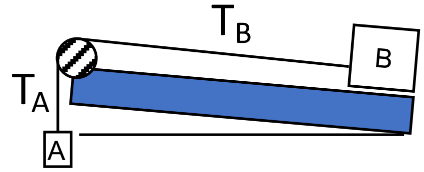
You will be graded on your *__COMMUNICATION__* of physics understanding

#1 You devise a way to lift a large block (B) on low friction wheels, up a 4 m incline, increasing height by 50 cm. The string is run over a pulley wheel (The wheel has *__considerable mass)__* that turns freely on its axel with the rope stretched over it. That is, the rope does not slip over the wheel's surface. I release the system from rest and it moves until mass *B* hits the pulley wheel.

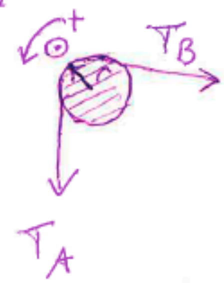


a) Assume we allow this low friction system to go from rest. Knowing what we do about the measurements of the system and the masses of blocks A and B, how would we determine which way it would accelerate? Explain briefly and clearly. Yes, we could solve this with a dynamics lens because the force of gravity on A and B causes the system to accelerate. However, only the parallel component of gravity on block B contributes to the acceleration, which we learn about this week. However, the best way to solve this is with an energy lens because the system will "fall" to a lower energy state. In order to accelerate to the left, block A must lose more potential energy than block B gains, or $\Delta E_P < 0$ or $m_A g\Delta H_A + m_B g\Delta H_B = m_A g(-4m) + m_B g(0.5\ m) < 0$. Another way to look at this: because block A drops 8 times as far as block B rises, the system will lose potential energy and accelerate to the left as long as $m_A > \frac{1}{8} m_B$.

b) As block B slides (and block *A* falls), how does T_A compare to the <u>force of gravity on A</u>, *AND*.. See student work.

c) How does T_A compare <u>to T_B</u>? Briefly and clearly explain how you know this to be true.

c) T_A and T_B act in opposite directions on the wheel. I will use the dynamics - <u>angular</u> dynamics lens because these Torques cause angular acceleration.



$\Sigma \vec{\tau} = I\vec{\alpha}$ — because the wheel accelerates in the + direction, $\tau_A > \tau_B$

$\tau_A - \tau_B = I\alpha$ — because they have the same radius, then $T_A > T_B$

$T_A r - T_B r = I\alpha$

d) You need to calculate everything about the system: the <u>final speed</u> when B hits the pulley wheel, <u>the acceleration of block B</u>, the <u>angular acceleration of the wheel</u>, and <u>T_A</u>. Explain how you would go about this. Be brief but clear, and a diagram is always good. I can find the final speeds by using the energy lens because the loss of potential energy from the blocks A and B turns into kinetic energy in the form of translational kinetic energy of the two blocks and the rotational kinetic energy of the wheel. From there I can find the time to fall, acceleration, and tensions.

d) Energy lens because $E_{p_A} \Rightarrow E_K + E_{p_B} = E_{K_A} + E_{K_B} + E_{rot} + E_{p_B}$

$$m_A g \Delta h_A = \frac{1}{2}(m_A + m_B) v_f^2 + \frac{1}{2} \underbrace{I_w}_{\frac{1}{2}mR^2} \underbrace{\omega_w^2}_{v_f/R} + m_B g \Delta h_B$$

$$(m_A \underbrace{\Delta h_A}_{4m} - m_B \underbrace{\Delta h_B}_{\frac{1}{2}m}) g = \left[\frac{1}{2}(m_A + m_B) + \frac{1}{2} I_w \frac{1}{R^2}\right] v_f^2$$

$$= \left[\frac{1}{2}(m_A + m_B) + \frac{1}{4} m_w\right] v_f^2$$

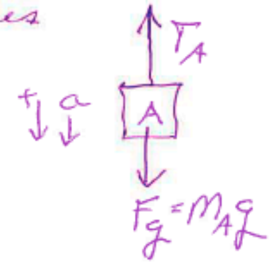
because we would know m_A, m_B, m_w, we can solve for v_f

$$v_{ave} = \frac{v_i + v_f}{2} = \frac{v_f}{2} \qquad v_{ave} = \frac{\Delta h_A}{\Delta t}; \ \Delta t = \frac{\Delta h_A}{v_{ave}} = \frac{2\Delta h_A}{v_f}$$

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - \cancel{v_i}^{\,0}}{\Delta t} = \frac{v_f}{\Delta t}$$

$$\alpha_{wheel} = \frac{a_{tan}}{r}$$

Using a dynamics lens because the forces on A cause it to accelerate:



$$\Sigma \vec{F}_A = m_A \vec{a}_A$$

$$F_{g_A} - T_A = m_A a_A$$

$$T_A = F_{g_A} - m_A a_A$$

Lastly, we could also find T_B using rotational dynamics because the torques on the wheel cause it to rotationally accelerate.

$\Sigma \vec{\tau} = I\vec{\alpha}$, already calculated

$$\vec{\tau}_A + \vec{\tau}_B = I\alpha = \frac{1}{2} m_w R^2 (\vec{\alpha})$$

$T_A \cancel{r}^{\,-} + T_B \cancel{r} = \frac{1}{2} m_w R^{\cancel{2}} \alpha$ $\quad \underline{r = R}$ so cancel

$T_B = T_A - \frac{1}{2} m_w R \alpha \quad \frac{1}{2} ma \quad$ because $a_{tan} = \underline{\alpha R}$

This is like a linear systems problem where the rotating wheel contributes a mass = $\frac{1}{2} m_w$

#2 You step onto the edge of a spinning carousel at the park. Your mass is 50 kg, and the carousel is a flat uniform disk of mass 100 kg and radius 2 m. The carousel is initially rotating at a rate of 1 revolution per second.

a) What is the final rotation rate after I step onto the carousel and hold on?
b) Was kinetic energy conserved in this process? If not, where did it come from/go?
c) Then you walk into the very center of the carousel and stand twirling in the middle. What is the final rotation rate? You may need to make some estimations here.
d) Was kinetic energy conserved as you walked into the center? If not, where did it come from/go?

The following are two great examples. However, note that these students mixed up frequency with angular velocity (ω). Angular velocity = frequency times 2π.

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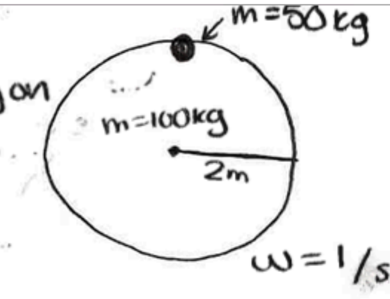
a) looking at this through the angular momentum lens because there are no outside torques acting on the system so, angular momentum is conserved.



$\ell = I\omega$

$I\omega_{disc} = I\omega_{disc} + I\omega_{person}$

$(\frac{1}{2}mr^2)(1/s) = (\frac{1}{2}mr^2)(\omega_f) + (mr^2)(\omega_f)$

$(\frac{1}{2}(100kg)(2m)^2)(1/s) = (\frac{1}{2}(100kg)(2m)^2)(\omega_f) + (50kg(2m)^2)(\omega_f)$

$50kg \cdot 4m^2 \cdot 1/s = 50kg \cdot 4m^2 \cdot \omega_f + 50kg\, 4m^2 \cdot \omega_f$

$200kgm^2/s = \omega_f(200kgm^2 + 200kgm^2)$

$\frac{200kgm^2/s}{400kgm^2} = \omega_f \cdot \frac{400kgm^2}{400kgm^2}$ $\boxed{\omega_f = \frac{1}{2}/s}$

b) I will be looking through the rotational energy lens because energy is conserved.

$\underbrace{KE_{rot}}_{wheel} \Rightarrow \underbrace{KE_{rot}}_{wheel} + \underbrace{KE_{rot}}_{man} + E_{th}$ from impact

$\frac{1}{2}(200kgm^2)(1/s)^2 \Rightarrow \frac{1}{2}(200kgm^2)(\frac{1}{2}/s)^2 + \frac{1}{2}(200kgm^2)(\frac{1}{2}/s)^2 + E_{th}$

$100kgm^2/s^2 \Rightarrow 100kgm^2 \cdot \frac{1}{4}/s^2 + 100kgm^2 \cdot \frac{1}{4}/s^2 + E_{th}$

$100kgm^2/s^2 \Rightarrow 25kgm^2/s^2 + 25kgm^2/s^2 + E_{th}$

$100kgm^2/s^2 \Rightarrow 50kgm^2/s^2 + E_{th}$, $E_{th} = 100kgm^2 - 50kgm^2/s^2 = \underline{50J}$

NO, as we can see there is a considerable amount of energy lost. This is energy escaping in the form of thermal, due to the impact from the man getting on to the wheel.

c) I will use the angular momentum lens again because due to no outside torques, momentum is conserved. (using info from above)

$I\omega_{disc} = I\omega_{disc} + \cancel{I\omega_{person}}$

$(mr^2) \rightarrow r=0$, so cancel $\Rightarrow$ initial rotation rate = final rotation rate, $\omega = 1/s$.

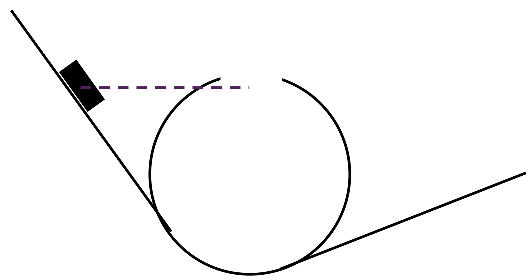
d) Looking at this through the energy lens because energy is conserved, we can see right off the bat the man is doing work to get to the center so there is lost energy from work, so kinetic energy is not conserved:

$KE_{rot\ disc} + KE_{rot\ man} = KE_{rot\ man} + KE_{rot\ disc}$

(from above) $50J + 50J = \frac{1}{2}(50kg \cdot \cancel{(0m)})(\omega_f)^2 + \frac{1}{2}(\frac{1}{2}(100kg \cdot (2m)^2)(\omega_f)$ hum

$100J = \frac{1}{2}(50kg \cdot 4m^2)\omega_f$

Solving in just 4 lines? We recognize that this is an angular momentum problem because Torque is the rate of change of angular momentum. The freely spinning carousel applies no torque, and so angular momentum is conserved: We do a little math and realize that the angular momentum of my body at full radius is the same as the angular momentum of the entire carousel, so when I step on, it doubles the momentum of inertial of the spinning body. We know $\vec{L} = I\vec{\omega}$, we should see that angular velocity must be cut in half and the kinetic energy is also cut in half… half the kinetic energy is transformed to thermal energy. When I move into the center of the carousel, my moment of inertia is tiny (only the spinning of my body about my center of mass), so the moment of inertia, rotational velocity, and kinetic energy reverts back to the original values. Where did the energy come from? I had to do work to walk into the center. I was pushing inward to achieve the centripetal acceleration keeping me in a circle as I walked inward.



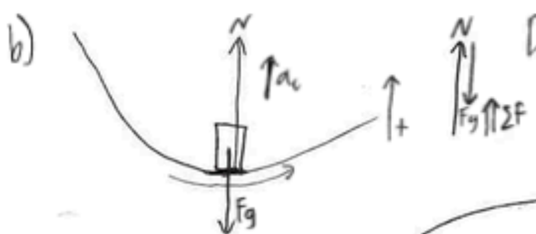
#3 You are standing in a waiting line for a (radius = 10 m) loop-de-loop carnival ride and you are somewhat concerned when the top chunck of the track drops off. The line thins rapidly and it is your turn to go on the ride. Your 100 kg friend says that there's no problem: He's going to request that they start the cart from the same height as the top of the track so that the cart will clear the track.

a) Is your friend's idea correct? Please explain clearly. What will happen if he goes on the ride as described.
b) Your friend goes on the ride while sitting on a scale. What does the scale read at the very bottom of the loop?

a) He is wrong $\Rightarrow$ Energy lens $\Rightarrow$ Energy is conserved $\Rightarrow$ $\underline{PE_g} \Rightarrow \underline{PE_g + KE}$

Because energy is conserved, if PE_g at the top of the loop is equal to PE_g initial, then KE @ top of loop will be zero. and you'll stop and fall to the bottom. To clear the gap, KE must be present at the top, thus PE_g initial must be greater than PE_g @ top of loop.

b)



Dynamics lens. $\Sigma\vec{F} = m\vec{a} = m\vec{a}_c$

$ma_c = N + {}^-F_g$

$N = ma_c + mg \qquad a_c = \frac{v^2}{r}$

$N = m\left(\frac{v^2}{r} + g\right)$

Energy lens: Energy is conserved $PE_g \Rightarrow KE$

$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2$

$v = \sqrt{2gh}$

nice!

A

$N = m\left(\frac{2gh}{r} + g\right)$

$= 100\text{kg}\left(\frac{2(10\text{m/s}^2)(\cancel{10\text{m}})}{\cancel{10\text{m}}} + 10\text{m/s}^2\right)$

$N = 5{,}000\text{ N}$

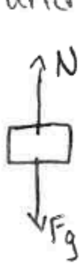
$\boxed{\text{scale reads } 5{,}000\text{ N}}$

a) Energy Lens → potential energy turns to kinetic energy

$P_E \Rightarrow K_E + P_E$ Do not get on the ride. The cart begins with only potential energy that turns

$mgh \Rightarrow \frac{1}{2}mv^2 + mgh$ all into kinetic energy at the bottom of the loop. As the ride begins back up the loop, kinetic energy is lost and potential energy returns to the cart. Once the cart reaches the same height as it started we know that because energy is conserved the KE must be 0 for the system because it started with only PE which is $mg\underline{h}$ (height) Not to mention some energy that transitioned to frictional heat The cart would have no velocity and would fall off the rail.

b) Dynamics lens → Gravitational and Normal forces causing acceleration. A scale reads the normal force and we know that $\Sigma \vec{F} = ma_c \Rightarrow a_c = \frac{v^2}{r}$



$\Rightarrow N - F_g = ma_c \Rightarrow N - F_g = m\frac{v^2}{r}$

$N - F_g = m\frac{400 \, m/s}{10 \, m}$

$N = m\frac{v^2}{r} + F_g$

$= m\frac{v^2}{r} + mg$

$= 100kg\left(\frac{400 \, m^2/s^2}{10 \, m}\right) + (100kg)(10 m/s^2)$

$4000 \, kg \, m/s^2 + 1000 \, kg \, m/s^2$

$\boxed{N = 5000 \, N}$

This is where an energy lens is used to find v because $mgh \Rightarrow \frac{1}{2}mv^2 + mgh$

$mgh = \frac{1}{2}mv^2 + 0$ (bottom of loop = no height)

$\frac{2mgh}{m} = v^2$

$v^2 = 2gh$

$= 400 \, m^2/s^2.$

A

show FB diagram

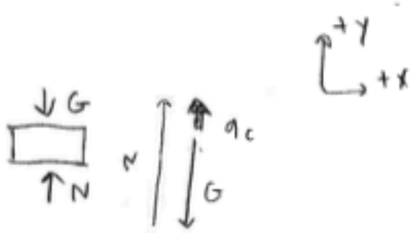
energy lens

$PE \rightarrow KE \rightarrow KE + PE$

$m \cdot g \cdot h = \frac{1}{2} m \cdot v^2 = m \cdot g \cdot h + \frac{1}{2} m \cdot v^2$

A. my friend's idea is not correct because at the top of the loop, energy exists as both potential energy AND kinetic energy, while at the beginning it exists as only potential energy. He will not be able to have an equivalent PE to the initial PE, and will not reach the height and will fall off the loop

B. dynamics lens



$mgh = \frac{1}{2} m v^2$

$2 \cdot 10 m/s^2 \cdot 20 m = v^2$

$400 m^2/s^2 = v^2$

$\Sigma F = m \cdot a_c = 100kg \cdot 40 m/s^2 = -G + N$

$a_c = \frac{v^2}{r} = \frac{400 m^2/s^2}{10 m} = 40 m/s^2$

$4000 kg m/s^2 = -10 m/s^2 \cdot 100kg + N$

$4000 N + 1000 N = N$

$5000 N = N$

$\boxed{\text{the scale reads } 5000 N}$

m=100kg & r=10m

a) lens: energy lens b/c energy is conserved in a system

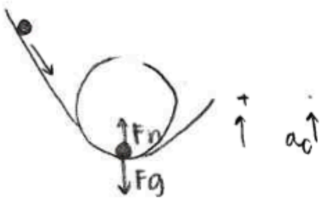
$E_{pg} \rightarrow E_K \rightarrow E_{pg} + E_K$

At the top, you have potential gravitational energy & kinetic energy (you need kinetic energy to keep you moving/staying onto the track/moving in a circle). Total energy is conserved in a system, so if you start at the same hieght at the top of the loop, then all of your energy would have been transformed into potential energy & no kinetic energy. Thus, the cart will just fall downwards (no kinetic energy to keep it moving). so the friend is incorrect

b) lens: rotational dynamics & forces cause acceleration

$\Sigma \vec{F} = m\vec{a} = F_n - F_g = ma_c$

Σa is "into" the circle and this is centripetal acceleration $[a_c = \frac{v^2}{r}]$



lens: energy $E_{pg} \rightarrow E_K \Rightarrow mgh \rightarrow \frac{1}{2}mv^2$

$(\cancel{100kg})(10m/s^2)(20m) = \frac{1}{2}(\cancel{100kg})v^2$

$v^2 = (2)(10m/s^2)(20m)$

$v^2 = 400\ m^2/s^2$

$ma_c = F_n - F_g$

$F_n = ma_c + mg$

$F_n = m(\frac{v^2}{r}) + mg$

$F_n = (100kg)(\frac{400m^2/s^2}{10m}) + (100kg)(10m/s^2)$

$F_n = 4000N + 1000N$

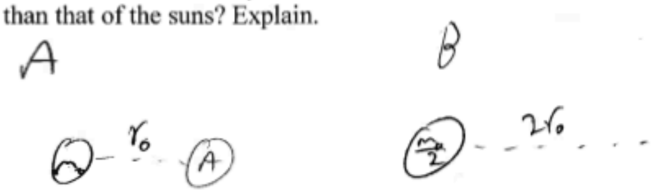
$F_n = 5000N$

↑scale reads 5000N

A+

#4 Two identical planets, planet A and planet B orbit two different suns. However, planet B is *twice* as far from the sun as planet A, and the mass of B's sun is *half* the mass as the sun that planet A orbits. ***You must explain your answers to receive credit.***

a) How do the planets' attractions to the sun compare? F_B = 1/8 F_A.
b) How do the accelerations of two planets compare? a_B = 1/8 a_A.
c) How do the speeds of the two planets compare? v_B = 1/2 v_A.
d) What difference (if any) would there be if the masses of the planets were not the same? Explain.
e) We assumed that the $m_{planet} << m_{sun}$. Would it be different if the mass of the planets were *not* much less than that of the suns? Explain.



A +

a) Dynamics - Forces are accelerating bodies

$m_A = m_B$

As $F_g = \frac{m_1 m_2}{r^2} G$

$F_a = \frac{m_o m_A G}{r_0^2}$ $\quad F_b = \frac{\frac{1}{2} m_o m_A G}{(2r_0)^2}$

$\frac{F_B}{F_A} = \frac{1}{8}$

$F_B = \frac{1}{8} F_a$

b) Dynamics, $\Sigma \vec{F} \Rightarrow \vec{a}$

As $m_a = m_b$

$\vec{F}_a = m_a \vec{a}_a \quad F_b = m_a a_b$

$\frac{\vec{F}_B}{\vec{F}_A} = \frac{\vec{a}_a \cancel{m_a}}{\vec{a}_b \cancel{m_a}}$

$\frac{\vec{F}_B}{\vec{F}_A} = \frac{1}{8} = \frac{\vec{a}_b}{\vec{a}_a}$

c) Rotational Dynamics

As $a_c = \frac{v^2}{R}$, and we know $a_{c(A)}, a_{c(B)}, R_{(B)}$, and $R_{(A)}$, we can find their relative speed

$a_{c(A)} = \frac{v_a^2}{r_0} \quad \frac{1}{8} a_{c(A)} = \frac{v_B^2}{2r_0}$

$v_A = \sqrt{a_{c(A)} r_0} \quad v_B = \sqrt{\frac{1}{4} a_{c(A)} r_0} = \frac{1}{2}\sqrt{a_{c(A)} r_0} \Rightarrow v_B = \frac{1}{2} v_A$

d) Dynamics $\rightarrow F = ma \left(F_g = \frac{Mm}{r^2} G\right)$

If the masses were different, they would not cancel out in this calculation, and thus would vary the ratio of F_B to F_A. v? a?

e) Dynamics $\left(F_g = \frac{m_1 m_2}{r^2} G\right)$

Yes the planets gravity on the sun would be significant and we could not longer consider the sun a stationary point of rotation.

Name ____