LECTURE 3
CHAPTER 5, 8

PHY 100. GRAVITY, ELECTRIC FIELD

RECITATIONS START THIS WEEK.

MONDAY	4.50	MOREY 505
WEDNESDAY	4.50, 7.40	MOREY 505
FRIDAY	2.00	HYLAN 105

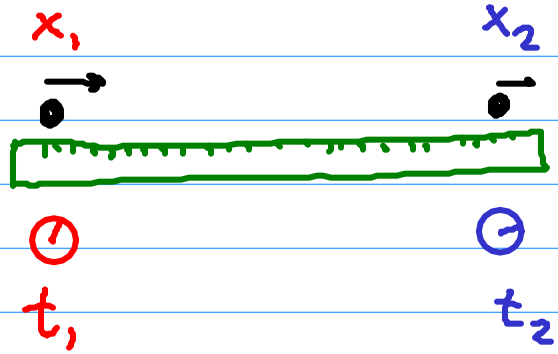
BRING CALCULATOR : COULD BE HELPFUL
COPY OF RECITATION PROBLEMS
PARTICIPATE!

RECAP FROM LAST LECTURE:

KINEMATIC VARIABLES:

AVE. SPEED $\equiv \dfrac{\Delta x}{\Delta t} = \dfrac{x_2 - x_1}{t_2 - t_1}$

(NO DIRECTION)



AVE. VELOCITY $\equiv \dfrac{\Delta x}{\Delta t}$ WITH DIRECTION INFORMATION

ACCELERATION $\equiv \dfrac{\Delta v}{\Delta t} = \dfrac{v_2 - v_1}{t_2 - t_1}$ HAS DIRECTION

NEWTON'S LAWS:

1) LAW OF INERTIA

A BODY PERSISTS IN ITS STATE OF MOTION UNLESS ACTED ON BY AN EXTERNAL FORCE.

2) FORCE LAW $F = ma$

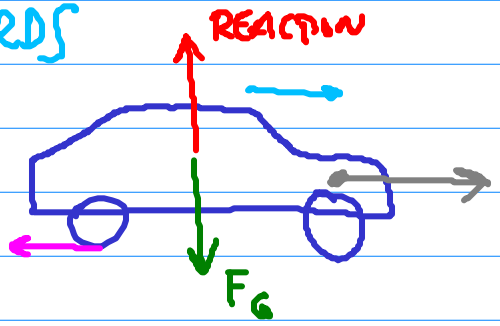
KEPLER'S LAWS:

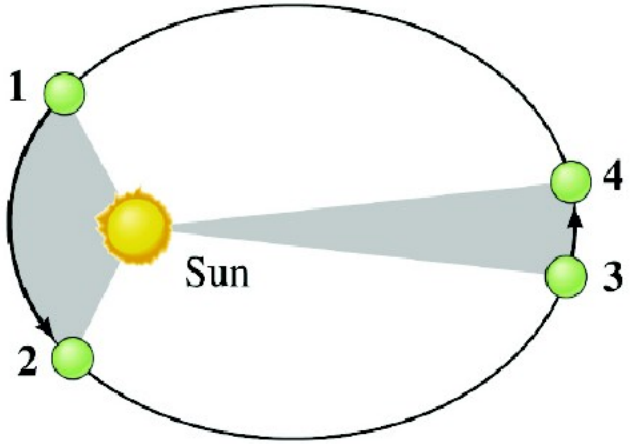
1) PLANETS DESCRIBE ELLIPSES AROUND SUN
2) PLANET SWEEPS OUT EQUAL AREAS IN EQUAL TIME INTERVALS
3) $s^2 \propto T^3$ RELATION BETWEEN AXIS OF ORBIT AND PERIOD

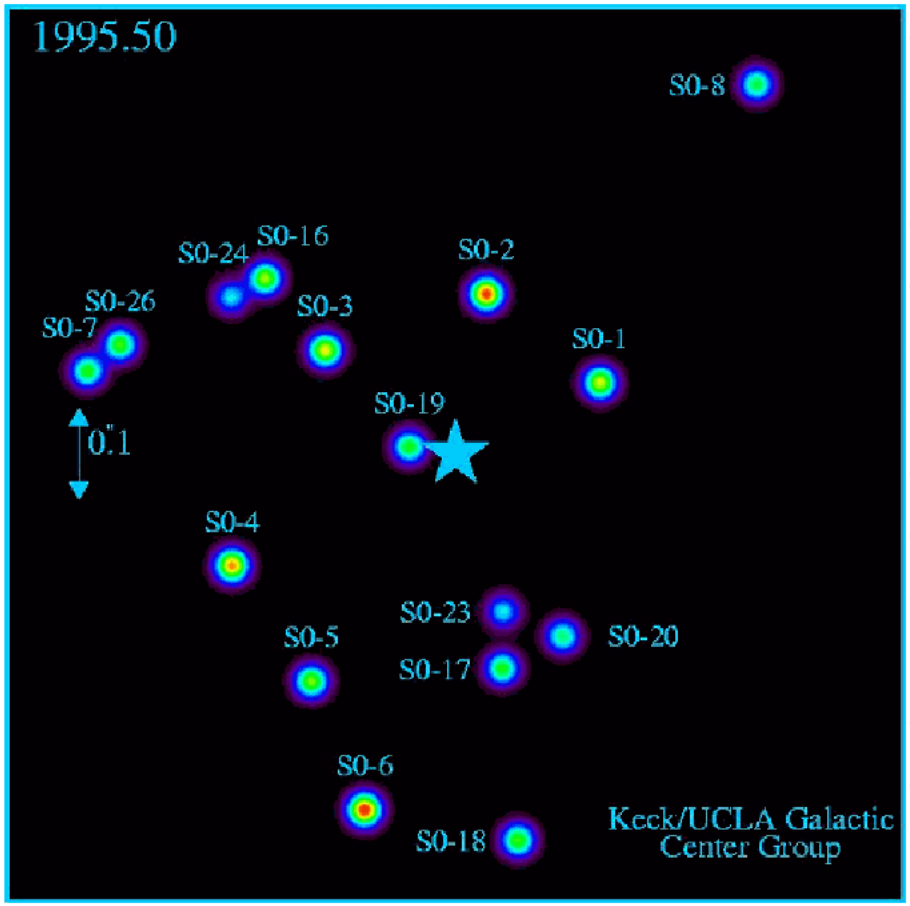
3) LAW OF ACTION - REACTION

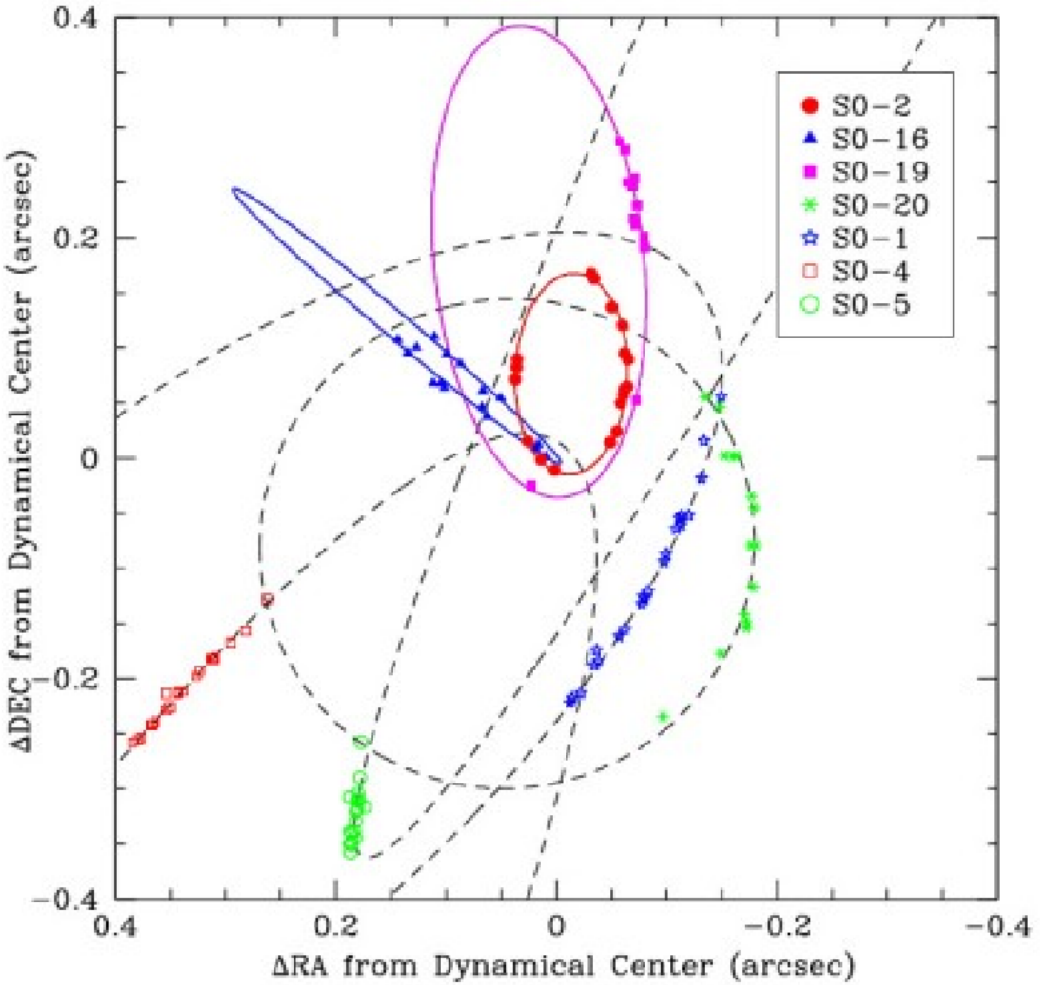
FOR EVERY ACTION THERE IS AN EQUAL AND OPPOSITE REACTION

→ THAT'S WHY CANNONS MOVE BACKWARDS AND ROCKETS MOVE UP.

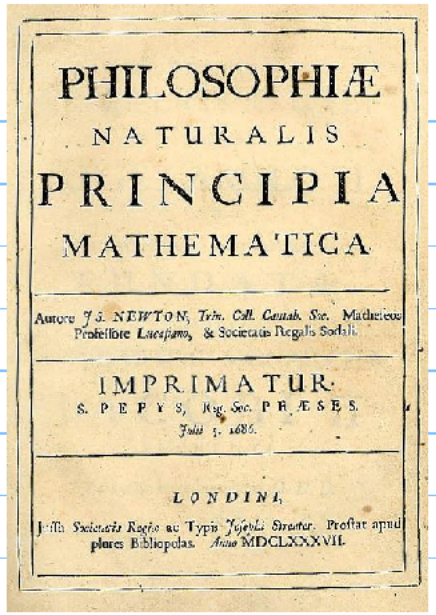








Animation:
http://www.ifa.hawaii.edu/~barnes/ast110_06/bhaq/2006orbits_animweb.gif



Sir Isaac Newton (1643-1727)

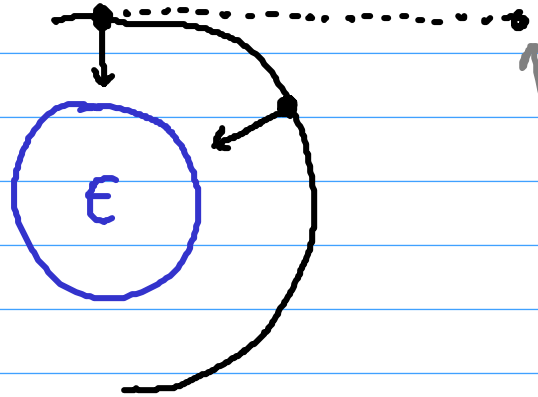
Philosophiæ Naturalis Principia Mathematica (1687)
Mathematical Principles of Natural Philosophy
Established: optics, mechanics, gravity, calculus

NEWTON'S LAWS + KINEM. VARS.
↓
ALLOW US TO MAKE DETAILED PREDICTIONS OF HOW OBJECTS MOVE/RESPOND UNDER THE INFLUENCE OF FORCES.
↓
DETERMINISTIC UNIVERSE

Newtonian universe includes everything but:
electromagnetism, quantum mechanics, mechanics of extreme velocity or extreme density

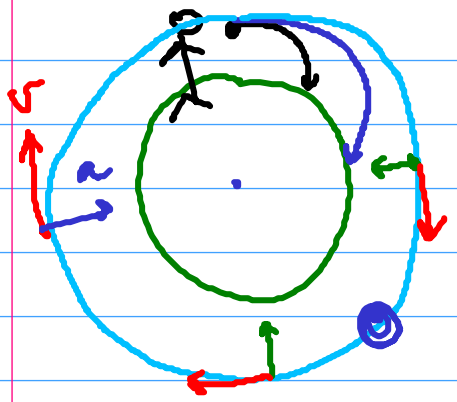
GRAVITY AS A FORCE:

THE MOON ORBITS AROUND THE EARTH, BUT THE FORCE OF THE EARTH OVER THE MOON IS DIRECTED TOWARDS THE CENTER OF THE EARTH



↑ INERTIA, IF THE EARTH WAS NOT THERE

APPLE FALLING AND MOON FOLLOW SAME ATTRACTION



TRY TO THROW BALL HORIZONTALLY UNTIL IT'S IN ORBIT.

LAW OF GRAVITATION

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

F ON BALL $\propto m_{ball}$

BUT THIRD LAW SAYS GRAVITY HAS SAME FORCE ON BOTH OBJECTS, SO

$F \propto m_{ball}\, m_{Earth}$

G = GRAVITATIONAL CONSTANT

$= 6.67 \times 10^{-11} \frac{m^3}{kg\,s^2}$

CHARACTERIZES THE STRENGTH OF THE FORCE.

$F \propto \frac{1}{d^2}$ THE FORCE IS INVERSELY PROPORTIONAL TO THE DISTANCE SQUARED. (DISTANCE BETWEEN THE CENTERS OF THE TWO OBJECTS)

↳ NEWTON INVENTED INTEGRAL CALCULUS TO BE ABLE TO DETERMINE THE CENTER OF COMPLICATED OBJECTS

$d \uparrow \Rightarrow F \downarrow$

THIS RELATION CAN BE DERIVED FROM THE VELOCITY OF THE MOON.

$d_M \sim 60\, R_E$

$T = 27$ days

$$a_M = \frac{v^2}{d_M} = \left(\frac{2\pi d_M}{T}\right)^2 \cdot \frac{1}{d_M} = \frac{4\pi^2 d_M}{T^2} = 0{,}0027\ m/s^2$$

(a_M: ACCEL. OF THE MOON; d_M: 360,000 km)

NOW COMPARE THE ACCELERATION OF THE MOON WITH THE ACCELERATION OF AN OBJECT IN THE SURFACE OF THE EARTH:

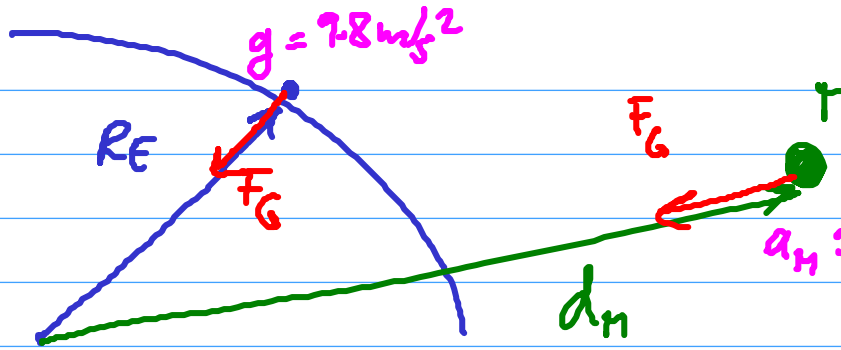
$a_{SURFACE} = g = 9.8\ m/s^2$

$$\frac{a_M}{a_{SURFACE}} = \frac{a_M}{g} = \frac{1}{d_M^2} \cdot \frac{R_E^2}{1}$$

$d_M \sim 60\, R_E \Rightarrow \frac{R_E}{d} = \frac{1}{60}$

$$\frac{a_M}{g} = \left(\frac{1}{60}\right)^2 \Rightarrow a_M = \frac{1}{3600}\, g \simeq 0{,}0027\ m/s^2$$

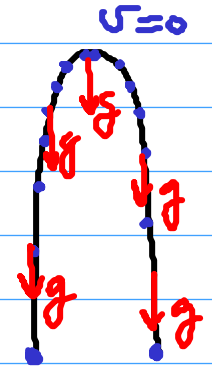
THAT "COINCIDENCE" CAN ONLY HAPPEN IF $F \propto \frac{1}{d^2}$



$$g = \frac{G M_E}{R_E^2}$$

$$a_M \simeq \frac{G M_E}{d^2} \simeq 0.0027\ m/s^2$$

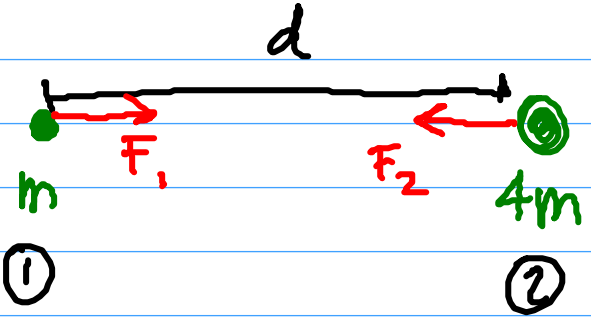
$$a_M = \frac{G M_E}{d_M^2}$$



$F = ma = g$

F SAME $\Rightarrow$ a SAME ALL POINTS

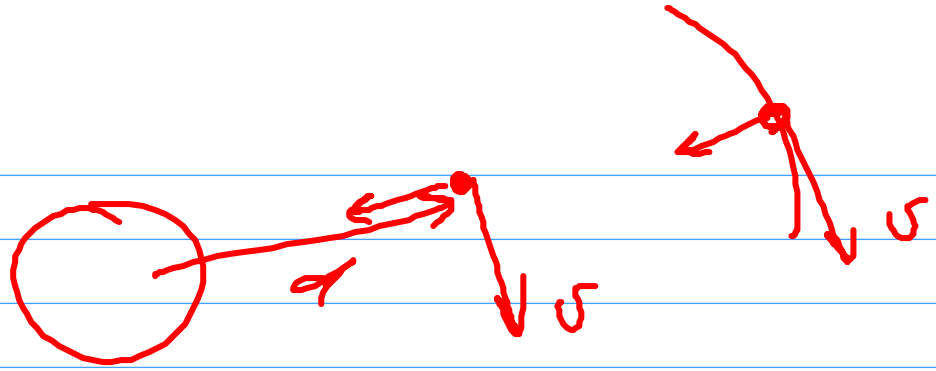
TWO STARS OF MASSES m AND $4m$ A DISTANCE d APART



HOW DOES GRAV. ATT. OF STAR 1 FOR STAR 2 COMPARE WITH THE GRAV. ATT. OF STAR 2 ON STAR 1?

$$F = G\frac{m_1 m_2}{d^2} = F_1 = F_2$$

ARE THE SAME!
ACTION – REACTION!



ELECTRIC FORCE (COULOMB 1736-1806) = COULOMB'S LAW

$$F_e = k \frac{q_1 q_2}{d^2}$$

k = COULOMB'S CONSTANT

ELECTRIC FORCE: CAN BE REPULSIVE OR ATTRACTIVE
G CAN ONLY BE ATTRACTIVE

q_1, q_2 = ELECTRIC CHARGES OF TWO OBJECTS

POSITIVE AND NEG. ELECTRIC CHARGES
+ → DEFICIT OF ELECTRONS (CONVENTION)
− → EXCESS OF ELECTRONS
MASS IS ONLY POSITIVE.

d = DISTANCE BETWEEN OBJECTS.

F_e IS MUCH STRONGER THAN F_G

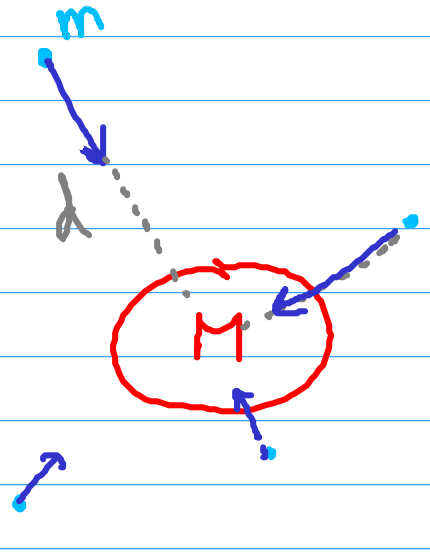
BOTH DECREASE WITH d^2

FIELDS : THE CONCEPT OF ACTION AT A DISTANCE IS DIFFICULT TO UNDERSTAND.
THE SUN IS 8 light-minutes AWAY BUT STILL MAKES THE EARTH GO AROUND ....

WE SAY THAT ANY MASS M AFFECTS THE SPACE WHERE m SITS SUCH THAT m FEELS THE GRAV. FORCE. SAME FOR Q AND q.

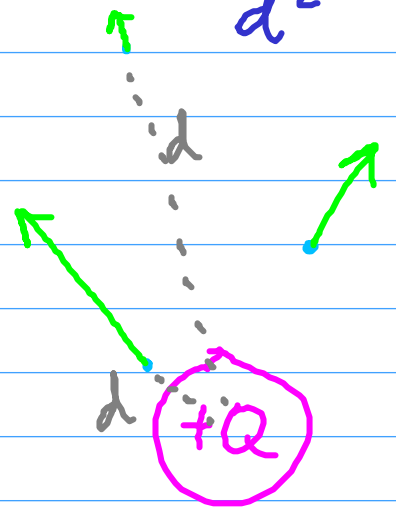
$$F_G = G\frac{Mm}{d^2} = a$$

$$\frac{F_{\text{test mass}}}{m_{\text{test mass}}} = \text{GRAV. FIELD} = \frac{GM}{d^2}$$



$$F_e = \frac{kQq}{d^2}$$

$$\text{ELEC. FIELD} = \frac{kQ}{d^2} = \frac{F_{\text{on test } q}}{q}$$



EVERY MASS / CHARGE IS SURROUNDED BY A FIELD THAT YOU CANNOT SEE BUT THAT YOU CAN FEEL WHEN THE FIELD EXERTS A FORCE ON A MASS OR A CHARGE.

FAMILIAR FIELDS

TEMP. FIELD

WIND FIELD