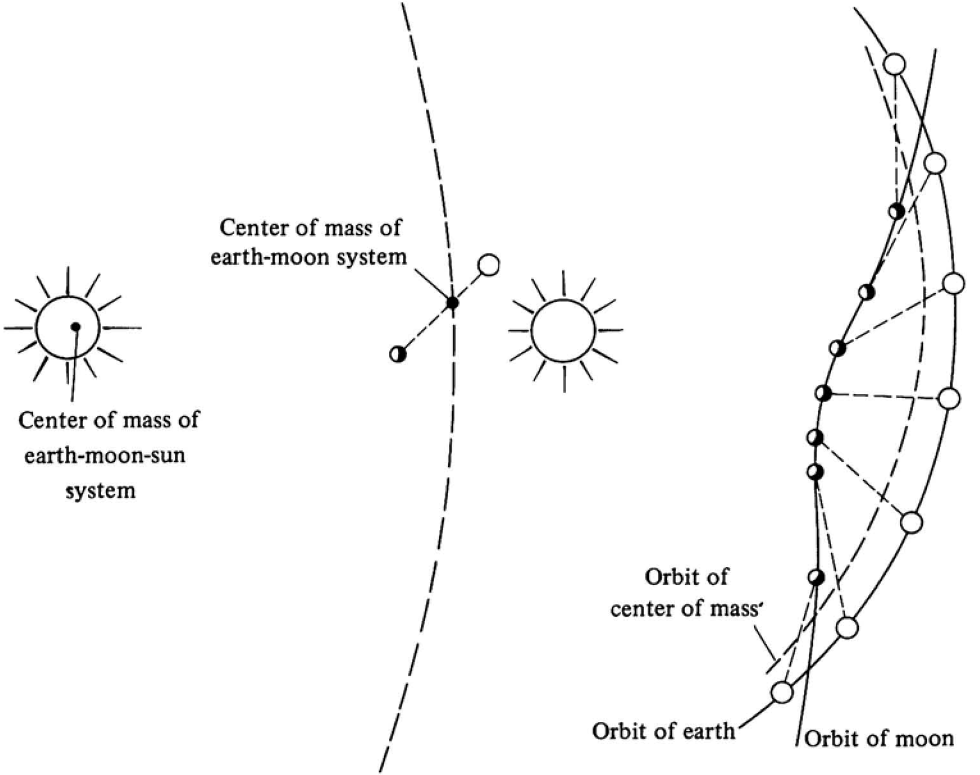
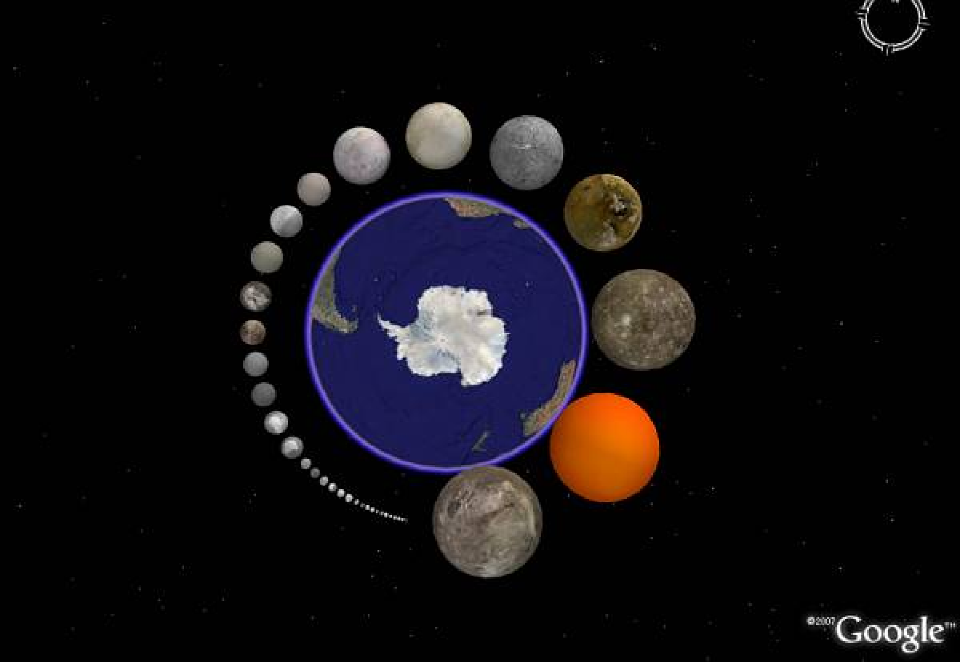

Center of mass of
earth-moon system
Center of mass of
earth-moon-sun
system
Orbit of
center of mass
Orbit of earth
Orbit of moon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Moon
Eris
Ceres
Charon
Pluto

Largest known trans-Neptunian objects (TNOs)

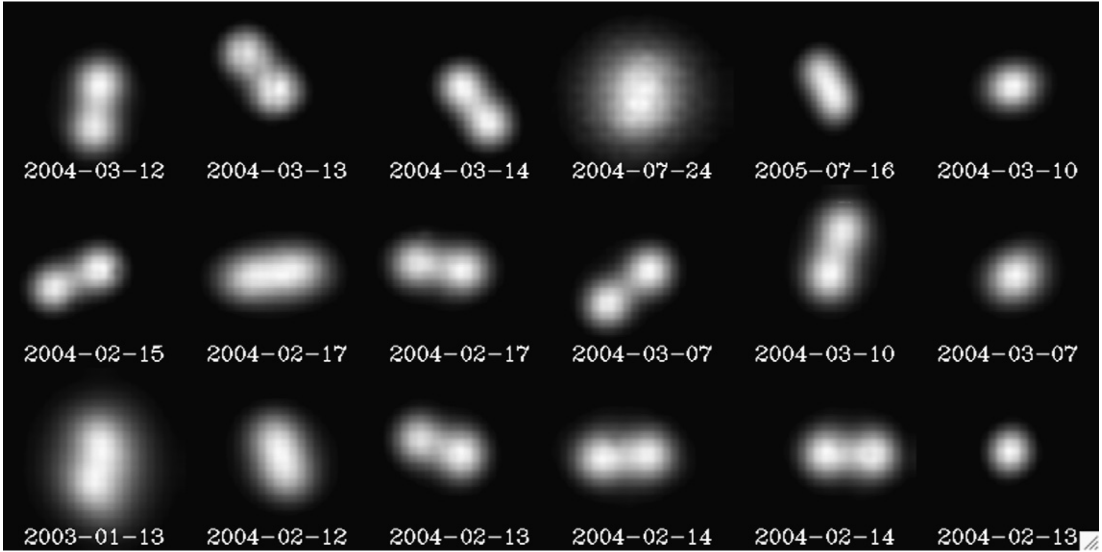
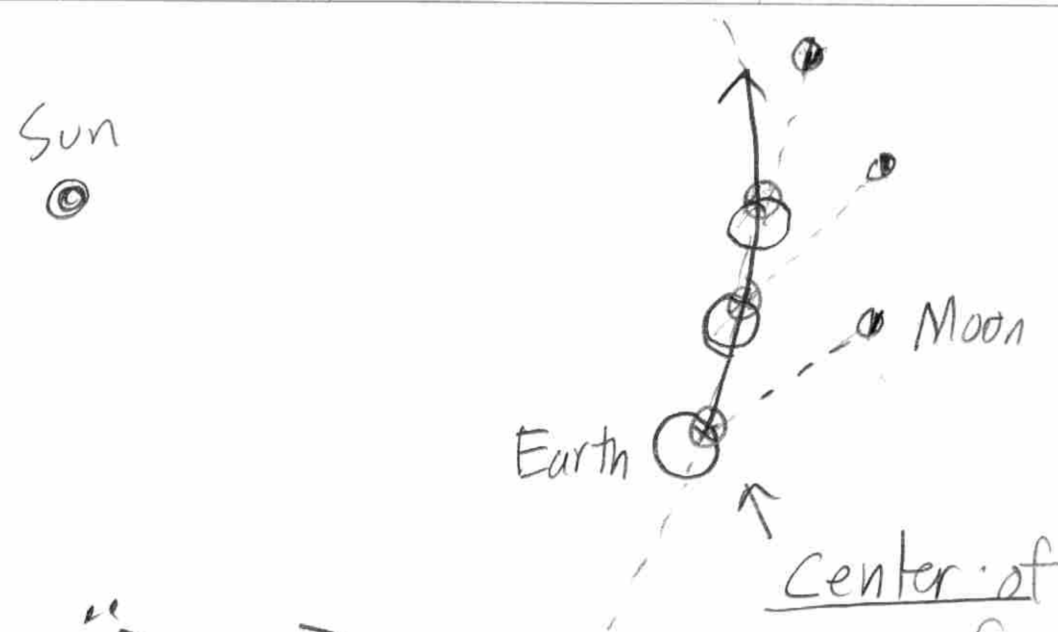


Fig. 1. (90) Antiope system observed with VLT NACO in 2004. The two components of the doublet system are clearly identified on these basic-processed (sky subtraction, flat-fielding, bad pixel removal) near infrared observations. The relative positions of the two components can be found in Table 1. We also displayed on the far right three PSF frames. Because the FWHM of the PSF is similar to the FWHM on the individual components of the double system, we can deduce that the two components cannot be resolved individually by the AO system. Their angular size is below the diffraction limit of the telescope (60 milli-arcsec for the VLT). The July 2004 observation was taken under very poor seeing conditions. In this case, the binary nature of (90) Antiope cannot be revealed.



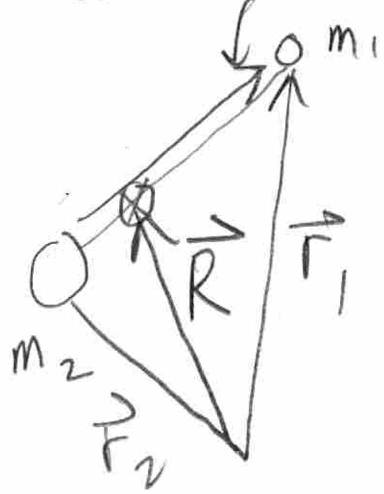
center of mass of earth/moon system follows orbit around sun.

$$M\ddot{\vec{R}} = \vec{F}_{ext,net}$$

Earth-Moon System Rotates about its center of mass ... .GIF

BINARY ASTEROIDS (recent)

idea:



$$\mu = \frac{m_1 m_2}{m_1 + m_2}, \quad \frac{1}{\mu} = \frac{1}{m_1} + \frac{1}{m_2}$$

$$\vec{r} \equiv \vec{r}_1 - \vec{r}_2 \qquad \hat{r} = \frac{\vec{r}}{|\vec{r}|} = \frac{\vec{r}}{r}$$

$$\mu\ddot{\vec{r}} = \vec{F}_{int,1}$$

gravity: $\vec{F}_{int,1} = -G\frac{m_1 m_2}{r^2}\hat{r}$

$$\frac{m_1 m_2}{m_1+m_2}\ddot{\vec{r}} = -G\frac{m_1 m_2}{r^2}\hat{r}$$

$$\ddot{\vec{r}} = -G\frac{(m_1+m_2)}{r^2}\hat{r}$$

ASSUME CIRCULAR

$$-\frac{v^2}{r} = -\frac{G(m_1+m_2)}{r^2}$$

$$v = \left[\frac{G(m_1+m_2)}{r}\right]^{1/2}$$

$$T = \frac{2\pi r}{v} = \frac{2\pi r}{\left[\frac{G(m_1+m_2)}{r}\right]^{1/2}}$$

$$T^2 = \frac{(2\pi)^2 r^3}{G(m_1+m_2)}$$

$$(m_1+m_2) = \frac{(2\pi)^2 r^3}{G T^2}$$

90 Antiope : show figure

$r = 171$ km $\quad T = 16.5$ hours

$$(m_1+m_2) = \frac{(2\pi)^2 \cdot (171\cdot 10^3)^3 \ m^3}{\frac{2}{3}\cdot 10^{-10}\ \frac{kg\cdot m}{s^2}\cdot\frac{m^2}{kg^2}\cdot(16.5\cdot 3600)^2}$$

$(m_1+m_2 \cong 8.4\cdot 10^{17}$ kg $\quad$ density $\simeq 1.25\ \frac{gm}{cm^3}$

→ no CM continuous distribution.

→ 

at rest

$\vec{p}_{initial} = 0$

→ only internal forces

$$\frac{d}{dt}(\vec{p}_1 + \vec{p}_2) = 0$$

$$\vec{P} = \vec{p}_1 + \vec{p}_2 = \vec{0}$$

$$-MV + mv = 0$$

$$\frac{v}{V} = \frac{M}{m}$$

use in your problem

What did happen.. an <u>impulse</u>

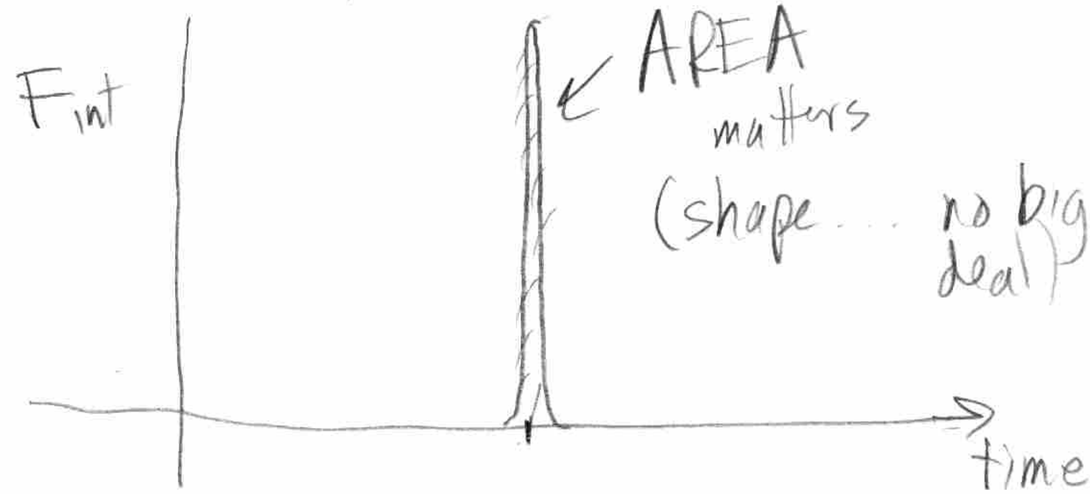
$$\vec{r} \equiv \vec{r}_1 - \vec{r}_2$$

$$\mu \ddot{\vec{r}} = \vec{F}_{int}$$

$\vec{r}(0)=0 \quad \mu(\dot{r}(t)-\dot{r}(0)) = \underbrace{\int_0^t \vec{F}_{int}\,dt}_{\text{the impulse } \vec{I} \text{ (my symbol)}} = \vec{P}_f - \vec{P}_i$

Two types here:

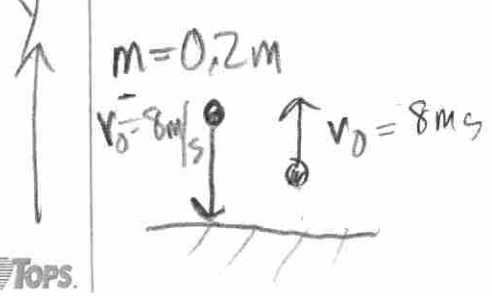
① $\vec{F}_{int}$ from an explosion...
large, brief.



OFTEN: ball, person + Earth
$M_e \to \infty$

$\mu \to m$

then $\vec{P}_f - \vec{P}_i = \vec{I}$



$\vec{P}_i = -mV_0\hat{j}$

$\vec{P}_f = mV_0\hat{j}$

Impulse then $mv_0\hat{j} - (-mv_0\hat{j}) = \vec{I}$

$$= -2mv_0\hat{j}$$

$$= -2 \cdot 0.2 \cdot 8\hat{j} = 3.2\hat{j}\ \frac{kg-m}{s}$$

$$\Delta t = 10^{-3}\ s$$

$$\vec{F}_{avg} \cdot \Delta t = 3.2\hat{j}\ \frac{kg \cdot m}{s}$$

$$\vec{F}_{avg} = \frac{3.2}{10^{-3}}\hat{j}\ \frac{kg\ m}{s^2}$$

$$\vec{F}_{avg} = 3200\hat{j}\ N\ !$$

Balls' acceleration ... $\frac{\vec{F}_{avg}}{m} \simeq 16{,}000\ m/s^2$

Neglected gravity,

(2) Truly constant force

$$F_{grav} \cdot \Delta t = 0.2 \cdot 9.8 \cdot 10^{-3}\ N$$

$$\simeq 2 \cdot 10^{-3}\ N$$

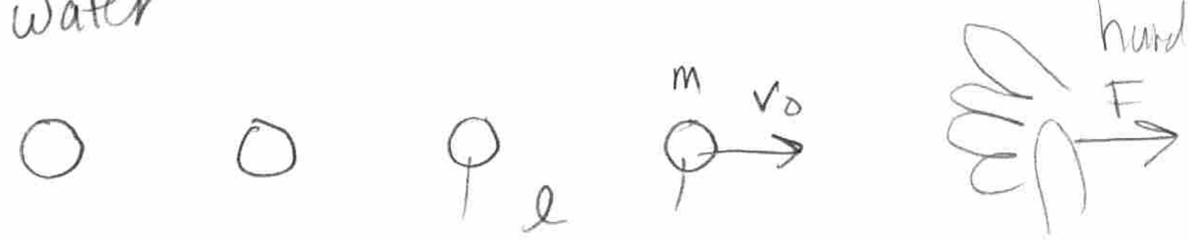
Negligible

To avoid broken limbs, make Δt as long as possible when you fall:

$$F_{avg} \sim \frac{2Mv}{\Delta t}$$

Continuous Tiny Impulses = Force

water



each loses mv_0

in time T, $\frac{v_0 \cdot T}{\ell}$ drops hit.

total momentum transfer

$$= \left(\frac{v_0 T}{\ell}\right) \cdot (mv_0)$$