PHY 107
Gravitation

Mohammad Murshed
Department of Math and Physics

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OUTLINE

- Newton's law of gravitation
- Superposition
- Potential Energy

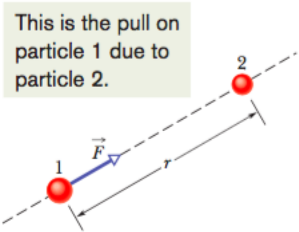
Newton's Law of Gravitation

Gravitation: Tendency of bodies to move toward one another

Newton's law of gravitation: Every particle attracts any other particle with a gravitational force of magnitude

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

$G = 6.67\ X\ 10^{-11} Nm^2/kg^2$



Principle of Superposition

Given a group of particles, we find the net (or resultant) gravitational force on any one of them from the others by using the principle of superposition.
For n interacting particles, we can write the principle of superposition for the gravitational forces on particle 1 as:
$\overrightarrow{F_{1,net}} = \overrightarrow{F_{12}} + \overrightarrow{F_{13}} + \overrightarrow{F_{14}} + ...\overrightarrow{F_{1n}}$

Newton's Law of Gravitation

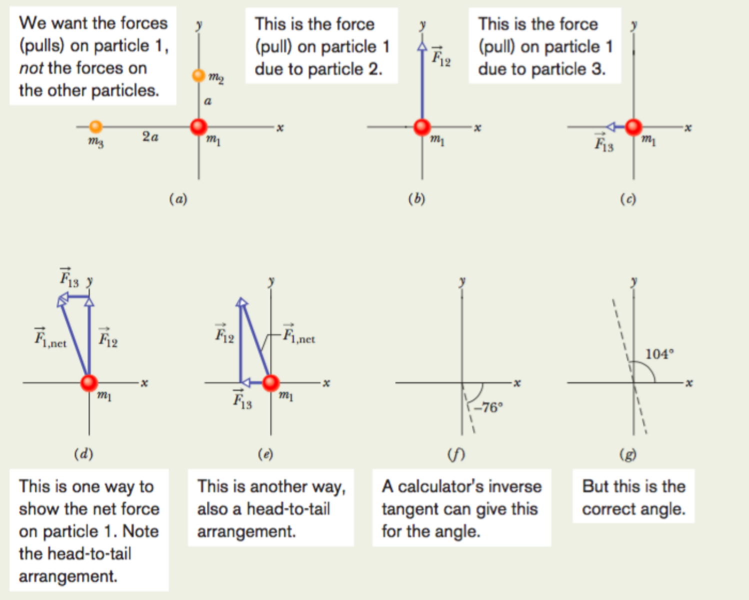
Example Figure shows an arrangement of three particles, particle 1 of mass $m_1 = 6.0$ kg and particles 2 and 3 of mass $m_2 = 4.0$ kg, and distance a $= 2.0$ cm. What is the net gravitational force $F_{1,net}$ on particle 1 due to the other particles?

Solution:

$F_{12} = \frac{Gm_1 m_2}{a^2}$

$F_{13} = \frac{Gm_1 m_3}{(2a)^2}$

Newton's Law of Gravitation



Gravitational Potential Energy

Let's broaden our view...

U=0 for $r = \infty$

Potential Energy is negative for any finite separation and becomes progressively more negative as the particles move closer together.

GPE of the two-particle system:

$U = -\frac{GMm}{r}$ (gravitational potential energy)

(Check the book for proof)

GPE: a property of the two particle system (rather than of either particle alone).

What would be the GPE for a three particle system?

Potential Energy and Force: $F = -\frac{dU}{dr}$

Escape speed

Consider a projectile of mass m leaving the surface of a planet with escape speed v:

$v = \sqrt{\frac{2GM}{R}}$ (Can be derived by COE)

M: mass of the planet

R: radius of the planet

Example

Asteroid falling from space, mechanical energy

An asteroid, headed directly toward Earth, has a speed of 12 km/s relative to the planet when the asteroid is 10 Earth radii from Earth's center. Neglecting the effects of Earth's atmosphere on the asteroid, find the asteroid's speed v_f when it reaches Earth's surface.

Solution:

COE: $K_f + U_f = K_i + U_i$

$0.5mv_f^2 - \frac{GMm}{R_E} = 0.5mv_i^2 - \frac{GMm}{10R_E}$

We solve for v_f

Problems of importance

Reference book (Extended 9th edition)
Newton's Law of Gravitation: 3
Gravitation and Principle of Superposition: 6

Reference

Fundamentals of Physics by Halliday and Resnik