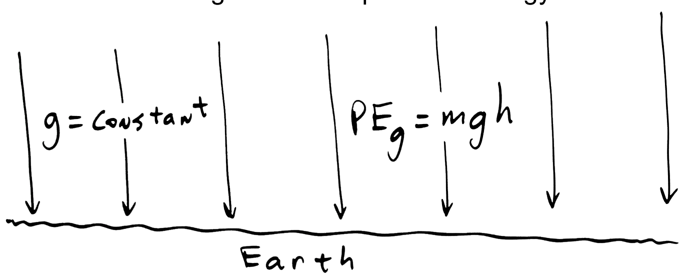
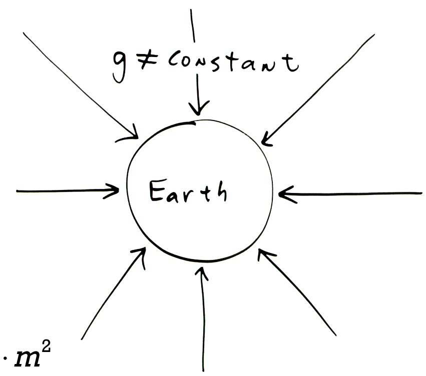
Flipping Physics Lecture Notes:

Universal Gravitation Potential Energy Introduction

Previous to today our only equation for gravitational potential energy was $PE_g = mgh$.

- h is the vertical height above the horizontal zero line.
- Remember to set your horizontal zero line
- This equation is true when the acceleration due to gravity is constant. Like on the surface of planet Earth, where we are for the majority of our lives.
- This is the gravitational potential energy which exists between an object and the planet.





Universal Gravitational Potential Energy is $U_g = -\frac{Gm_1m_2}{r}$.

- G is the Universal Gravitational Constant: $G = 6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$
- m_1 and m_2 are the two masses which have the gravitational potential energy.
- r is the distance between the centers of mass of the two objects.
- This equation is always true for the gravitational potential energy which exists between two objects.
- This has a predetermined zero line where the two objects are infinitely far apart, r = ∞. A reason the zero line is located infinitely far away is to make Newton's Universal Law of Gravitation and universal gravitational potential energy both be zero when the objects are at the same locations.

It is helpful to compare these two equations to the two we have for the force of gravity:

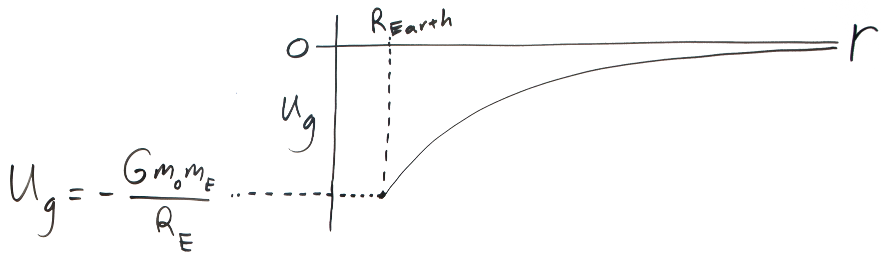
- $F_g = m_o g$ which is true on the surface of a planet. (Comparable to when we use $PE_g = mgh$)
- $F_g = \frac{Gm_1m_2}{r^2}$ which is always true. (Comparable to when we use $U_g = -\frac{Gm_1m_2}{r}$)

The gravitational potential energy which exists between an object and the Earth:

- When the object is on the surface of the planet: $U_g = -\frac{Gm_o m_E}{R_E}$
    - Also because $g_{Earth} = \frac{Gm_E}{R_E^{\ 2}}$ ♥ at r = R_E,

      $$U_g = -\frac{Gm_o m_E}{R_E} = \left(-\frac{Gm_o m_E}{R_E}\right)\left(\frac{R_E}{R_E}\right) = -\left(\frac{Gm_E}{R_E^{\ 2}}\right) m_o R_E = -m_o g R_E$$

      which is remarkably like $PE_g = mgh$.
- When the object is infinitely far from the planet: $U_g = -\frac{Gm_o m_E}{\infty} = 0$
- Between r = R_E and r = ∞ the shape of the graph is concave down as shown below.



Three things students need to be careful of:

1) Please do not forget the negative in $U_g = -\frac{Gm_1 m_2}{r}$.
2) Gravitational potential energy requires two objects. In other words, one object cannot have gravitational potential energy by itself.
3) The variable "r" is ***not*** squared in universal gravitational potential energy. It is in Newton's Universal Law of Gravitation, which means students have a tendency to add a square, it's not there, beware.

♥ Previously derived in "Deriving the Acceleration due to Gravity on any Planet and specifically Mt. Everest". http://www.flippingphysics.com/mount-everest-gravity.html