Problem Set #4 due beginning of class, Thursday May 3. Please state the lens you are using and why. Remember that you are graded on your ***communication*** of physics understanding.

1. Hand in perfect corrections for MT#1 – The exam and my comments and some answers are on the main class website. See midterm #1 Solutions on Main Class Website.
2. Friction: please do exercises 2 and 3, in section 3.2. For exercise 2, you have to first establish if the car moves or not. If not, then the force of friction is only as large as the applied force. If the car moves, then you use the coefficient of dynamic friction. For exercise 3, you just conserve energy: You start with kinetic energy and then subtract from it the work done by friction. The difference is the remaining kinetic energy.
3. Section 4.0 Exercise 1, collision of rotating bodies – what is the linear analogue for this problem?

A 2) (4.0, #1) Two identical disks ("A" and "B") are spinning in opp. directions in space, $\omega_A = 3\omega_B$.

I would use an angular momentum lens since I'm comparing their angular momentums. $\vec{l}_A = I\vec{\omega}$. For disk A, it would be $\vec{l}_A = I_A\omega_A$, and for B it's, $\vec{l}_B = I_B\vec{\omega}_B = I_B(\frac{1}{3}\omega_A)$. Since this disks are identical, $I_A = I_B$. So, $\vec{l}_B = \frac{1}{3}\vec{l}_A$ ... $\boxed{\vec{l}_A = 3\vec{l}_B}$

For their kinetic energies, I would use a rotational kinetic energy lens since I'm dealing with their transfers of energy. $E_R = \frac{1}{2}I\vec{\omega}^2$ $\quad I_A = I_B = I$

$E_{R(A)} = \frac{1}{2}I_A\vec{\omega}_A^2 = \frac{1}{2}I(3\vec{\omega}_B)^2$ $\qquad E_{R(B)} = \frac{1}{2}I_B\vec{\omega}_B^2 = \frac{1}{2}I\vec{\omega}_B^2$

$E_{R(A)} = 9(\frac{1}{2}I\vec{\omega}_B^2)$ $\qquad E_{R(B)} = \frac{1}{2}I\vec{\omega}_B^2$

$\boxed{E_{R(A)} = 9E_{R(B)}}$

- The two bodies collide and stick together.
- The linear analogue to these disks colliding would be two carts or blocks colliding.
- I would use an angular momentum lens here since this collision is in an isolated system and therefore momentum is conserved. (No outside forces)

$\vec{l}$ is a vector

$\vec{\omega}_A = -3\vec{\omega}_B$

$\vec{l}_i = \vec{l}_f \rightarrow I_A\vec{\omega}_A + I_B\vec{\omega}_B = (I_A + I_B)\vec{\omega}_f$, $\rightarrow I_A = I_B = I$

$$\omega_f = \frac{I_A\vec{\omega}_A + I_B\vec{\omega}_B}{I_A + I_B} = \frac{I(3\omega_B) + I\omega_B}{2I} = \frac{\cancel{4}I\omega_B}{\cancel{2}I} = \cancel{2}\omega_B = \vec{\omega}_B$$

$\omega_B = \frac{1}{3}\omega_A \Rightarrow \omega_f = \cancel{2}\omega_B = \cancel{2}(\frac{1}{3}\omega_A) = \boxed{\frac{1}{3}\omega_A = \omega_f}$

- I would use an energy lens here since I see that there's a transformation of energy in this collision.

$\sum\vec{E}_{Ri} = \sum\vec{E}_{R(A)} + \sum E_{R(B)}$ $\qquad \sum\vec{E}_{Rf} = \frac{1}{2}I_{A+B}\vec{\omega}_f^2$

$= 9E_{R(B)} + E_{R(B)}$ $\qquad = \frac{1}{2}(I_A + I_B)(\frac{1}{3}\omega_A)^2$

$= 10E_{RB}$ $\qquad = \frac{1}{2}(2I)(\frac{1}{9}\omega_A^2)$

$= 10(\frac{1}{2}I\vec{\omega}_B^2)$ $\qquad = \frac{1}{9}I(3\omega_B)^2$

$= 5I\vec{\omega}_B^2 = 10(\frac{1}{2}I\vec{\omega}_B^2)$ $\qquad = \cancel{1}I\omega_B^2 = \cancel{2}2(\frac{1}{2}I\omega_B^2)$

$= 10E_{R(B)} = \sum\vec{E}_{Ri} \longrightarrow$ $\qquad = \cancel{2}2E_{R(B)} = \sum\vec{E}_{Rf}$

80% of the original $E_K \Rightarrow E_{th}$

Is this the same as in an inelastic collision?

m → $v_0$ $\quad$ $\frac{3v_0}{2}$ ← m

and that $E_{RA} = 9E_{RB}$

Using $E_{RB}$, I found the initial and final energies of the system. $\sum E_{Ri} = 10E_{RB}$ while $\sum\vec{E}_{Rf} = 2E_{RB}$. Therefore, we see that an energy equal to 8 $E_{RB}$ was "lost" to heat due to the collision.

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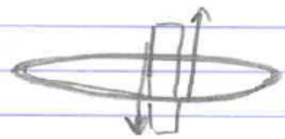
4. Section 4.1 Example 1, Rotation Direction

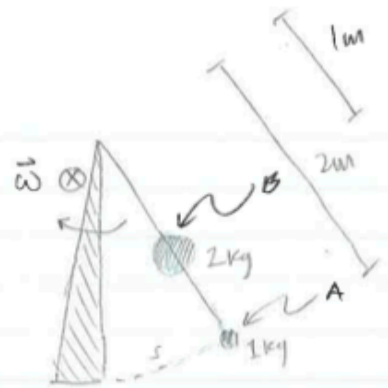
4.1 Ex 1

(rotational acceleration)

$\boxed{C.}$ Shows torque in the leftward $-\hat{x}$ direction.



5. Section 4.2 Exercise 1, Rotation and kinetic energy of two masses




)(4.2, # 1) Rigid rod, driven by motor, rotates about pivot at top of triangular support at $\vec{\omega} = 10\ \text{rad/s}$. The 2m long rod is very light, w/ 1 kg mass @ end and 2 kg mass in the middle of the rod.

a) I would use a rotational kinematics lens for this since I'm analyzing the rod's rotational motion as an explicit function of time.

$\vec{\omega}: 10 \frac{\text{rad}}{\text{s}} \times \frac{1\ \text{revolution}}{2\pi\ \text{rad}} \times \frac{60\ \text{s}}{1\ \text{min.}} = \boxed{95.493\ \text{rpm}}$ *without a calculator*

b) I would use a rotational kinematics lens for the same reason. I know that the rod rotates at $\vec{\omega} = 10\ \text{rad/s}$, therefore each mass must also rotate at $\vec{\omega} = 10\ \text{rad/s}$, like any point on the rod, since they all cover the same $\Delta\theta$ in the same $\Delta t$. However, mass A must move faster translationally than mass B since mass A covers a larger arc length "s" in the same $\Delta t$ that mass B covers a smaller s, since $s = r\Delta\theta$,

$\vec{V} = \frac{ds}{dt} = \frac{r\,d\theta}{dt} = r\vec{\omega} \Rightarrow \vec{V}_A = (2\text{m})(10\ \text{rad/s}) = \boxed{20\ \text{m/s} = \vec{V}_A}$

$\vec{V}_B = (1\text{m})(10\ \text{rad/s}) = \boxed{10\ \text{m/s} = \vec{V}_B}$

c) I would use a rotational kinetic energy lens for this since I'm find the $E_K$ of each mass $\Rightarrow$ there's energy transformation. We know $E_{RK} = \frac{1}{2} I \omega^2$ and $I = mr^2$, *But you could also just use $E_K = \frac{1}{2}mv^2$*

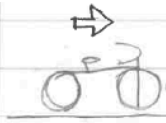
$E_{RK(A)} = \frac{1}{2} I_A (\omega_A)^2$
$= \frac{1}{2} m_A (r_A)^2 (\omega_A)^2$
$= \frac{1}{2}(1\text{kg})(2\text{m})^2(10\ \text{rad/s})^2$
$= 200\ \text{kg m}^2/\text{s}^2 = \boxed{200\text{J}}$

$E_{RK(B)} = \frac{1}{2} I_B (\omega_B)^2$
$= \frac{1}{2} m_B (r_B)^2 (\omega_B)^2$
$= \frac{1}{2}(2\text{kg})(1\text{m})^2(10\ \text{rad/s})^2$
$= 100\ \text{kg}\cdot\text{m}^2/\text{s}^2 = \boxed{100\ \text{J}}$

d) I use a rotational kinetic energy lens here for the same reason. $\sum E_K = \sum E_{KR} = E_{RK(A)} + E_{RK(B)}$
$= 200\ \text{J} + 100\ \text{J}$
$= \boxed{300\ \text{J}}$

6. Section 4.2 Exercise 2, Rotation and linear speed, bicycle problem

(4)



$d = 0.700 m$ $\quad \Delta t = 5 s$ $\quad v = 10 m/s$

a.) kinematics lens

$\vec{a} = \frac{\Delta v}{\Delta t} = \frac{10 m/s}{5 s} = 2 m/s^2$ ← possible on level ground

b.) rotational kinematics lens

$\vec{\omega} = \frac{\vec{v}}{r} = \frac{10 m/s}{\frac{1}{2}(0.7 m)} = \boxed{28.57 \text{ rad}/s}$

right hand rule ⇒ ⊗

c.) $\vec{\alpha} = \frac{\Delta \omega}{\Delta t} = \frac{28.57 r/s}{5 s} = \boxed{5.71 \text{ rad}/s^2}$

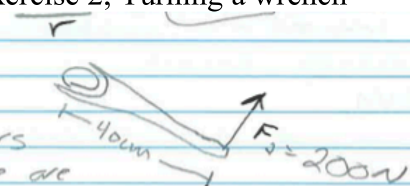
d.) $\vec{\omega} = \frac{\Delta \vec{\theta}}{\Delta t} \Rightarrow \Delta \vec{\theta} = \vec{\omega}_{average} \Delta t$

$= \frac{(28.57 \text{ rad}/s)(5 s)}{2}$

$= \boxed{71.45 \text{ rad}}$

7. Section 4.3 Exercise 2, Turning a wrench

(6) 4.3 Ex) 2




a) First, dynamics lens b/c there are $\tau$'s and $\alpha$'s

$\tau = F \cdot r = 200N \cdot .4m = (80 Nm)$

Now, energy lens, b/c work is done on the nut as it turns

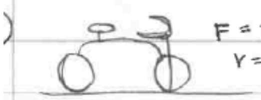
$W = \tau \cdot \Delta\theta = 80Nm \cdot 2\pi \approx (500 J)$

b) This energy was converted to heat through friction.

c) $P = \frac{W}{\Delta t} = \frac{500J}{2s} = (250W)$

great!

8. Section 4.3 Exercise 4, Pedaling a bicycle



$F = 200 N$ $\quad \vec{\omega} = 90 rpm$

$r = 175 mm$

a.) rotational dynamics lens

$\tau = r \vec{F}_\perp$

$= (0.175 m)(200 N)$

$= \boxed{35 Nm}$

$\frac{90 r}{1 min} \cdot \frac{2\pi \text{ rad}}{1 r} \cdot \frac{1 min}{60 sec}$

$\vec{\omega} = 9.42 \text{ rad}/sec$

$P = \frac{\Delta E}{\Delta t} = \frac{W}{\Delta t} = \tau \Delta \vec{\omega} = (35 Nm)(9.42 \text{ rad}/sec)$

$\approx \boxed{330 W}$

b.) rotational kinematics lens

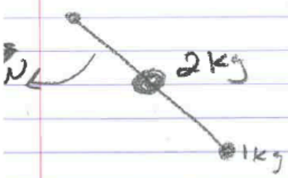
$\vec{v} = \frac{\Delta s}{\Delta t} = \frac{r \Delta s}{\Delta t} = r\vec{\omega} = (0.175 m)(9.42 \text{ rad}/s) = \boxed{1.64 m/s}$

$p = \frac{\Delta E}{\Delta t} = \frac{F \Delta x}{\Delta t} = F \cdot \vec{v} = (200 N)(1.64 m/s) \approx \boxed{330 W}$

9. Section 4.4 Exercise 2, Kinetic energy of two masses

7) 4.4 Ex 2

$\omega = 10/s$




Lens: Energy. Finding inertia as how difficult to rot. move and KE.

e) $I = m_1r_1^2 + m_2r_2^2$

$= 2kg(1m)^2 + 1kg(2m)^2$

$\boxed{I = 6\,kgm^2}$ ✓

f) $E_R = \frac{1}{2} I \omega^2$

$= \frac{1}{2}(6\,kgm^2)(10/s)^2$ ✓

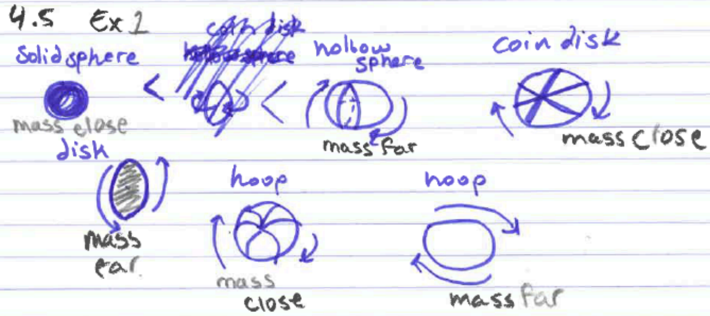
$= 30\,kg\frac{m^2}{s^2} = \boxed{300J} = E_R$

g) My answer agrees!

h) Finding KE w/ rotational equations is better because there's one less step without having to find $V_{Tan}$.

10. Section 4.5 Exercise 1, Ranking Several Objects

4.5 Ex 1

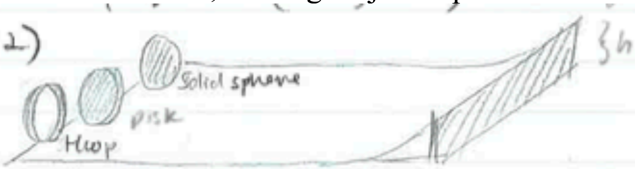



Solid sphere < hollow sphere < coin disk < standing hoop ✓

< disk < hoop.

11. Section 4.5 Exercise 2, Rolling Objects up a hill

1c) (4.5, #2)




$I_{Solid\ Sphere} = \frac{2}{5}mr^2$

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

$I_{Hoop} = mr^2$

I use a rotational dynamics lens since I see that torques are causing rotational acceleration. We know that moment of inertia is a measure of how hard it is to rotationally accelerate a body; the more I a body has, the harder it is to apply an angular acceleration on it. Because the hoop has the highest I, it will go further up the hill than the others because it's harder for the force of gravity, and therefore friction to apply an angular acceleration (negative) to slow the disk down. great! I would use Energy lens to get the same answer! Can you try that too?