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Lecture 1

25 AUG 2014

Instructor introduction:

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Nicholson 447

Class website: www.phys.lsu.edu/classes/phys2113

Section 1 web site: markwilde.com/teaching

useful Section 2 web site: www.phys.lsu.edu/~jdowling/PHYS21132

Text: Fundamentals of Physics by Halliday, Resnick, & Walker

9th edition

Ch. 13 & 21-33

Important to Show up for Lab: PHYS 2109 (go this week or be dropped)

Homework: Sign up @

www.webassign.net/student.html

Username: pawsusername@lsu
Institution: lsu
Password: lsuidnumber

Section 1 Class Key: lsu 7071 4383

1 assignment per week, due 11:59PM Fridays

1st assignment posted & due

cover 13-1, 13-2, 13-3, 13-4

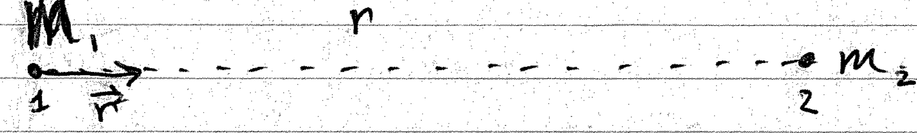
purpose of this week is to understand the gravitational force as a field in order to make our understanding of the electric field easier.

13-1 & 13-2

- One of the great unifying ideas of Newton was to show that the force which the Earth exerts on the Moon is the same as that which the Sun exerts on the Earth is the same which Earth exerts on an apple (this was a principal step in taking humanity out of the middle ages and into a scientific revolution and the Enlightenment)
- The force is also responsible for some of the most exotic objects in our universe: black holes.
- What do we mean by a "field"? can think of a temperature field as an analogy. In the room, every place has a certain temperature depending on location. will return to this later

What is the gravitational force?

for simplicity, focus on just two point masses



Newton's law of universal gravitation

$$\vec{F}_{12} = G\frac{m_1 m_2}{r^2}\vec{r}$$

force on particle 1 due to particle 2

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

gravitational constant (extremely small)

(Newton didn't know G. Determined later in the Cavendish experiment)

m_1 + m_2 are masses of particles

r is the magnitude of the distance between them

$\vec{r}$ is a unit vector (length one) pointing in the direction of m_2

force is always attractive

<u>Question:</u> What is the force on a mass of 1kg due to a mass of 1kg that is 1 meter away?

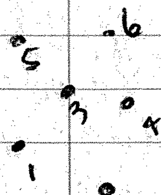
<u>Question:</u> What is the force on particle 2 due to particle 1?

<u>Hint:</u> Newton's 3rd law of equal & opposite reaction

can speak of a force between the particles w/ magnitude $F = G\frac{m_1 m_2}{r^2}$

13-3 Principle of Superposition for Gravity

Suppose we have n particles now instead of just ~~two~~. We would like to know the gravitational force that all of the other particles exert on the 1st.



the principle of superposition gives the answer:

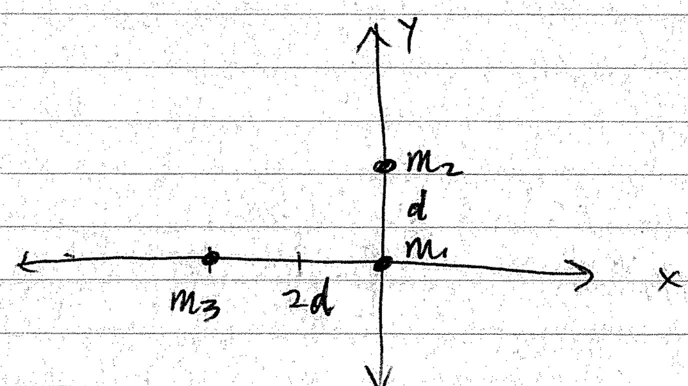
We determine $\vec{F}_{12}$, $\vec{F}_{13}$, ..., $\vec{F}_{1n}$ (each of the vector forces that another particle exerts on particle 1)

& then we simply add them up:

$$\vec{F}_{1,net} = \vec{F}_{12} + \vec{F}_{13} + \dots + \vec{F}_{1n}$$

$$= \sum_{i=2}^{n} \vec{F}_{1i}$$

Example:



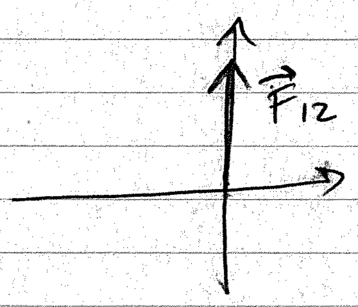
What is $\vec{F}_{1,net}$?

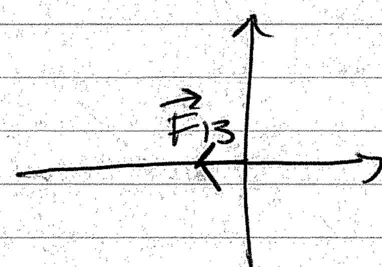
let $m_1 = 6.0\,kg$, $m_2 = m_3 = 4.0\,kg$,

$d = 2.0\,cm$

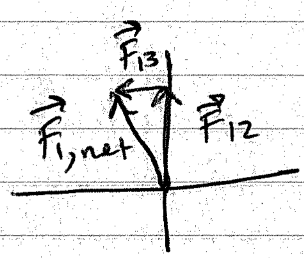
Drawing diagrams can be helpful:

m_2 is $\overset{2x}{\text{closer}}$ to m_1 than m_3 is,
so the force magnitude
should be 4 times as large:





add up the vectors:



calculate (force magnitudes)

$$F_{12} = \frac{G m_1 m_2}{d^2}$$

$$= \frac{\left(6.67 \times 10^{-11}\ \frac{N \cdot m^2}{kg^2}\right)(6.0kg)(4.0kg)}{(0.020\,m)^2}$$

$$= 4.00 \times 10^{-6}\ N$$

Similarly, $F_{13} = \frac{G m_1 m_3}{(2d)^2} = 1.00 \times 10^{-6}\ N$

due to the fact that $\vec{F}_{12}$ & $\vec{F}_{13}$ are perpendicular, we get that

$$F_{1,net} = \sqrt{F_{12}^2 + F_{13}^2}$$

$$= \sqrt{(4.00 \times 10^{-6} N)^2 + (1.00 \times 10^{-6} N)^2}$$

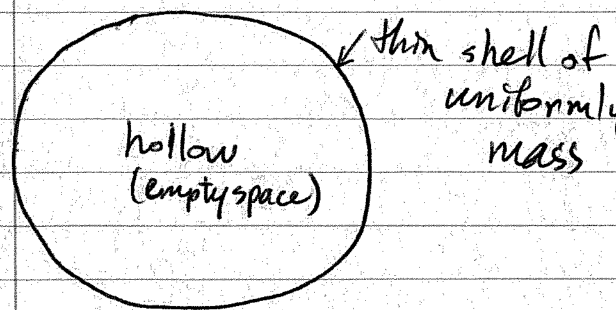
$$= 4.1 \times 10^{-6} N$$

We can calculate the angle as

$$\sin^{-1}\left(\frac{1.00 \times 10^{-6}}{4.1 \times 10^{-6}}\right) + 90^\circ$$

$$= 104^\circ$$

Newton's shell theorem is an important consequence of the law of universal gravitation (in fact, one of the reasons he invented calculus was for proving this) Stated simply: Given is a ~~unifor~~ spherical shell of uniform mass i.e.



1) then for a point mass m outside the shell, the gravitational force on m due to the shell can be modeled as if all of ~~the~~ its mass is concentrated at the center as a point mass.

2) for a point mass m inside the shell, the gravitational force on m due to the shell is zero. (i.e., the force ends up canceling out) due to symmetry

this will be important as well when we get to electric fields

(see en.wikipedia.org/wiki/Shell_theorem for a derivation)

13-4 Gravitation near Earth's surface

Suppose that Earth is a uniform sphere of mass M.

By shell theorem, the magnitude of gravitational force

on mass m at distance r is

$$F = G\frac{M \cdot m}{r^2}$$

We would like to determine gravitational acceleration a_g. By Newton 2nd law

$$F = m a_g$$

so

$$a_g = \frac{GM}{r^2}$$

at Earth's surface, this works out to the famous $a_g = 9.8 \text{ m/s}^2$

Concept of a Gravitational Field

gravitational field – vector field
representing the force that would be applied
on a test mass of 1 kg, at a given location
(units are acceleration)

We need some other masses in order
to have a gravitational field

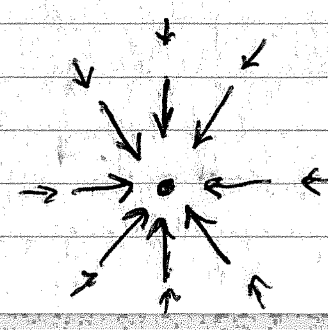
$\cdot M$ $\qquad\qquad\qquad\qquad \cdot m=1$

$$\vec{g}(\vec{r}) = -\frac{GM}{r^2}\,\vec{r}$$

(if location of M is taken to be the
center of the coordinate system)

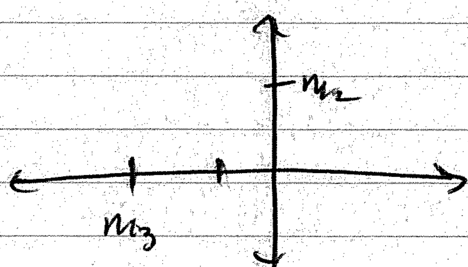
So we can draw the gravitational
field around M as

So M acts as a "sink",
attracting other particles
towards it

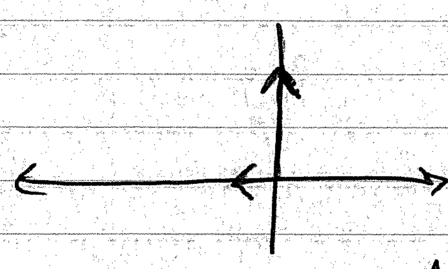


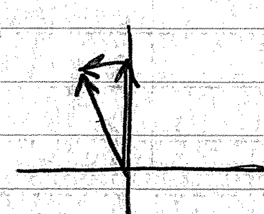
If youknow the field at every point, then you can calculate the force & vice versa.

Returning to the example from before, we can find the field at the origin

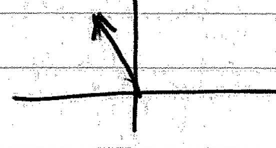


What is $\vec{g}(\vec{0})$?





Again add up vectors w/ test mass = 1 kg
so at the origin the gravitational field is represented as a vector



w/ magnitude $\frac{4.7\times10^{-6}N}{6.0kg}$