#1: Gravity

Gravity: One of the (4) fundamental forces

Objects with mass attract other objects with mass
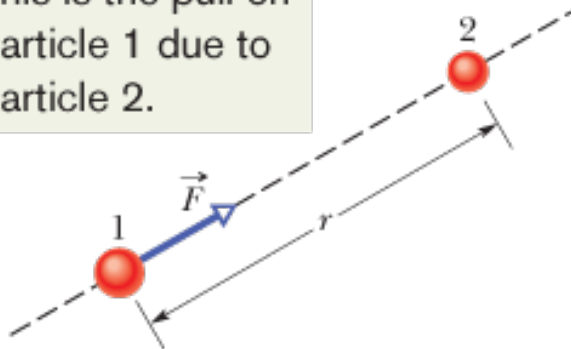
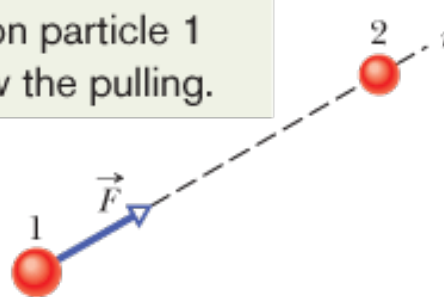**Newton's Law of Gravitation:** $\left|\vec{F}\right| = G\dfrac{m_1 m_2}{r^2}$

Gravity is a very weak force $\quad G = 6.67 \times 10^{-11} N\dfrac{m^2}{kg^2}$

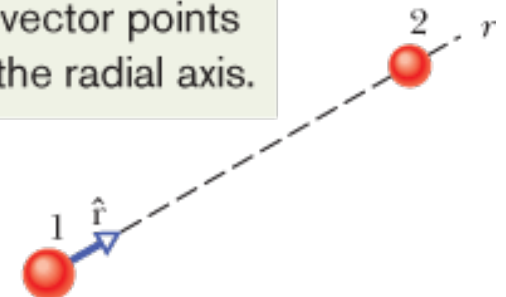It is a vector! $\quad \vec{F} = G\dfrac{m_1 m_2}{r^2}\hat{r}$

This is the pull on particle 1 due to particle 2.

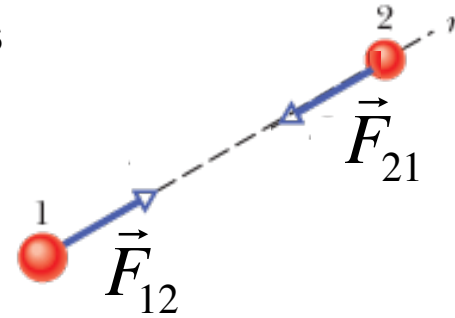Draw the vector with its tail on particle 1 to show the pulling.

A unit vector points along the radial axis.

Gravity is attractive on a line that connects the ***center-of-mass*** of the objects

The force of attraction between two objects
is always equal and opposite

$$\vec{F}_{12} = -\vec{F}_{21}$$

What's the force on the ball?

$$m_e = 5.97 \times 10^{24}\, kg \qquad\qquad r_e = 6.37 \times 10^6\, m$$

$$\left|\vec{F}_b\right| = G\frac{m_e m_b}{r^2} = \left(6.67 \times 10^{-11}\, N\,\frac{m^2}{kg^2}\right)\frac{5.97 \times 10^{24}\, kg}{\left(6.37 \times 10^6\, m\right)^2} m_b = 9.8\,\frac{N}{kg} m_b$$

$$g = G\frac{m_e}{r_e^2}$$

What's the force on the **earth**? $$\left|\vec{F}_e\right| = 9.8\,\frac{N}{kg} m_b$$

$$\left|\vec{a}_b\right| = \frac{\left|\vec{F}_b\right|}{m_b} = 9.8\,\frac{m}{s^2}$$ Is the earth accelerating? $$\left|\vec{a}_e\right| = \frac{\left|\vec{F}_e\right|}{m_e} = 9.8\,\frac{m}{s^2}\left(\frac{m_b}{m_e}\right)$$

Principle of superposition: $\vec{F}_{1,net} = \displaystyle\sum_{i=1,n} \vec{F}_{1i}$

Net force on an object is found by summing (vectors!) the individual forces arising from other objects.
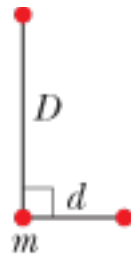
What is the net force on B?   On C?
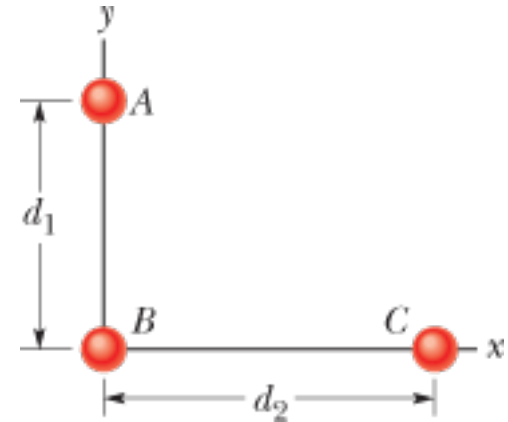
The figure shows four arrangements of three particles of equal masses. Rank the arrangements according to the magnitude of the net gravitational force on the particle labeled m, greatest first.
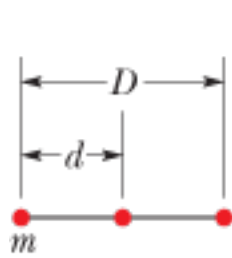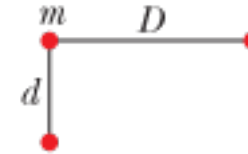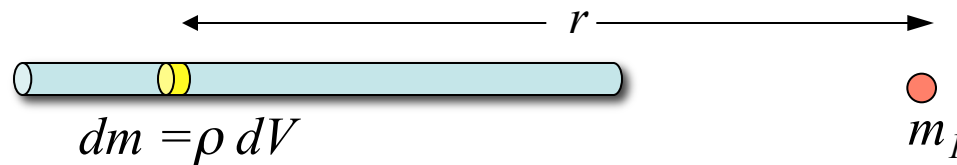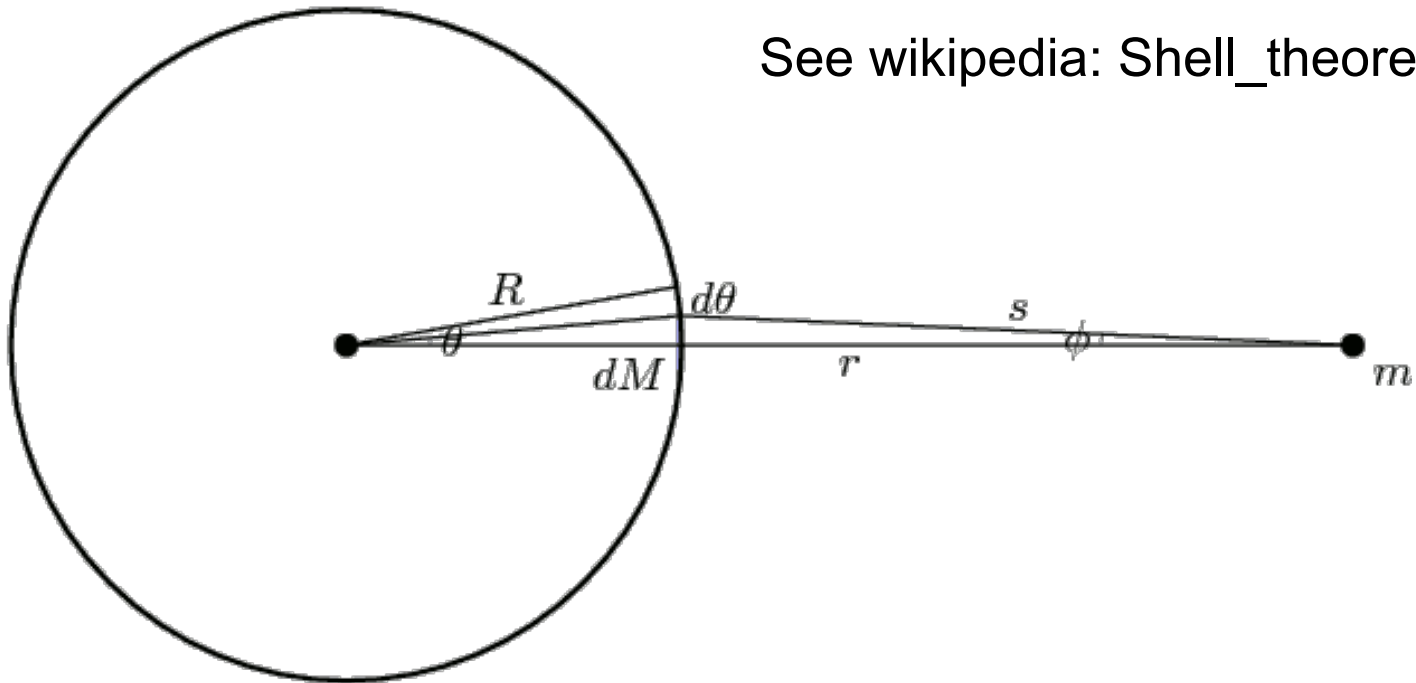

(1)   (2)   (3)   (4)

Extended object?   Sum → Integral: $\vec{F}_{1,net} = \int \vec{F}_{1dm} = \int G \dfrac{m_1 dm}{r^2}\hat{r} = Gm_1 \int \dfrac{dm}{r^2}\hat{r} = Gm_1\rho \int \dfrac{dV}{r^2}\hat{r}$

$\xleftarrow{\hspace{3cm}} r \xrightarrow{\hspace{3cm}}$

$dm = \rho\, dV$

m_1

Shell theorems:

1. A uniform shell of material attracts an object outside the shell as if all the shell's mass was concentrated at the center.

2. A uniform shell of matter exerts no net force on a particle inside the shell.

See wikipedia: Shell_theorem

A lead sphere of radius R =4.0 cm has a spherical hollow that passes through the center of the sphere and "touches" the right side of the sphere. The mass of the sphere before hollowing was M =3.0 kg . With what gravitational force does the hollowed-out lead sphere attract a small sphere of mass m =0.431 kg that lies at a distance d =9.0 cm from the center of the lead sphere, on the straight line connecting the centers of the spheres and of the hollow?