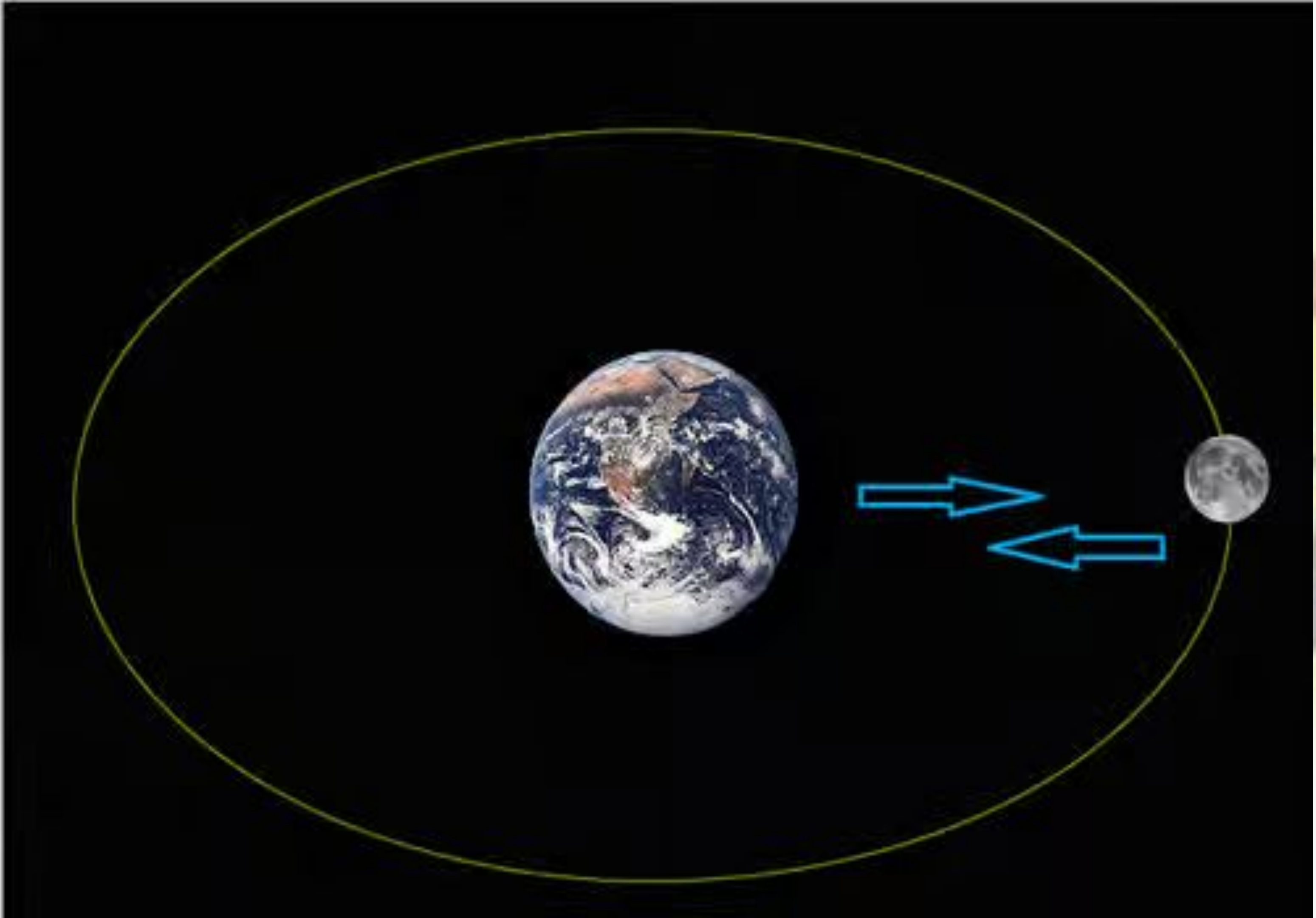
Universal Law of Gravitation

- Every object in the universe attracts every other object.
- The force of attraction is directly proportional to the product of their masses.
- The force of attraction is inversely proportional to the square of the distance between them.
- This force is called gravitational force.
- The formula is: $F = G * (M1 * M2) / R^2$, where G is the Gravitational Constant (6.67×10^{-11} Nm^2/kg^2)

Key points about Gravitational force:

- It's always attractive.
- It doesn't depend on what's between the objects.
- It's a conservative force.
- It acts along the line connecting the centers of the two objects.
- It follows the inverse square law (force weakens as distance increases).



Acceleration due to Gravity (g)

- It's the acceleration caused by Earth's gravity.
- On Earth, g is approximately 9.8 m/s^2

$$g = \frac{GM_e}{R_e^2}$$

$$g = \frac{GM_e}{R_e^2} = \frac{G\frac{4}{3}\pi R_e^3 \rho}{R_e^2} = \frac{4}{3}\pi G R_e \rho$$

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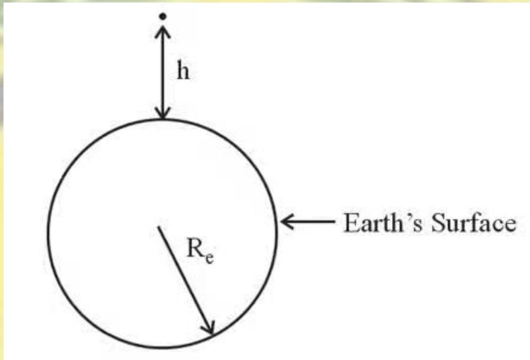
How 'g' changes:

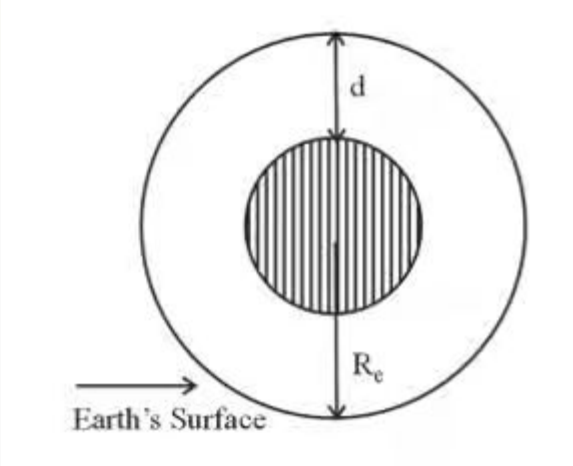
- **Altitude (height above Earth):** As you go higher, 'g' decreases.

$$g_h = g\left(1 - \frac{2h}{R_e}\right)$$

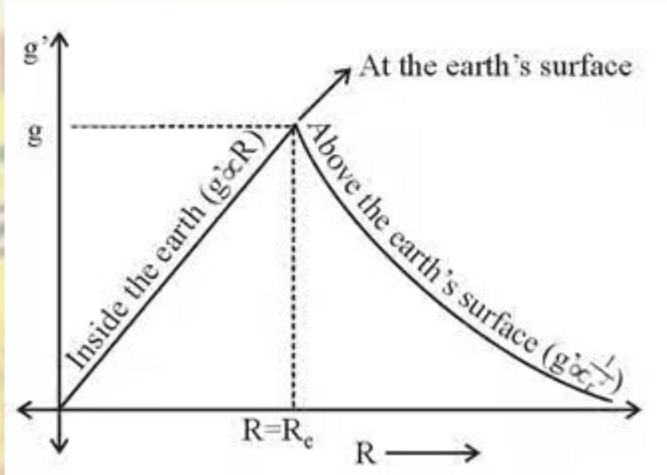


- **Depth (below Earth's surface):** As you go deeper, 'g' decreases, becoming zero at the center.

$$g_d = g\left(1 - \frac{d}{R_e}\right)$$

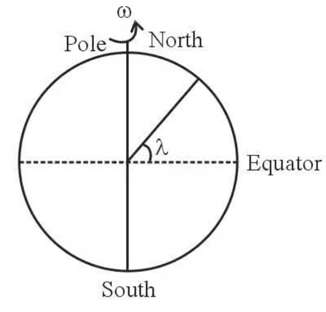


- **Latitude:** 'g' is slightly higher at the poles than at the equator due to Earth's rotation



- **Earth's Rotation:** If Earth stopped rotating, 'g' would increase everywhere except at the poles. If Earth rotated faster, 'g' would decrease everywhere except at the poles.

$$g_\lambda = g - R_e\omega^2 \cos^2 \lambda$$

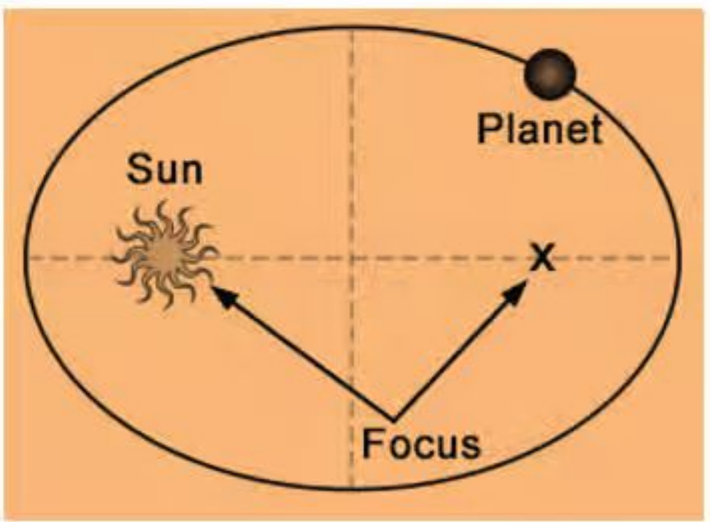


$$g_{equator} = g - R_e\omega^2$$

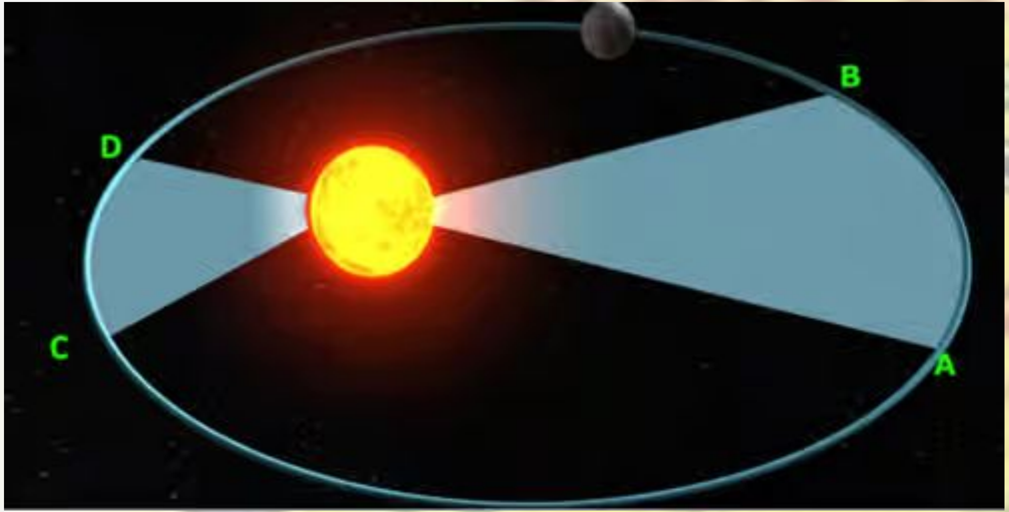
$$g_{pole} = g$$

Kepler's Laws of Planetary Motion

- **1st Law (Law of Orbits):** Planets orbit the Sun in elliptical paths, with the Sun at one focus.



- **2nd Law (Law of Areas):** The line connecting a planet to the Sun sweeps out equal areas in equal times. The planet moves faster when closer to the Sun.



$$\frac{d\vec{A}}{dt} = constant$$

- **3rd Law (Law of Periods):** The square of a planet's orbital period is proportional to the cube of its orbit's semi-major axis.

$$T^2 \propto R^3$$

$$T^2 = \frac{4\pi^2 R^3}{GM}$$

Gravitational Field and Potential Energy

- **Gravitational Field (E):** The space around a massive object where its gravitational pull is felt.

$$E = \frac{GM}{r^2}$$

- **Gravitational Potential (V):** The work done to bring a unit mass from infinity to a point in the field.

$$V = -\frac{GM}{r}$$

$$E = -\frac{dV}{dr}$$

- **Gravitational Potential Energy:** The work done to bring an object from infinity to a point in the field.

$$U = -\frac{GMm}{r}$$

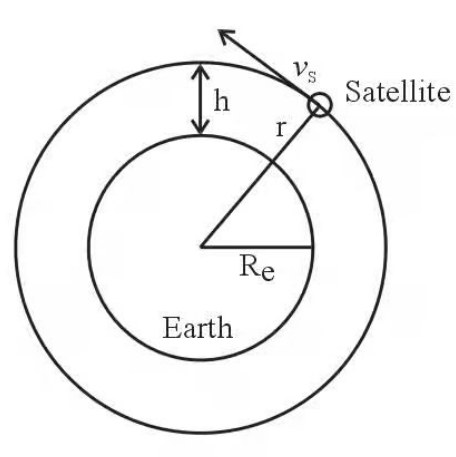
Satellites and their Velocity

- **Satellite:** A natural or artificial body orbiting a planet.
- **Escape Velocity:** The minimum velocity needed to escape a planet's gravitational pull.

$$v_e = \sqrt{\frac{2GM}{R}}$$

- **Orbital Velocity:** The velocity required for a satellite to maintain its orbit around a planet.

$$v_o = \sqrt{\frac{2GM_e}{r}} = \sqrt{\frac{GM_e}{R_e + h}} = R_e\sqrt{\frac{g}{R_e + h}}$$



$$v_o = \sqrt{gR_e}$$

$$v_e = \sqrt{2}v_o$$

Time Period of a Satellite

- The time it takes for a satellite to complete one orbit around the Earth.
- The formula for the time period when the satellite is close to Earth's surface is: $T = 2\pi\sqrt{(Re/g)}$

$$T = \frac{2\pi r}{v_o} = 2\pi\sqrt{\frac{r^3}{GM_e}} = 2\pi\sqrt{\frac{(R_e+h)^3}{GM_e}} = \frac{2\pi}{R_e}\sqrt{\frac{(R_e+h)^3}{g}}$$

$$T = 2\pi\sqrt{\frac{R_e}{g}}$$

Energy of an Orbiting Satellite

- **Kinetic Energy (KE):** The energy possessed by the satellite due to its motion.

$$K = \frac{1}{2}mv_o^2 = \frac{1}{2}\frac{GM_e m}{r} = \frac{1}{2}\frac{GM_e m}{(R_e + h)}$$

- **Potential Energy (PE):** The energy possessed by the satellite due to its position in Earth's gravitational field.

$$U = -\frac{GM_e m}{r} = -\frac{GM_e m}{(R_e + h)}$$

- **Total Energy (TE):** The sum of the satellite's kinetic and potential energy.

$$E = K + U = -\frac{GM_e m}{2r} = -\frac{GM_e m}{2(R_e + h)}$$

Geostationary Satellite

- Orbits Earth at the same speed and direction as Earth's rotation.
- Has a fixed height of 36,000 km above Earth's surface.
- Orbits in the equatorial plane.
- Has a period of revolution of 24 hours.

Polar Satellite

- Orbits Earth in a north-south direction, passing over the poles.
- Situated at a lower altitude than geostationary satellites (around 850 km).
- Provides detailed information about clouds and storms.

Weightlessness

- The experience of having no support force acting on the body.
- Occurs when an object is in free fall with an acceleration equal to the acceleration due to gravity.