9.2 Space Summary

KC Notes

9.2.1 Gravity

$F = mg$ and $F = G\frac{m_1 m_2}{d^2}$ are on your data sheet.

They give you force on object and force between two objects.

Equate forces for $g = \frac{GM}{d^2}$.

Equate the two forces and you'll get the gravitational acceleration.

g is affected by **altitude, local crust density, oblation/shape** and spin

E_p/GPE decreases from zero, while KE increases.

At an infinite distance, $E_p \to 0$, so must be negative (lost energy).

$E_p = -G\frac{m_1 m_2}{r}$

Note: This is just **inversely proportional** (not squared).

Remember we used $T = 2\pi\sqrt{\frac{l}{g}}$ for the pendulum prac.

9.2.2 Projectiles

Separate into horizontal and vertical components.

Horizontal: $x = ut$ and $v = u$. There's no acceleration.
Vertical: $y = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$ and $v = u + at$. $a = g$.

Aristotle and Galileo :D

Aristotle suggested **impetus** (air rushing below object) pushed object
Galileo deduced a **parabolic shape** by projecting a ball from an inclined table – horizontal and vertical motion.

9.2.2 Orbits

Centripetal force: force acting on an object moving in a circular path. Towards centre, $F = \frac{mv^2}{r}$.

Without centripetal force, Newton's First Law (inertia and object moving in a single direction at same speed) would make object fly off.

Orbital velocity is $v = \sqrt{\frac{Gm}{r}}$ for a stable orbit.

We get this by equating F_c, the centripetal force, and F_g, the force between two objects.

Kepler's Third Law of Periods: $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$

We get this by equating F_c to F_g and using $v = \frac{2\pi r}{T}$.

Geo-stationary Orbits vs Low Earth Orbits

Differ in **altitude, period, position and view**. Geo-stationary satellites do not experience orbital decay (friction against atmosphere).

Geo-stationary used for **communication, GPS, military and weather** LEOs are used for military and weather purposes.

9.2.2/9.2.3 Launches

Escape velocity is $v = \sqrt{\frac{2GM}{r}}$ to leave orbit.

Don't get it confused with **orbital velocity** – that is always much lower, and is the speed to keep orbit.

Equate KE to GPE (energy required to escape gravitational pull).

Newton's concept is that an object would follow a **parabolic / circular / elliptical / parabolic / escape** orbit path.

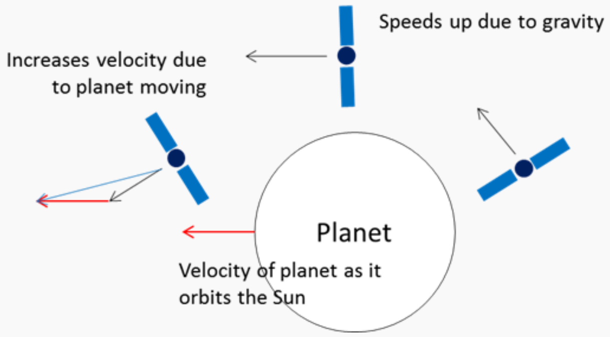
Velocity Boost from Earth

As Earth spins **west to east**, launching towards the east increases velocity. Launching at equator also helps.

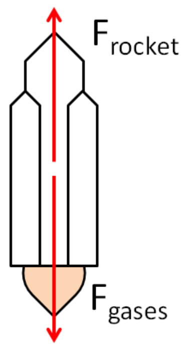
As Earth **orbits the Sun**, heading towards direction increases velocity.

Slingshot Effect – weeeee!

Using a planet's gravitational field to accelerate and save fuel. The **Conservation of Momentum** applies here – as the rocket moves closer, it gains momentum from gravity. The planet also loses the same amount (but $p = mv$ and mass is very large, so Δv is small).



Law of Conservation of Momentum – Newton's Third Law



During any **interaction** in a closed system the **total momentum of the system remains unchanged**. So, when gases are pushed out, the rocket is pushed forward (thrust is this reaction force).

Thrust can be measured with $F = ma$. As mass decreases when gases are ejected, **acceleration increases hyperbolically.**

In multistage rockets, **acceleration will become 0 (weightlessness)** when each section detaches, as second stage ignites.

Safe Re-entry and Landing

- Re-entry angle (too steep or too shallow, $approx\ 5.2° \ to\ 7.2°$)
- Heat from friction of atmosphere, ionisation blackout
- High g-forces (Astronauts reclined + transverse to allow blood flow)

- Weather conditions and landing speed (splashdown, parachute)

Robert Goddard

Proposed that rockets can **fly in vacuums – Newton's Third Law**. Contrary to belief, introduced the concept of travelling in space.

Tested rocket fuels – **liquid Hydrogen and Oxygen (1909)**. Developed liquid-fuel valving, solid fuels.

G-forces and Astronauts, $g\text{–}force = \frac{apparent}{actual}$

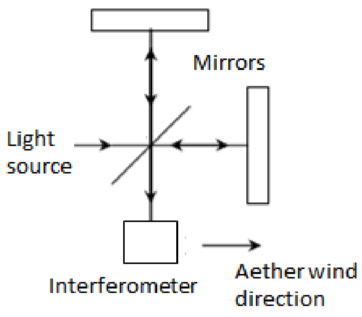
The reaction force on **astronauts** is the chair pushing upwards. This increases (**apparent weight** increases) during lift-off.

G-force is the multiple of an astronaut's actual weight, measured as $g\text{–}force = \frac{mg+ma}{mg}$.

Don't go above 3-4g's – this causes unconsciousness or death.

9.3.4 Relativity

Michaelson-Morley and the Aether



The aether was the **proposed medium of light** – undetectable, filled all space, perfectly elastic, permeated and permeable. **Maxwell.**

1905: Aim of the MM experiment was to detect the aether wind. Two light rays sent towards and across the wind, but there was **no interference measured** – disproved the existence of the aether.

Inertial/Non-inertial Frames of Reference

Frame of reference: anything **with respect to** which we describe motion and take measurements. **No absolute frame of reference**.

Inertial: constant or non-motion frame of reference e.g. Car
Non-inertial: accelerating frame of reference, e.g. Earth

Velocity of light is constant regardless of frame of reference – which is why we measure metres as a $\frac{1}{299792458}^{th}$ of a second, rather than distance.

What does relativity MEAN?

Simultaneous events are relative. The two lights at the end of the train may appear both simultaneous or not. Person outside will see it at $t = \frac{d}{c} = \frac{d'}{c}$ (equal distance d = d'). Person inside will have different times $t = \frac{d+vt}{c}\ or\ t = \frac{d\prime-vt}{c}$ as train moves at speed v.

Length contracts, time and mass increases. For **time dilation**, think of a light clock and the distance light needs to travel. Mirrors, regardless of frame of reference, would work even when travelling at the speed of light.