Physics 113 - October 22, 2013

- If submitted regrade request - can pick up after class
- Mid-term survey

Last Time

Energy is Conserved ... NOT always useful for you

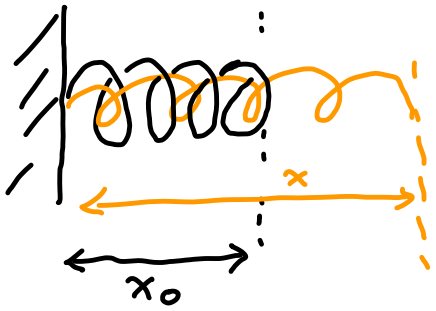
$$W_{NC} = \Delta KE + \Delta PE$$

W_{NC}: nonconservative work

↳ friction ... hand of God whatever

Think your way through the energy flow

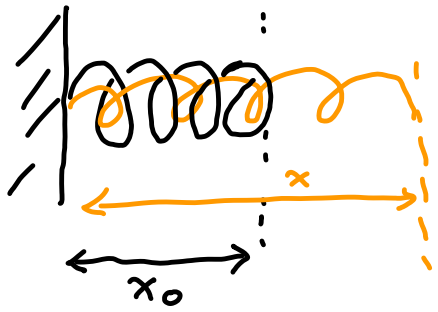
Two conservative systems considered so far: gravity, springs



$$\vec{F} = -k(\vec{x} - \vec{x}_0)$$

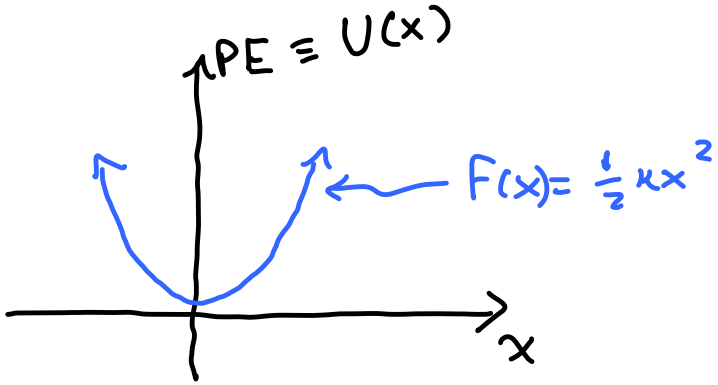
We looked at $dW = \vec{F} \cdot d\vec{s}$ to stretch spring

$$PE_{spring} = \frac{1}{2}k(x - x_0)^2 = \frac{1}{2}kx^2$$ if $x_0 = 0$



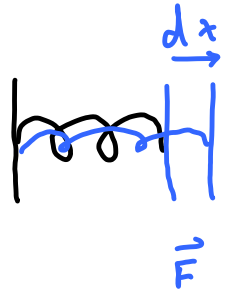
As we change x → PE in system changes

$$PE = \frac{1}{2}kx^2 \qquad (\text{let } x_0 \equiv 0)$$



I stretch spring $dW \sim F\,dx$

$dU \sim \Delta PE$



$$\frac{dU}{dx} = F_x$$

Better to ask what is force of spring on something + how that is related to U flips sign on work

$$-\frac{dU}{dx} = F_x$$

In general $\boxed{F_s = -\frac{dU}{ds}}$ along coordinate s

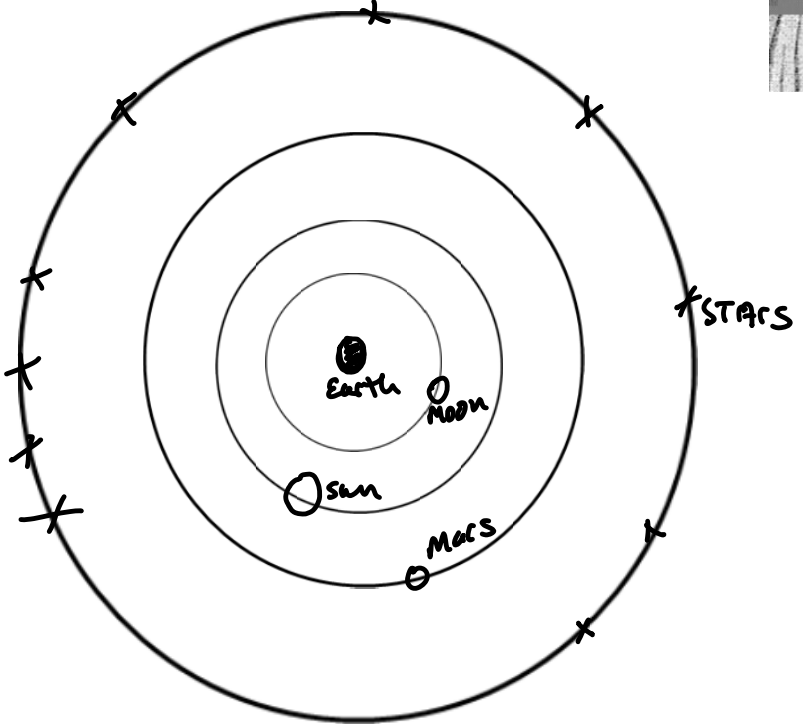
Example $PE_{spring} = \frac{1}{2}kx^2$ $\quad F_{spring} = -\frac{d(PE)}{dx} = -kx$

Let's look at gravitation + come back to this ...

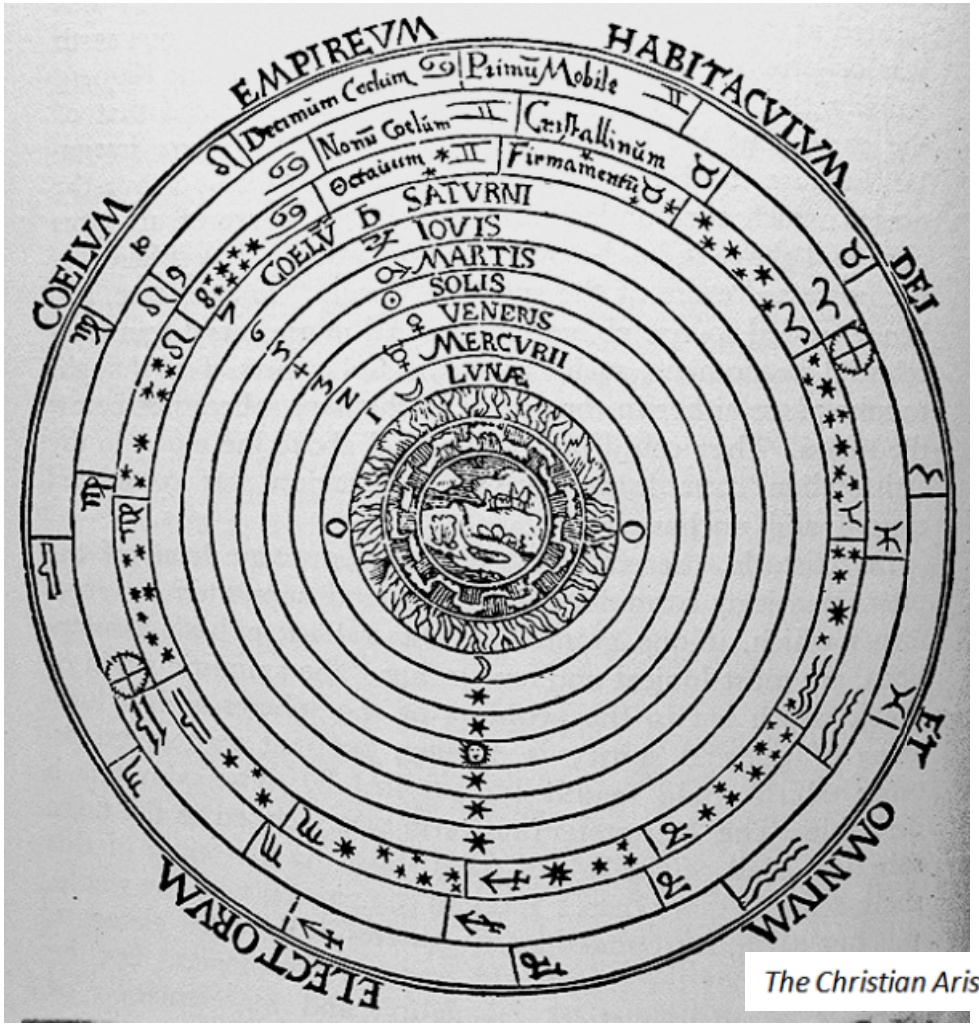
Newton's
Law of universal
gravitation
+ Why it was
a BFD

Pythagorian theory

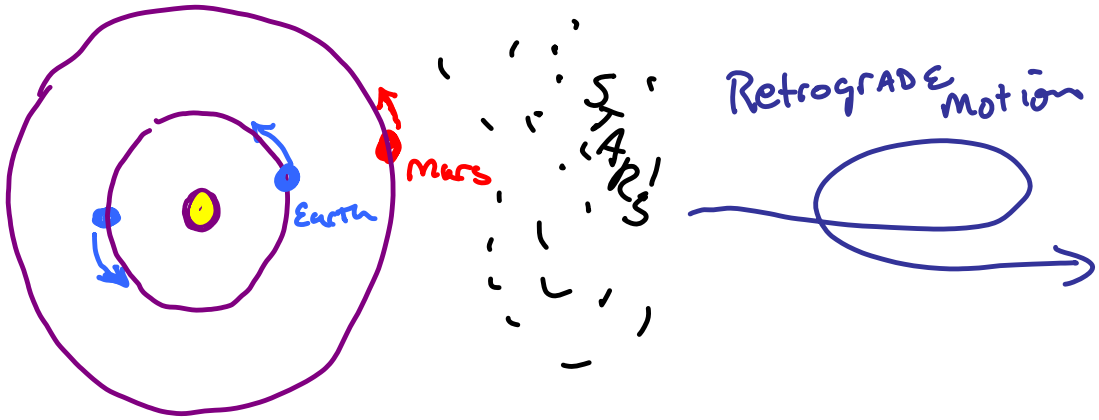
Early Greek view of the universe



Pythagoras
of
Samos
~500BC

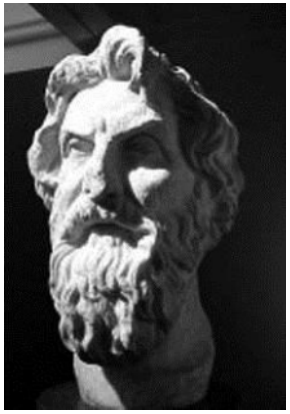


The Christian Aristotelian cosmos, engraving from Peter Apian's Cosmographia.



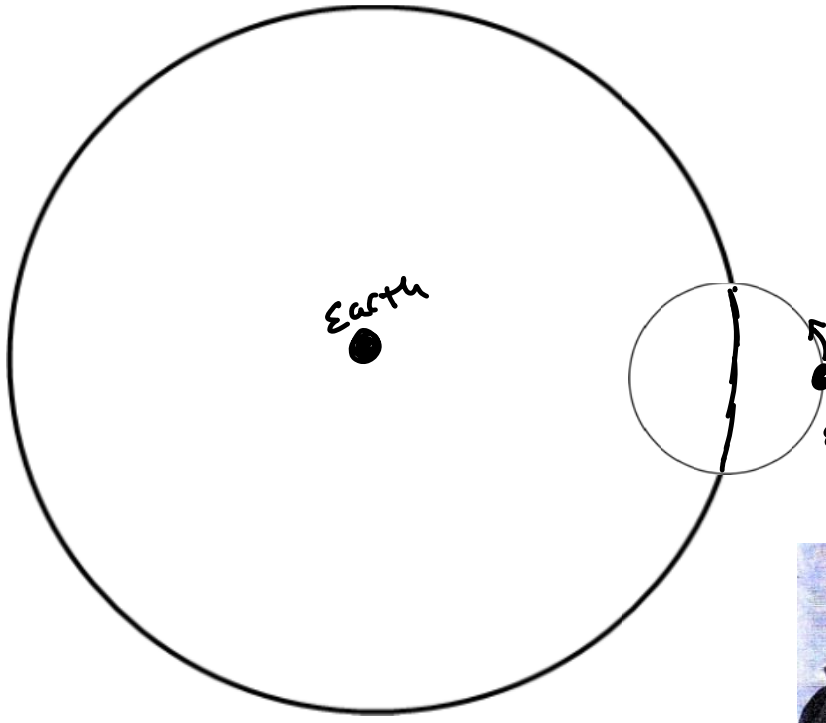
Fix the theory

Plato ~400 BC ~ Multiple spheres



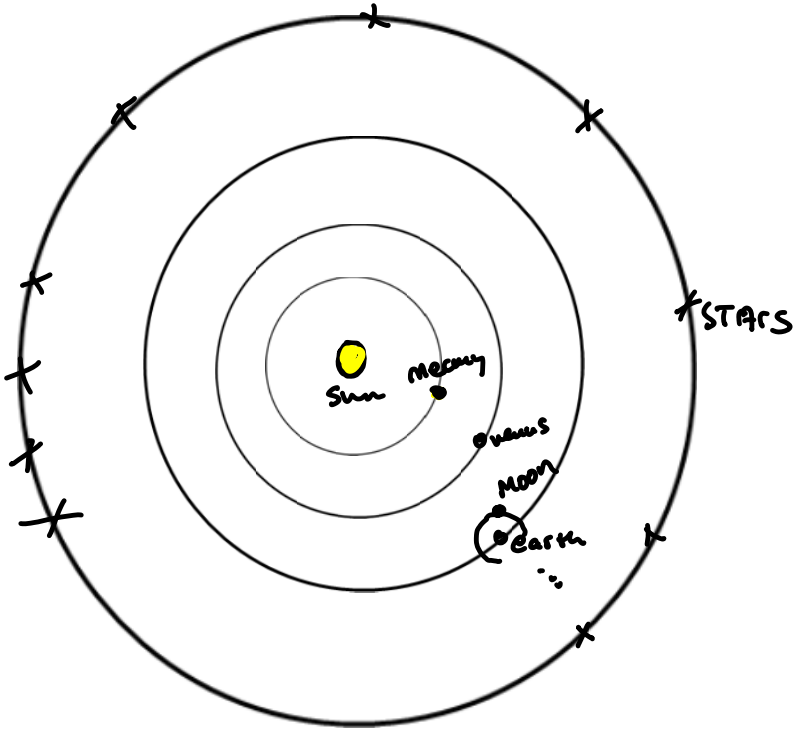
Aristarchus ~310 - 230 BC
(Greek)

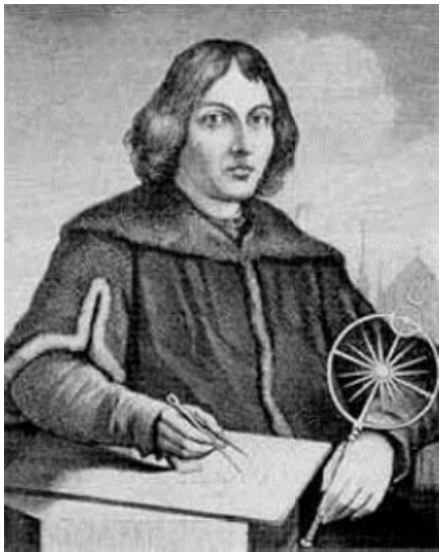
Proposed sun-centered universe
→ rejected



Ptolemy
~100 AD

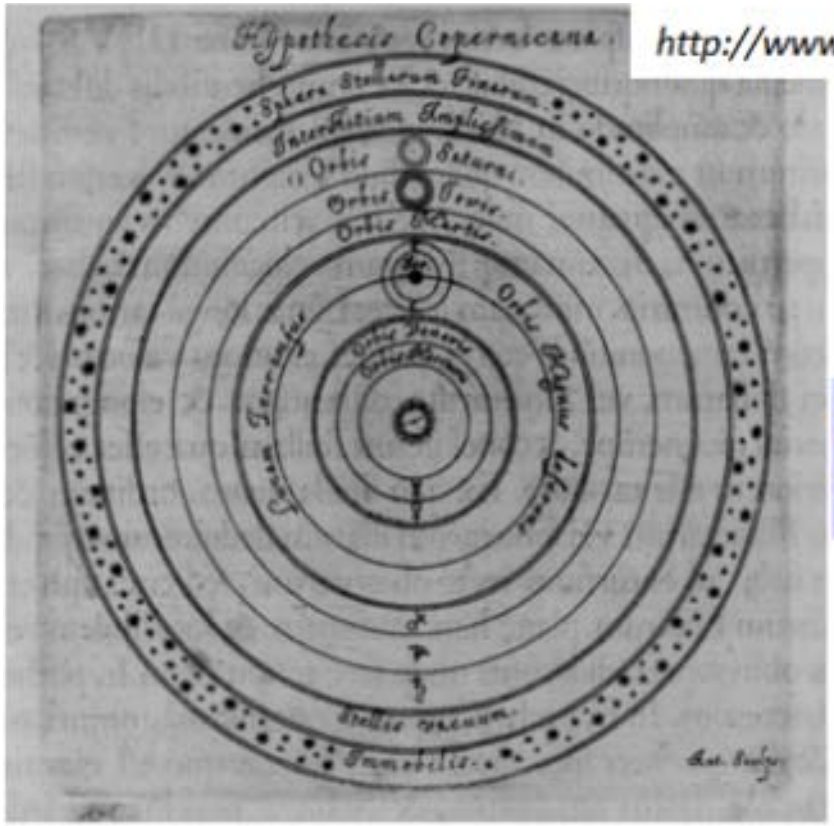
The Heliocentric universe





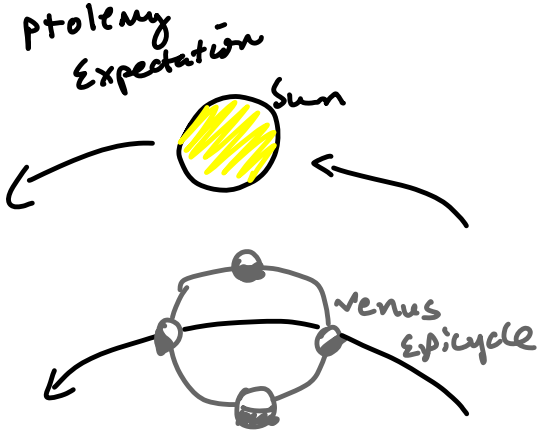
Nicolaus Copernicus
1473-1543
(Poland)

On the Revolutions of the Heavenly Spheres

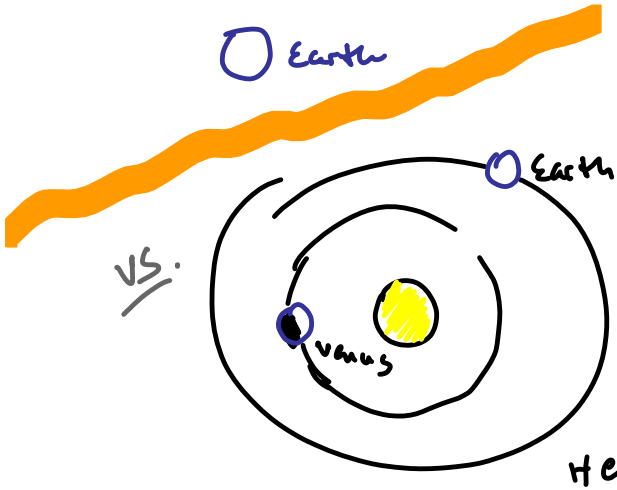


http://www.hps.cam.ac.uk/starry/copercosmol.html

Representation of Copernicus' Cosmos taken from Johannes Hevelius' *Selenographia*.



Galileo Galilei:
(1564 - 1642)



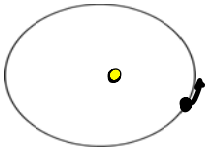
Observed phases of venus

Heliocentric expectation

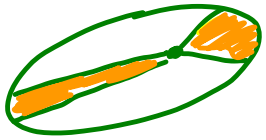
Tycho Brahe
1546 - 1601
(Dane)
careful observations
of positions
of sun, moon, planets

Brahe's data did NOT fit perfectly
with Copernicus' theory

Johannes Kepler
1571 - 1630
(German)



⇒ Elliptical orbits
fits the data !



Determined 3 laws
that mathematically
describe orbits seen —
relate periods, areas, axes ....

Sir Isaac Newton
1643 - 1727
(England)

universal law of gravitation

$$F = G\frac{M_1 M_2}{r^2}$$

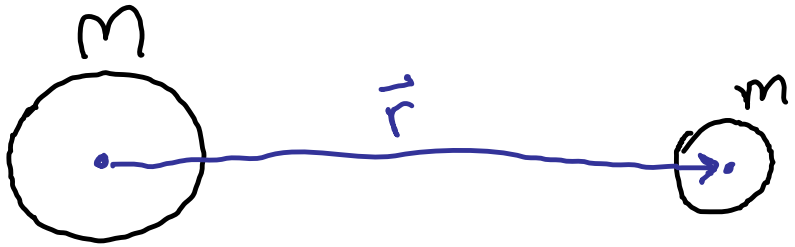
+

Laws of Motion

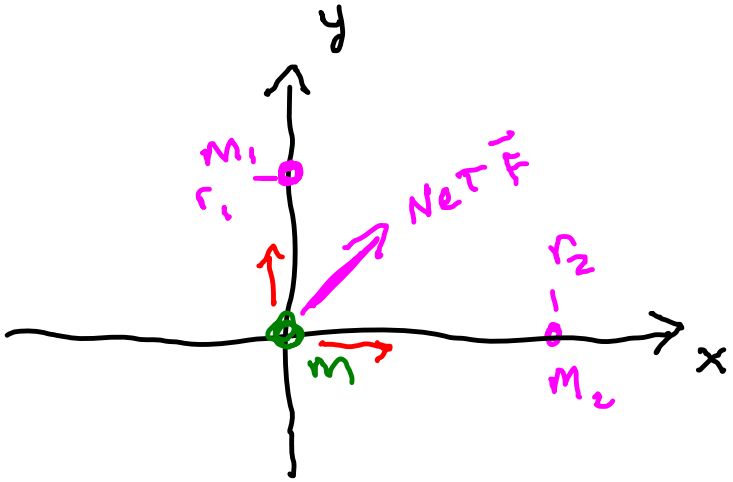
$\Rightarrow$ derived Kepler's
3 laws of planetary motion

In your text
Sect 6.5
Not stressed here

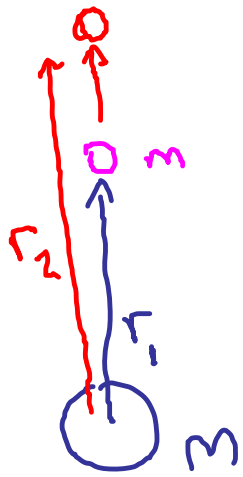
same law that governs Motion on Earth



$$\vec{F}_{\substack{\text{of} \\ M \text{ on } m}} = -\frac{GMm}{r^2}\hat{r}$$

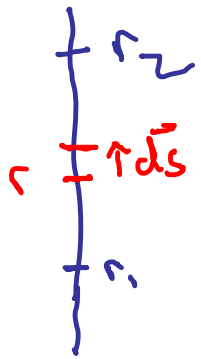


$$\vec{F}_{\substack{\text{on} \\ m}} = \frac{GM_1m}{r_1^2}\hat{y} + \frac{GM_2m}{r_2^2}\hat{x}$$



$r_2 > r_1$

How much work is done moving m from $r_1 \rightarrow r_2$ (along radial line)



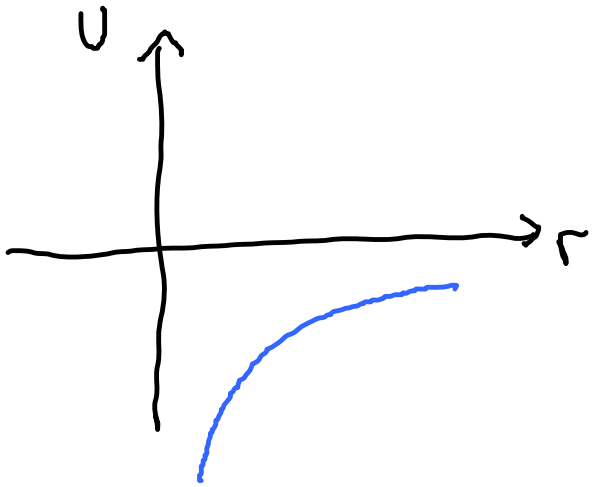
$$dw = \vec{F} \cdot d\vec{s} = F\,ds = F\,dr$$

$$W = \int_{r_1}^{r_2} F\,dr = \int_{r_1}^{r_2} \frac{GMm}{r^2}\,dr$$

$$= GMm \int_{r_1}^{r_2} \frac{1}{r^2}\,dr = -\frac{GMm}{r}\Big|_{r_1}^{r_2} = -GMm\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$$

$$W = -G\frac{Mm}{r_2} + G\frac{Mm}{r_1}$$

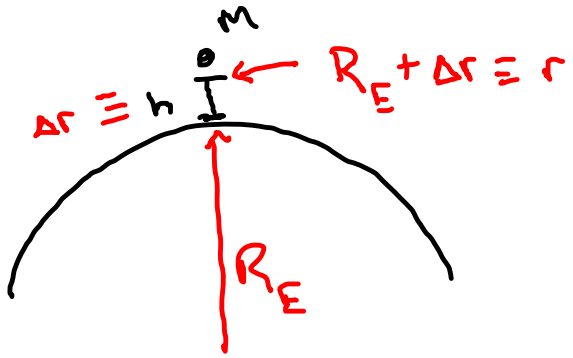
define $PE_{gravitational} = -\frac{GMm}{r}$



WTF ?

grav PE $\sim mgh$

$$-\frac{d\left(-\frac{GMm}{r}\right)}{dr} = -\frac{GMm}{r^2}$$



ΔPE go from $R_E \rightarrow R_E + \Delta r = r$

$$\Delta PE = \underbrace{-\frac{GM_E m}{r}}_{\text{end PE}} - \underbrace{-\frac{GM_E m}{R_E}}_{\text{starting PE}}$$

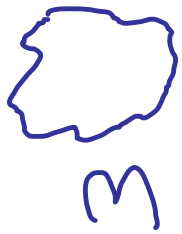
$$= \frac{-GM_E m R_E + GM_E m r}{r R_E} = \frac{GM_E m (r - R_E)}{R_E r}$$

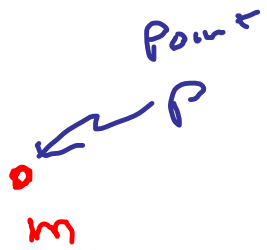
$$\Delta PE = \frac{G M_E m (R_E + \Delta r - R_E)}{R_E (R_E + \Delta r)} = \frac{G M_E}{R_E^2} m h$$

$R_E + \Delta r = R_E$

g

$= mgh$

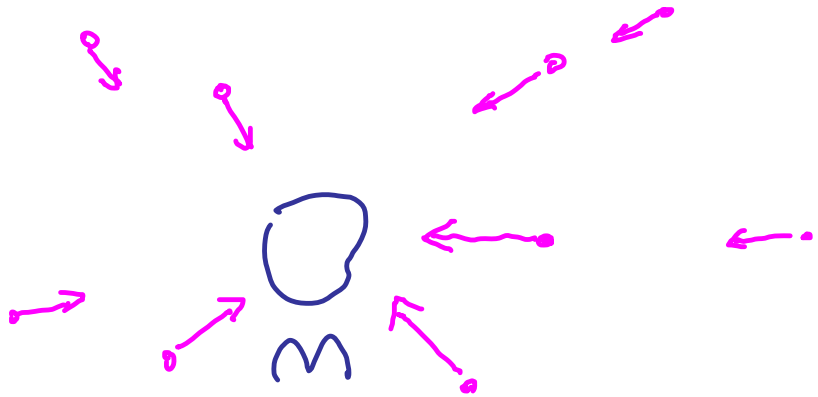




$\vec{g} \equiv$ gravitational Field

$\frac{\vec{F}}{m}$ at that point P

$\equiv -\frac{GM}{r^2}\hat{r}$


M


a = 1g