Phy 2A - Gravity Lecture

Wednesday, June 21, 2017 12:14 PM

Goals for the Lecture:

1) Understand Newton's Universal Law of Gravity and how to use it to solve problems
2) Understand gravitational potential energy when objects are not close to the earth's surface
3) Understand escape speed and be able to calculate it

Potential Energy:

gravity on Earth:

$$F_g = mg$$

$$W_g = F_g\, y = mgy$$

$$U_g = mgy$$

spring:

$$F_{sp} = kx$$

$$W = \int F\, dx$$

$$W_{sp} = \frac{1}{2} k x^2$$

$$U_{sp} = \frac{1}{2} k x^2$$

universal gravity:

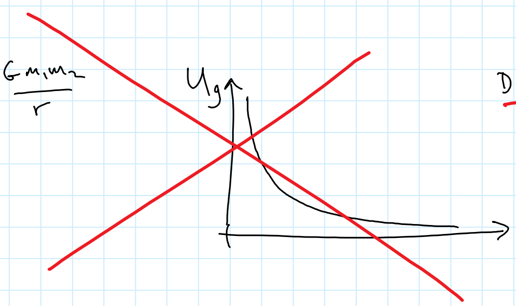
$$F = \frac{G m_1 m_2}{r^2}$$

using $W = \int F\, dr$

$$W = -\frac{G m_1 m_2}{r}$$

$$U_g = -\frac{G m_1 m_2}{r}$$

if $U_g = +\frac{G m_1 m_2}{r}$

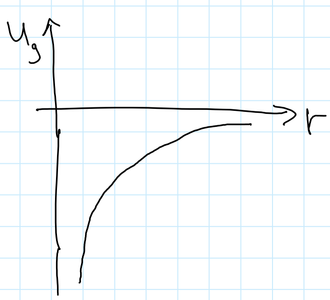


Does Not work

U must go down as r decreases

U must increase as r increases

if $U_g = -\frac{G m_1 m_2}{r}$



this works!

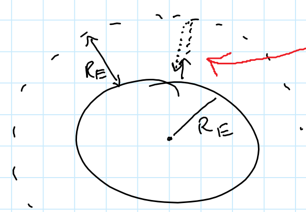
- Negative is okay
- zero is maximum PE
- cannot define zero anywhere

$U_g = 0$ only at $r = \infty$

$U_g = 0$ only at $r = \infty$

you cannot define zero to any other location

Problem: Throw a ball straight up so it reaches a height of R_E above the surface of the earth (No air resistance)



this is a large distance, so Force of gravity decreases (it is Not constant over the entire path)

cannot use kinematics, because F_g changes over this large distance (a is Not constant)

→ must use energy

So, do Not use kinematics → use energy

$$E_i = E_f$$

$$K_i + (U_g)_i = K_f + (U_g)_f$$

mass of ball

mass of earth

$$\frac{1}{2} m v_i^2 - \frac{G m M_E}{R_E} = \cancel{\frac{1}{2} m v_f^2}^{\,0} - \frac{G m M_E}{2R_E}$$

$$\frac{1}{2} \cancel{m} v_i^2 = \frac{G \cancel{m} M_E}{2R_E}$$

$$v_i = \sqrt{\frac{G M_E}{R_E}}$$

Prob: Find the escape speed from Earth's surface:

$$E_i = E_f$$

$$K_i + (U_g)_i = K_f + (U_g)_f$$

$$\frac{1}{2} m v_i^2 - \frac{G m_1 M_E}{R_E} = 0 + 0$$

$r = \infty$, so $U_g = 0$

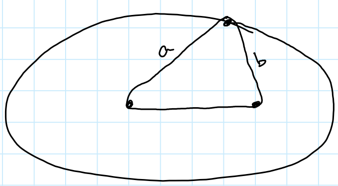
object just comes to rest at $r = \infty$

$$\frac{1}{2} \cancel{m} v_i^2 = \frac{G \cancel{m} M_E}{R_E}$$

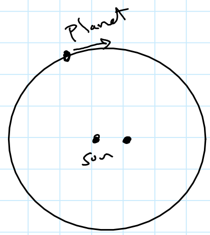
$$v_i = \sqrt{2 \frac{G M_E}{R_E}}$$

Kepler's Laws (Not on the exam)

1) Planets move in eliptical orbits with the sun at one focus

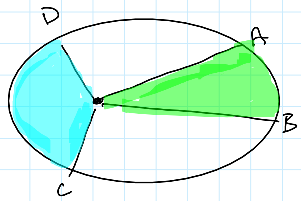


$a + b =$ constant



just a slight ellipse

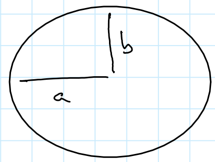
2)



$$(\text{Area})_{AB} = (\text{Area})_{CD}$$

so, planets speed up when close to the sun and slow down when far from the sun from the sun

3)

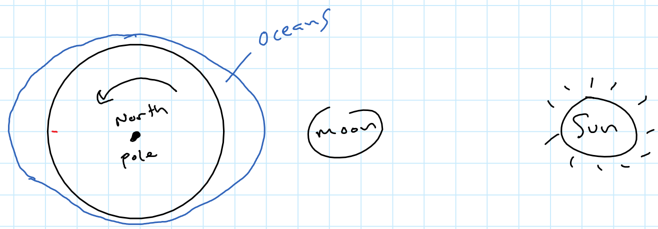


T = period (time it takes to complete one revolution)

$T^2 \propto a^3$

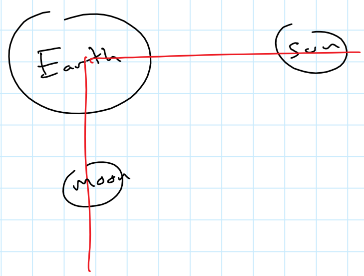
Tides:

Top view:



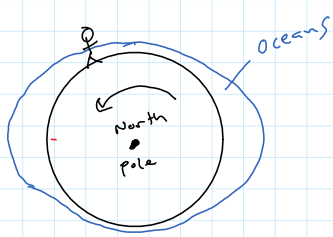
or

max tides either way



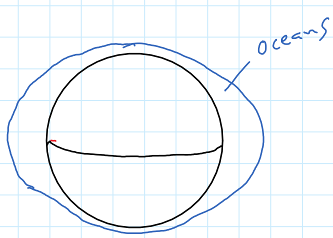
minimum tides

Top view:



as the earth rotates the water levels rise and fall

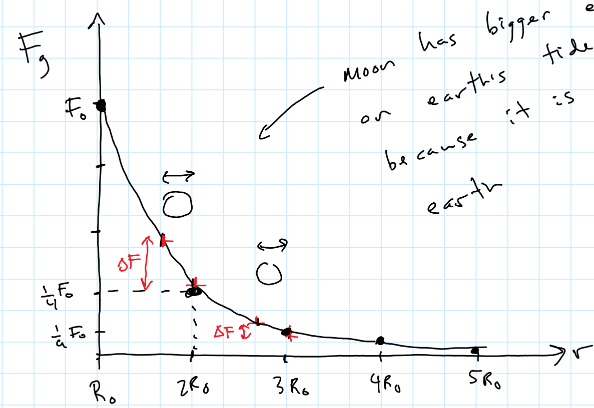
Side View:



$F = \frac{G m M_E}{r^2}$ $F_g \uparrow$

moon has bigger effect tides this close to

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



moon has bigger effect on earth's tides because it is close to earth

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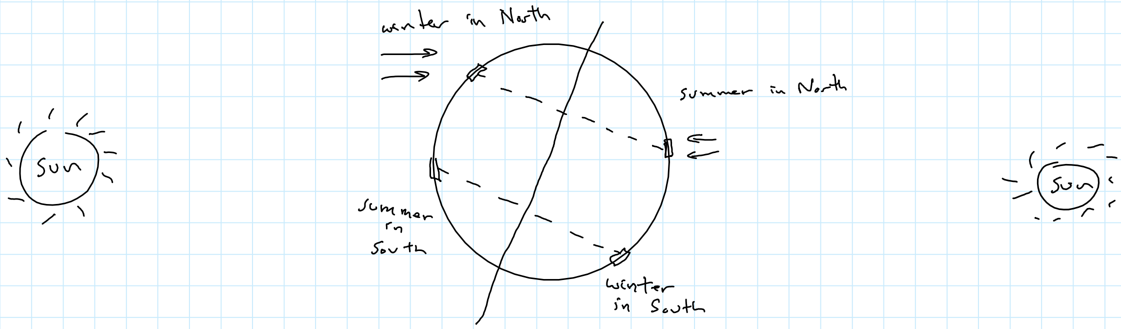
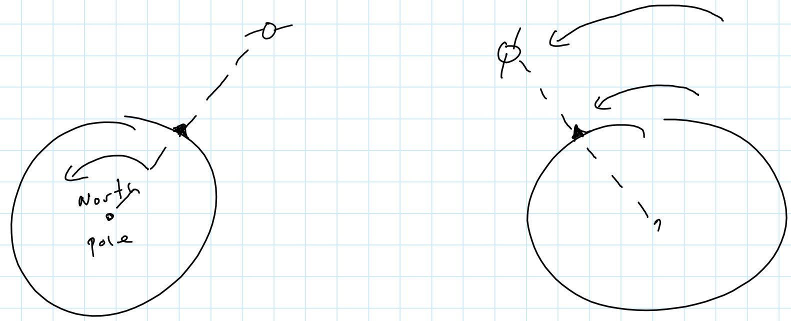
Seasons:



six months later

Geosynchronous orbit



Find r (distance from center of earth) for geosynchronous orbit

circular motion: $\Sigma F_{radial} = m a_{cp}$

$$\frac{G \cancel{m} M_E}{r^2} = \cancel{m}\frac{v^2}{r}$$

mass of satellite cancels out

what is v?

$$v = \frac{\text{distance}}{\text{time}} = \frac{2\pi r}{(1\ \text{day})\left(24\ \frac{\text{hr}}{\text{day}}\right)\left(3600\ \frac{\text{s}}{\text{hr}}\right)}$$

$$= \frac{2\pi r}{(24)(3600)}$$

$$\frac{G M_E}{r^2} = \frac{1}{r}\left[\overbrace{\frac{2\pi}{(24)(3600)} r}^{v}\right]^2$$

$$\frac{G M_E}{\left[\frac{2\pi}{24(3600)}\right]^2} = r^3$$