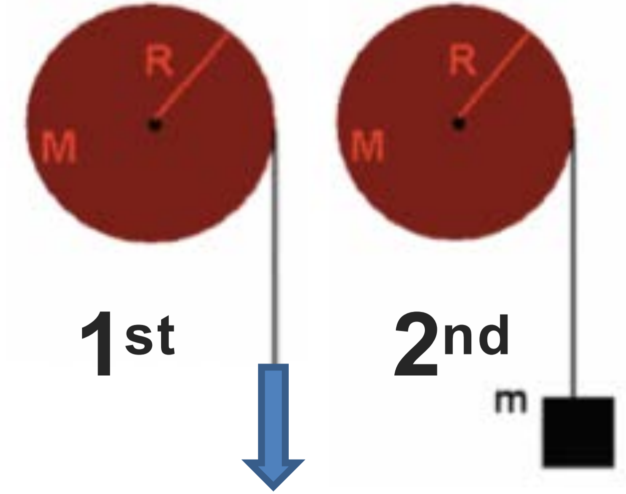
Lab 7 is in SCI 136 (!)

Note: exam room change:
Exams 2, 3 take place in STO B50

Please, login into webassing, locate LectureMCQ_L16 (PY105) and answer question 1 (but ONLY Q1!).

Pleas sign in using the sign-in sheets on the bench. Thank you

Good morning!

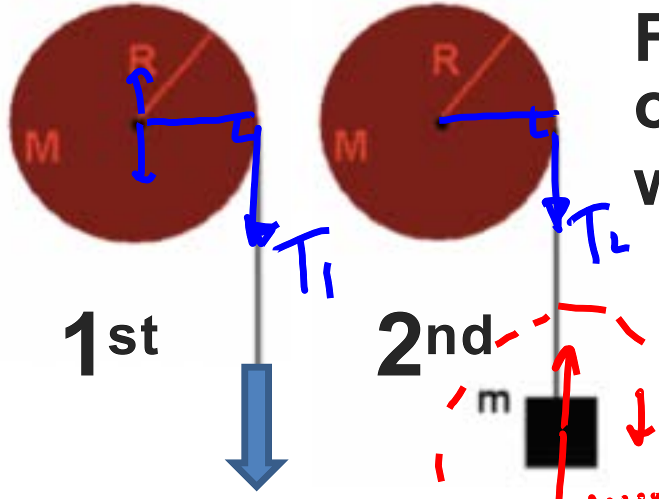


First time we pulled on a string applying a force of 10 N. Second time we attached to a string a weight of 10 N.

Webassign: L16 Q2

When did the disc have a *higher* angular acceleration?

1. 1st time
2. 2nd time
3. It was the same
4. there is not enough information
5. there is too much information



First time we pulled on a string applying a force of 10 N. Second time we attached to a string a weight of 10 N.

When did the disc have a *higher* angular acceleration?

$T_1 = 10\,N$

$T_1 \cdot R = I \cdot \alpha_1$

$\alpha_1 = \frac{T_2 \cdot R}{I}$

$\alpha_2 = \frac{T_2 \cdot R}{I}$

; $\alpha_1 = \frac{10\,R}{I}$; $\alpha_2 = \frac{9 \cdot R}{I}$

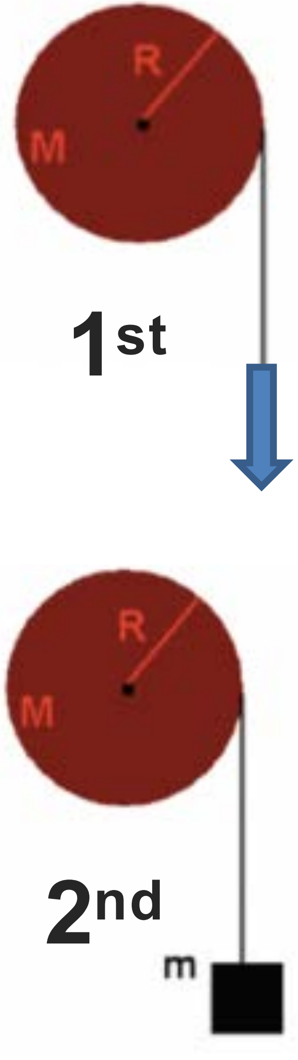
$\alpha_1 \begin{matrix} \boxed{>} \\ = \\ < \end{matrix} \alpha_2$

N2L: $T_2 - W = m(-a)$

$T_2 = \underline{10} - \underline{m \cdot a}$

das not matter

$\underline{T_2 < 10}$



First time we pulled on a string applying a force of 10 N. Second time we attached to a string a weight of 10 N. When did the disc *have* a higher angular acceleration?

1. [✓ 1st time]
2. 2nd time
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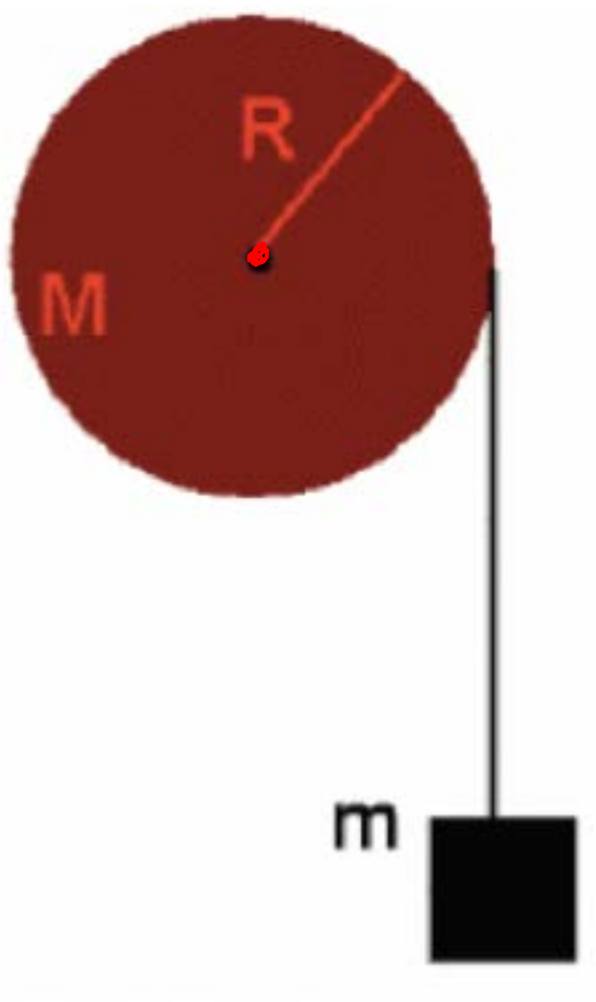
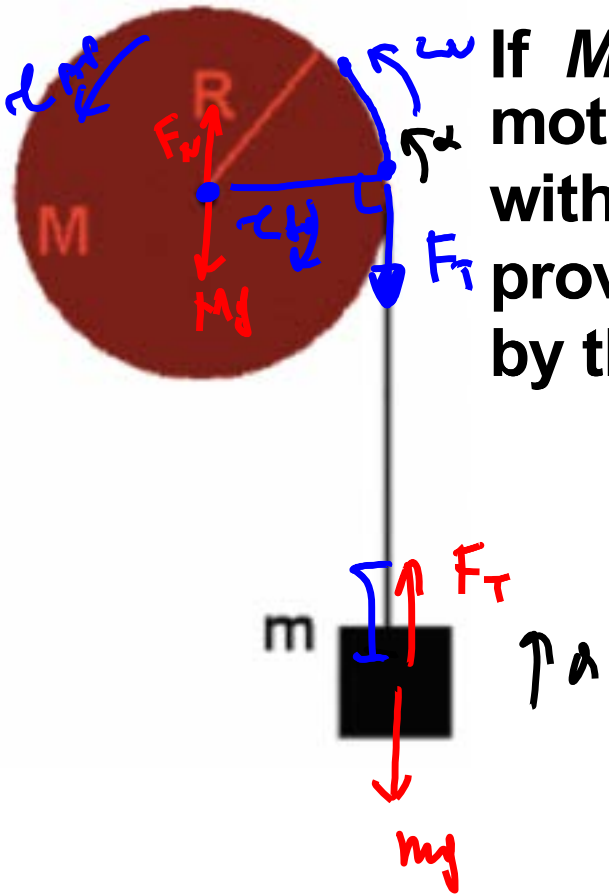


If $M = 10$ kg, $m = 5$ kg, $R = 25$ cm, what torque a motor should apply to the disc in order to lift the box with the acceleration of 0.1 m/s^2? Assume friction provides a torque equal to 0.1 of the torque provided by the motor.



If $M = 10$ kg, $m = 5$ kg, $R = 25$ cm, what torque a motor should apply to the disc in order to lift the box with the acceleration of 0.1 m/s^2? Assume friction provides a torque equal to 0.1 of the torque provided by the motor.

N2LR: $\tau_{ap} - \tau_{fr} - \tau_{F_T} + 0 + 0 = I \cdot \alpha$

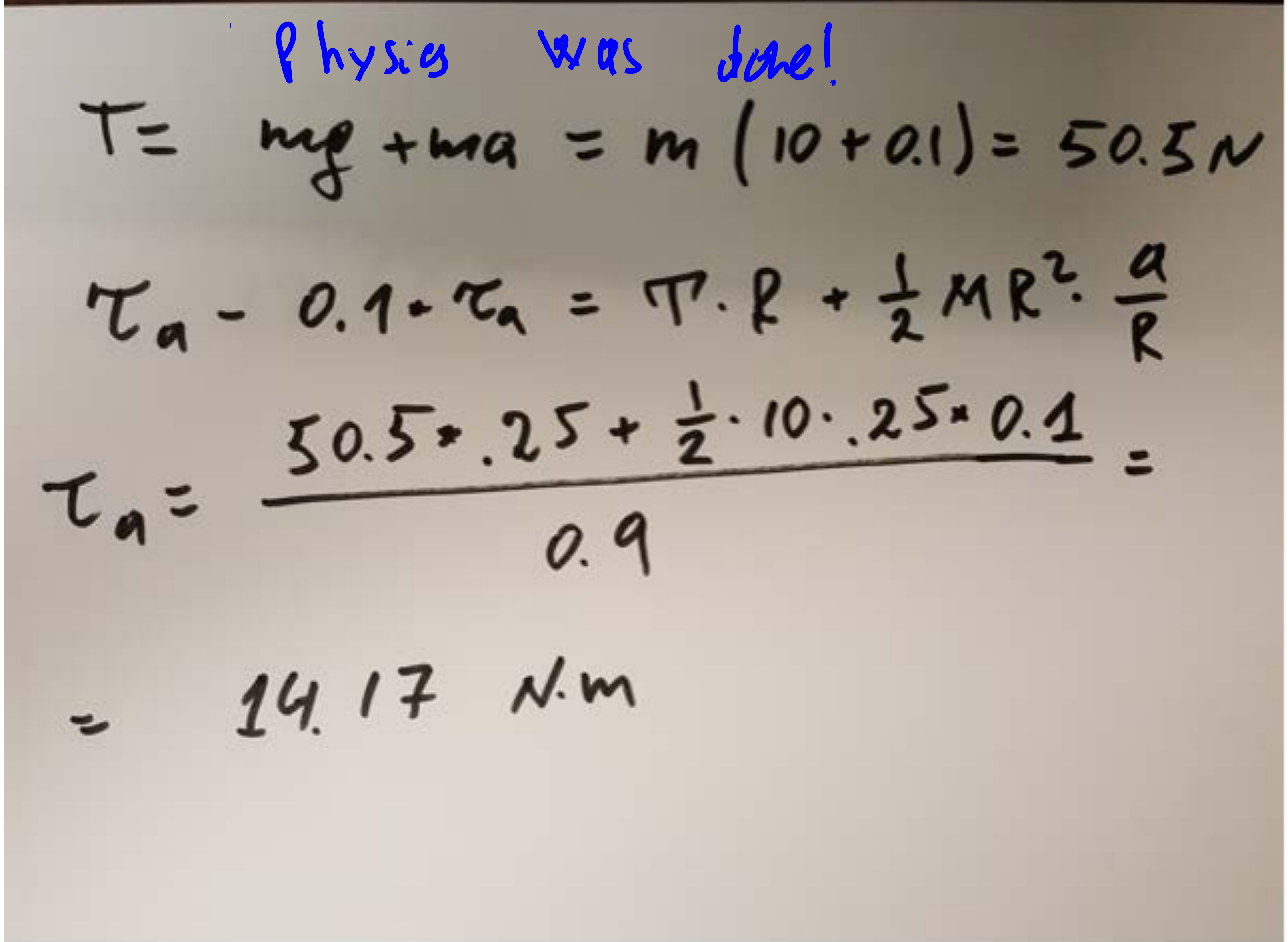
$I = \frac{1}{2} M \cdot R^2$

$|F_{T_1}| = |F_{T_2}| = F_T$;

$\phi = \frac{s}{R}$; $\omega = \frac{v}{R}$; $\alpha = \frac{a_\tau}{R} = \frac{a}{R}$, $a = 0.1$ m/s^2

N2L: $F_T - mg = m \cdot (+a)$

$\tau_{fr} = 0.1 \cdot \tau_{ap}$ → $\tau_{ap} = ?$



Physics was done!

$$T = mg + ma = m(10 + 0.1) = 50.5N$$

$$\tau_a - 0.1 \cdot \tau_a = T \cdot R + \frac{1}{2} MR^2 \cdot \frac{a}{R}$$

$$\tau_a = \frac{50.5 \cdot .25 + \frac{1}{2} \cdot 10 \cdot .25 \cdot 0.1}{0.9} =$$

$$= 14.17 \ N.m$$

A solid sphere with a mass of 10 kg and diameter of 50 cm is rotating with an angular speed of 60 rad/s about an axis passing through its center. By applying a normal force, the rotation of the sphere is slowed down to 2 rad/s. If the coefficient of friction was .8, what was the magnitude of the normal force applied to the sphere, if the slowing down lasted for 10 s?

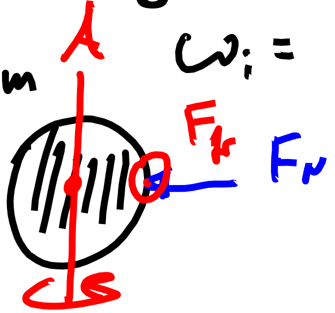
A solid sphere with a mass of 10 kg and diameter of 50 cm is rotating with an angular speed of 60 rad/s about an axis passing through its center. By applying a normal force, the rotation of the sphere is slowed down to 2 rad/s. If the coefficient of friction was .8, what was the magnitude of the normal force applied to the sphere, if the slowing down lasted for 10 s?

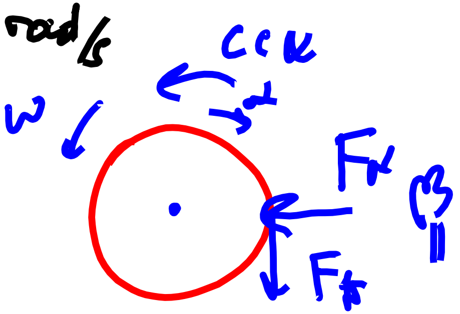
$D = \frac{1}{2}\,m$

$\Downarrow$

$\underline{R = \frac{1}{2} D}$

$\omega_i = 60\ \text{rad/s}$





$F_k = \mu \cdot F_N = 0.8 \cdot F_N$

$\omega_i \searrow \omega_f = 2\ \text{rad/s} \quad t = 10\,s$

$\alpha = \frac{2-60}{10} = -5.8\ \text{rad}/s^2$

$\underline{I = \frac{2}{5} m \cdot R^2 = \frac{2}{5} 10 \cdot \left(\frac{1}{2 \cdot 2}\right)^2}$

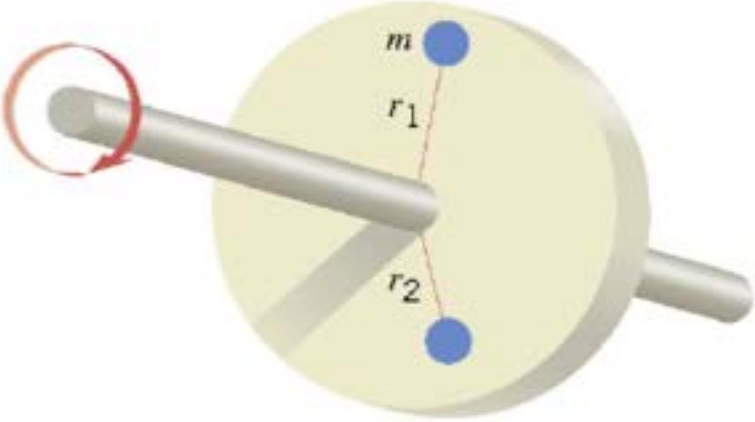
$\underline{0.8 \cdot F_N \frac{1}{2 \cdot 2}} = F_f \cdot R = |\tau_{fr}| = I \cdot |\alpha| = \underline{\frac{2}{5} \cdot 10 \cdot \left(\frac{1}{2 \cdot 2}\right)^2 \cdot 5.8}$

Rotational Energy

For a point-like object

$$KE = \tfrac{1}{2} m v_T^2 = \tfrac{1}{2} m r_1^{\,2} \omega^2$$

$$v_T = r_1 \omega$$

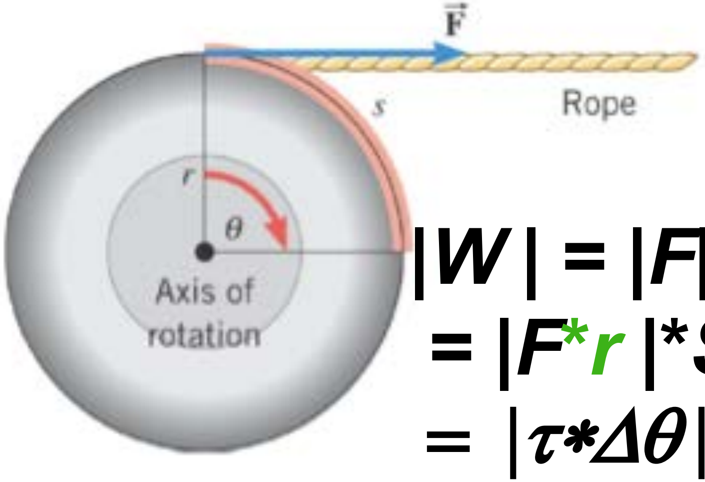


For a solid object

$$\underline{KE} = \sum \left(\tfrac{1}{2} m r^2 \omega^2 \right) = \tfrac{1}{2} \left(\sum m r^2 \right) \omega^2 = \underline{\tfrac{1}{2} I \omega^2}$$

Work done by torque

Webassign: L16 Q3



$$|W| = |F||S|$$
$$= |F*r|*S/r|$$
$$= |\tau*\Delta\theta|$$

Requirement: The angle must be expressed in radians.

SI Unit of Rotational Work: joule (J)

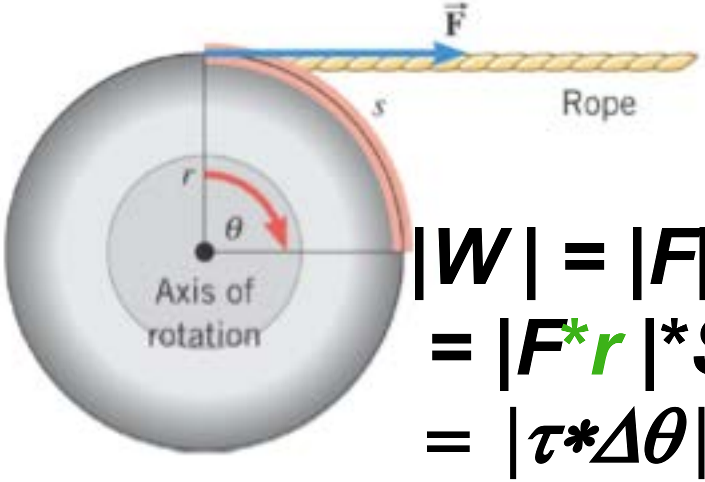
In this equation θ …

1. **Angle between force and displacement**
2. **Always acute**
3. **None of the above**

$$|W| = |\tau\ \Delta\theta|$$

Work done by torque

Webassign: L16 Q3



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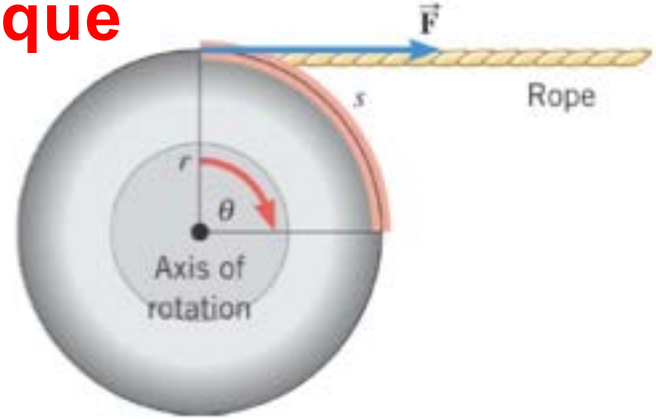
Work done by torque



Requirement: The angle must be expressed in radians.

SI Unit of Rotational Work: joule (J)

Angular displacement

For 1-D rotation

$$\cos\theta = \pm 1$$

Magnitude

$$|W| = |\tau \Delta\theta|$$

$$W = |\tau \Delta\theta| \cos\theta$$

Actual value

The angle between the torque and angular displacemen

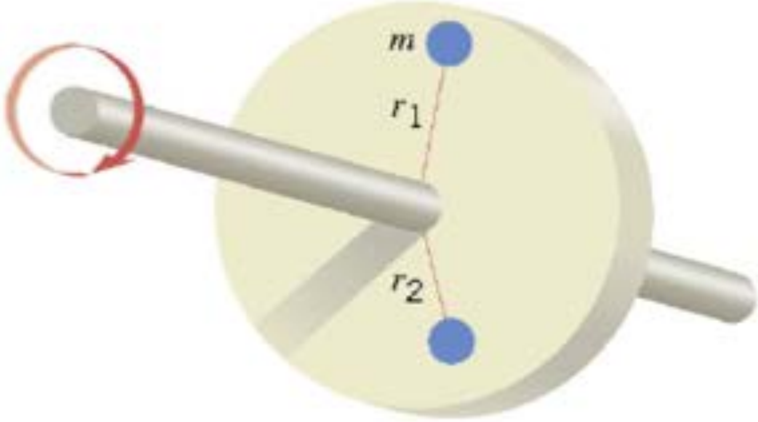
Rotational Energy

$$W = |\tau\, \Delta\theta| \cos\theta$$

For a point-like object

$$KE = \tfrac{1}{2} m v_T^2 = \tfrac{1}{2} m r_1^{\,2} \omega^2$$

$$v_T = r_1 \omega$$



For a solid object

$$\underline{KE} = \sum\left(\tfrac{1}{2} m r^2 \omega^2\right) = \tfrac{1}{2}\left(\sum m r^2\right)\omega^2 = \underline{\tfrac{1}{2} I \omega^2}$$

WKET (RM) $K_f - K_i = W_{net}$

What is the minimum amount of work that has to be done to speed up a 5 kg disk with the radius of 10 cm from rest to 100 rev per second?

↳ rad!

$$\underset{\swarrow}{K_f} - \underset{\swarrow\; 0}{K_i} = W \Rightarrow K_f = W$$

$$\Downarrow$$

$$W = \frac{1}{2} I \cdot \omega_f^2 = \frac{1}{2} \cdot \frac{1}{2} 5 \cdot (.1)^2 \cdot (100 \cdot 2\pi)^2 \, J$$

Let's review: **IMT** $\sum \vec{F}\,\Delta t = \Delta(mv)$ => ***LCLM***

As we did for straight-line motion, we can write Newton's second law in a different form:

N2LR

$$\Sigma\tau = I\alpha = I\frac{\Delta\omega}{\Delta t} = I\,\frac{\omega_f - \omega_i}{t} = \frac{I\omega_f - I\omega_i}{t} = \frac{\Delta(I\omega)}{\Delta t}$$

<u>or</u>

$$\Sigma\tau = \frac{\Delta(I\omega)}{\Delta t}$$

$$\boxed{\sum \vec{\tau}\,\Delta t = \Delta(I\omega)}$$

Net external torque

Newton’s second law for rotational motion

$$\sum \vec{\tau}\Delta t = \Delta(\underbrace{I\vec{\omega}}_{\text{Something new}})$$

Net external torque

Angular momentum

New variable => new name and new notation.

$$\boxed{I\vec{\omega} = \vec{L} \qquad \textit{angular momentum}}$$

The Law of Conservation of Angular Momentum

$$\Sigma\vec{\tau}\,\Delta t = \Delta\vec{L}$$

When no external torques act on a system, the angular momentum of the system is conserved.

$$\boxed{\tau_{\text{Net}} = 0 \quad => \quad \vec{L} = \text{const}}$$

$$\Downarrow$$

$$\boxed{\vec{L}_{\text{initial}} = \vec{L}_{\text{final}}}$$

Figure Skater

A spinning figure skater starts spinning with her arms outstretched. When she moves her arms close to her body,

[Webassign: L16 Q4](#)

$$L_i = L_f$$

or

$$I_i\,\omega_i = I_f\,\omega_f$$

A) She spins faster.

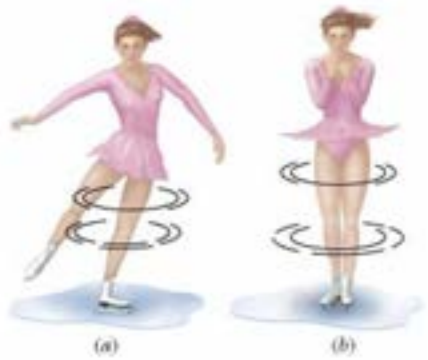
B) She spins slower.

C) The angular velocity stays the same.

Figure Skater

A spinning figure skater starts spinning with her arms outstretched. When she moves her arms close to her body, her moment of inertia decreases I↓

Conserving angular momentum says:



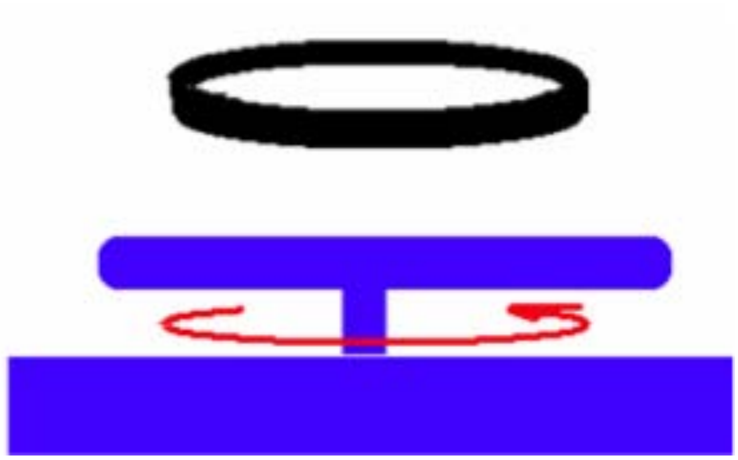
$$L_i = L_f$$

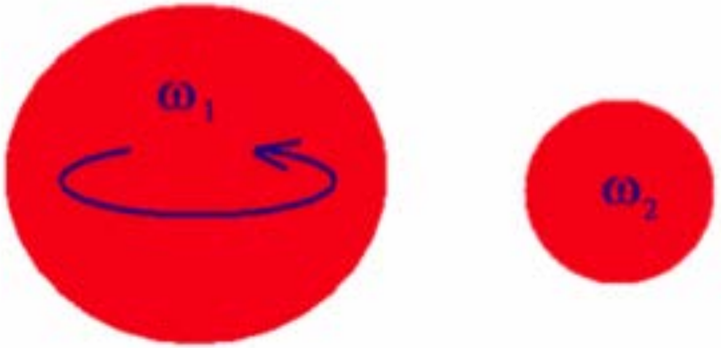
<u>or</u>

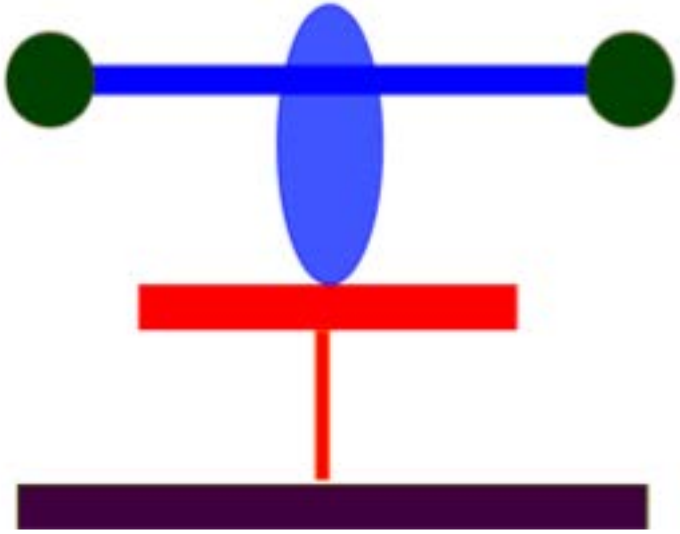
$$I_i\,\omega_i = I_f\,\omega_f$$

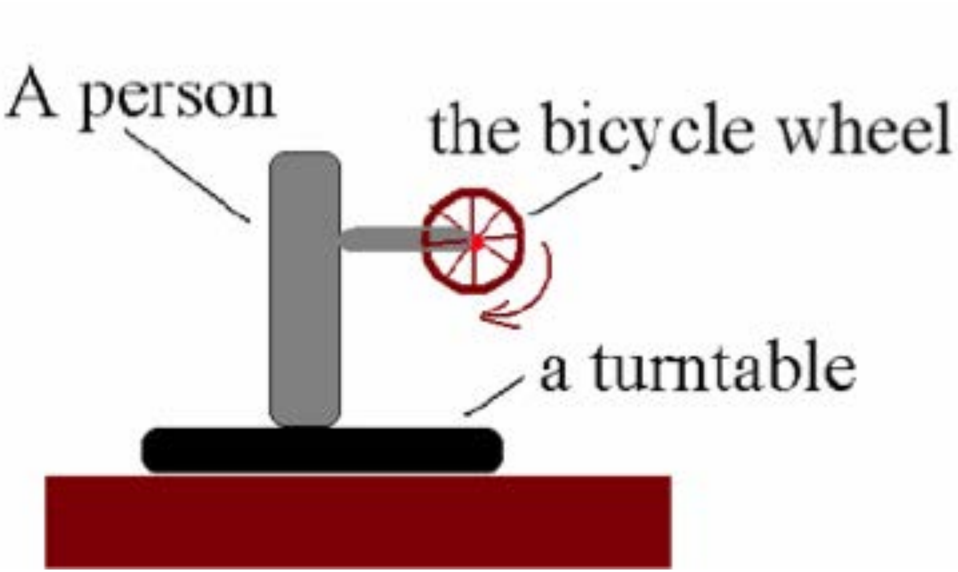
$$I_f < I_i \quad => \quad \omega_f > \omega_{fi}$$

A) She spins faster.

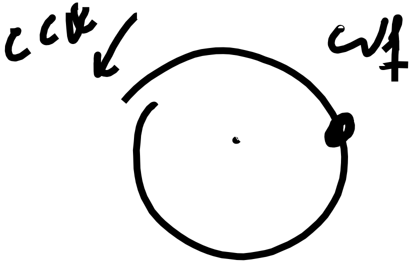



ω_1
ω_2




A person
the bicycle wheel
a turntable

You drop a 1 kg lump of clay on a turning table rotating at 3 rev/s. The clay sticks to the rim of the turntable. Find the new angular velocity of the table (with the clay) if the mass of the table is 5 kg and its radius is 30 cm.



$$L_f = \left(\frac{1}{2} MR^2 + \underline{mR^2} \right) \cdot \underline{\omega_f}$$

$$\longrightarrow L_i = L_f$$

$$L_i = I \cdot \omega_i = \frac{1}{2} MR^2 \cdot \omega_i$$

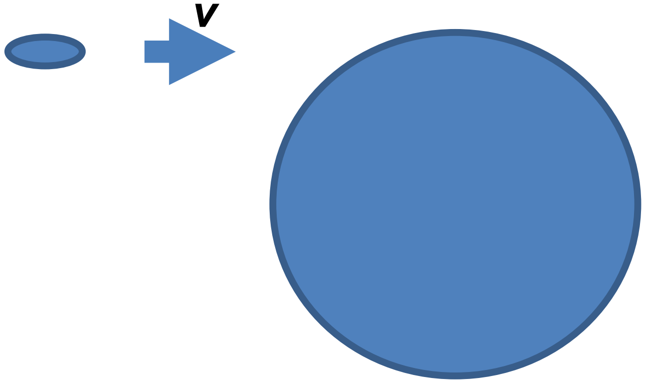
Phy sis is done!

A traveling bullet hits a resting disk. The bullet is stuck in a massless catcher located right at the rim of the disc. After the collision the disc …

1. **Remains at rest**
2. **Spins CW**
3. **Spins CCW**

(refer to the picture on the right)

Webassign: L16 Q5

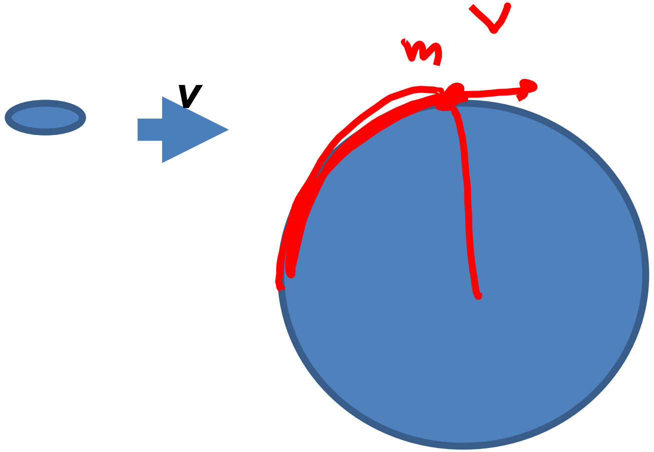


A 100 g bullet traveling at 100 m/s hits a 10 kg resting disk with the diameter of 50 cm. The bullet is stuck in a massless catcher located right at the rim of the disc. Find the angular speed of the disk right after the collision

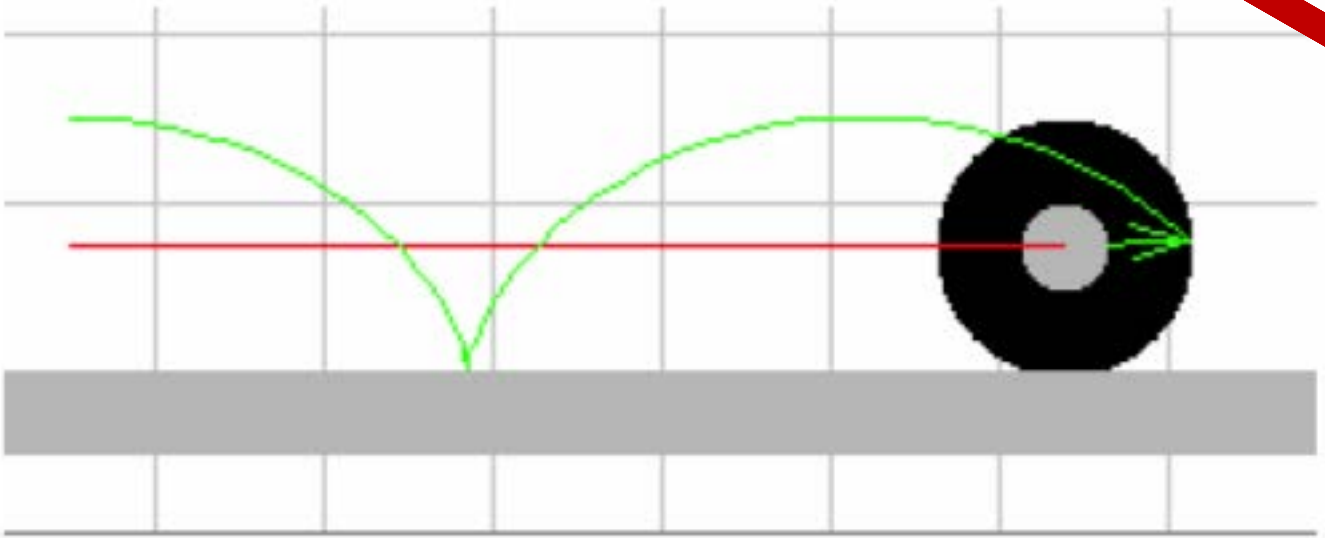
$$L_{BAC} = L_i = I \cdot \omega_i = m \cdot R^2 \cdot \frac{v}{R} \qquad \omega = \frac{v}{R}$$

$$L_f = (I_{disk} + I_B) \cdot \omega_f$$

$$L_f = L_i$$

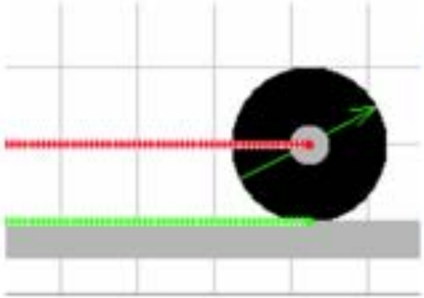


Rolling with NO slipping



Translational motion is coupled with rotational motion!

Distance traveled by the center relative to the ground is equal to the distance traveled by any point on the rim about the center.



When a wheel rolls **without slipping**, the straight-line distance traveled by the wheel's center-of-mass (in red on the simulation) is exactly equal to the rotational distance traveled by a point on the edge of the wheel (in green).

If the wheel has a constant angular velocity, the rotational speed is:

$$v_r = \frac{2\pi r}{T}$$

Because the distances and times are equal, the translational speed of the center of the wheel equals the rotational speed of a point on the edge of the wheel.

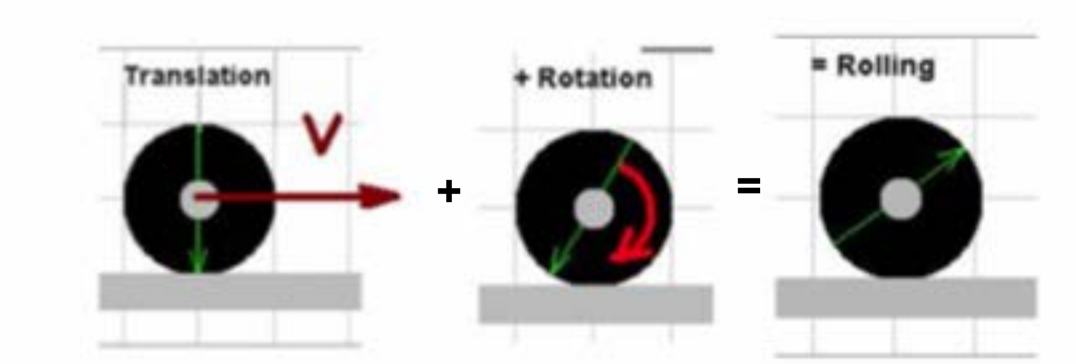
$$V_r = V_{CoM}$$

We say "acceleration" we mean "the acceleration of the center of mass"!

Angular speed of the wheel relative to its center

$$\omega = v / r$$

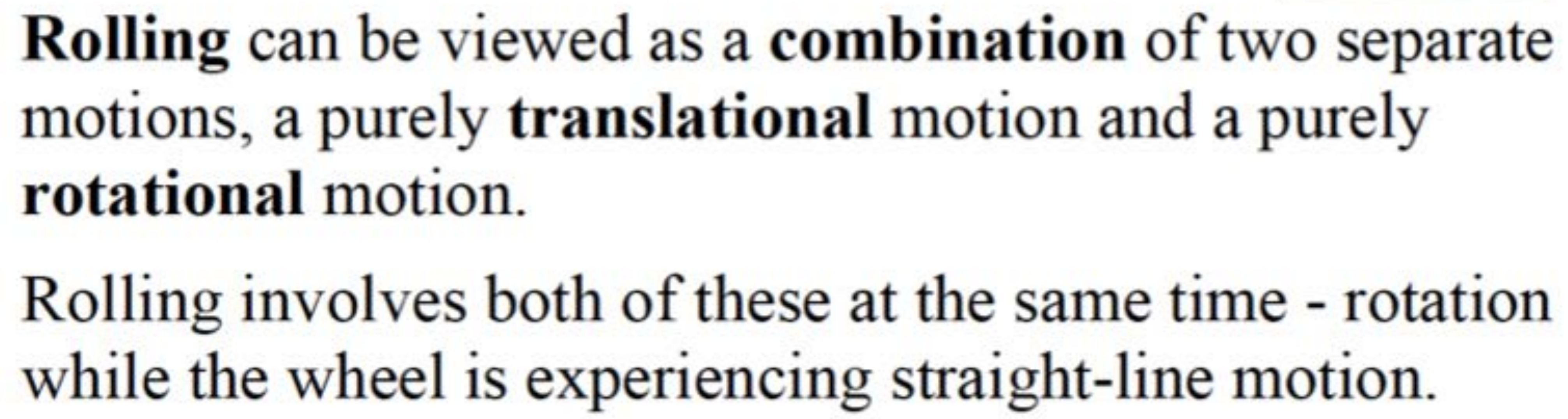
Linear speed of the center of the wheel relative to the ground



$$\omega = v / r$$

When an object is rolling with *no slipping* its translational motion is coupled with its rotational motion.

$$V_r = V_{CoM}$$


Rolling can be viewed as a **combination** of two separate motions, a purely **translational** motion and a purely **rotational** motion.

Rolling involves both of these at the same time - rotation while the wheel is experiencing straight-line motion.

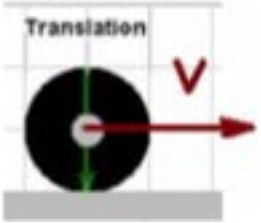
Kinetic Energy

$$I_{cyl} = \frac{1}{2}mr^2$$

$$I_{sph} = \frac{2}{5}mr^2$$

$$I_{ring} = mr^2$$

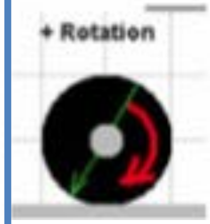
When and object is in a *translational* motion only:



$$K = ½ mv^2$$

<u>of</u> CofM

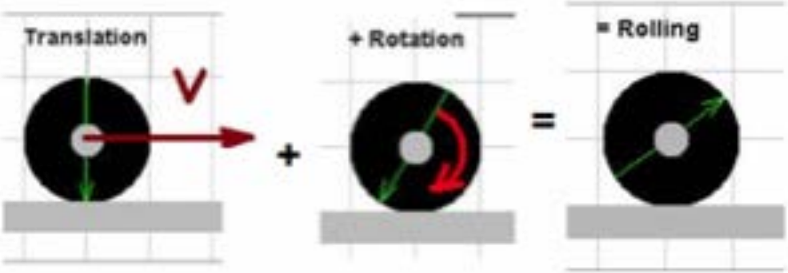
When and object is in a *rotational* motion only:



$$K = ½ I\omega^2$$

<u>about</u> CofM

When and object is *rolling*:



Total KE

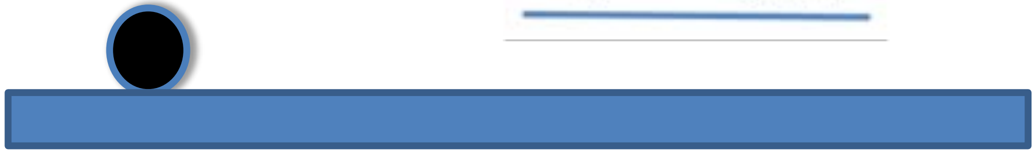
$$K = ½ mv^2 + ½ I\omega^2$$

<u>NO slipping</u>

$$\omega = v / r$$

Rolling with NO slipping

$\omega = v / r$



$V_r = V_{CoM}$

$K = \frac{1}{2} mv^2 + \frac{1}{2} I\omega^2$ when an object is rolling

WKET(rolling) $K_f - K_i = W_{net}$ **or**

the law of conservation of energy (no slipping)

$W_{appl} + U_i + K_i = U_f + K_f$

e.g. a hand

⇩

$W_{fr} = 0$

We have three objects of the same mass and radius: a solid disk, a ring, and a solid sphere.

The moments of inertia:

Webassign: L16 Q6

$$I_{disk} = \{1/2\}mR^2 \qquad I_{ring} = mR^2 \qquad I_{spere} = \{2/5\}mR^2$$

The correct ranking is…

1. $I_{disk} > I_{ring} > I_{sphere}$

2. $I_{disk} > I_{sphere} > I_{ring}$

3. $I_{sphere} > I_{ring} > I_{disk}$

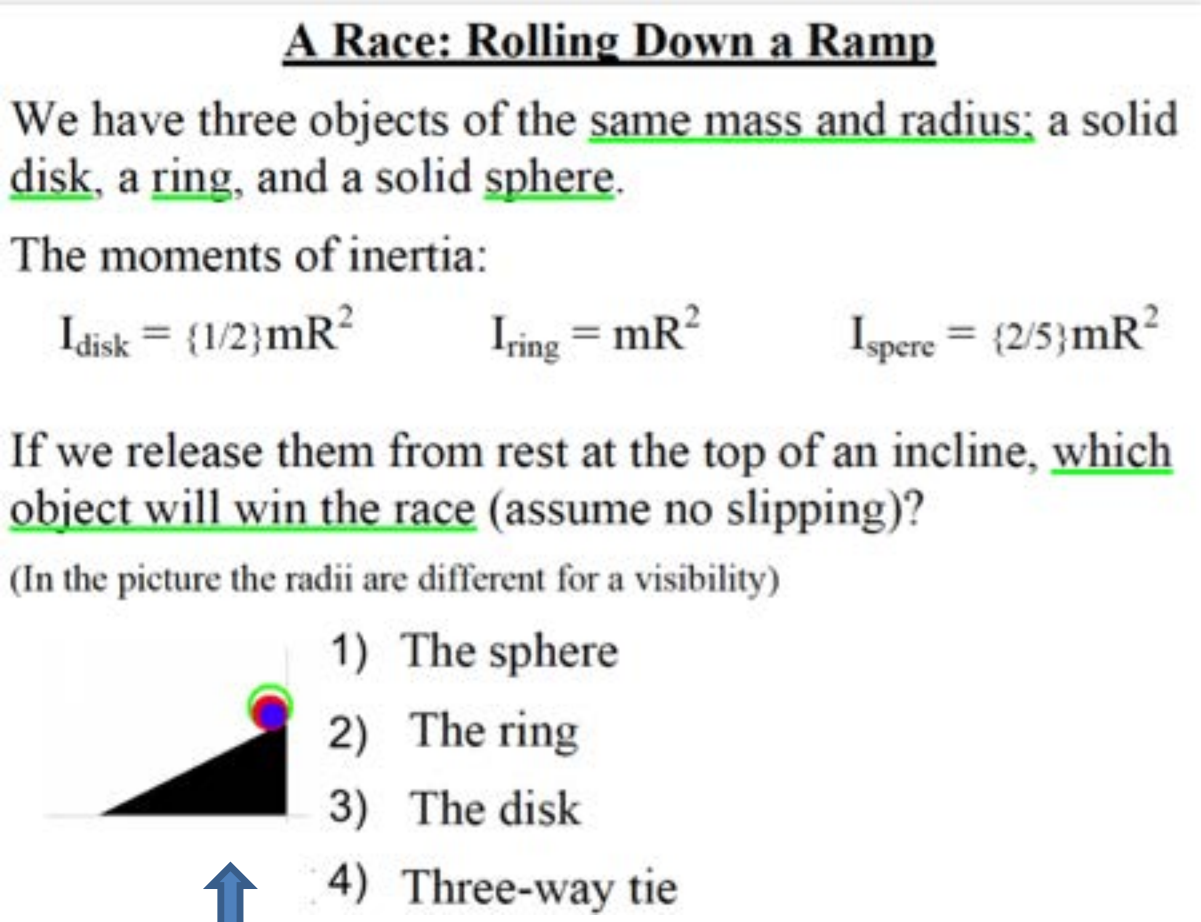
4. $I_{sphere} > I_{disk} > I_{ring}$

5. $I_{ring} > I_{disk} > I_{sphere}$

6. $I_{ring} > I_{sphere} > I_{disk}$

7. I see too many *I*s

8. What is *I*?



A Race: Rolling Down a Ramp

We have three objects of the same mass and radius: a solid disk, a ring, and a solid sphere.

The moments of inertia:

$I_{disk} = \{1/2\}mR^2$ $I_{ring} = mR^2$ $I_{spere} = \{2/5\}mR^2$

If we release them from rest at the top of an incline, which object will win the race (assume no slipping)?

(In the picture the radii are different for a visibility)

1) The sphere
2) The ring
3) The disk
4) Three-way tie

Webassign: L16 Q7

Which object wins the race?

Webassign: L16 Q6

The correct ranking is…

1. $I_{\text{disk}} > I_{\text{ring}} > I_{\text{sphere}}$
2. $I_{\text{disk}} > I_{\text{sphere}} > I_{\text{ring}}$
3. $I_{\text{sphere}} > I_{\text{ring}} > I_{\text{disk}}$
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The moments of inertia: **Webassign: L16 Q7**

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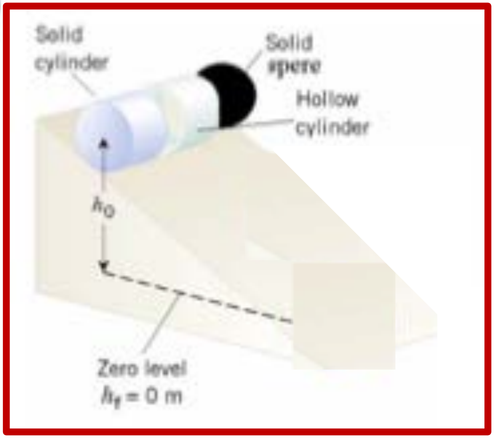

Webassign: L16 Q7

The correct ranking is…

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5. $I_{\text{ring}} > I_{\text{disk}} > I_{\text{sphere}}$
6. $I_{\text{ring}} > I_{\text{sphere}} > I_{\text{disk}}$
7. I see too many *I*s
8. What is *I*?

Let's do it!

We have three objects of the same mass and radius; a solid disk, a ring, and a solid sphere.

The moments of inertia: **1 > ½ > 2/5 !**

$I_{ring} = mR^2$ $I_{disk} = \{1/2\}mR^2$ $I_{spere} = \{2/5\}mR^2$

If we release them from rest at the top of an incline, which object will win the race (assume no slipping).

"More inertia" => longer time!

The sphere wins (the disk is next; the ring comes last)

A Race: Rolling Down a Ramp

We have three objects of the same mass and radius: a solid disk, a ring, and a solid sphere.

1 > ½ > 2/5 !

The moments of inertia:

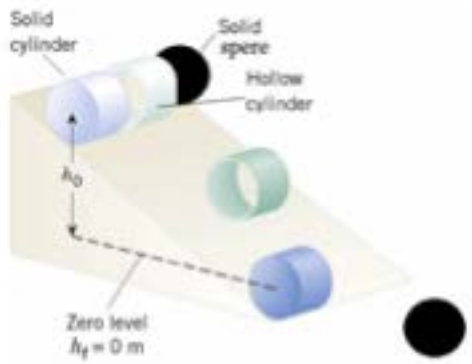
$$I_{disk} = \{1/2\}mR^2 \qquad I_{ring} = mR^2 \qquad I_{spere} = \{2/5\}mR^2$$

Which object wins the race?

If we release them from rest at the top of an incline, which object will win the race (assume no slipping)?

(In the picture the radii are different for a visibility)

1) The sphere
2) The ring
3) The disk
4) Three-way tie



The correct ranking is…

1. $I_{\text{disk}} > I_{\text{ring}} > I_{\text{sphere}}$
2. $I_{\text{disk}} > I_{\text{sphere}} > I_{\text{ring}}$
3. $I_{\text{sphere}} > I_{\text{ring}} > I_{\text{disk}}$
4. $I_{\text{sphere}} > I_{\text{disk}} > I_{\text{ring}}$
5. $I_{\text{ring}} > I_{\text{disk}} > I_{\text{sphere}}$
6. $I_{\text{ring}} > I_{\text{sphere}} > I_{\text{disk}}$
7. I see too many *I*s
8. What is *I*?

We have three objects of the same mass and radius; a solid disk, a ring, and a solid sphere.

The moments of inertia:

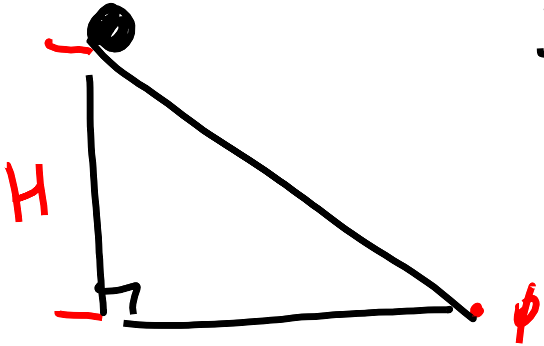
$I_{disk} = (1/2)mR^2$ $\quad$ $I_{ring} = mR^2$ $\quad$ $I_{spere} = (2/5)mR^2$

If we release them from rest at the top of an incline, which object will win the race (assume no slipping).

"More inertia" => longer time!

The sphere wins (the disk is next; the ring comes last)

$$I = c \cdot m \cdot R^2$$



$$E_i = mgh + 0$$

$$E_f = 0 + \frac{mv_f^2}{2} + \frac{1}{2} I \omega^2$$

$$\omega = \frac{v}{R}$$

$$\cancel{m}gh = \frac{\cancel{m}v^2}{2} + \frac{1}{2} \cdot c \cdot \cancel{m} \cdot \cancel{R^2} \cdot \left(\frac{v_f}{\cancel{R}}\right)^2$$

$$gh = \frac{v_f^2}{2} + \frac{1}{2} \cdot c \cdot v^2 = \frac{1}{2} v^2 (1 + c)$$

$$v_f^2 = \frac{2gh}{1+c} \quad ; \quad v_f = \sqrt{\frac{2gh}{1+c}} \quad ; \quad v_{av} = \frac{0 + v_f}{2} = \frac{s}{t}$$

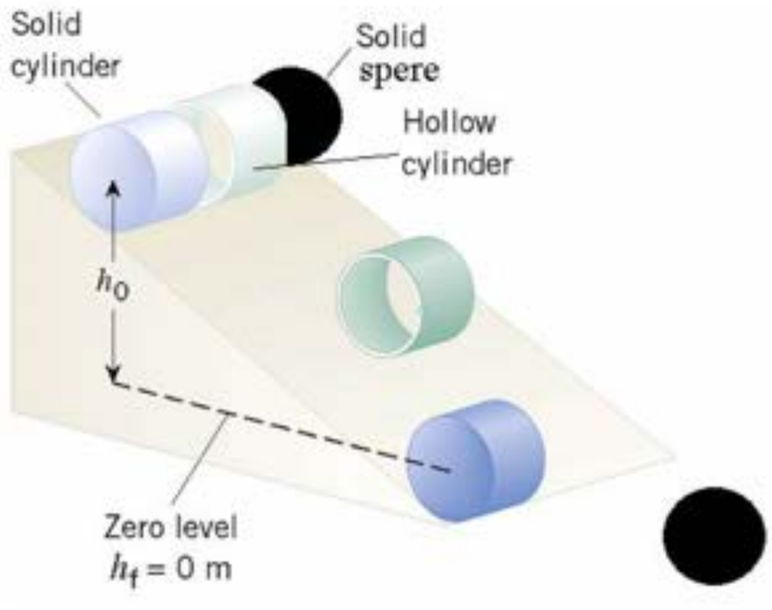
$$t = \frac{2 \cdot s}{v_f} = \frac{2s\sqrt{1+c}}{\sqrt{2gh}}$$

A Race: Rolling Down a Ramp

We have three objects of the same mass and radius; a solid disk, a ring, and a solid sphere.

The moments of inertia:

$$I_{disk} = \{1/2\}mR^2 \qquad I_{ring} = mR^2 \qquad I_{spere} = \{2/5\}mR^2$$



If we release them from rest at the top of an incline, which object will win the race (assume no slipping).

$$U_i + K_i = U_f + K_f$$

Let’s apply LCME.

A Race: Rolling Down a Ramp (another solution)

Let's take an object with a mass m and a radius R, and a moment of inertia of CmR^2.

$$I_{disk} = \{1/2\}mR^2 \qquad I_{ring} = mR^2 \qquad I_{spere} = \{2/5\}mR^2$$

Hence; $\boxed{I = CmR^2}$

$$C_{disk} = 1/2 \qquad C_{ring} = 1 \qquad C_{spere} = 2/5$$

(for the sliding block $C = 0$; no ration!)

Let's apply *the law of conservation of energy* (no slipping)

$$U_i + K_i = U_f + K_f$$

The initial potential energy is mgh. The initial kinetic energy is zero. The final kinetic energy is made up of translational and rotational kinetic energies.

$$mgh = \tfrac{1}{2}\, mv^2 + \tfrac{1}{2}\, I\omega^2$$

<u>Plugging in</u> $I = CmR^2$: we have

$$mgh = \tfrac{1}{2}\, mv^2 + \tfrac{1}{2}\, CmR^2\, \omega^2$$

<u>or</u>

$$2gh = v^2 + CR^2\, \omega^2$$

For rolling without slipping, $v = \omega R$, hence we can write

$$2gh = v^2 + \frac{CR^2\, v^2}{R^2}$$

This gives:

$$2gh = v^2 + Cv^2$$

and solving for v

$$v = \left(\frac{2\,g\,h}{1 + C}\right)^{½}$$

So, the larger the value of C (and moment of inertia!), the smaller the speed is (C↑ => v↓).

The center of mass of each object moves at constant acceleration; hence $S = ½v \cdot t$

Because the distance S covered by the objects is the same, when v↓ the time t↑. At the end: C↑ => t↑ or C↓ => t↓

The object with the smallest C wins (the sphere or block)!

We have three objects of the same mass and radius; a solid disk, a ring, and a solid sphere.

1 > ½ > 2/5 !

The moments of inertia:

$I_{disk} = \{1/2\}mR^2$ $I_{ring} = mR^2$ $I_{spere} = \{2/5\}mR^2$

If we release them from rest at the top of an incline, which object will win the race (assume no slipping).

"More inertia" => longer time!

The sphere wins (the disk is next; the ring comes last)

A sphere rolls down a ramp without slipping and a small piece of ice slides down the same ramp without friction. If they both start from rest form the same height, which object will win the race?

$$t_{sph} = \frac{2S\sqrt{1+c}}{\sqrt{2gh}} ;$$

$$c = \frac{2}{5}$$

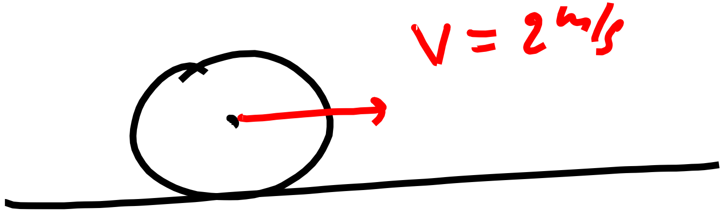
$$t_{cart} = \frac{2S\sqrt{1+c}}{\sqrt{2gh}}$$

$$c = 0$$

$$t_{cart} < t_{sph}$$

A 5 kg ball *rolls without slipping* on a horizontal floor so that its center of mass has a speed of 2 m/s. How much work must be done on the ball to completely stop it (calculate the magnitude of the work)?

$\omega = \frac{v}{R}$



$I = \frac{2}{5} m R^2$

$c = \frac{2}{5}$

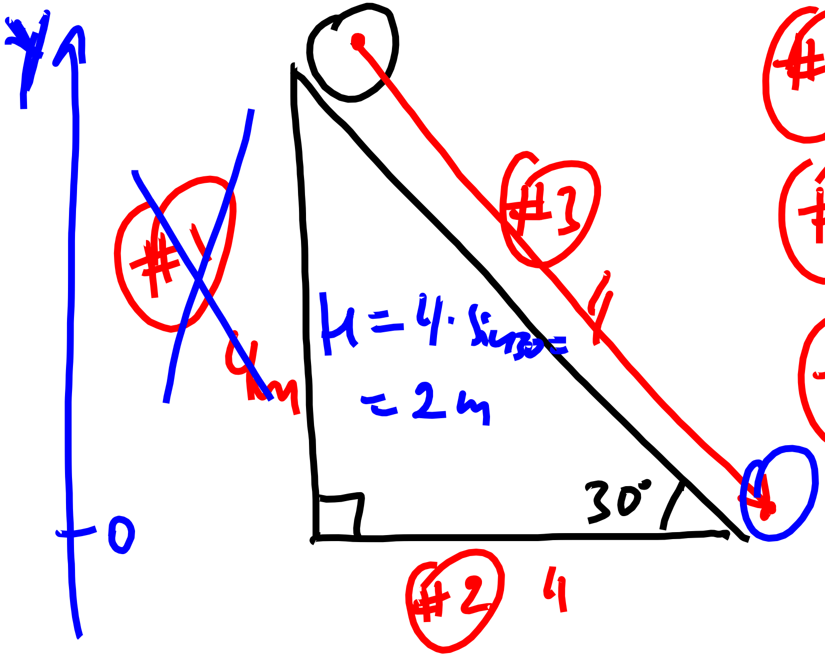
$KE = \frac{1}{2} m v^2 + \frac{1}{2} I \omega^2 =$

$= \frac{1}{2} \cdot 5 \cdot 2^2 + \frac{1}{2} \cdot \frac{2}{5} \cdot 5 \cdot R^2 \cdot \omega^2 =$

$= 10 + \cancel{R^2} \cdot \left(\frac{2}{\cancel{R}}\right)^2 = 10 + 4 = \underline{\underline{14 J}}$

$|W| = |\Delta K| = 14 J$

A solid cylinder with the mass of 2 kg rolls without slipping from rest down a ramp inclined at 30°. Find the speed of the cylinder (i.e. of its CofM) after traveling 4 m.



#4 There is no ramp

#5 I don't like physics

#6 I'm not here

$KE_i = 0$

$PE_i = mgh =$

$= 2 \cdot 10 \cdot 2 \; J$

$ME_i = 40 \; J$

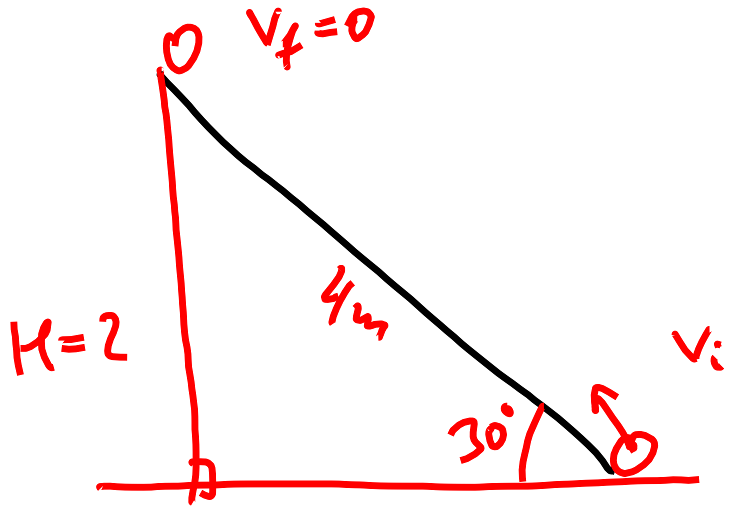
$PE_i = 0$

$KE_i = \frac{1}{2} m V^2 + \frac{1}{2} I \omega^2$

$$40 = \frac{1}{2} \cdot 2 \cdot V_f^2 + \frac{1}{2} \cdot \frac{1}{2} 2 \cdot \cancel{R^2} \left(\frac{V_f}{\cancel{R}} \right)^2$$

$V_f = \ldots$

A solid cylinder with the mass of 2 kg rolls without slipping up a ramp inclined at 30°. Find the minimum speed for the cylinder (i.e. of its CofM) needed to travel 4 m.



$$\omega = \frac{v}{R}$$

$$ME_i = PE_i + KE_i = 0 + \frac{1}{2} m V_i^2 + \frac{1}{2} I \omega_i^2$$

$$ME_f = mgH + 0$$

$$ME_i = ME_f$$

$$\downarrow$$

$$\frac{1}{2} \cdot 2 \cdot V_i^2 + \frac{1}{2} \cdot \frac{1}{2} \cdot 2 \cdot \cancel{R^2} \left(\frac{V_i}{\cancel{R}}\right)^2 = 2 \cdot 10 \cdot 2$$

NO Friction!

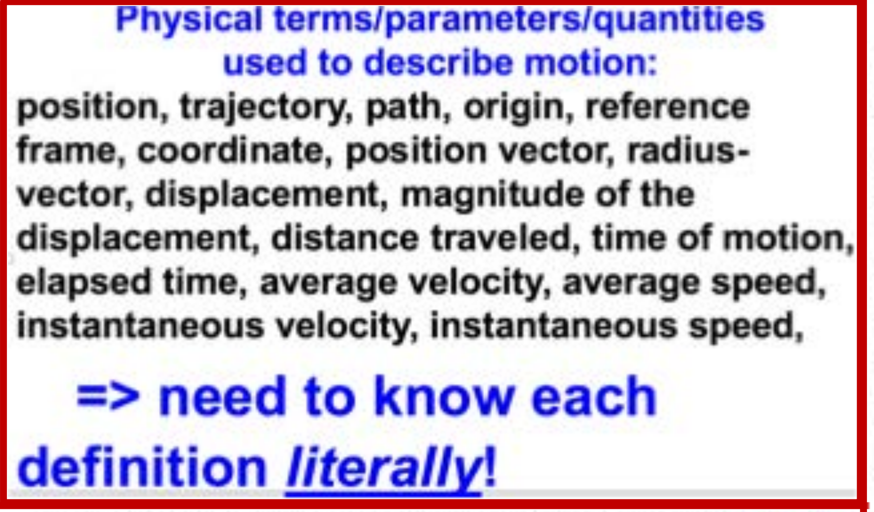
⇓

NO Rotation!

$$KE = \frac{1}{2} m v^2 + \frac{1}{2} I \omega^2$$

$$\omega \neq \frac{v}{R}$$

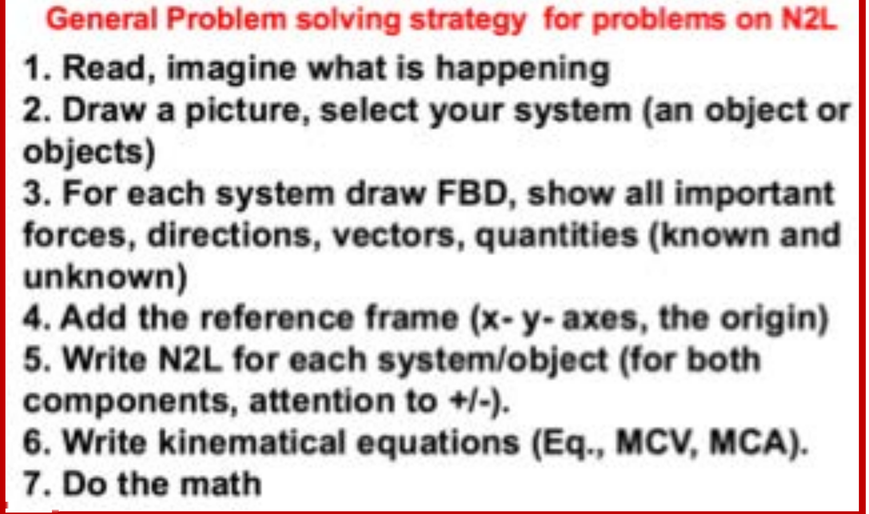
$$\omega = 0$$



Physical terms/parameters/quantities used to describe motion:

position, trajectory, path, origin, reference frame, coordinate, position vector, radius-vector, displacement, magnitude of the displacement, distance traveled, time of motion, elapsed time, average velocity, average speed, instantaneous velocity, instantaneous speed,

=> need to know each definition *literally*!

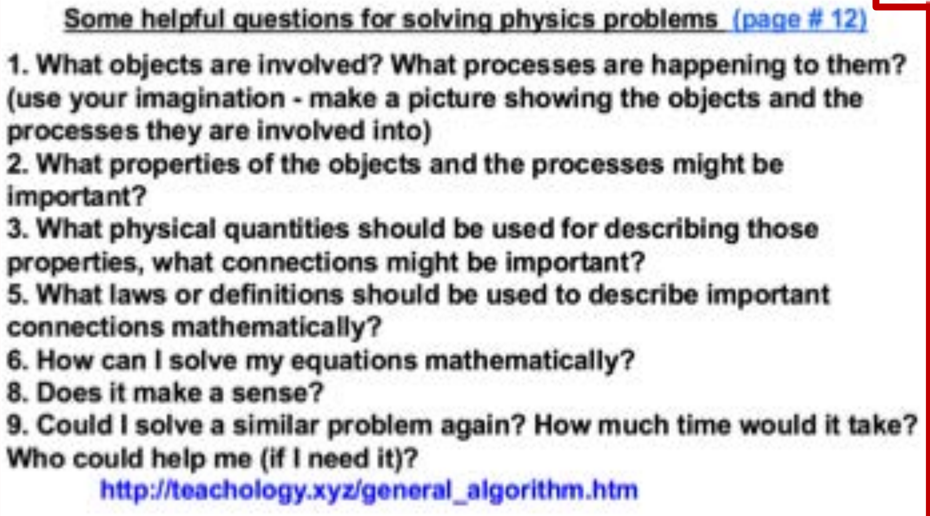


General Problem solving strategy for problems on N2L

1. Read, imagine what is happening
2. Draw a picture, select your system (an object or objects)
3. For each system draw FBD, show all important forces, directions, vectors, quantities (known and unknown)
4. Add the reference frame (x- y- axes, the origin)
5. Write N2L for each system/object (for both components, attention to +/-).
6. Write kinematical equations (Eq., MCV, MCA).
7. Do the math

Circular and Rotational motion, Rolling:

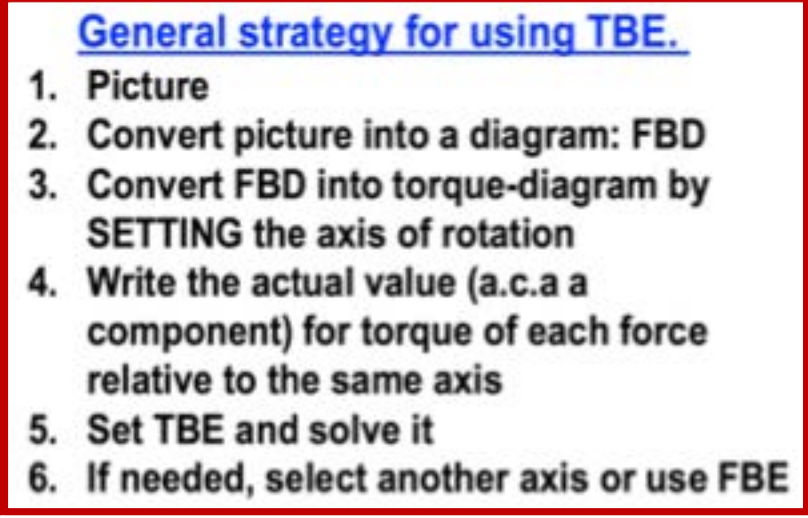
Linear and angular variables, Centripetal acceleration, Moment of inertia, N2LforRM, RKE, Angular momentum, Work of torque



Some helpful questions for solving physics problems (page # 12)

1. What objects are involved? What processes are happening to them? (use your imagination - make a picture showing the objects and the processes they are involved into)
2. What properties of the objects and the processes might be important?
3. What physical quantities should be used for describing those properties, what connections might be important?
5. What laws or definitions should be used to describe important connections mathematically?
6. How can I solve my equations mathematically?
8. Does it make a sense?
9. Could I solve a similar problem again? How much time would it take? Who could help me (if I need it)?

http://teachology.xyz/general_algorithm.htm



General strategy for using TBE.

1. Picture
2. Convert picture into a diagram: FBD
3. Convert FBD into torque-diagram by SETTING the axis of rotation
4. Write the actual value (a.c.a a component) for torque of each force relative to the same axis
5. Set TBE and solve it
6. If needed, select another axis or use FBE

Friction, Energy and Work, momentum, collisions: Kinetic and static friction, work of a constant force, kinetic and potential energy, WKET, LCME, LCLM.