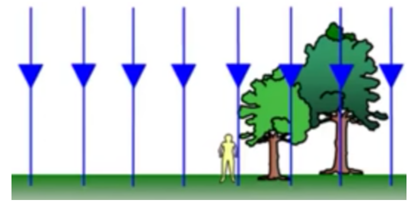
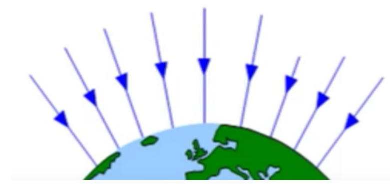
Unit 3: Gravitational, electric, and magnetic fields
Lesson 3.1: Gravitational Field

Part I: Universal Gravitation (6.1)





Universal Law of Gravitation: Gravitational attraction is between any two objects. If the objects have masses m_1 and m_2 and their centres are separated by a distance r, the magnitude of the gravitational force on either object is directly proportional to the product of m_1 and m_2 and inversely proportional to the square of r.

$$\boldsymbol{F_g = \frac{Gm_1m_2}{r^2}},\ Inverse - square\ law$$

$\boldsymbol{G = 6.67 \times 10^{-11} N \cdot m^2/kg^2}$ - gravitational constant.

As combining the force of gravity and the universal law of gravitation, we can easily obtain that the value of g (**gravitational field strength**) varies as you were standing at the different point of Earth.

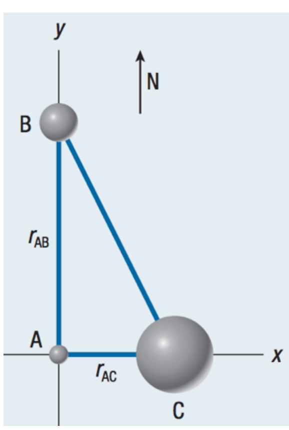
Table 1 Gravity versus Distance from Earth's Surface

Altitude (km)	*g* (m/s²)
1 000	7.33
2 000	5.68
3 000	4.53
4 000	3.70
5 000	3.08
6 000	2.60
7 000	2.23
8 000	1.93
9 000	1.69
10 000	1.49
50 000	0.13

$$\because m_1 g = \frac{Gm_1M}{r^2} \qquad \therefore \boldsymbol{g = \frac{GM}{r^2}}, where\ M\ is\ the\ mass\ of\ Earth$$

Hence, the value of g in North or South pole is greater than the value of g in _________.

Example 1: Calculating the force of gravity in a three-body system
In the figure, it shows three large, spherical asteroids in space, which are arranged at the corners of a right triangle ABC. Asteroid A has a mass of $1.0 \times 10^{20}\ kg$. Asteroid B has a mass of $2.0 \times 10^{20}\ kg$ and is 50 million kilometres from asteroid A. Asteroid C has a mass of $4.0 \times 10^{20}\ kg$ and is 25 million kilometres away from asteroid A along the other side of the triangle. Determine the net force on asteroid A from asteroids B and C.



Practice: Textbook pg293. #2, 3

Table 2 Surface Gravitational Field Strength of the Planets in the Solar System

Planet	Value of g_{planet} relative to Earth	Value of g (N/kg)
Mercury	0.38	3.7
Venus	0.90	8.8
Earth	1.00	9.8
Mars	0.38	3.7
Jupiter	2.53	24.8
Saturn	1.06	10.4
Uranus	0.90	8.8
Neptune	1.14	11.2

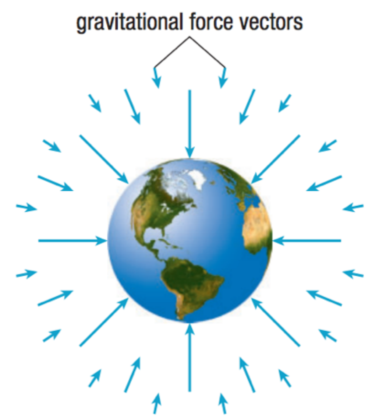
Example 2: Determine the ratio of Saturn's gravitational field strength to Earth's gravitational field strength given Saturn has a perfectly spherical radius of $6.03 \times 10^7\ m$ and the mass is $5.69 \times 10^{26}\ kg$.

Practice: Textbook pg295. #2 & pg296. #3, 6, 8, 9

Part II: Universal Gravitational Potential Energy – AP Physics

From the lessons in past, we have already discussed gravitational potential energy. $E_g = mgh$.

However, as we have seen, g is not a constant but rather depends on ____________________ and ____________________, so we need to find a new way to calculate gravitational potential energy.



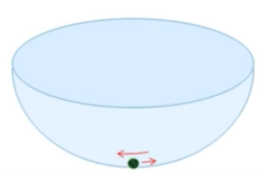
According to, $g = \frac{GM}{r^2}$ and $E_g = mgh$ where:

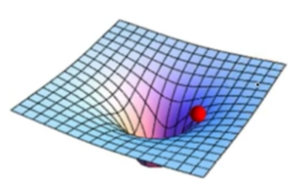
- *M* is the mass of central planet and *m* is satellite that orbiting around;
- *r* and *h* are the same

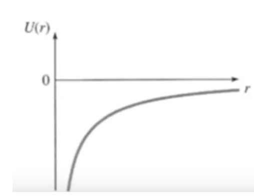
So we combine two equations, we get: $\boldsymbol{E_g = -\frac{GmM}{r}}$, but why negative?

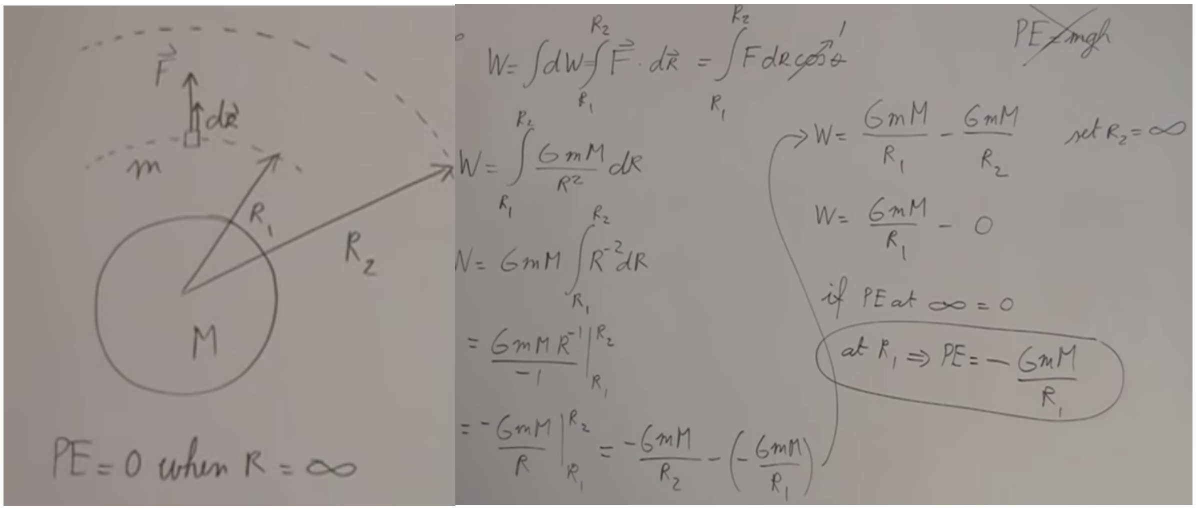
- As we move an object away from Earth, radius ↑, gravitational field strength ↓, $F_g \to 0$, so we assign ZERO E_g at infinite far.
- no attraction – no gravitational pull – free to escape - system unbound
- Imagine, if we want to send an object to outer space, we need a positive Ek input to escape.

https://phet.colorado.edu/sims/my-solar-system/my-solar-system_en.html
https://www.youtube.com/watch?v=NIGYo_Z4Rmk https://www.youtube.com/watch?v=loul_Ncp6gY









Example 3: A 2500 kg satellite is in orbit $3.60 \times 10^{7} m$ above the Earth's surface. What is the TOTAL energy of the satellite? Given: $m_{Earth} = 5.98 \times 10^{24} kg, r_{Earth} = 6.38 \times 10^{6} m$

The funny thing about satellites…