FORM 4 SPM PHYSICS SHORTHAND NOTES
Chapter 3 Gravitation
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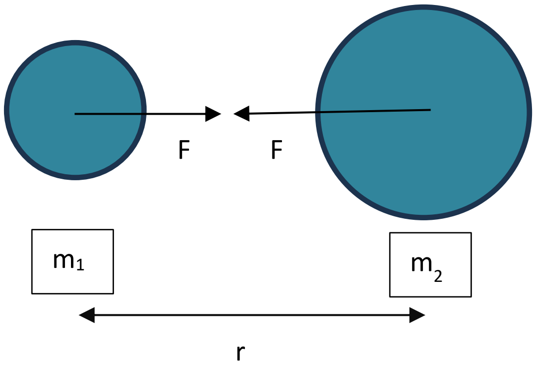
3.1 Newton's Universal Law of Gravitation



Newton's Universal Law of Gravitation is a fundamental principle in physics that describes the gravitational force between two point masses. The formula gives it:

$$F = G\frac{m_1 m_2}{r^2}$$

Where:
F is the gravitational force between the masses,
G is the gravitational constant (6.67×10^{-11} N m^2 kg^{-2}),
m_1 and m_2 are the masses of two objects,
r is the distance between the centers of the masses.

The force of gravity is inversely proportional to the square of the distance between the masses. As the distance (*r*) increases, the force (*F*) decreases rapidly.

G is a constant that determines the strength of the gravitational force. It is the same for all masses in the universe.

The gravitational force is directly proportional to the product of the masses ($m_1.m_2$). The larger the masses, the greater the force.

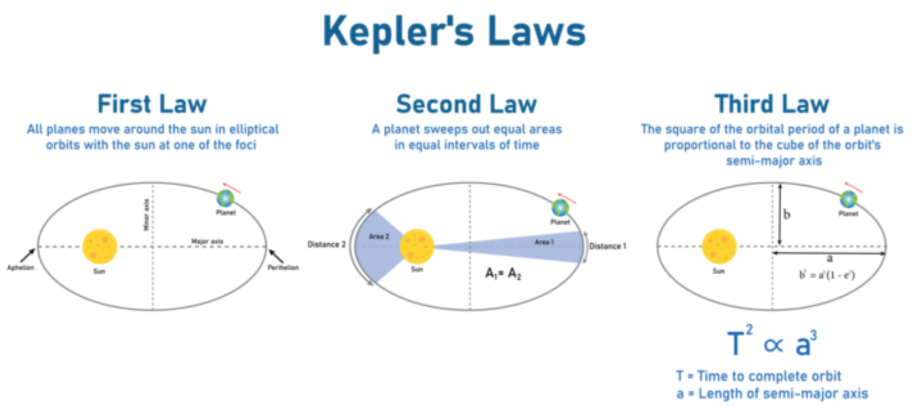
Newton's law explains the motion of planets, moons, and other celestial bodies in our solar system. The gravitational force between the Sun and these objects determines their orbits.

Calculate the gravitational force between two objects with masses m_1 = 50 kg and m_2 = 80 kg separated by a distance of r = 2m.

Explain how the gravitational force between two masses changes if their distance is doubled while keeping the masses constant.

If the gravitational force between two objects is 400N and the masses are 60 kg and 80 kg, respectively, calculate the distance between the objects.

3.2 Kepler's Laws



Kepler's First Law: The Law of Elliptical Orbits
Each planet in our solar system moves along an **elliptical path around the Sun**.

Visualize planetary orbits as elliptical trajectories resembling stretched circles. The Sun occupies a central position, and each planet elegantly traces its path along this elliptical route, adding a layer of uniqueness to its orbital journey.

Kepler's Second Law: The Law of Equal Areas
A line segment that connects a planet to the Sun will sweep out **equal areas in equal time intervals**.

In the diagram above, assuming the time taken to cover Distance 1 and Distance 2 is the same, according to Kepler's second law, Area 1 and Area 2 would be the same.

Kepler's Third Law: The Law of Harmonic Orbits
The square of a planet's orbital period is directly proportional to the cube of the semi-major axis of its orbit.

The easiest way to understand this is by observing the diagram provided for the Third Law. According to this law, if you square the time it takes for a planet to orbit the sun (represented by T^2), it will be directly proportional to the cube of the radius of the orbit (represented by a^3).

$$T^2 \alpha a^3$$

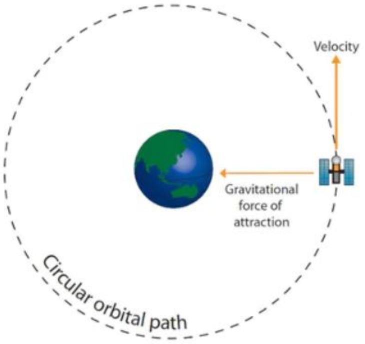
Or

$$\frac{T^2}{a^3} = k$$

3.3 Man-made satellites

Man-made satellites are artificial objects placed in orbit around celestial bodies, with Earth being a primary target for satellite deployment. These satellites serve various purposes, including communication, weather monitoring, navigation, and scientific research.

The satellites must maintain a certain velocity to counteract the Earth's gravitational pull and maintain equilibrium with the centripetal force.



The formula gives the linear speed (v) of a satellite in orbit:

$$v = \sqrt{\frac{GM}{R+h}}$$

Where:
v is the linear speed,
R is the radius of the Earth,
h is the height of the satellite

if

$$v < \sqrt{\frac{GM}{R+h}}$$

The satellite will fall to the earth. However if,

$$v > \sqrt{\frac{GM}{R+h}}$$

The satellite will fly off into space.

There are **two types** of man made satellites:

Geostationary Satellites:
Geostationary satellites have an orbital period equal to the Earth's rotation period (approximately 24 hours). They appear stationary relative to a specific point on Earth's surface, making them ideal for communication and weather monitoring.

Non-Geostationary Satellites:
Non-geostationary satellites have diverse orbital periods, ranging from a few hours to several days. Their orbits may have inclinations relative to the equator. Non-geostationary satellites are in constant motion relative to Earth's surface.

Characteristic	Geostationary Satellites	Non-Geostationary Satellites
Orbital Period	Approximately 24 hours (Synchronous with Earth's rotation)	Varied, ranging from a few hours to several days
Motion Relative to Earth	Appears stationary relative to a specific point on Earth	In constant motion relative to Earth's surface
Ideal Orbits	Equatorial orbits	Various orbits, including polar and inclined orbits
Communication Uses	Primary for communication and weather monitoring	Communication, Earth observation, and scientific research
Examples	Communication satellites (e.g., communication and weather satellites)	Earth observation satellites (e.g., imaging and scientific satellites), GPS

Escape velocity is an object's **minimum speed** to **break free** from a celestial body's gravitational influence. The escape velocity (v_{esc})

$$v_{esc} = \sqrt{\frac{2GM}{R}}$$

Where
M is the mass of the celestial body
R is the distance from the object's center to the surface

A spacecraft is on the surface of Mars, which has a mass (M) of 6.39×10^{23} kg and a radius (R) of 3.37×10^{6} m. Calculate the escape velocity from the surface of Mars.

Compare the escape velocities on Earth and Mars. Provide reasons for any differences.