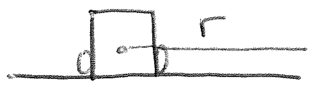
AP Physics Review

Circular Motion

Scenario #1 - Car going around a turn on a <u>flat</u> surface



Car is coming out of page at you and is making a turn w/a radius (r)

<u>What we know:</u>

$F_c = \frac{mv^2}{r}$ and acts towards center

$F_{\text{Static friction}} = \mu_s N$ where $N = mg$ (because road is flat)

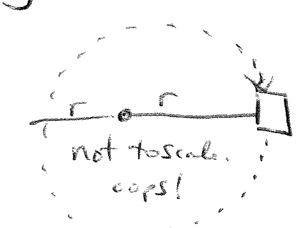
<u>What we can figure out:</u>

Maximum Velocity: $\frac{\cancel{m}v^2_{max}}{r} = \mu_s N = \mu_s \cancel{m} g$

$$V_{max} = \sqrt{\mu_s r g}$$

<u>Scenario #2</u> mass on a string being swung in a circle

F_c = Tension on string $= \frac{mv^2}{r} = ma_c$



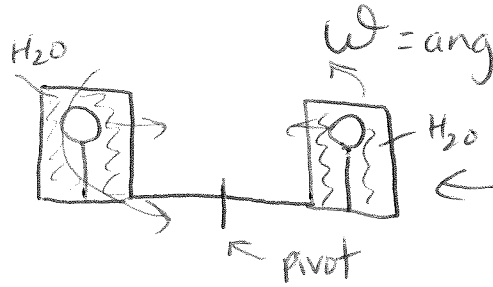
You can find Tension: $T = ma_c = \frac{mv^2}{r}$

You can find acceleration: $a_c = \frac{T}{m} = \frac{v^2}{r} = r\omega^2$

You can find Tangential Velocity: $V = \sqrt{a_c r} = \sqrt{\frac{rT}{m}}$

NOTE: Acceleration is always towards center

ω = angular speed = $\frac{V_{Tangent}}{r}$



← Rotate This and The bobs will bend inward (direction of acceleration)

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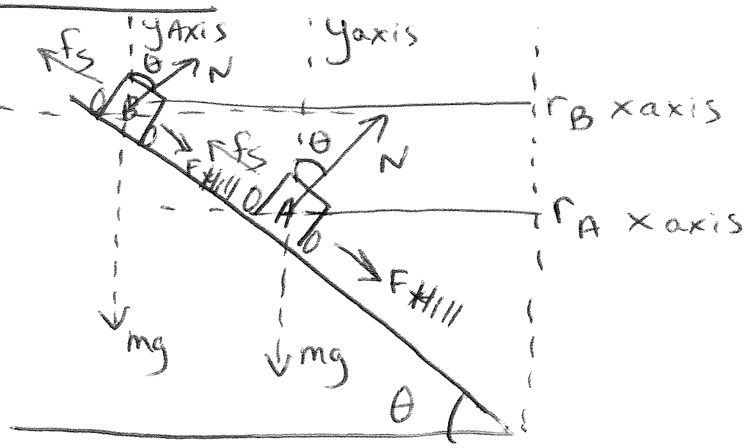
Scenario #3 – A car on a banked Turn (Ch. 7 #55)



NOTE: Car A + B are coming out of page at you.
- Notice That xaxis is along F_c.
- $r_B > r_A$
- mg acts in $-y$ direction
- N acts in θ away from y direction
  $N = \frac{mg}{\cos\theta}$
- Car Tries to slide down hill @ F_{Hill}. It is Prevented by f_s ($\mu_s N$)

What We Know:

$N = \frac{mg}{\cos\theta}$ $\quad N_{x\,direction} = N\sin\theta$

$f_s = \mu_s N$ $\quad f_{s\,x\,direction} = f_s\cos\theta$

$$F_c = \frac{mv^2}{r} = N\sin\theta + f_s\cos\theta$$

$$a_c = \frac{v^2}{r} = g(\mu_s + \tan\theta)$$

← if frictionless, This is zero

$$\omega = \sqrt{\frac{a_c}{r}} = \frac{v}{r}$$

$$\tan\theta = \frac{v^2}{gr} - \mu_s$$

$$V = \sqrt{gr(\mu_s + \tan\theta)} = (r\omega)^2$$

What This tells us:

- As $V \uparrow$, The car must climb The wall (r increase) because θ of hill is constant.

$\boxed{\text{θ of hill can be less for a given velocity if } \mu_s \text{ is present.}}$

- Mass of car doesn't matter.
- As Velocity ↑, ω (revolutions less) ↓ (notice That distance Car B would have to go around turn is greater Than Car A)
- a_c is constant so long as θ and μ_s are too!

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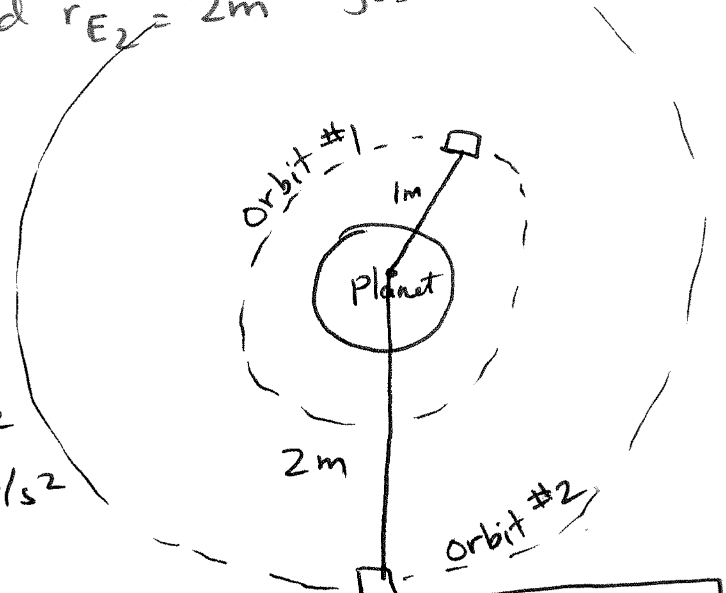
Scenario: you are in a Spacecraft orbiting ~~the Earth~~ a Planet

$$F = \cancel{m_1} g = \frac{G \cancel{m_1} m_E}{(r_E)^2}$$

$$g = \frac{G m_E}{(r_E)^2}$$

let's call This value 1 just to make life easy

lets Say $r_{E_1} = 1m$ and $r_{E_2} = 2m$ just for fun



$$g_1 = \frac{1}{(1m)^2} = 1 m/s^2$$

$$g_2 = \frac{1}{(2m)^2} = 0.25 m/s^2$$

$\therefore$ Spacecraft #1 has a g of $1 m/s^2$
Spacecraft #2 has a g of $0.25 m/s^2$

NOTE: a_c is not constant for orbiting satellites! It is for a banked turn, however.

$$a_{c_1} = \frac{V_1^2}{r_1} = 1 m/s^2 = \frac{V_1^2}{1m} \qquad V_1 = 1 m/s$$

$$a_{c_2} = \frac{V_2^2}{r_2} = 0.25 m/s^2 = \frac{V_2^2}{2m} \qquad V_2 = 0.707$$

V_T of any Satellite

$$V_T = \sqrt{\frac{G M_{Earth}}{r}}$$

$$\omega = V/r$$

<u>As you increase radial distance:</u> (p. 239 Table 7.3)

$V_{Tangent}$ decreases

a_c decreases

ω decreases — opposite to a banked Turn.

KE decreases

U increases (smaller negative value)

$E_{Total} = KE + U$ ↑

<u>As you increase $V_{Tangent}$</u> (fire retro booster rockets):

radius must grow to satisfy a_c. But, by virtue of The fact That r grows, a_c will decrease and Therefore, when you go to engine shut-down, your $V_{Tangent}$ at your new, higher orbit, will be <u>less</u> Than it was before you fired your boosters).

Circular Motion

Big ideas:

For a car on a slanted (banked) curve:

- As $V\uparrow$, $\omega\downarrow$ (revs/sec decrease)
- As $V\uparrow$, Radius $\uparrow$ (climbs the wall)
- a_c is constant
- V is greatest w/ largest R (got to go fast to stay up high)
- As $R\uparrow$, $\omega\downarrow$ (Same as for an orbiting satellite)

For an orbiting satellite

- As $V\uparrow$, $\omega\uparrow$ (you are getting close to Earth when $V\uparrow$)
- As $V\uparrow$, Radius $\downarrow$ (" " " " ")
- a_c is not constant. a_c is greatest closest to planet (Gravity pulls you in)
- V is greatest w/ smallest R
- V_T orbit $= \sqrt{\dfrac{GM_E}{r}}$
- $V_{\text{Escape velocity}} = \sqrt{\dfrac{2GM_E}{R_E}} = \sqrt{2gR_E}$
- $E_{\text{Total}} = -\dfrac{GmM_E}{2r}$
- As $R\uparrow$, $\omega\downarrow$ (same as for a banked curve)