5-10-13
5-8-13

Test 4 next week takehome

on CH 10, 11, 14, and possibly 13.

?

Final May 29th (wed)

arrange a 3-hour

~~time period~~:

1:30 — 4:30

2 — 5 pm

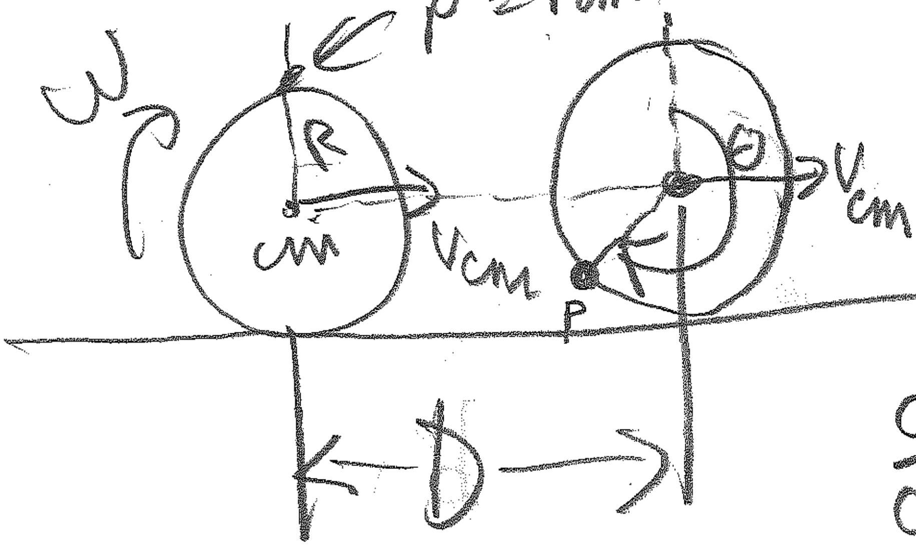
RM TBA (1803?)

Start CH10, CH11, Review

CH10 BASIC cheat sheet (continued)

Rolling sec 10.3

P = point on RIM



$$\theta = \frac{d}{R}$$

$$D = R \cdot \theta$$

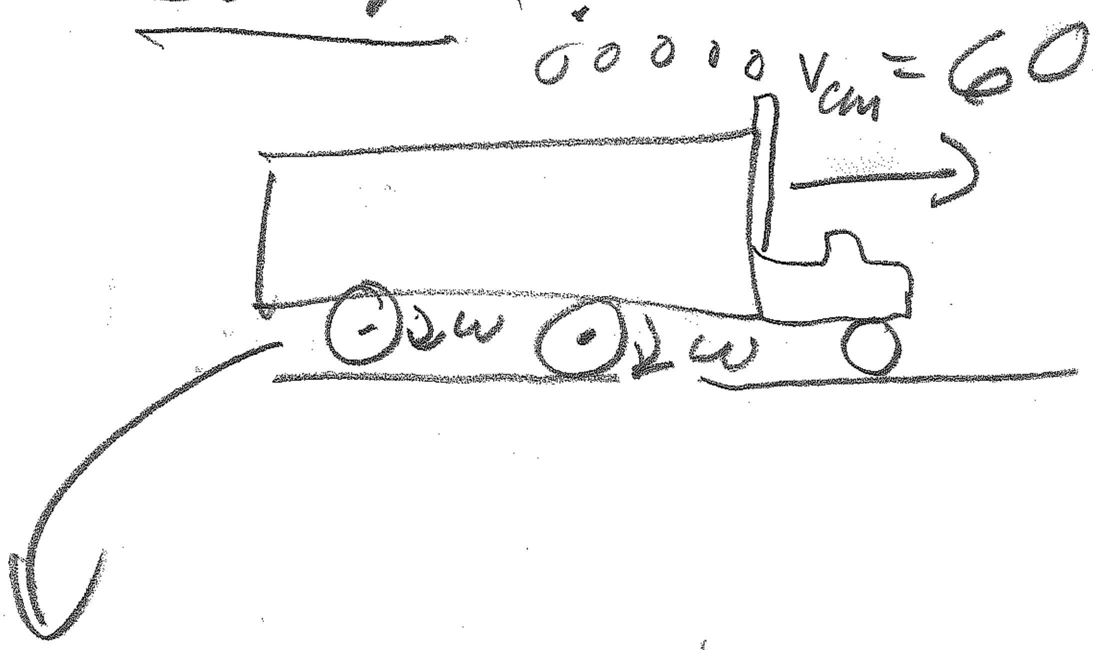
$$\frac{dD}{dt} = V_{cm}$$

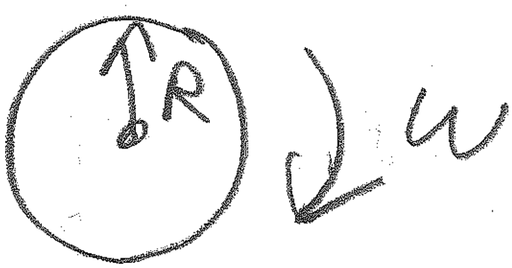
= linear speed of C.M.

$$\frac{dD}{dt} = R\frac{d\theta}{dt}$$

$$\boxed{V_{cm} = R \cdot \omega}$$ Rolling w/o slipping

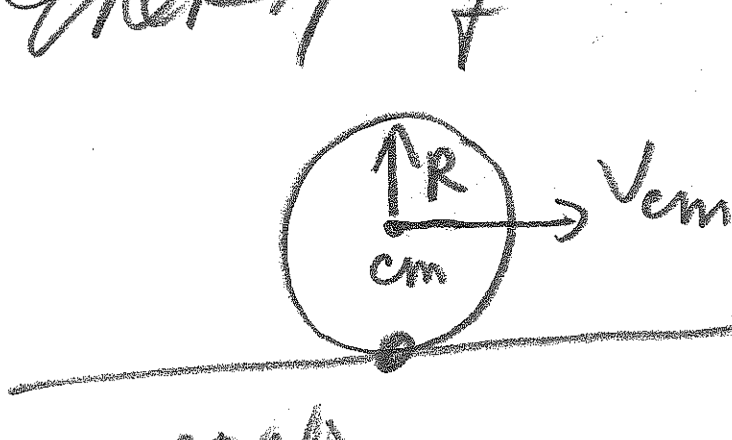
Example: Truck on 580





$$\omega \cdot R = 60\text{ mph}$$
$$\Rightarrow V_{cm}$$

Energy of Rolling: 2 Reference frames:

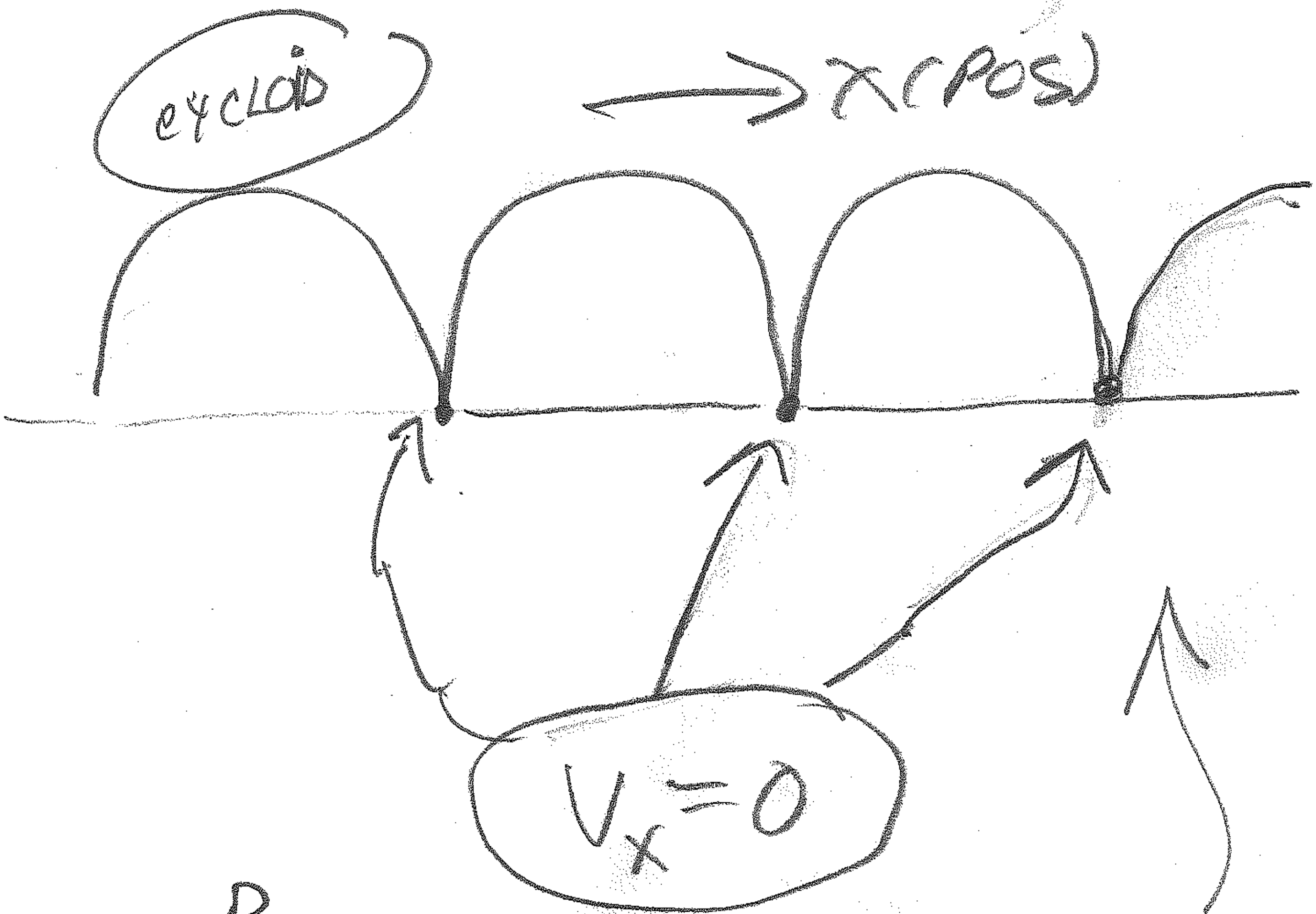


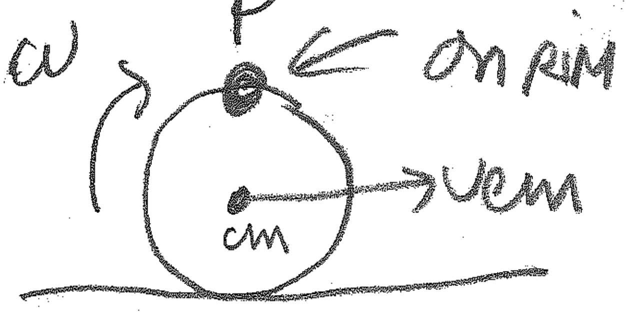
(A) at rest relative to GROUND

(B) at rest relative to the cm.

observer on ground:

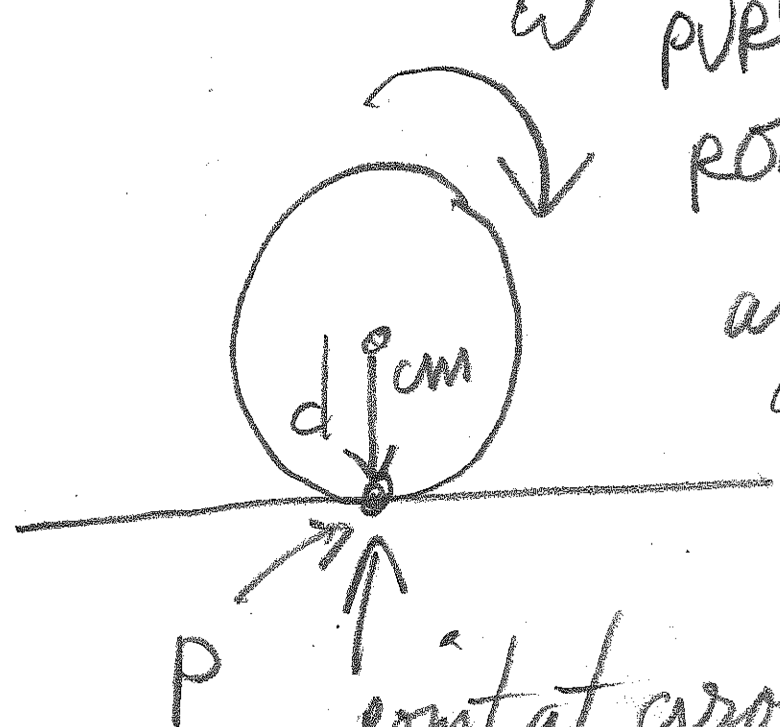
PLOT path of a point on the rim:





PLOT of P on RIM as wheel turns

pretend: pure rotation about AXIS at GROUND



point at ground $v_x = 0$

$$KE = \frac{1}{2} I_p \omega^2$$

Parallel-Axis thm: $I_p = I_{cm} + Md^2$

but $d = R$ = Radius

$$KE = \frac{1}{2}(I_{cm} + MR^2)\omega^2$$

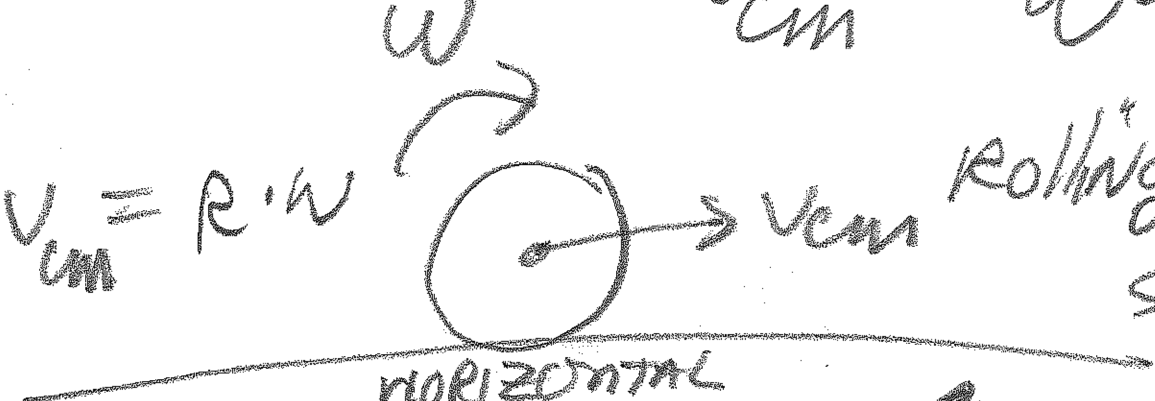
$$= \frac{1}{2} I_{cm}\omega^2 + \frac{1}{2} MR^2\omega^2$$

$KE = KE_{ROT} + KE_{TRAN}$

$= \frac{1}{2} I_{cm} \omega^2 + \frac{1}{2} M V_{cm}^2$

$V_{cm} = \omega \cdot R$

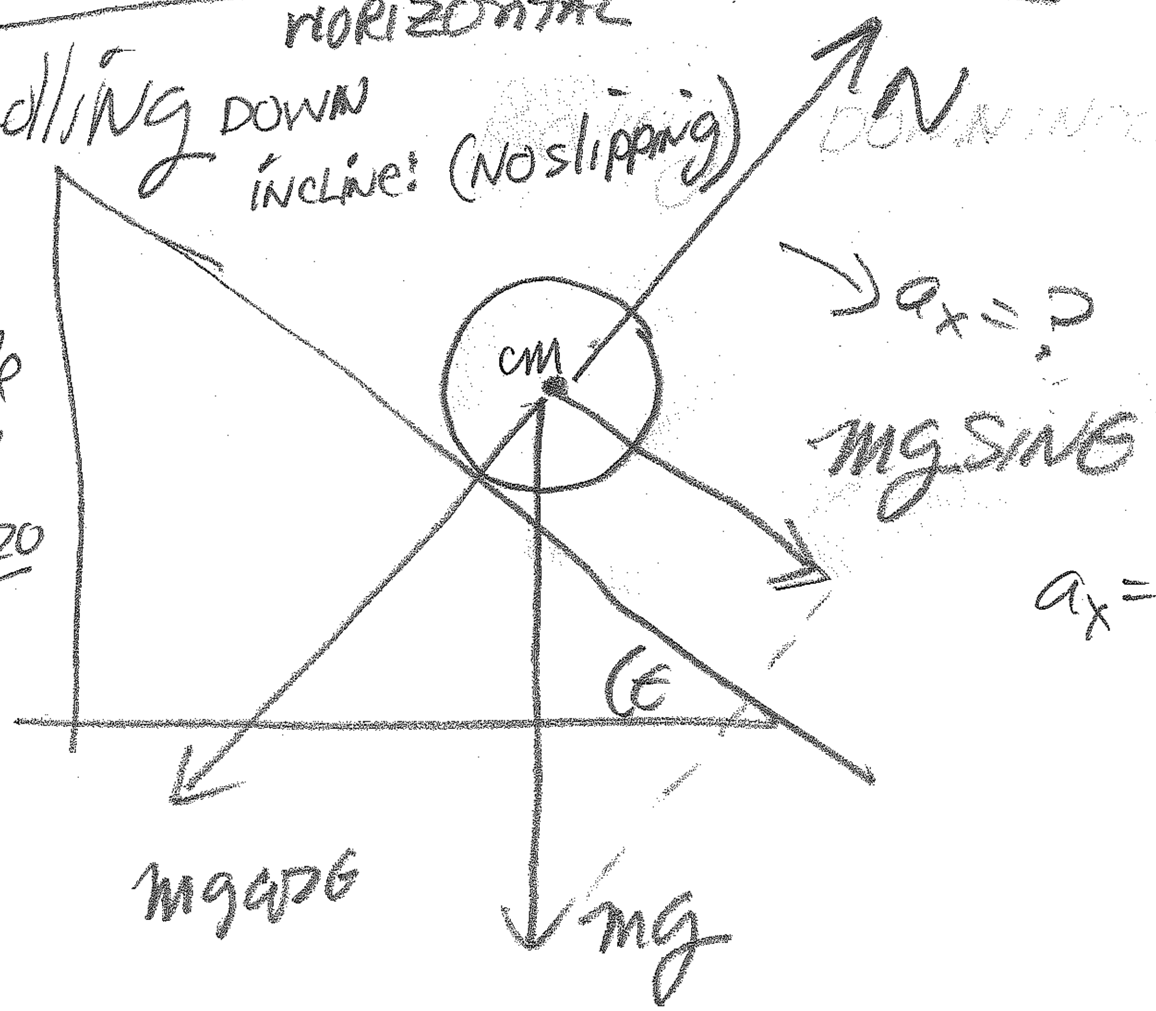
$V_{cm} = R \cdot \omega$



ROLLING W/O SLIPPING

ROLLING DOWN INCLINE: (NO SLIPPING)

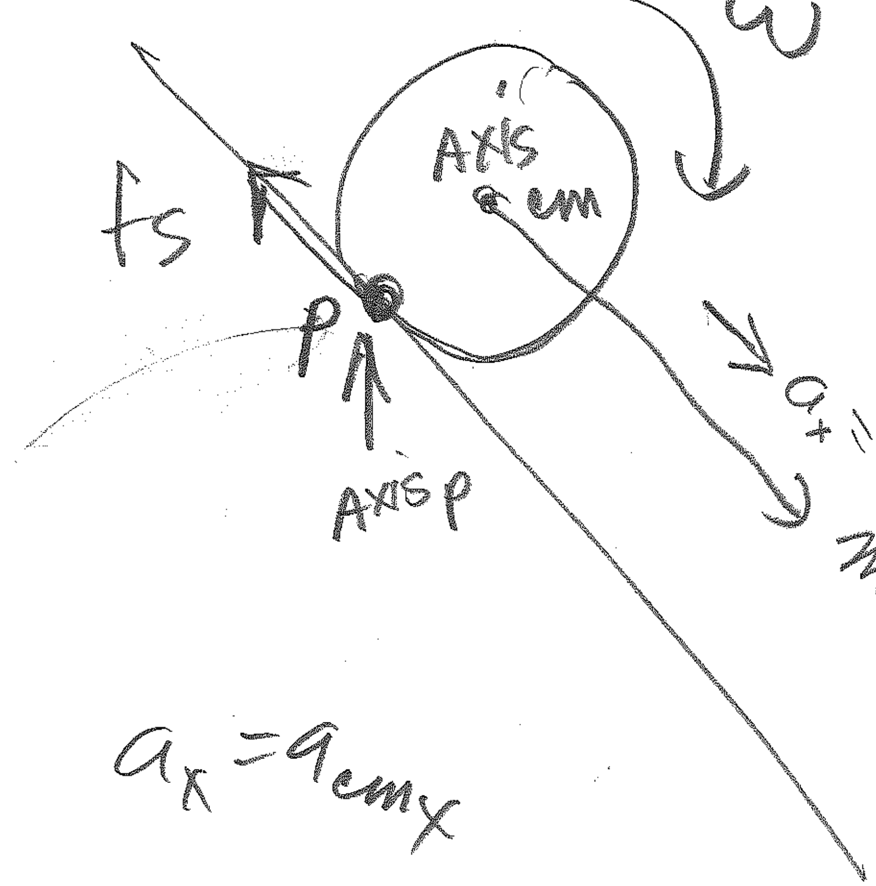
- Example 10-7
- fig 10.20



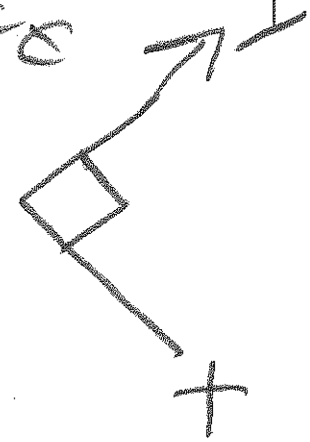
$a_x = a_{x\,cm}$

Roll w/o slipping

w DOWN incline



f_s = static friction, prevents slipping



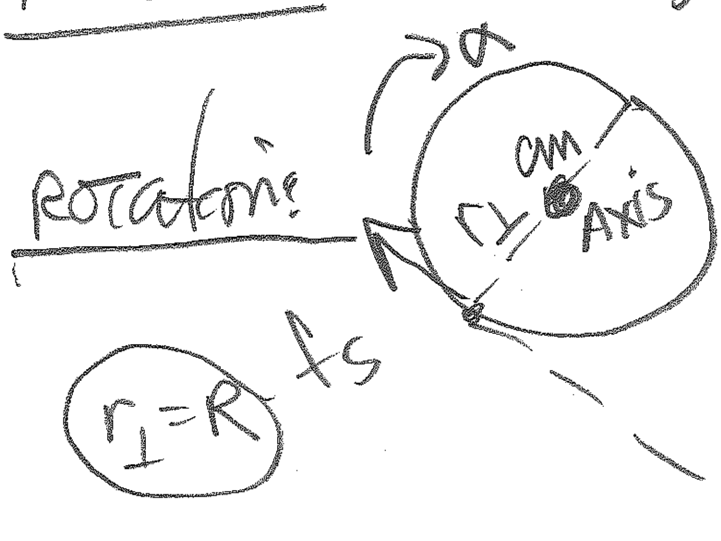
$a_x = a_{cmx}$

$\sum F_x$ = pos − neg

Translation: $ma_x = mg\sin\theta - f_s$

$\sum$ unknowns a_x, f_s.

Rotation:



$\tau = I \cdot \alpha$ and $\alpha = a_x/R$

$r_\perp \cdot f_s = I \cdot \frac{a_x}{R}$; $\alpha = \frac{a_x}{R}$

(CH9)

note $a_x = a_{x\,cm}$ ∴

<u>TRANSLATION</u>: $ma_x = mg\sin\theta - f_s$

<u>ROTATION</u>: $R \cdot f_s = I\frac{a_x}{R}$

$$\Rightarrow \quad f_s = I\frac{a_x}{R^2}$$

Solve for a_x:

ADD, cancel f_s

$$a_x\left(m + \frac{I}{R^2}\right) = mg\sin\theta$$

$$a_x = \frac{mg\sin\theta}{\left(m + \frac{I}{R^2}\right)} < g\sin\theta$$

COMPARE

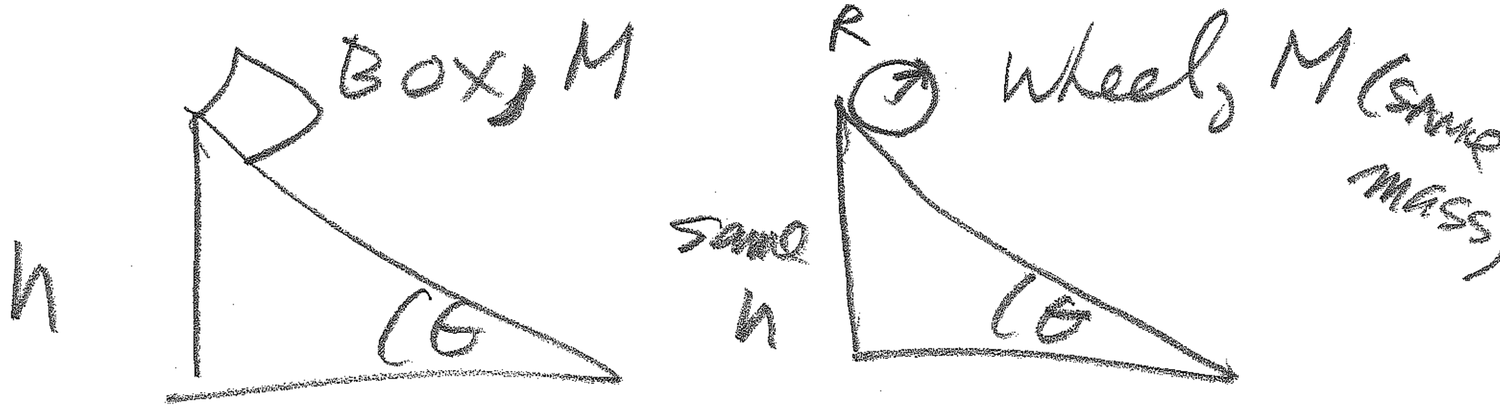
SLIDING → BUT NO FRICTION

$a_x = g\sin\theta$

ω

$a_x < g\sin\theta$ BECAUSE of I

Race between



No f_k.

Who wins?

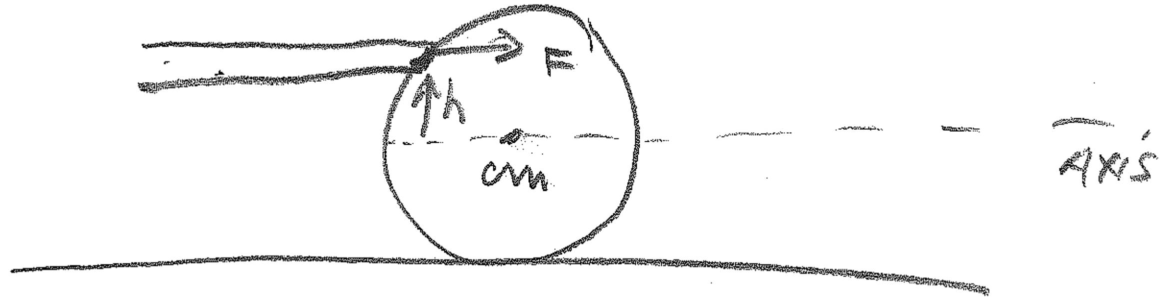
Box!

$$g\sin\theta > \frac{Mg\sin\theta}{\left(M+\frac{I}{R^2}\right)}$$

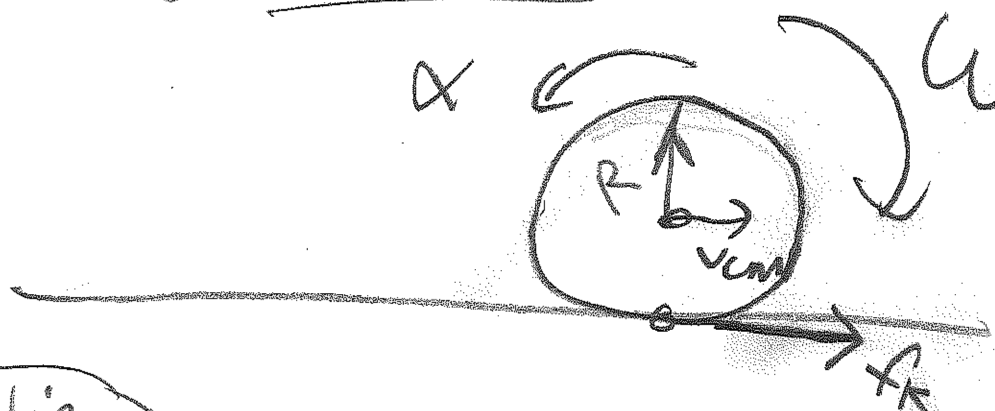
You can also use conservation of energy to see who wins: See Example 10.5: $mgh = \frac{1}{2}I\omega^2 + \frac{1}{2}mV^2$

where $\omega = \frac{V}{R}$; find V (at bottom).

Example of Pool stick impulse on cue ball.



(ENGLISH) EXTRA SPIN



Define positive direction: ↻

$V_{cm} < \omega \cdot R$

ω decreases as cm moves right.

→ f_k exerts a torque that reduces ω.

kinetic friction

$\boxed{I\alpha = -R \cdot f_k}$; $\alpha = \frac{d\omega}{dt}$

Translation $\sum F_x = pos - neg$

$$ma_x = f_K$$

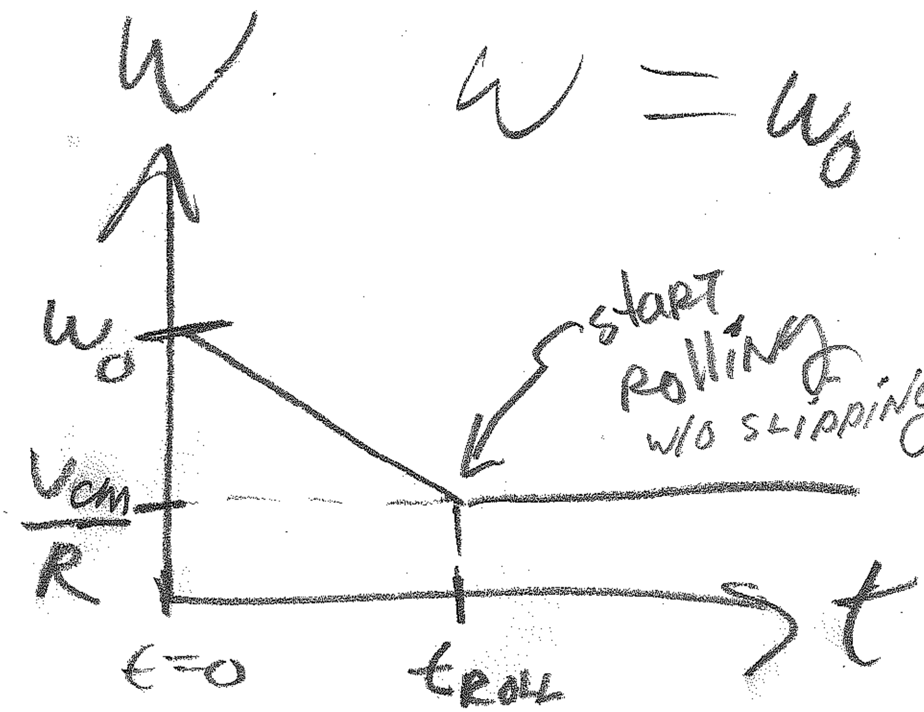
$$m\frac{dv_{cm}}{dt} = f_K \Rightarrow v_{cm} = V_0 + \frac{f_K}{m}\cdot t$$

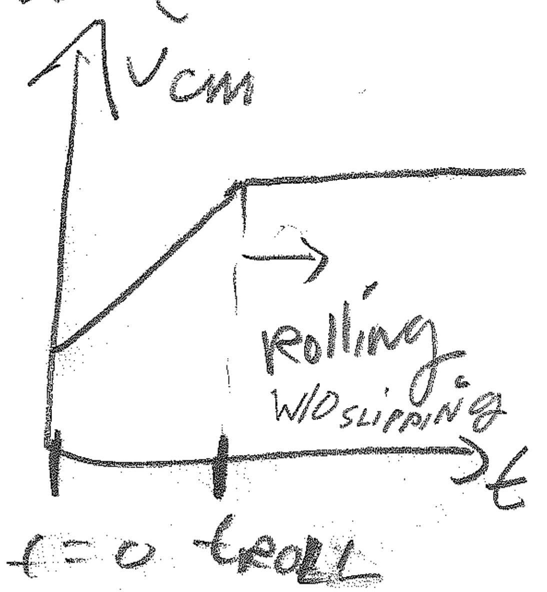
Rotation $I\alpha = -R\cdot f_K$

$$I\frac{d\omega}{dt} = -R\cdot f_K \Rightarrow \boxed{\omega = \omega_0 - \frac{Rf_K}{I}t}$$

$$\alpha = -\frac{Rf_K}{I}$$

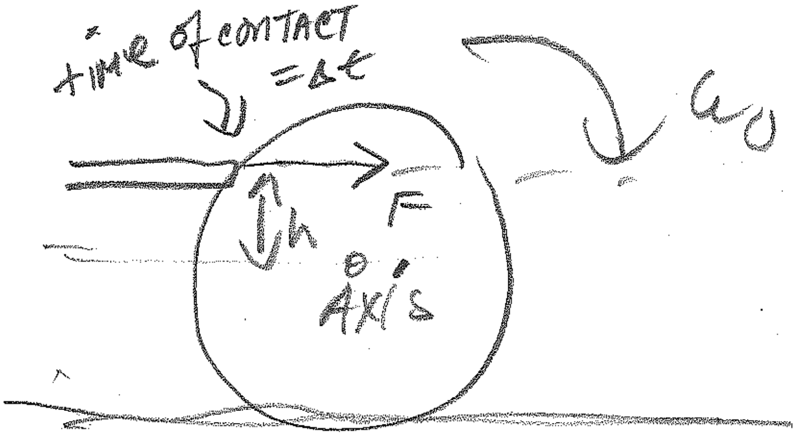
$$\omega = \omega_0 + \alpha\cdot t$$





$v_{cm} = \omega\cdot R \Rightarrow \omega = \frac{v_{cm}}{R}$ (Rolling)

Z-AXIS ⊥ PAGE.



$$\text{Torque} = \frac{\Delta L_z}{\Delta t}$$

$$h \cdot F = \frac{I(\omega_0 - 0)}{\Delta t}$$

Note:

$$\boxed{\omega_0 = \frac{hF\Delta t}{I}}$$

where Δt = time of impulse by stick on ball.

The cm speeds up until $v_{cm} = \omega \cdot R$.

$$v_0 + \frac{f_k}{m} \cdot t = \left(\omega_0 - \frac{Rf_k}{I} t\right) \cdot R$$

solve for $t = t_{ROLL}$ when rolling w/o slipping starts. Note: $F = \frac{\Delta P_x}{\Delta t}$

$$F = \frac{mv_0 - 0}{\Delta t}$$

Thus: $\boxed{v_0 = \frac{F\Delta t}{m}}$

MOMENT OF INERTIA PART 2 LAB

SEE EXAMPLE 10.3 OF TEXTBOOK

TODAY WE WILL VERIFY THE KINEMATIC LAW RELATING THE ANGLE OF ROTATION AND THE TIME. FROM PART 1, WE KNOW from EXAMPLE 10.3:

h = $\frac{1}{2}at^2$, where a is the linear acceleration of and h the vertical distance the hanging mass falls in a time t if it starts from rest. We also know the pulley's angular acceleration is α=a/r, where r is the radius of the pulley axle drum. IN ADDITION WE KNOW $\theta = \frac{1}{2}\alpha t^2$ AND ALSO θ= h/r. ***Thus, we can we plot θ vs. t^2 with the expectation of a straight line whose slope is $\alpha/2$.***

FOR 3 GIVEN ROTATING SYSTEMS YOU WILL PLOT θ vs. t^2 for 4 values of the time t, picking the values of h that produce equally spaced value of t^2. Here's how you do this. For a given value of maximum drop height h you will reduce the drop height 3 times so t^2 changes in equal increments. Suppose for example the maximum value of the height is H. Thus: $t_1 = t_{max} = \sqrt{\frac{2H}{a}}$, here H = h_1. We want the next time to be such that $t_2^{\ 2} = \frac{3}{4}t_{max}^{\ 2}$, thus $h_2 = \frac{3}{4}H$; $t_3^{\ 2} = \frac{1}{2}t_{max}^{\ 2}$, thus $h_3 = \frac{1}{2}H$; $t_4^{\ 2} = \frac{1}{4}t_{max}^{\ 2}$, thus $h_4 = \frac{1}{4}H$.

YOU WILL PLOT THE ANGLE VS THE SQUARE OF TIME AND VERIFY THE LAW OF ROTATION BY OBSERVING A STRAIGHT LINE. YOU WILL MAKE THREE PLOTS OF ***θ vs. t^2 : With the spindle underneath,*** YOU WILL PERFORM THE EXPERIMENT WITH (1)THE **DISK ALONE**, (2) THE **RING ALONE** AND THE (3) **RING PLUS THE DISK** AND COMPARE THE SLOPES OF THE LINES GIVEN BY = θ vs. t^2. You will get time t with a digital timer.

FOR EACH PLOT YOU WILL HAVE 4 DROP HEIGHTS AND FOR EACH OF THE 4 DROP HEIGHTS h , YOU WILL DROP THE HANGING MASS 4 TIMES AND COMPUTE THE AVERAGE TIME. For a particular drop height the angle is the height/r, where r is the radius of the axle drum you will measure.

DATA SHEET:	
r =	
SPINDLE + RING	
h_1 =H = max h	θ_1
TIME t	
a	
b	
c	
d	
Average t	
h_2 =3H/4	θ_2
TIME t	
a	
b	
c	
d	
Average t	
h_3 =H/2	θ_3
TIME t	
a	
b	
c	
d	
Average t	
h_4 =H/4	θ_4
TIME t	
a	
b	
c	
d	
Average t	

SPINDLE + DISK	
h_1 =H = max h	θ_1
TIME t	
a	
b	
c	
d	
Average t	
h_2 =3H/4	θ_2
TIME t	
a	
b	
c	
d	
Average t	
h_3 =H/2	θ_3
TIME t	
a	
b	
c	
d	
Average t	
h_4 =H/4	θ_4
TIME t	
a	
b	
c	
d	
Average t	

DO NOT DO TODAY unless you have time

SPINDLE + DISK +RING	
h_1 =H = max h	θ_1
TIME t	
a	
b	
c	
d	
Average t	
h_2 =3H/4	θ_2
TIME t	
a	
b	
c	
d	
Average t	
h_3 =H/2	θ_3
TIME t	
a	
b	
c	
d	
Average t	
h_4 =H/4	θ_4
TIME t	
a	
b	
c	
d	
Average t	

FOR EACH SYSTEM, PLOT $\boldsymbol{\theta}$ ***vs.*** $\boldsymbol{t^2}$ ***. USE LOGGER PRO (WITH NO DEVICE CONNECTED) OR EXCEL TO***

GRAPH THE LINE AND FIND THE SLOPE OF θ vs. t^2 .

Q1: EXPLAIN THE DIFFERENCES BETWEEN THE SLOPES OF THE 3 GRAPHS. DOES THE ORDERING OF THE SLOPE MAGNITUDES MAKE SENSE? WHICH SLOPE IS THE LARGEST? THE SMALLEST? IINTERMEDIATE? EXPLAIN USING PHYSICAL PRINCIPLES AND EQUATIONS.

Q2: FROM YOUR SLOPE VALUE FOR THE SPINDLE + DISK, COMPUTE $I_{SP} + I_{DISK}$ AND COMPARE WITH THE VALUE OF $I_{SP} + I_{DISK}$ YOU OBTAINED IN PART 1 OF THIS LABORATORY.

Q2

$$\alpha = \frac{a}{r} = \frac{mg}{\left(\frac{I}{r} + mr\right)}$$

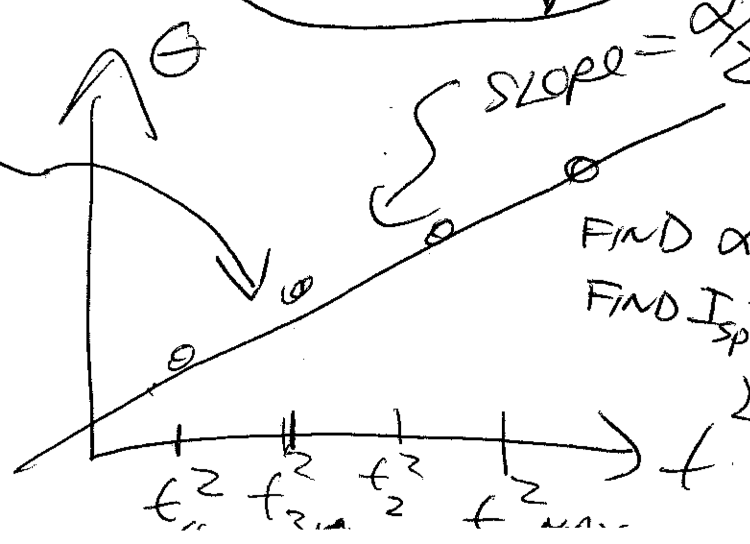
$$\alpha = \frac{mgr}{I + mr^2}$$

solve for $I_{DISK} + I_{SP}$

COMPARE with $I_{DISK} + I_{SP}$ of PART I LAB

$$\boxed{\theta = \frac{\alpha}{2} t^2}$$

SPINDLE +DISK



FIND α

FIND $I_{SP} + I_D$

GRAPH THE LINE AND FIND THE SLOPE OF θ vs. t^2 .

Q1: EXPLAIN THE DIFFERENCES BETWEEN THE SLOPES OF THE 3 GRAPHS. DOES THE ORDERING OF THE SLOPE MAGNITUDES MAKE SENSE? WHICH SLOPE IS THE LARGEST? THE SMALLEST? IINTERMEDIATE? EXPLAIN USING PHYSICAL PRINCIPLES AND EQUATIONS.

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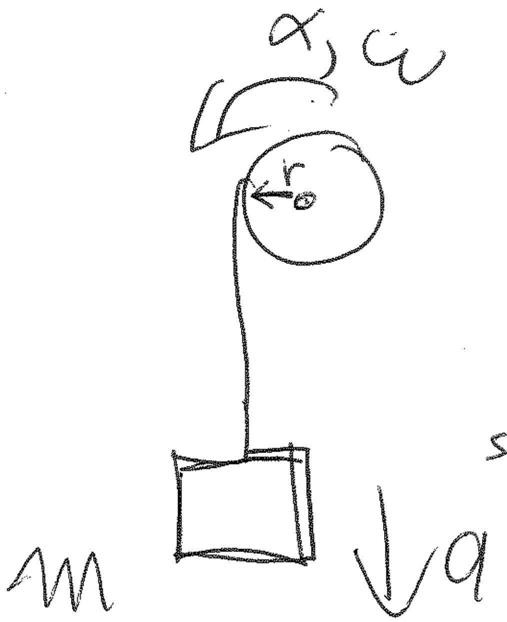
Q2

$$\alpha = \frac{a}{r} = \frac{mg}{\left(\frac{I}{r} + mr\right)}$$

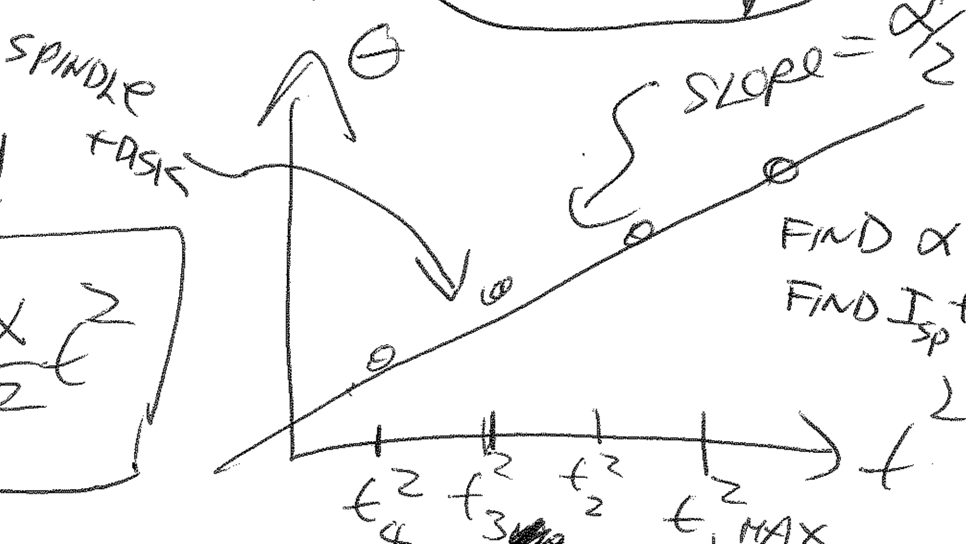
$$\alpha = \frac{mgr}{I + mr^2}$$

COMPARE with $I_{DISK} + I_{SP}$ of PART 1 LAB

solve for $I_{DISK} + I_{SP}$



$$\boxed{\theta = \frac{\alpha}{2} t^2}$$



FIND α

FIND $I_{SP} + I_D$