where

- $F\ is\ the\ force\ of\ gravity\ between\ two\ objects$
- $G\ is\ the\ universl\ gravitational\ constant$
  - $6.67 \times 10^{-11} Nm^2kg^{-2}$
- $m_1 and\ m_2\ are\ the\ masses\ of\ the\ two\ objects$
- $r\ is\ the\ distance\ between\ the\ two\ masses$

Your weight

- Your weight is the result of your mass being acted on by the mass of the Earth
- It is

$$F = \frac{Gm_1m_2}{r^2}$$

- You can calculate that force using your mass, the mass of the Earth, the distance between the centre of the Earth and the centre of you

Lets do it …

$$m_e = 5.97 \times 10^{24} kg$$

$$m_m = 82.0 kg$$

$$r = 6.37 \times 10^{6} m$$

$$G = 6.67 \times 10^{-11} N m^2 kg^{-2}$$

$$F = \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 82.0}{6.37 \times 10^{6^2}}$$

$$= 805 N$$

So, how fast do I fall with gravity (N2L)

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

$$\vec{a} = \frac{805}{82}$$

$$= 9.81 ms^{-2}$$

Quick algebra

- Why does everything fall at $9.80ms^{-2}$

$$\vec{a} = \frac{\vec{F}}{m_m} \text{ and } F = \frac{Gm_e m_m}{r^2}$$

$$\vec{a} = \frac{\frac{Gm_e m_m}{r^2}}{m_m}$$

$$\vec{a} = \frac{\frac{Gm_e \cancel{m_m}}{r^2}}{\cancel{m_m}}$$

$$\vec{a} = \frac{Gm_e}{r^2}$$

'because you don't matter'

aside

- This is why all satellites have a simple relationship between speed and altitude.
- Every satellite at a specific altitude has the same speed.
- But … more on that later

Back to gravity

- Everything in freefall near the surface of the Earth falls at $9.80ms^{-2}$

- Brian Cox gravity video https://www.youtube.com/watch?v=E43-CfukEgs