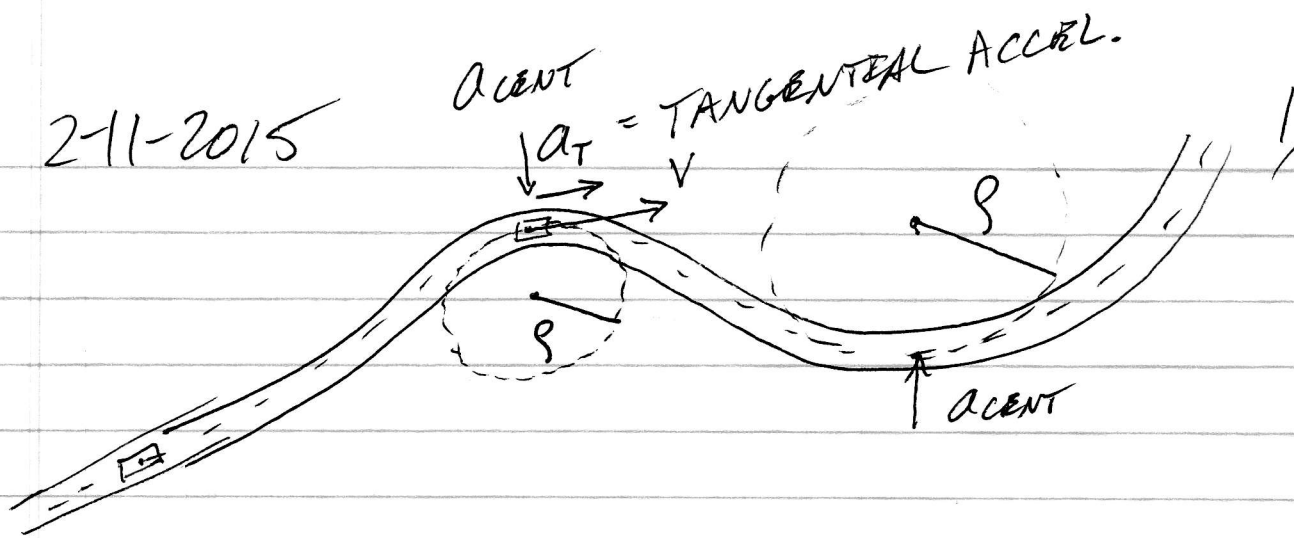


2-11-2015



CURVILINEAR MOTION - NON-CIRCULAR PATH

SPEED MAY BE CHANGING

'RHO' = ρ = INSTANTANEOUS RATE OF CURVATURE

a_T = SPEED CHANGE (BRAKE OR GAS)

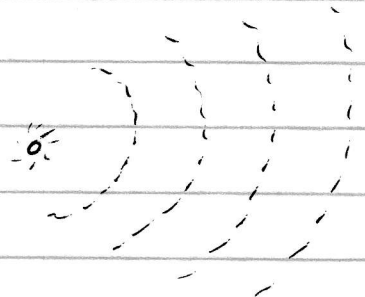
a_{cent} = DIRECTION CHANGE (STEERING WHEEL)

$$a_{cent} = \frac{v^2}{\rho} \quad \text{INWARD TO CURVE}$$

CIRCULAR AND ELLIPTICAL ORBITS

PRIOR TO KEPLER (1500-1600)

SUN WAS CENTER OF
CIRCULAR ORBITS

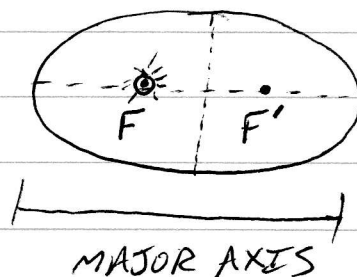


KEPLER PROPOSED 3 LAWS
OF PLANETARY MOTION

LAW OF
ORBITS

I. THE ORBITS OF THE PLANETS ARE ELLIPSES WITH THE SUN AT ONE FOCUS.

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$



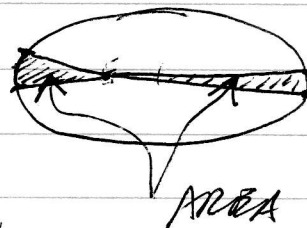
a = SEMI-MAJOR AXIS

LAW OF
AREAS

II. "A LINE FROM PLANET TO SUN SWEEPS OUT EQUAL AREA IN EQUAL TIME."

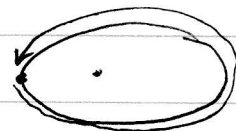
IN Δt

AN ~~ORB~~ PLANET NEAR THE SUN IN ITS ORBIT MOVES FASTER THAN WHEN FARTHER FROM THE SUN



LAW OF
PERIODS

III. THE PERIOD OF A PLANET SQUARED IS PROPORTIONAL TO ITS SEMI-MAJOR AXES CUBED.

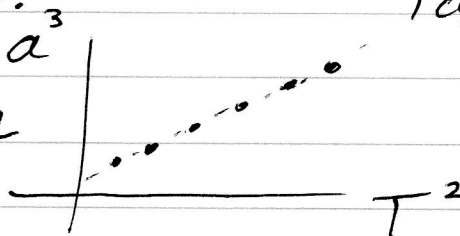


T = PERIOD
 T = 1 CYCLE

$$T^2 = a^3$$

IN EARTH YEARS

IN ASTRONOMICAL
UNITS



1 ASTRONOMICAL UNIT = AVERAGE DIST. OF
EARTH TO SUN
= 150 MILLION km
= 1.50×10^{11} m
= 93 MILLION MILES

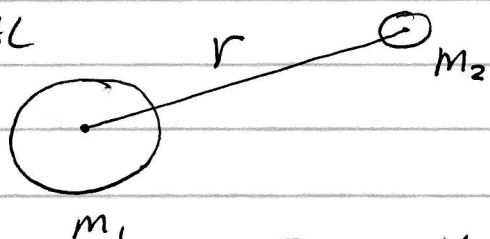
PLUTO EXAMPLE $a = 39.5$ AU. (EARTH)
 $T = \sqrt{a^3} \approx 247$ YEARS

NEWTON'S LAW OF UNIVERSAL GRAVITATION

F_G DEPENDS ON: • MASS OF BODY 1
• MASS OF BODY 2
• (DISTANCE BETWEEN THEIR CENTERS)²

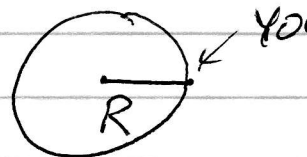
• UNIVERSAL GRAVITY CONSTANT

G



$$F_G = \frac{G m_1 m_2}{r^2}$$

TOWARD ATTRACTING OBJECT



ON THE SURFACE OF EARTH:

$$F_G = \frac{G M_E m}{R_E^2} = \left(\frac{G M_E}{R_E^2} \right) \cdot m$$

$$= g = 9.81 \text{ m/s}^2$$

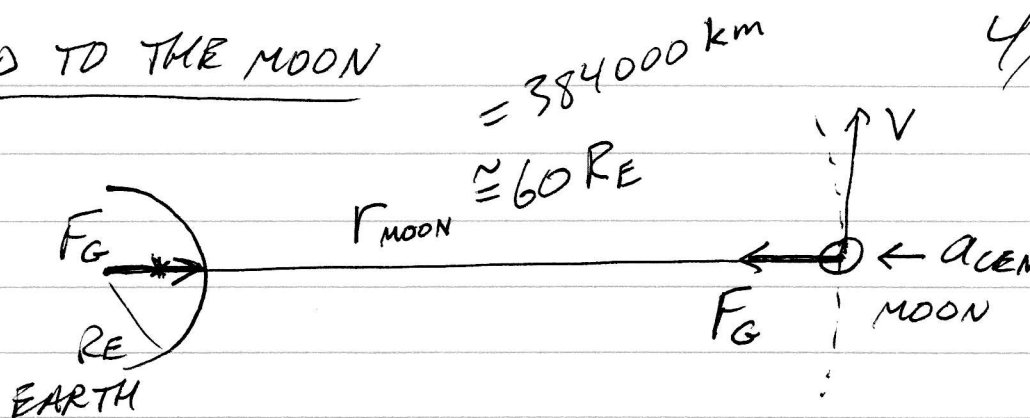
$$M_1 = M_E = 5.98 \times 10^{24} \text{ kg}$$

$$r = R_E = 6378136 \text{ m}$$

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

$$m_1 = m$$

APPLIED TO THE MOON



FORCE OF GRAVITY OF EARTH ON THE MOON

$$F_G = \frac{GM_E m}{r_{MOON}^2}$$

$$F_{NET} = ma$$

$$F_G = m a_{CENT} = m \frac{V^2}{r_{MOON}}$$

$$\frac{GM_E m}{r^2} = \frac{V^2}{r} m$$

NEWTON KNEW V, r, GM_E

FROM $g = \frac{GM_E}{R_E^2}$

$$GM_E = g R_E^2$$

- HIS MODEL CHECKED AGAINST OBSERVATION
- EXPLAINS KEPLER'S LAWS

SOME ORBIT FACTS

- ORBITS ARE PLANAR
- a AND b REPLACED WITH a AND e = ECCENTRICITY (HOW CIRCULAR)

APOL-
HELION



PERI-

PERIHELION (NEAR)

$$0 \leq e \leq 1$$