Gravity

1. Introduction

Of the four fundamental forces; the strong nuclear force, the weak nuclear force, the electromagnetic force, gravity has the most influence on our everyday life. It is responsible for the formation of stars, planets and galaxies. It keeps us from floating into space. Yet, gravity is the weakest of the four fundamental forces. In fact the electromagnetic force of the proton on the electron is 10^{40} times stronger than gravity. (1). Isaac Newton was the first person to formulate a theory about gravity and formulated the inverse square law meaning that the force of gravity reduced in proportion to the square of the distance.

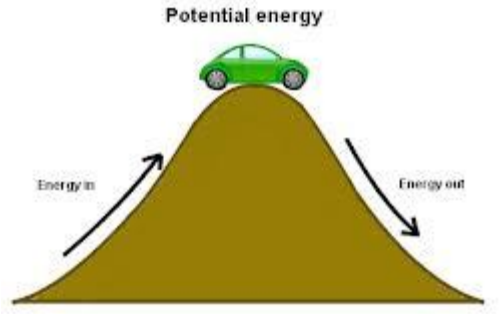
2. A different way to look at gravity

Instead of using Newton's inverse square law to describe the force of gravity, it is more convenient to talk about gravity as a quantity known as gravitational potential. It measures the amount of potential energy an object has by its presence in a gravitational field. As we shall see potential energy can be converted into kinetic energy; that is movement energy. It is usually denoted by the Greek letter ϕ (capital phi) and is a function of position and time. Forces always act to reduce the potential energy and are always in the direction where the potential reduces quickest. For the mathematically inclined it can be written as:

$\vec{a} = -\nabla\phi$

where $\vec{a}$ is the vector unit (it has direction and momentum) and it is measured per unit mass. ∇ is the gradient operator taking the derivative in each direction. Please note that this law gives acceleration, not direction.

Please skip the mathematics if you wish, I will explain it so you can understand it. If you hold a glass of water in your hand, the water is subject to gravitational potential energy. Pour it out and the gravitational potential energy is converted into kinetic energy. Of course when the water reaches the ground it is again subjected to gravitational potential energy. This will remain so until the water reaches the centre of the Earth. Every object on Earth is subjected to this energy, our bodies, even the air we breathe is subject to it. See illustration below.



Similarly, in astronomy, instead of talking about the gravitational force of a planet, a moon, a star, a galaxy, etc. scientists often use gravitational potential energy. In fact it is widely used instead of the usual reference to a "gravitational force".

3. Conservation of energy

Gravitation potential energy, like any other energy is subject to the law of conservation of energy within any system. If we pour the water out of the glass, the potential energy is converted into kinetic energy, but the total quantity of energy (when the water reaches the Earth and energy is again converted to gravitational potential), should remain constant.

4. Conclusion

Instead of referring to gravity as a force we should rather refer to gravitational potential energy. It is used widely to describe gravitational interactions. It is used to describe the gravitational field of the Milky Way Galaxy or more generally, for clusters of galaxies to define density perturbations, i.e. slight deviations in density, that gave rise to the formation of large scale structures.

1) Liddle A. Loveday J. 2008. Oxford Companion to Cosmology. Oxford University Press.

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