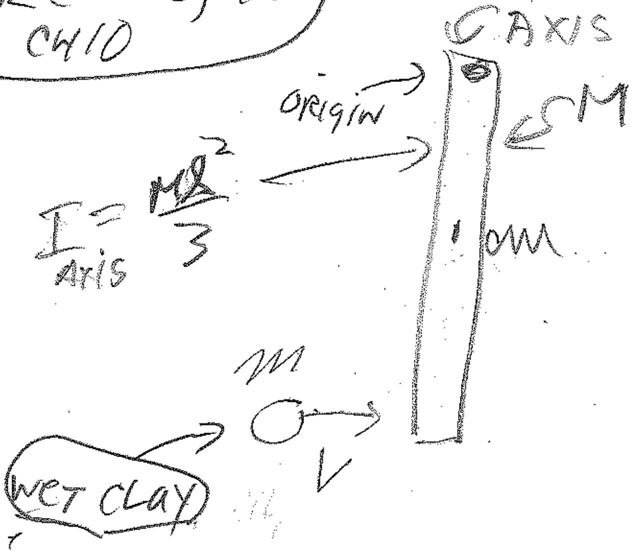
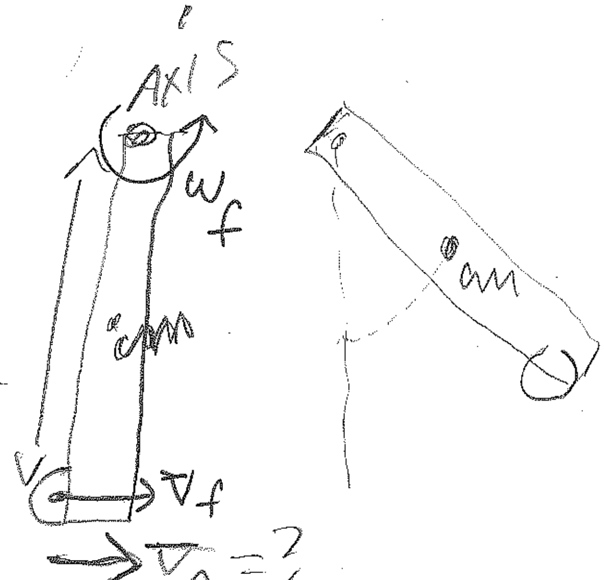
CH10 5-13-13

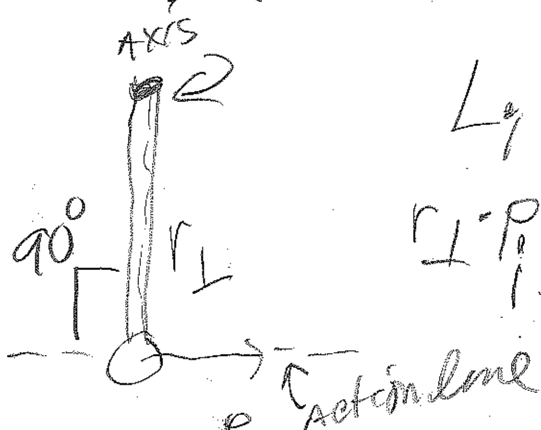
missing topics on test 4

Famous door collision problem

(Like #46, 48 CH10)







$mv = p_i$

$|\vec{p}| = mv$

$$L_i = L_f$$

$$r_\perp \cdot p_i = r_\perp p_f + I_{AXIS} \cdot \omega_f \ ; \quad \omega_f = \frac{v_f}{\ell}$$

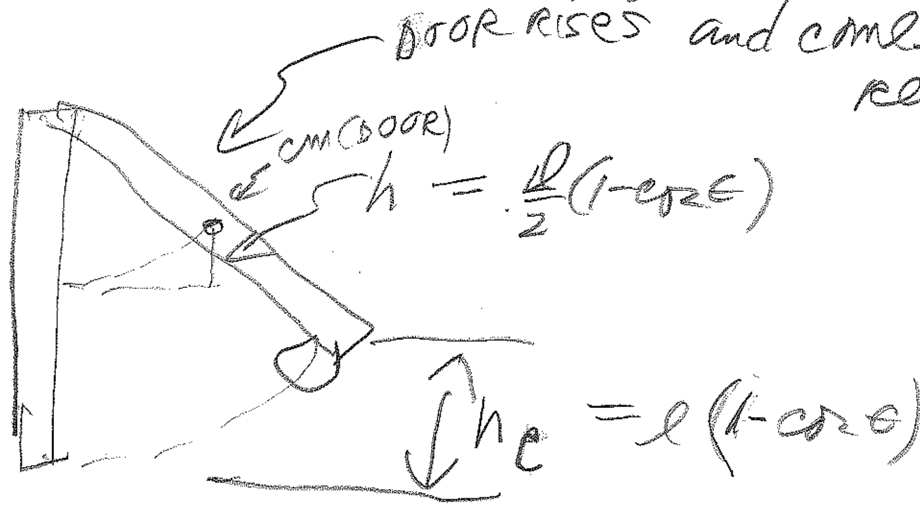
(DOOR-I)

$$\ell \cdot mv = \ell m v_f + I_{AXIS} \cdot \frac{v_f}{\ell}$$

$$\ell m v = \left(\ell m + \frac{I_{Axis}}{\ell}\right) \cdot v_f$$

$$v_f = \frac{\ell m v}{(m \cdot \ell + I/\ell)} \ ; \quad I = I_{AXIS}$$

Conservation of energy:



$$\frac{1}{2}mv_f^2 + \frac{1}{2}I_{AXIS}\,\omega_f^2 = Mg\frac{l}{2}(1-\cos\theta) + mgl(1-\cos\theta)$$

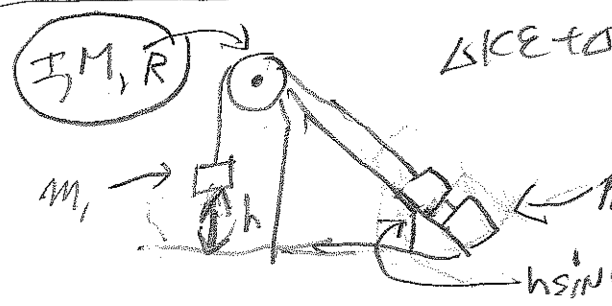
$$\omega_f^2 = \frac{v_f^2}{l^2}$$

$$\Delta KE + \Delta U_g = 0$$

$$0 - \frac{1}{2}mv_f^2 - \frac{1}{2}I\frac{v_f^2}{l^2} + Mg\frac{l}{2}(1-\cos\theta) + mgl(1-\cos\theta)$$

Same idea for test 3

$$\Delta KE + \Delta U_g = 0$$



CH14 pendulum

(1) Ideal — mass-less string, Bob.

(2) Physical

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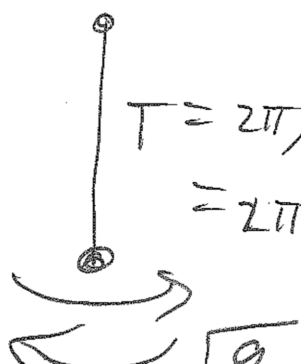
(1)

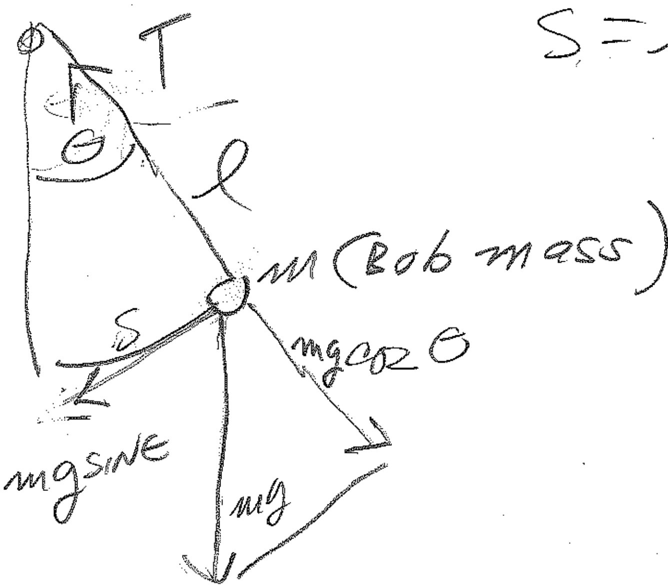
$s = l \cdot \theta$



$T = 2\pi/\omega$

$= 2\pi\sqrt{\frac{l}{g}}$

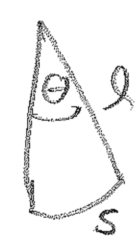
$\omega = \sqrt{\frac{g}{l}}$



Facts: (A) $\frac{mv^2}{l}$ = pos − neg = $T - mg\cos\theta$ ← (NOT needed)

(B) $m \cdot \frac{d^2 s}{dt^2} \approx -mg\sin\theta$ ← negative: restoring force

Note:



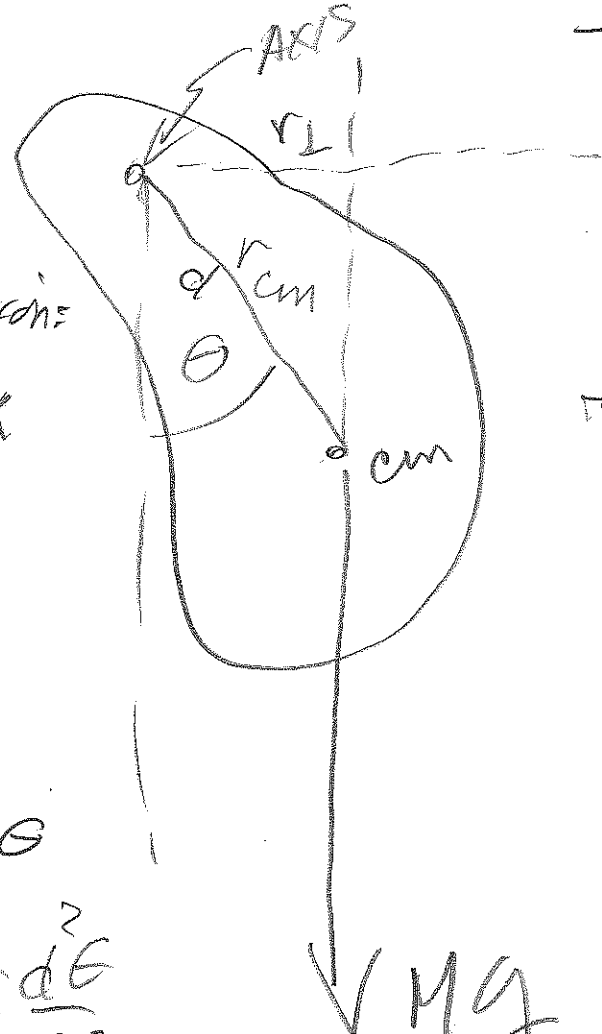
$s = l \cdot \theta$

$m \cdot l \frac{d^2\theta}{dt^2} = -mg\theta$; assume $\theta \ll 1$, $\sin\theta \approx \theta$

$l \frac{d^2\theta}{dt^2} = -g\theta \Rightarrow \theta = A\cos(\omega t + \phi)$

$\omega = \sqrt{g/l}$

② physical pendulum See test 4 and test 3



$I = I_{AXIS}$

CH10: Newton's law of rotation:

$\tau = -r_\perp \cdot Mg = I\alpha$

"restoring" torque

$-r_{cm} \cdot \sin\theta \cdot Mg = -I \frac{d^2\theta}{dt}$

$\theta << 1 \Rightarrow \sin\theta \simeq \theta$

$-r_{cm} \cdot \theta Mg = I \frac{d^2\theta}{dt^2}$

$I \frac{d^2\theta}{dt^2} = -r_{cm} Mg\theta \iff m\frac{d^2x}{dt^2} = -kx \Rightarrow \omega = \sqrt{\frac{k}{m}}$ (CH14)

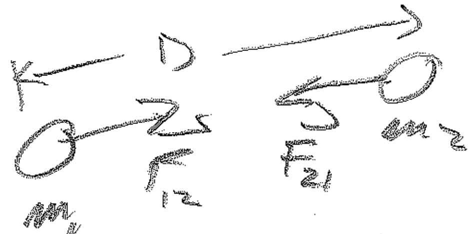
$\theta = A \cdot \cos(\omega t + \phi)$

$\omega = \sqrt{\frac{Mg r_{cm}}{I}} = \sqrt{\frac{Mgd}{I}}$ $(r_{cm} = d)$

CH 13 GRAVITY

Main issues

(1) Universal law of gravitation



$$\vec{F}_{12} = -\vec{F}_{21}$$ and

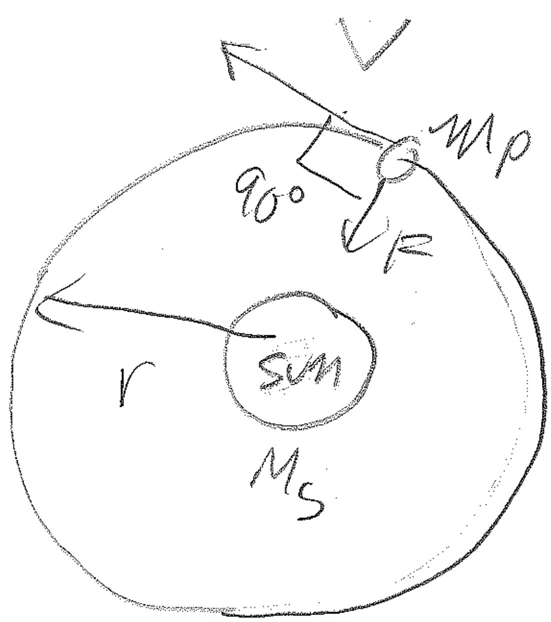
$$F_{12} = F_{21} = \frac{G m_1 m_2}{D^2}$$

Always attractive!

(Physics 4B: Attractive or repulsive inverse square law - Electric fields)

We will do practice vector problems.

(2) ORBITS and KEPLER'S LAW.



$$F = \frac{G m_p M_S}{r^2}$$

and $$F = \frac{m_p V^2}{r}$$

THUS: $$\frac{m_p V^2}{r} = \frac{G m_p M_S}{r^2}$$

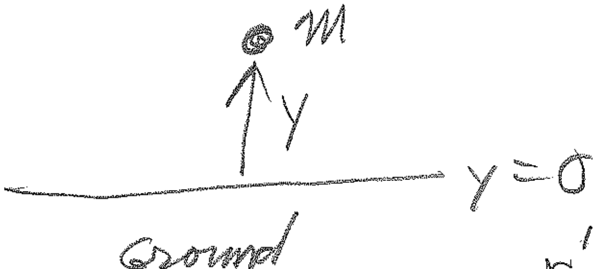
$$V^2 = \frac{G M_S}{r}$$

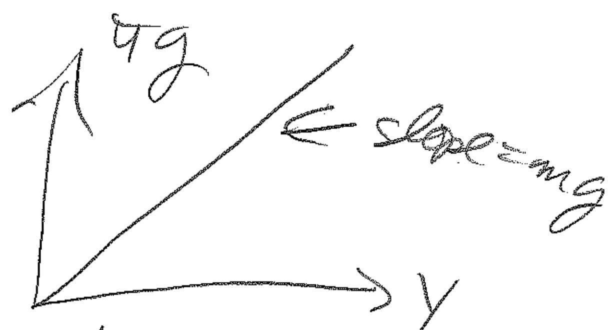
note: $V = \frac{2\pi r}{T}$, T = PERIOD

$$V^2 = \frac{4\pi r^2}{T^2} = \frac{G M_S}{r} \rightarrow \boxed{T^2 = \frac{4\pi}{G M_S} r^3}$$ KEPLER'S LAW

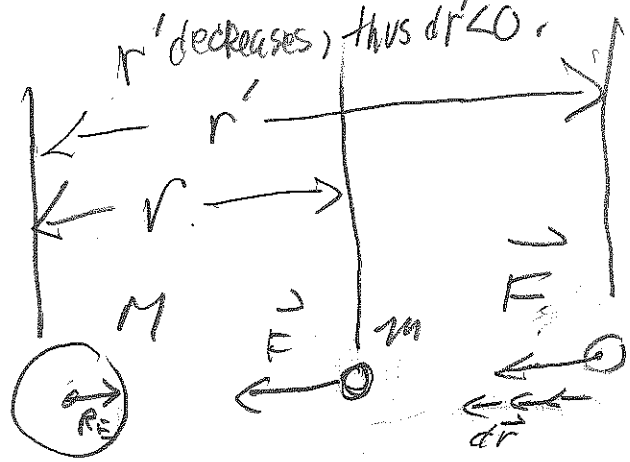
(3) Potential energy and Escape speed

Comparison CH 7 $U_g = mgy$





CH 13



dr' = dummy variable

r = final radius

$-dr' > 0$ since $dr' < 0$

$-dr' = |d\vec{r}|$

Theory:

CH 7

$\Delta U = -W$

W = work done by field

$$dU = -dW$$

$$dU = -\vec{F} \cdot d\vec{r}$$

$$dU = -|\vec{F}||d\vec{r}|\cos 0$$

$$dU = -|\vec{F}||d\vec{r}| < 0 \; ; \; dU = -\frac{GMm}{r'^2}(-dr')$$

$$dU = \frac{GMm}{r'^2} dr' < 0$$

since $dr' < 0$

$$U = \int_{\infty}^{r} \frac{GMm\, dr'}{r'^2}$$

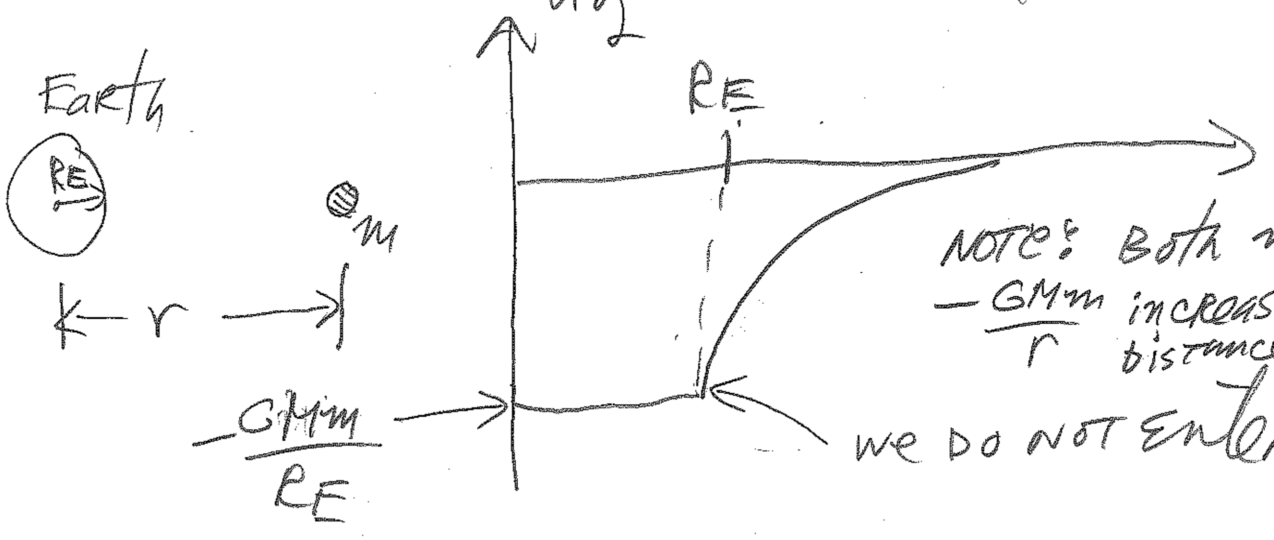
$$= -GMm\left[\frac{1}{r} - \frac{1}{\infty}\right]$$

M = Earth

m = planet (or satellite) mass

$$\boxed{U = -\frac{GMm}{r}} \quad ; \; r \geq R_E$$

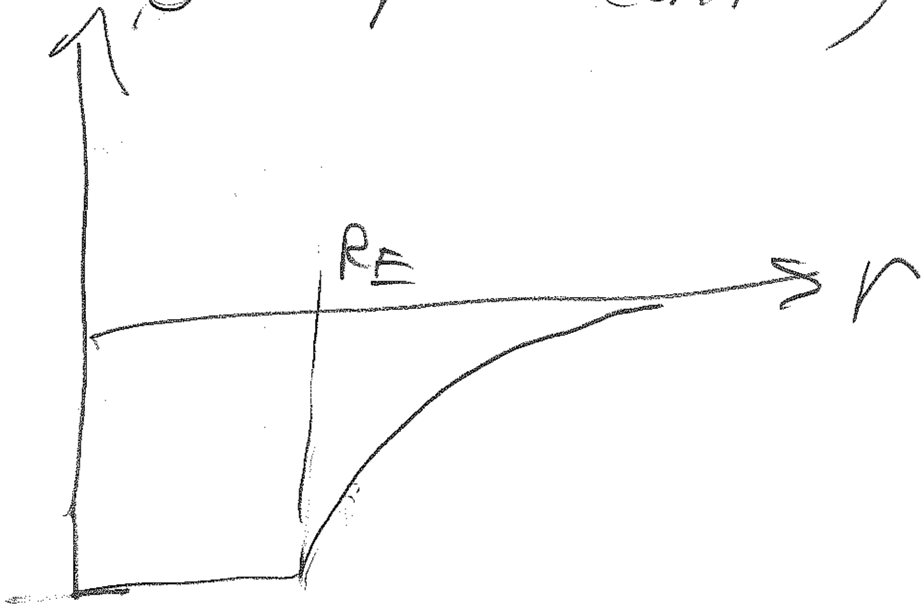
NOTE: $U(\infty) = 0$



NOTE: Both mgy and $-\frac{GMm}{r}$ increase with distance from Earth.

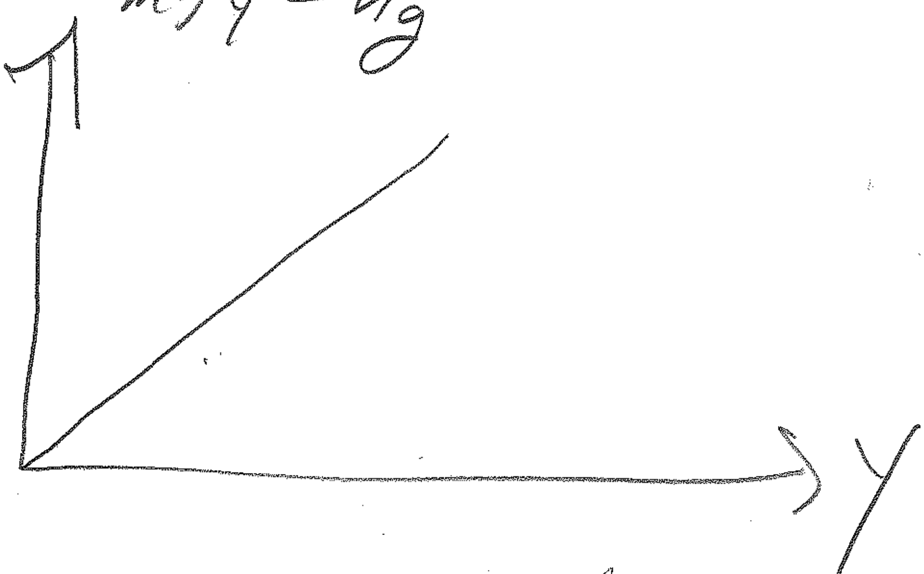
We do not enter Earth.

$U_G = -\frac{GMm}{r}$ (CH 13)



near Earth approximation (CH 7)

$mgy = U_g$



Both mgy and $-\frac{GMm}{r}$ increase with distance from Earth you can prove that

$$-\frac{GMm}{(R_E+y)} + \frac{GMm}{R_E} = mgy$$

when: (i) $y << R_E$

use TAYLOR'S EXPANSION about $y=0$.

when $y << R_E$

$$\frac{-GMm}{R_E\left(1+\frac{y}{R_E}\right)} + \frac{GMm}{R_E} = mgy$$

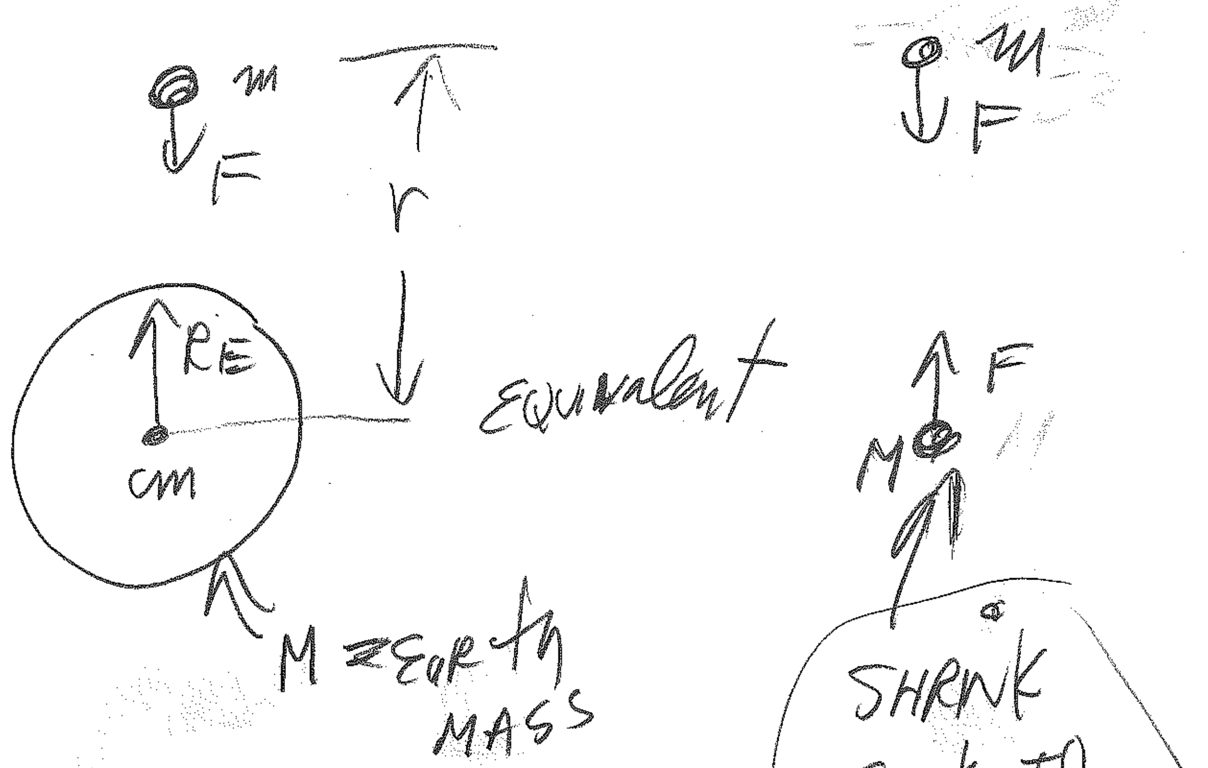
$$-\left[\frac{GMm}{R_E}\left(1-\frac{y}{R_E}\right)\right] + \frac{GMm}{R_E} = mgy$$

1ST ORDER TAYLOR'S EXPANSION

$$-\frac{GMm}{R_E} + \frac{GMm}{R_E^2}\cdot y + \frac{GMm}{R_E} = mgy$$

$$\boxed{\frac{GMm}{R_E^2} = mgy}$$

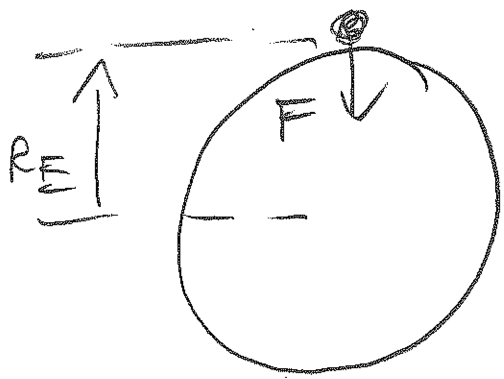
TRUE IF $\frac{GM}{R_E^2} = g = 9.8\,\frac{m}{s^2}$



SHRINK Earth TO a single POINT.

Earth feels same pull:

$$F = \frac{GMm}{r^2}$$



$$\cancel{m}g = \frac{GM\cancel{m}}{R_E^2}$$

$$g = \frac{GM}{R_E^2} = 9.8\,\frac{m}{s^2}$$

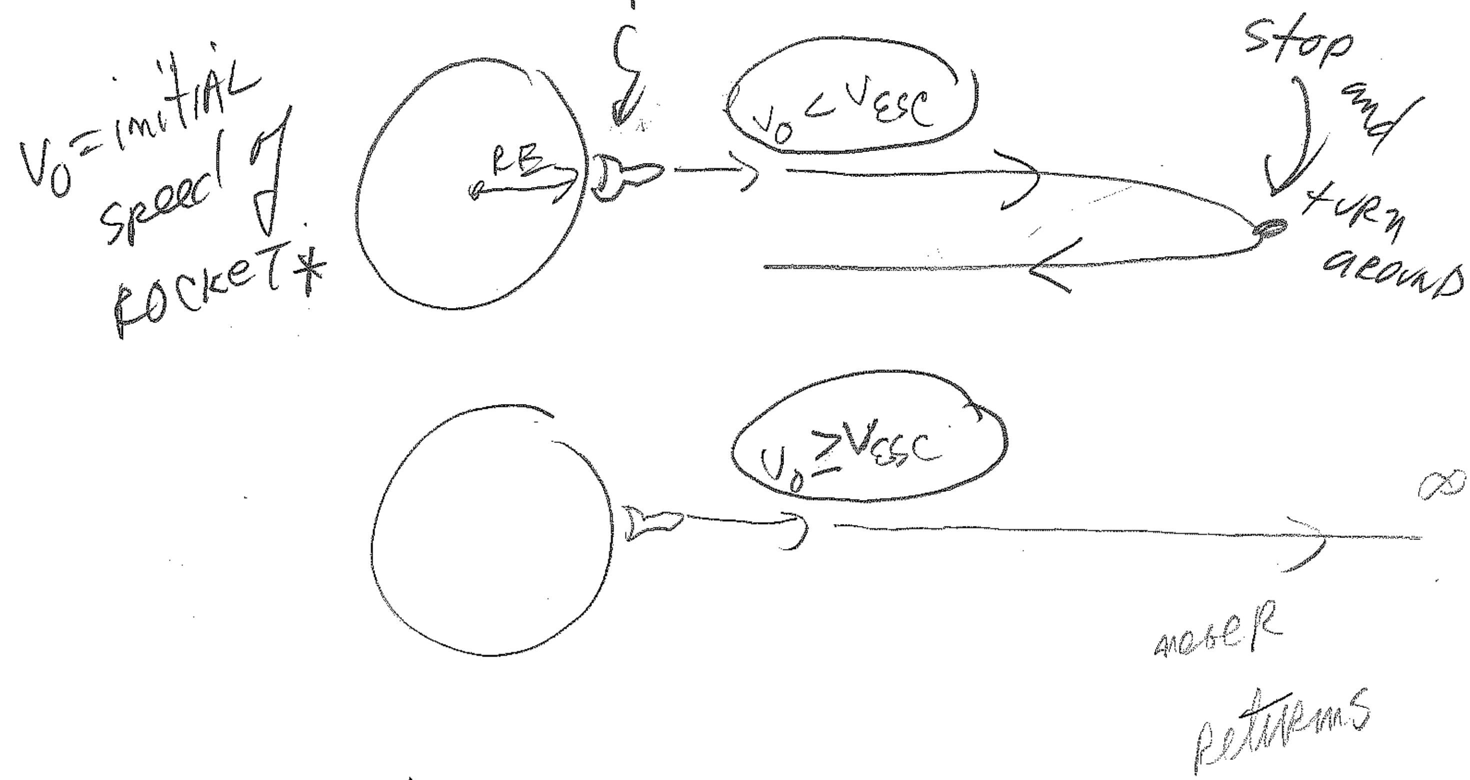
M = Earth mass

<u>note</u> moon: $g_{moon} = \dfrac{G\,M_{moon}}{R_{moon}^2}$

$$\cong \frac{g_{earth}}{6}$$

Escape speed

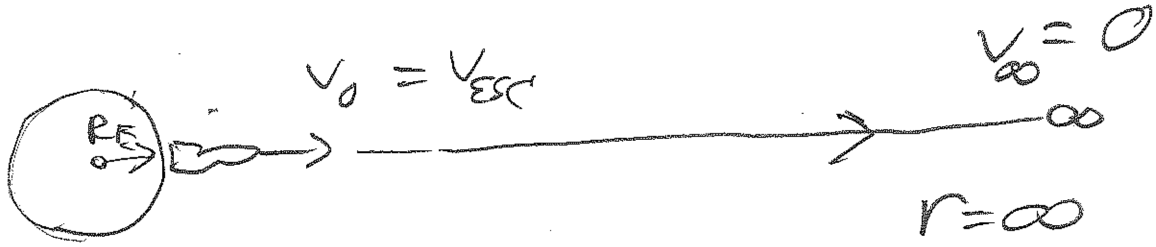
see test 4 "sample problem



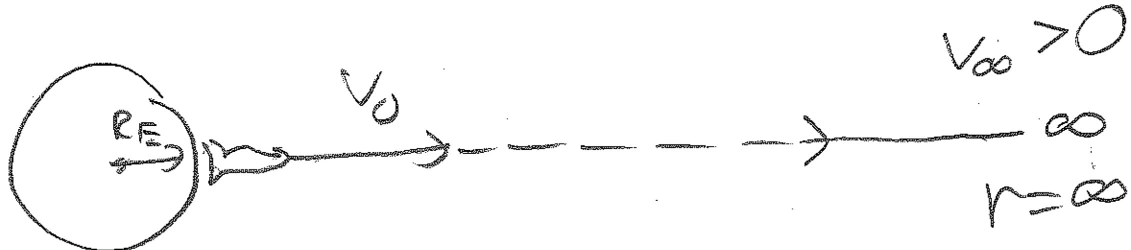
* v_0 = speed after an initial thrust that lasts for an instant.
(like shooting a gun vertically up)

Definition of v_{esc} is v_0 such that:

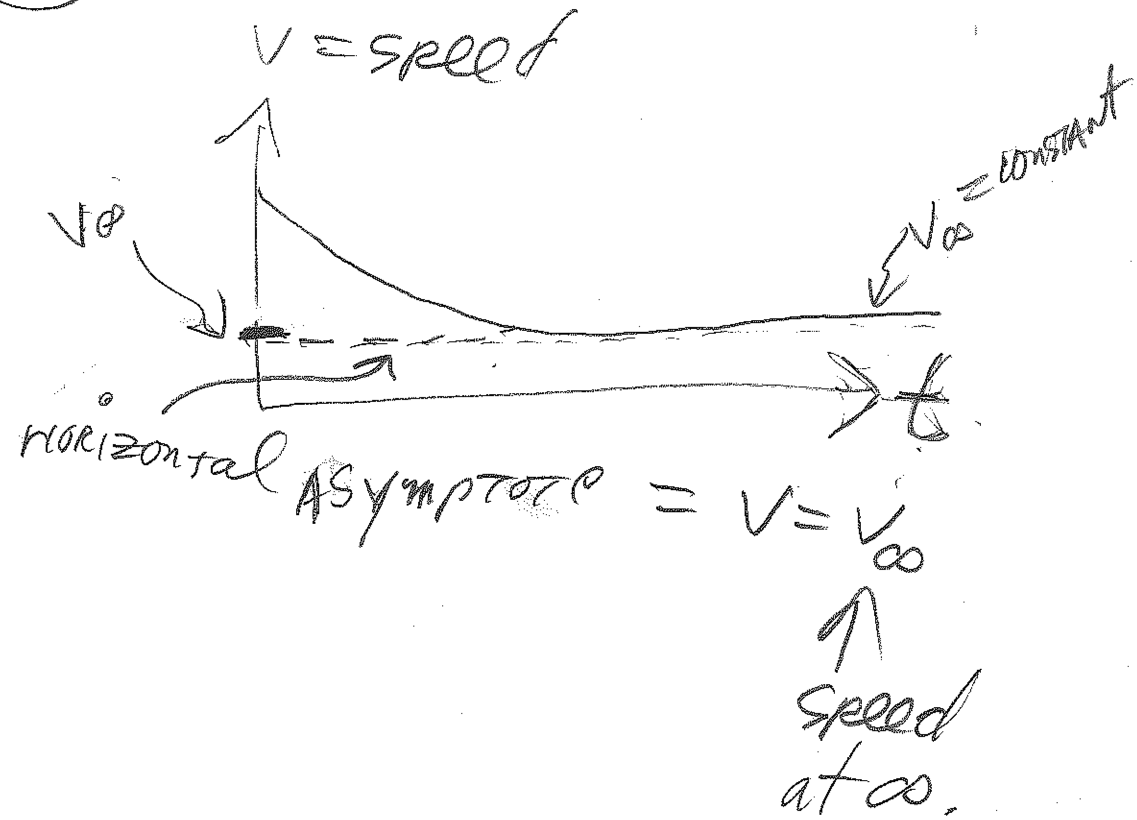
at $r = \infty$, $v = 0$



R_E
$V_0 = V_{ESC}$
$V_\infty = 0$
∞
$r = \infty$



R_E
V_0
$V_\infty > 0$
∞
$r = \infty$



V = speed
V_0
V_∞ = CONSTANT
t
horizontal ASYMPTOTE = $V = V_\infty$
speed at ∞.

Earth escape speed

$\longrightarrow V_0 = 11.2\,\frac{km}{s}$ (Earth) $V_\infty = 0$, ∞, $r = \infty$

$U_g = U_0 = -\frac{GMm}{R_E}$

$$KE_0 + U_0 = KE_\infty + U_\infty$$

at $r = R_E$ $= 0 + 0$

$$\frac{1}{2} m V_0^2 + \left(-\frac{GMm}{R_E}\right) = 0 \qquad U_\infty = -\frac{GMm}{\infty}$$

$$V_0 = \sqrt{\frac{2GM}{R_E}}$$

Example 13.5

$$V_0 = \sqrt{\frac{2GM_p}{R_p}}, \quad p = \text{any planet}$$

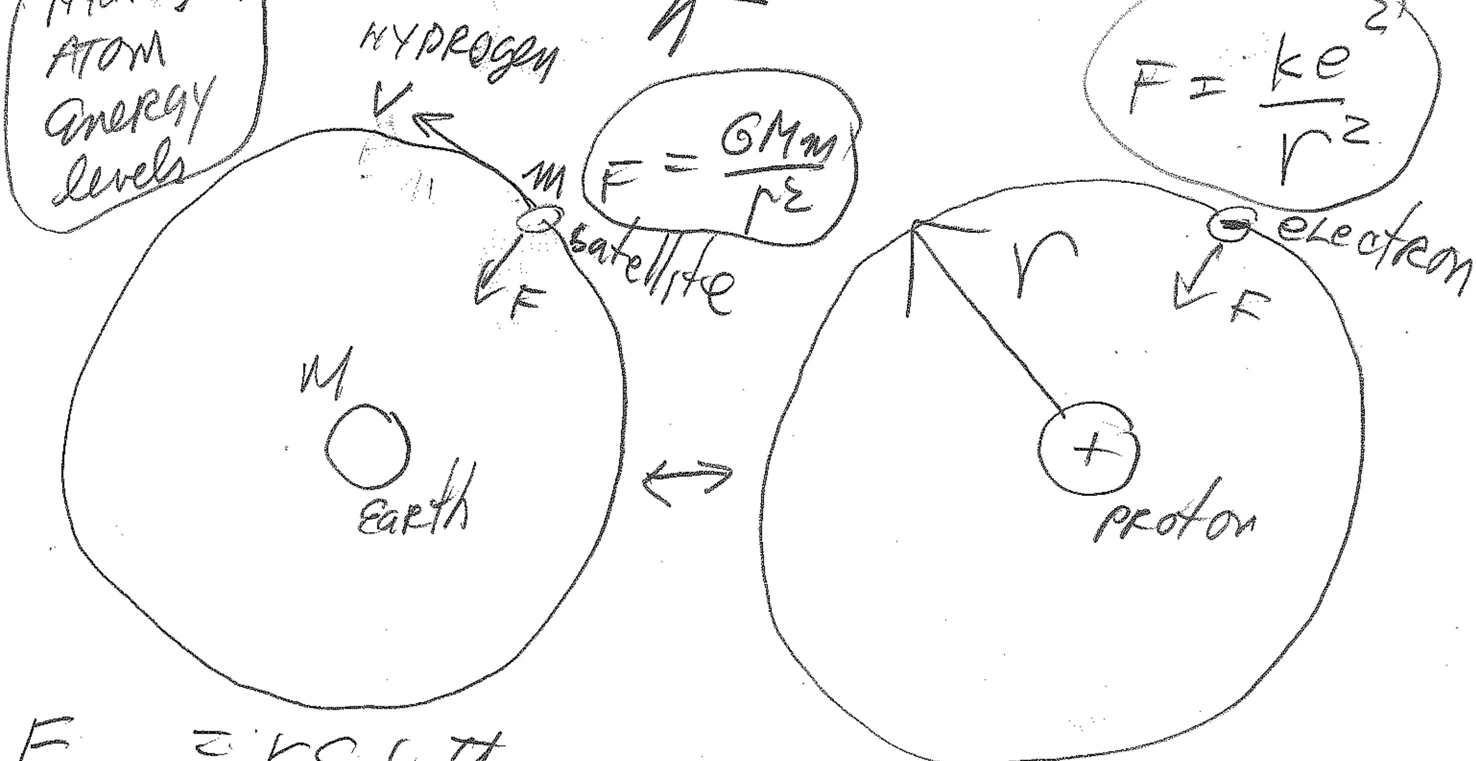
Planet	Vesc
Jupiter	59.5 km/s
Earth	11.2 km/s

LAST point: related TO

chem 1B OR nuclear PHYSICS.

atomic PHYSICS:

$$E_n = -\frac{13.6\,eV}{n^2} < 0$$



$$E_{TOTAL} = KE + U$$

$$E_{TOTAL} = \frac{1}{2}mv^2 - \frac{GMm}{r} < 0 \longleftrightarrow E_n = -\frac{13.6\,eV}{n^2} < 0$$

Bohr + Newton

$$\frac{mv^2}{r} = \frac{GMm}{r^2}$$

$$\rightarrow mv^2 = \frac{GMm}{r}$$

THUS: $E_{TOTAL} = \frac{GMm}{2r} - \frac{GMm}{r} = -\frac{GMm}{2r} < 0$ SINCE $U \equiv -\frac{GMm}{r}$.

after Break:

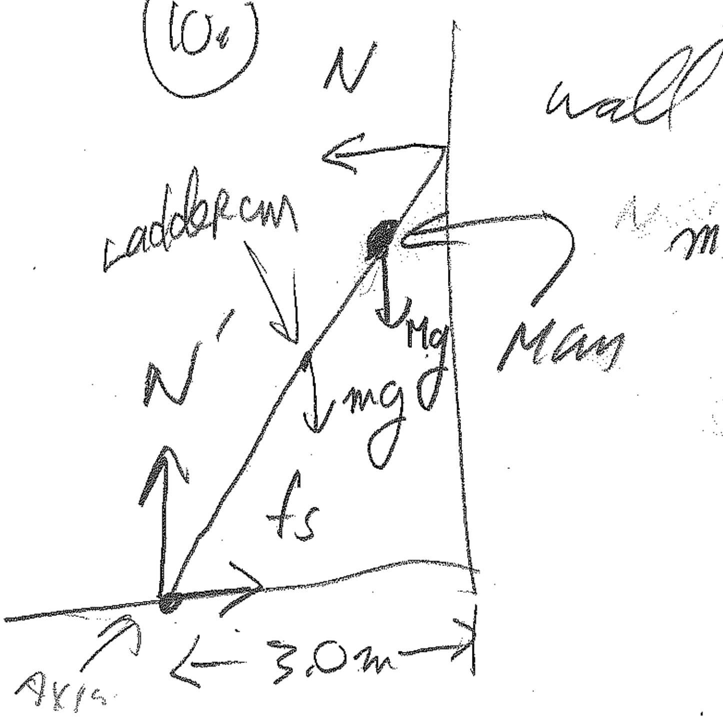
work on CN 11, 13

Final CH11 problems

(10), (50) = good representation for final (5-29)

CH11

(10)



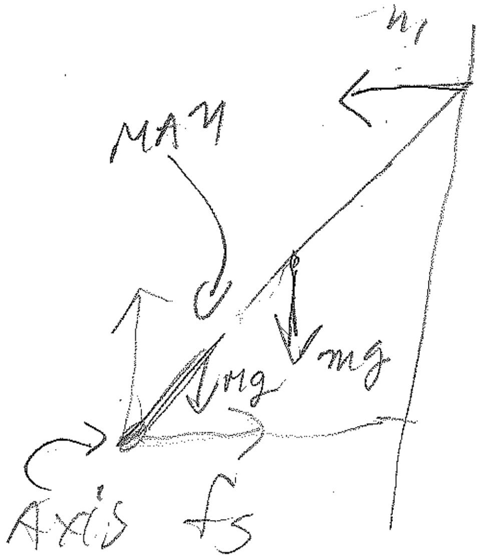
DO (a) first

(a) $f_{s\,max} = \mu_s N'$ where $N' = mg + Mg$

IF $f_s \geq f_{s\,max} \Rightarrow$ SLIPPING

(10) CHill

(b)



find n_1 from torque equation ← see example 11.3

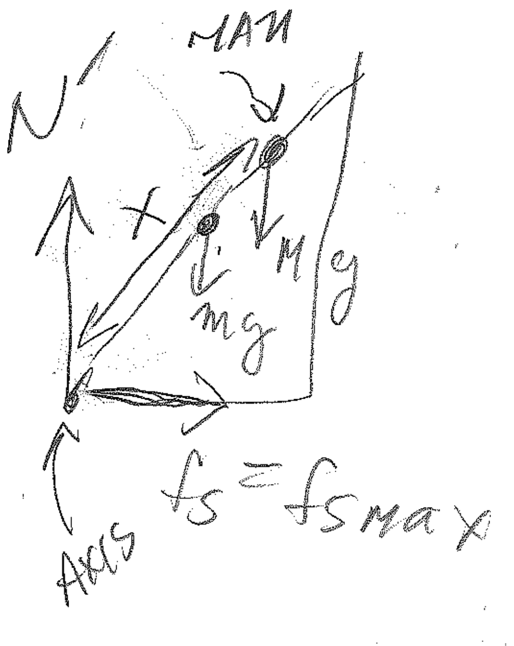
$\Sigma \tau = 0 = ↺ - ↻$

Axis

see class notes

$n_1 = f_s \Rightarrow f_s = n_1 \le f_{s\,MAX} \rightarrow \mu_s \cdot (Mg + mg)$

(c) find X such that



WORK BACKWARDS

(i) use $n_1 = f_{s\,max}$

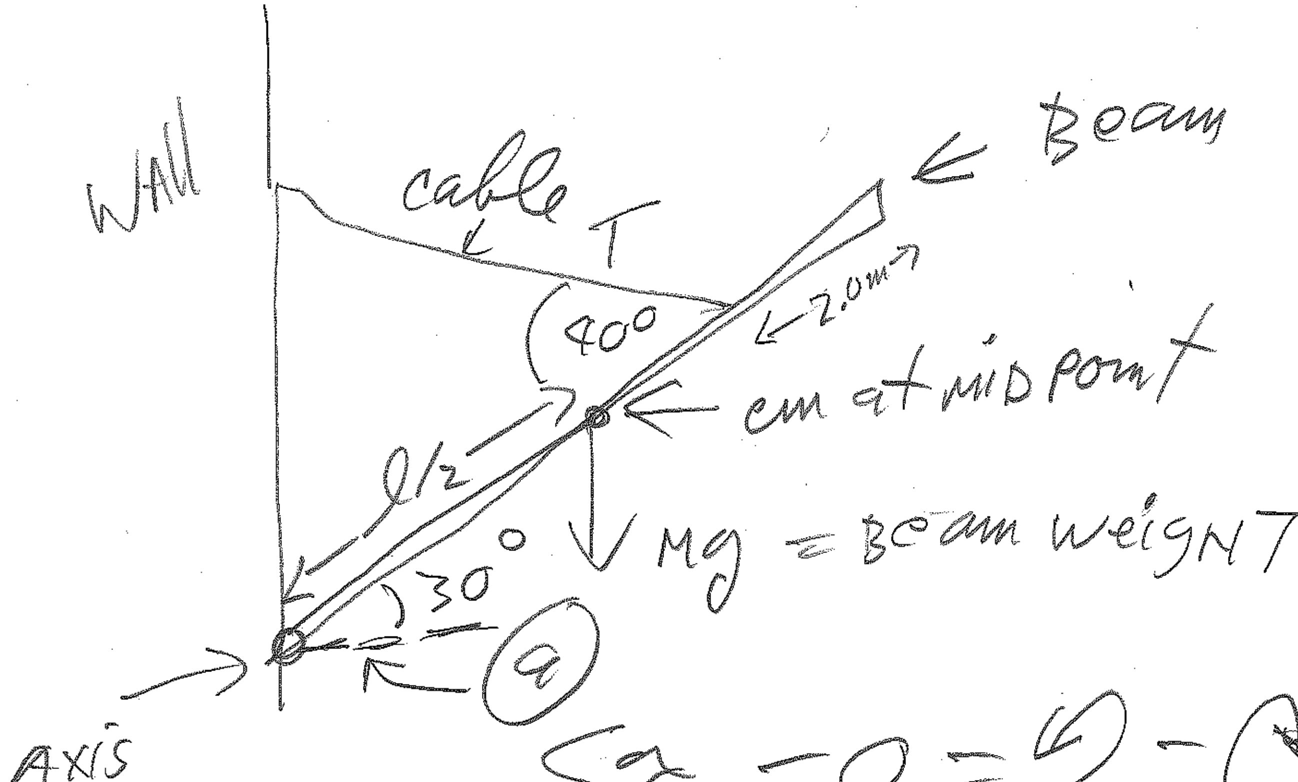
$n_1 = \mu(Mg + mg)$

$= \mu N$

(ii) use $n_1 = f_{s\,MAX}$ and get x from torque equation (class notes)

CH11

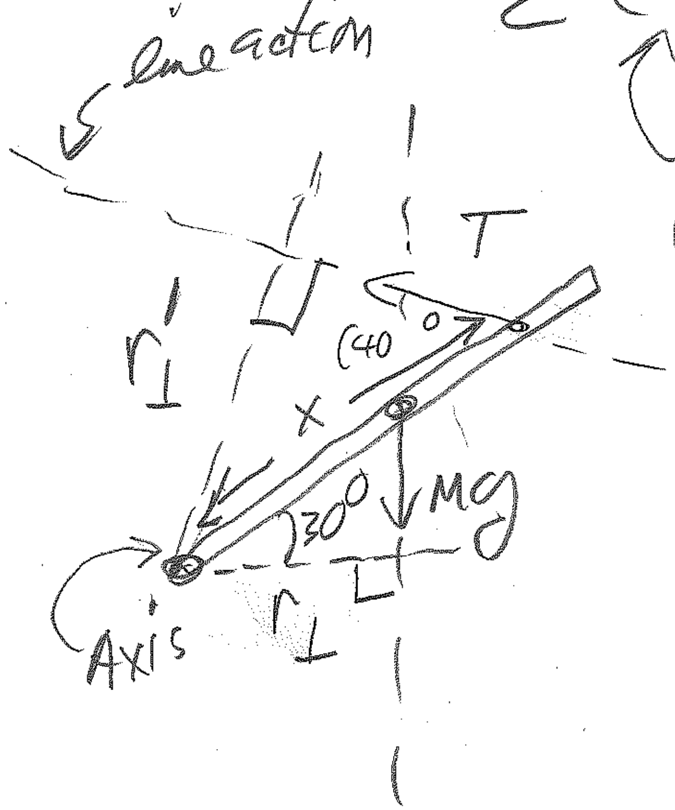
(50)



$\sum \tau = 0 = ↺ - ↻$

$0 = pos - neg$

(b)



$\tau_g = r_{\perp} Mg$ ↻

$r_{\perp} = \frac{l}{2} \cos 30^{\circ}$

$\tau_T = r'_{\perp} \cdot T$

$r'_{\perp} = x \cdot \sin 40$

ch 11

(9) $0 = \tau_T - \tau_g$

$0 = x \cdot \sin 40 \cdot T - \frac{l}{2} \cos 30^\circ \cdot Mg$

$\longrightarrow \quad T = \dfrac{Mg \cdot l/2 \cos 30^\circ}{x \cdot \sin 40^\circ}$

note: (i) limit as $x \to 0$

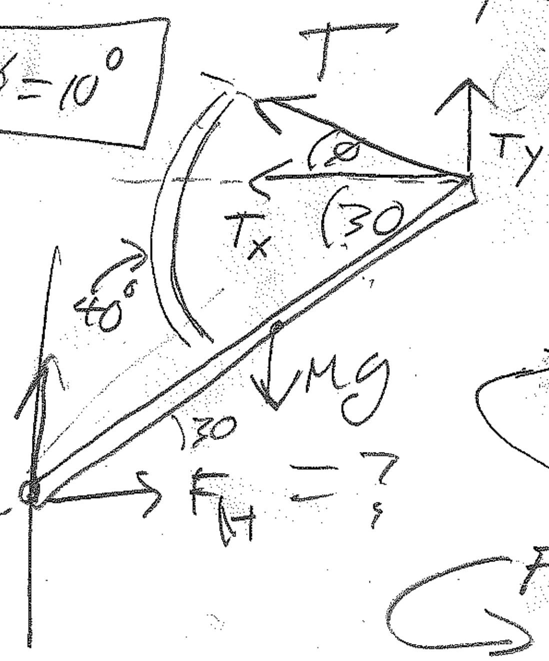
$T \to \infty$ (makes sense)

physics

$10 = 40 - 30 \Leftrightarrow \phi = 10^\circ$

(b)

? = F_V



$\Sigma F_x = 0 = pos - neg$
$= F_H - T \cdot \cos 10$

$F_H = T \cdot \cos 10$

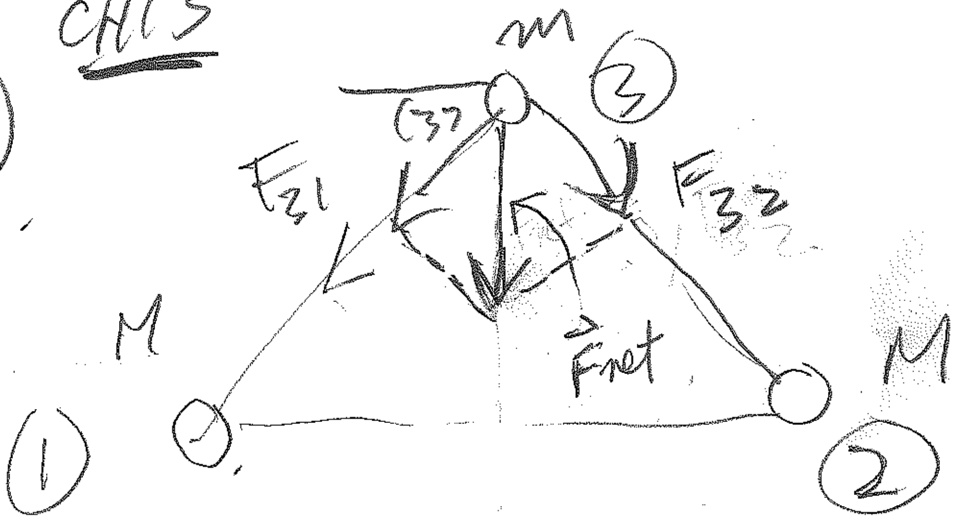
$F_V = Mg - T \sin 10$

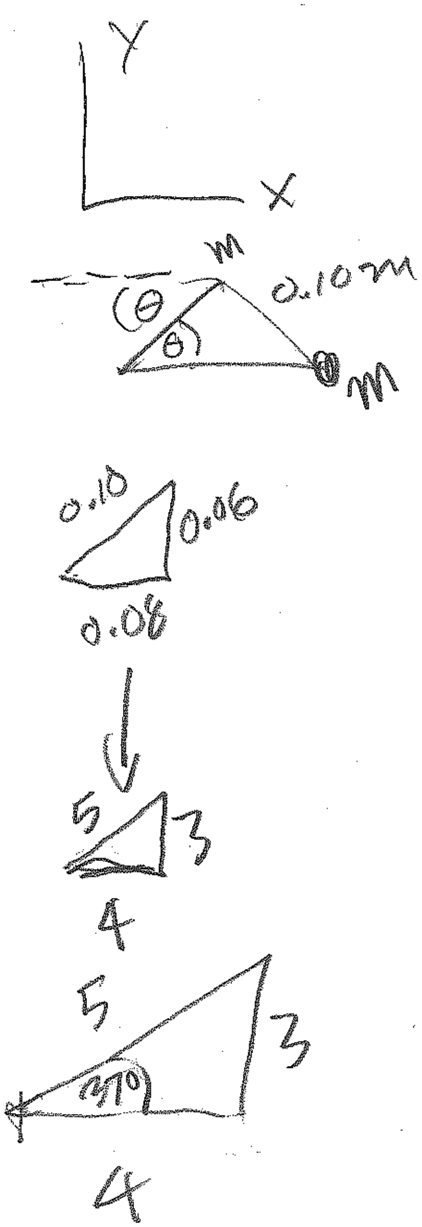
$\Sigma F_y = 0 = F_V + T \sin 10 - Mg$

5-16-13

CH13

(10)





$$F_{x\,net} = 0$$

$$F_{31} = F_{32} = \frac{GmM}{(0.10m)^2}$$

$$F_{net\,x} = F_{32}\cdot\cos 37 - F_{31}\cos 37 = 0$$

$$F_{net\,y} = -F_{32}\sin 37 - F_{31}\sin 37$$

$$= -2F_{32}\sin 37$$

$$= -\frac{2\cdot GmM}{(0.10m)^2}\cdot\sin 37$$

note: $\sin 37 = \frac{4}{5}$