What is Gravity?

We have already discussed that any object near the Earth is attracted to the Earth with the force mg where m is object's mass and g is the free fall acceleration. But this formula could only work near the surface of the Earth as the strength of gravity should decrease as one gets further away from the Earth. How does gravity change with distance? Furthermore, we have discussed that different planets have different values of free fall acceleration. Which properties of a planet determine the free fall acceleration on its surface? Finally, is gravitational attraction somehow restricted to cosmic objects or does it act between any objects, no matter how small they are?

Gravity is the invisible force that **pulls everything together**. It keeps your feet on the ground, makes apples fall from trees, and keeps the planets moving around the Sun.

More than 300 years ago, **Sir Isaac Newton** discovered that gravity works not just on Earth but everywhere in the Universe.

Newton's famous law can be written like this:

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

It sounds amazing, but this formula describes the gravitational force between any two objects in the universe: it could tell us how stars attract each other, or how the Earth pulls the Moon, or how the Earth pulls an ant, or how an ant pulls another ant!

Where:

- **F** – gravitational force (in newtons, N) between two objects with masses $\mathbf{m_1}$**,** and $\mathbf{m_2}$
- **r** – distance between the centers of the objects (in meters, m)
- **G** – gravitational constant: $G = 6.67\times10^{-11}\ \mathrm{N{\cdot}m^2/kg^2}$

This number is very small, which is why you don't feel the pull of gravity from nearby people — only very massive objects like the Earth have a noticeable effect

Example - How hard does the Earth pull on a person?

Suppose a person has a mass of **m1** = 60kg. The Earth's mass is **m2** = 5.97×10^{24} kg
and its radius is **r** = 6.37×10^{6}m.
This gives:

$$F = 6.67 \cdot 10^{-11}\mathrm{N} \cdot (\mathrm{m2/kg2}) \cdot \frac{60(\mathrm{kg})\cdot 5.97\cdot 10^{24}(kg)}{\left(6.37\cdot 10^{6}(\mathrm{m})\right)^2} \approx 588N$$

That is exactly the person's **weight** — the force with which the Earth pulls the person down!

Why do we use **F = mg** formula?
This expression is approximal and can be used only if the object is close to the Earth surface.

$$g = \frac{GM}{R_E^2}$$

The same formula would work for any planet: we see that free fall acceleration grows with mass of the planet but decreases with the size of the planet.

Homework:

1) An apple has a mass of 0.1 kg. Using $g = 9.8\ m/s^2$, find its weight.

2) Imagine that you are a NASA engineer in the early days of a Mars exploration program and you need to come up with a project of the first Martian rover. For this project it is critical to know the free fall acceleration on Mars, but no one has been there yet to measure it. Luckily, from astronomical measurements you know mass and radius of Mars.
Mass of Mars is $M_M = 6.4x10^{23}$ kg and radius of Mars is $R_M = 3400$ km.
Use this information to calculate the free fall acceleration on Mars for success of the rover project.

3) Find the gravitational force acting on you from the the Sun. Use Google search to find the necessary mass (in kg) and distance (in m).