Today 17.1

$\boxed{L27}$

Today 17.1

$\boxed{L27}$

Energy methods for rigid bodies

Today 17.1

Friday 17.1 & 17.2

$\boxed{L27}$

Today 17.1

$\boxed{L27}$

Friday 17.1 & 17.2

Momentum methods

L27

Today 17.1

Friday 17.1 & 17.2

Monday 17.2

ASU

$\boxed{L27}$

<u>Today</u> 17.1

<u>Friday</u> 17.1 & 17.2

<u>Monday</u> 17.2

<u>Wednesday Nov 4th</u> : Review

L27

Today 17.1

Friday 17.1 & 17.2

Monday 17.2

Wednesday Nov 4th : Review

Friday Nov 6th : Exam #3

From last time

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$$U_{1\to 2} = T_2 - T_1, \text{ where } T = \frac{1}{2}m\bar{v}^2 + \frac{1}{2}\bar{I}\omega^2$$

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For rotation about some fixed point P

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And for torques (Moments)

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And for torques (Moments) about some point O

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ASU

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$$U_{1\to 2} = \int_{\theta_1}^{\theta_2} M_O \, d\theta$$

As previous, if only conservative forces.

From last time

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As previous, if only conservative forces, then

$$T_I + V_I = T_F + V_F$$

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As previous, if only conservative forces, then

$T_I + V_I = T_F + V_F$. In general:

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As previous, if only conservative forces, then

$T_I + V_I = T_F + V_F$. In general: $T_I + V_I + U^{NC}_{I\to F} = T_F + V_F$

Now I want to show that there is no energy lost due to friction for a wheel that is rolling without slipping.

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We will analyze the motion of a disk rolling down an incline 2 ways

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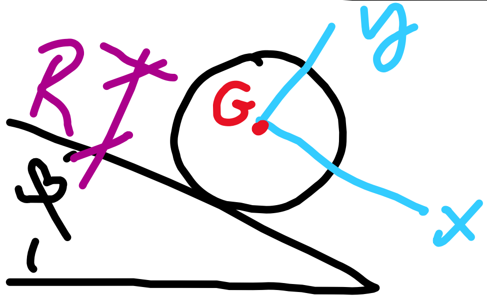

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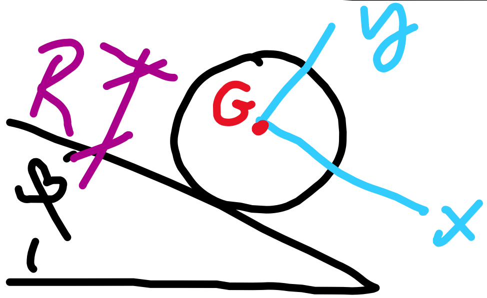

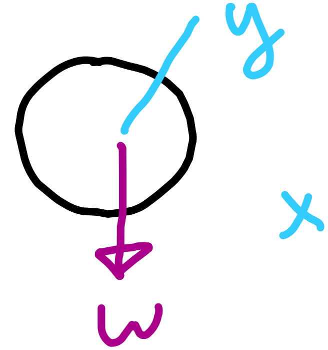

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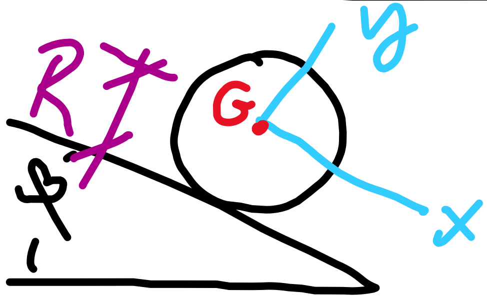

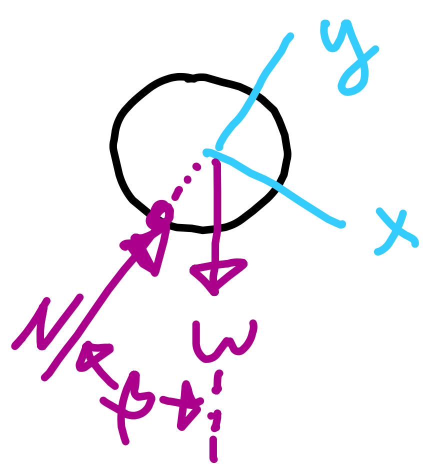

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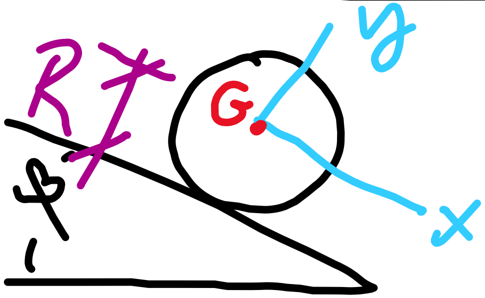

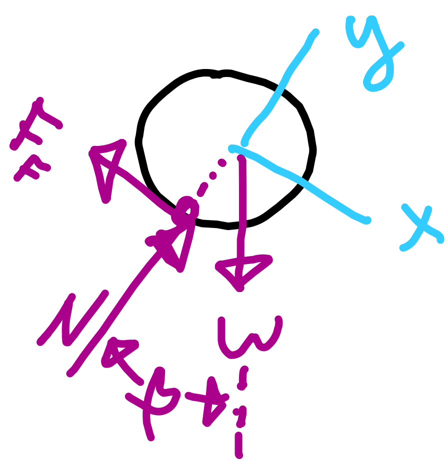

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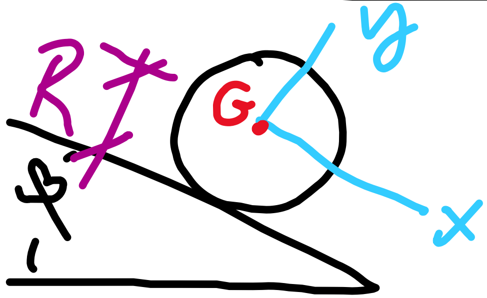

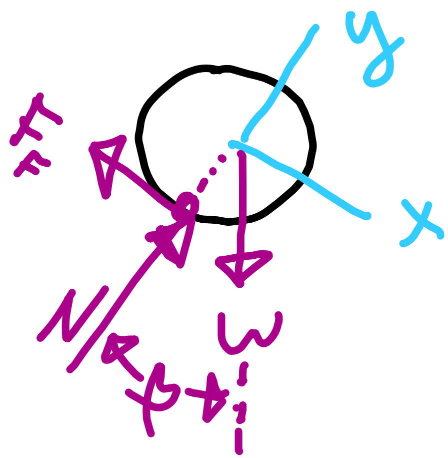

$\Rightarrow W_x = W \sin\beta$

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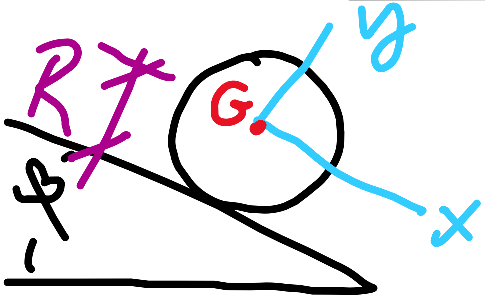

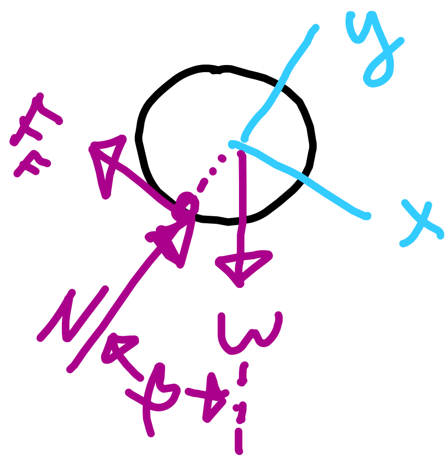

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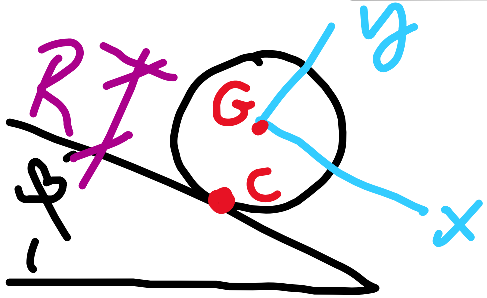

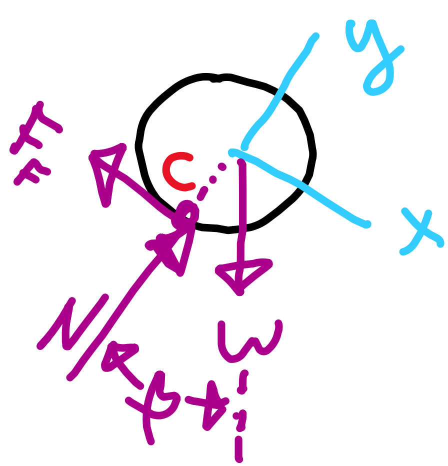

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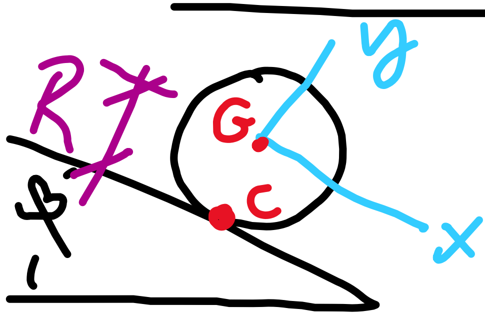

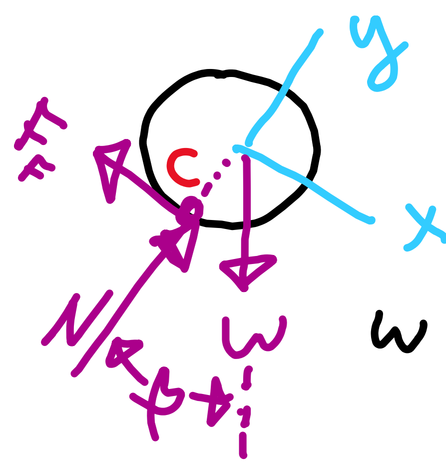

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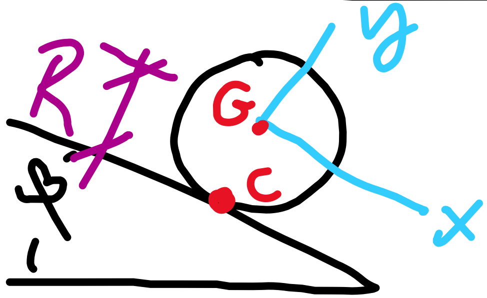

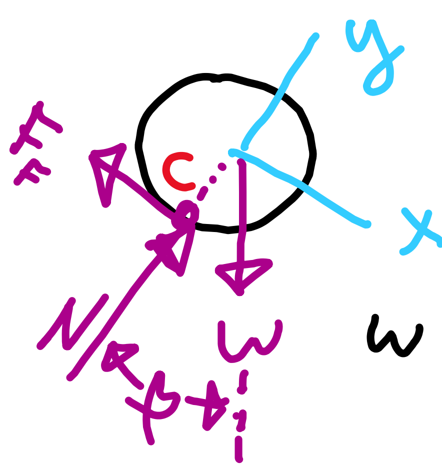

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Take $\alpha = \omega \dfrac{d\omega}{d\theta}$

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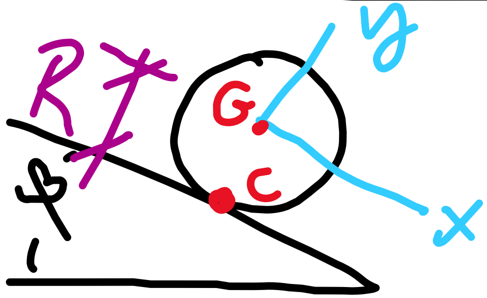

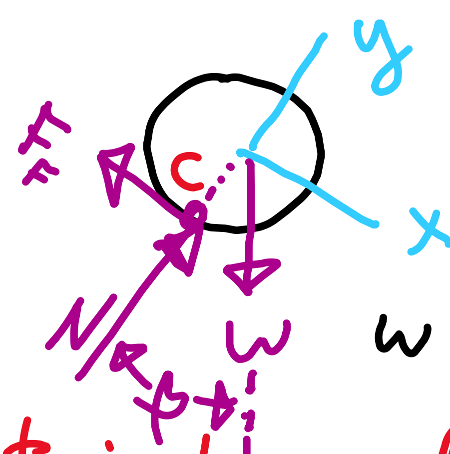

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Take $\alpha = \omega\dfrac{d\omega}{d\theta}$ & integrate over θ

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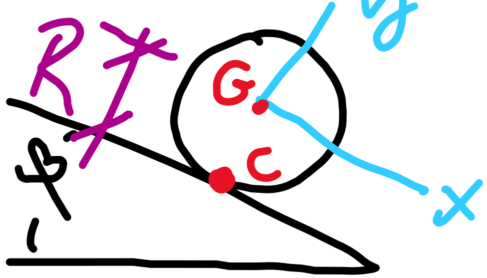

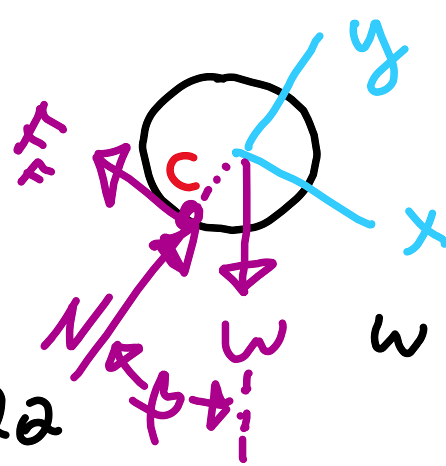

$$\Rightarrow W_x = W \sin\beta$$
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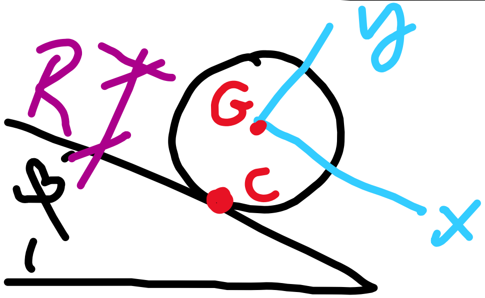

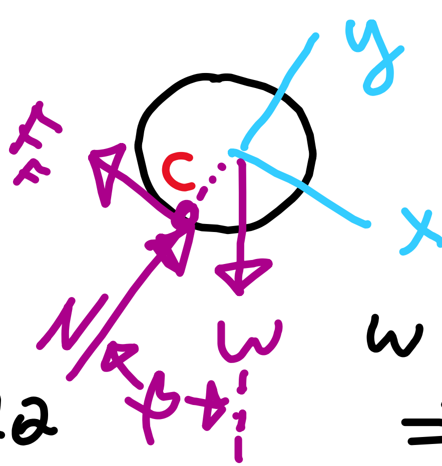

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$\Rightarrow$

$W(\sin\beta)R\int d\theta = I_c\int \omega\, d\omega$

$W(\sin\beta)R\,\Delta\theta = \frac{1}{2}I_c(\omega_F^2 - \omega_I^2)$

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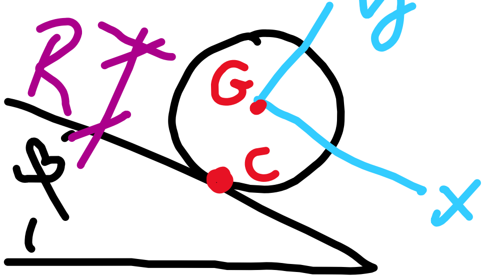

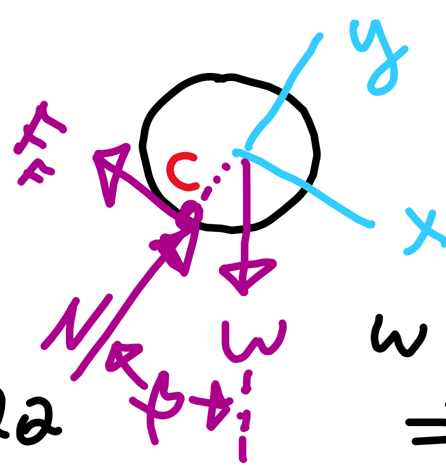

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$w(\sin\beta)R\int d\theta = I_c\int \omega\, d\omega \qquad \Rightarrow$

$$W(\sin\beta)R\,\Delta\theta = \underbrace{\tfrac{1}{2}I_c(\omega_F^2 - \omega_I^2)}_{\text{Looks like kinetic energy}}$$

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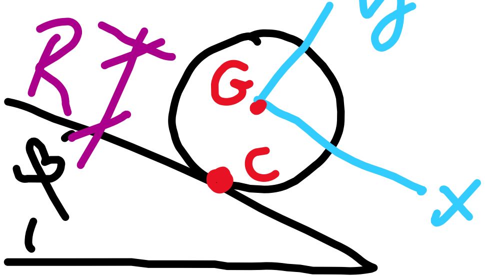

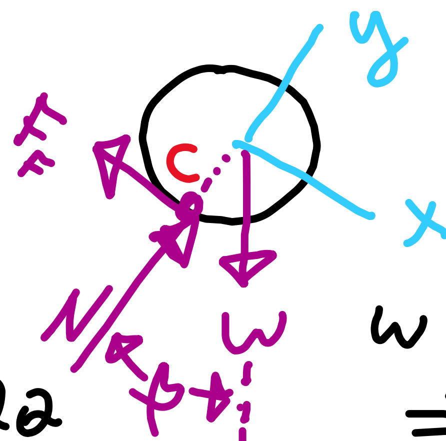

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$$W(\sin\beta)R\int d\theta = I_c\int \omega\, d\omega$$

want to see this in terms of potential energy

$$\boxed{W(\sin\beta)R\,\Delta\theta} = \underbrace{\tfrac{1}{2}I_c(\omega_F^2 - \omega_I^2)}_{\text{Looks like kinetic energy}}$$

ASU

We have $\omega R(\sin\beta)\Delta\theta = \frac{1}{2} I_c \left(\omega_F^2 - \omega_I^2\right)$

We have $wR(\sin\beta)\Delta\theta = \frac{1}{2} I_c (\omega_F^2 - \omega_I^2)$

The disk has rolled down the incline a distance $l = R\Delta\theta$

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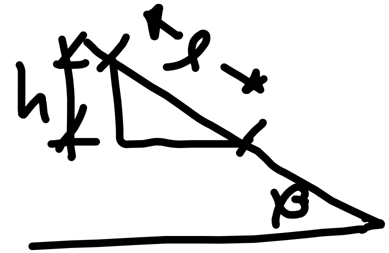

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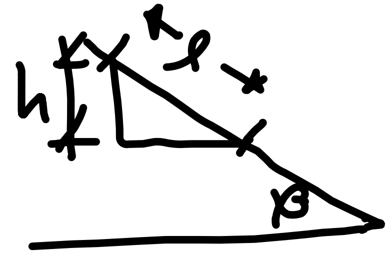

since $\sin\beta = \frac{\ell}{h}$

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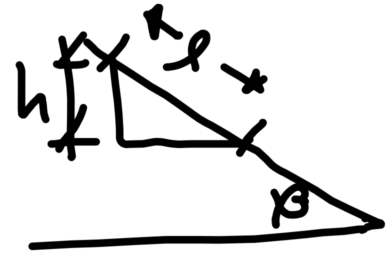

since $\sin\beta = \frac{l}{h}$

then $h = l\sin\beta$

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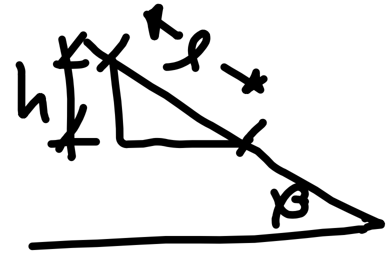

since $\sin\beta = \frac{\ell}{h}$

then $h = \ell \sin\beta$

$\Rightarrow \quad h = R\Delta\theta \sin\beta$

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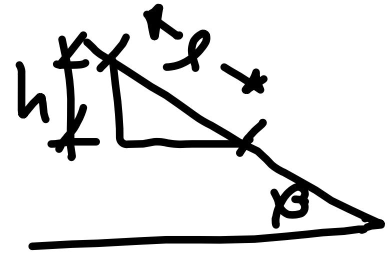

since $\sin\beta = \frac{l}{h}$
then $h = l\sin\beta$

$\Rightarrow \quad h = R\Delta\theta\sin\beta$

Now $wR\Delta\theta\sin\beta = wh$

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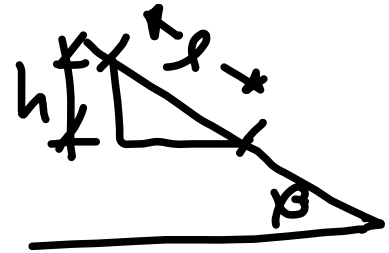


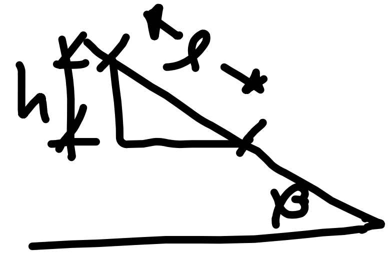
since $\sin\beta = \frac{l}{h}$ then $h = l\sin\beta$

$\Rightarrow \quad h = R\Delta\theta\sin\beta$

Now $wR\Delta\theta\sin\beta = wh$ & since $w = mg$

We have $wR(\sin\beta)\Delta\theta = \frac{1}{2} I_c (\omega_F^2 - \omega_I^2)$

The disk has rolled down the incline a distance $l = R\Delta\theta$



since $\sin\beta = \frac{l}{h}$ then $h = l\sin\beta$

$\Rightarrow \quad h = R\Delta\theta\sin\beta$

Now $wR\Delta\theta\sin\beta = wh$ & since $w = mg$ we have $mgh = \frac{1}{2} I_c (\omega_F^2 - \omega_I^2)$

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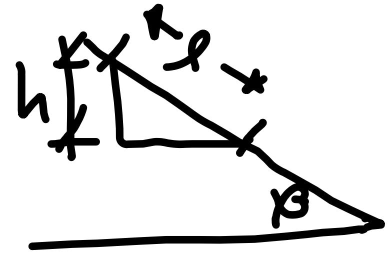

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$I_c = \bar{I} + MR^2$

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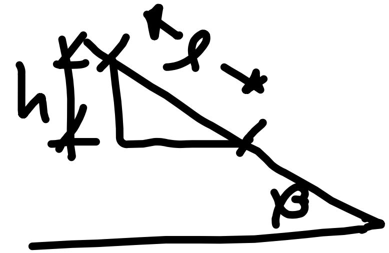

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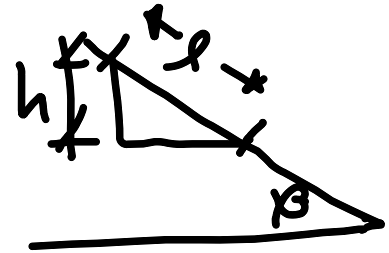

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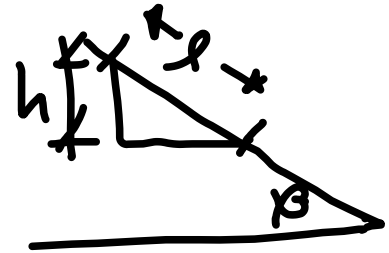

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We have $wR(\sin\beta)\Delta\theta = \frac{1}{2} I_c (\omega_F^2 - \omega_I^2)$

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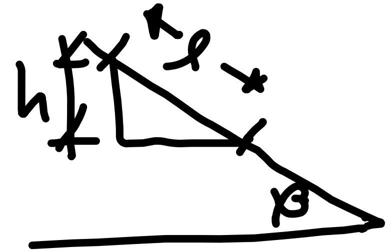

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Now use conservation of energy:

$T_I = \frac{1}{2}\bar{I}\omega_I^2 + \frac{1}{2}M\bar{v}_I^2$

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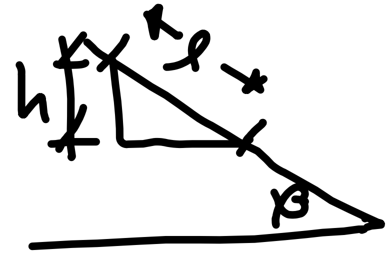

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But $\bar{v} = R\omega$ so $mgh = \frac{1}{2}\bar{I}(\omega_F^2 - \omega_I^2) + \frac{1}{2}M(\bar{v}_F^2 - \bar{v}_I^2)$

Now use conservation of energy:

$T_I = \frac{1}{2}\bar{I}\omega_I^2 + \frac{1}{2}M\bar{v}_I^2$, $T_F = \frac{1}{2}\bar{I}\omega_F^2 + \frac{1}{2}M\bar{v}_F^2$

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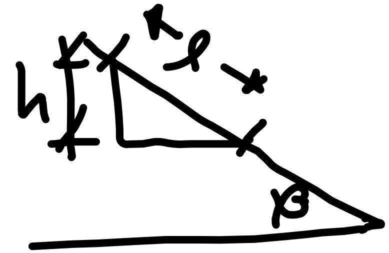

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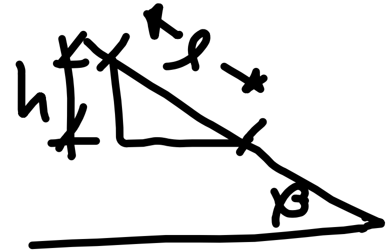
Now use conservation of energy:

$T_I = \frac{1}{2}\bar{I}\omega_I^2 + \frac{1}{2}m\bar{v}_I^2$, $T_F = \frac{1}{2}\bar{I}\omega_F^2 + \frac{1}{2}m\bar{v}_F^2$, $V_I = mgy_I$

We have $wR(\sin\beta)\Delta\theta = \frac{1}{2} I_c (\omega_F^2 - \omega_I^2)$

The disk has rolled down the incline a distance $l = R\Delta\theta$



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$T_I = \frac{1}{2}\bar{I}\omega_I^2 + \frac{1}{2}m\bar{v}_I^2$, $T_F = \frac{1}{2}\bar{I}\omega_F^2 + \frac{1}{2}m\bar{v}_F^2$, $V_I = mgy_I$ & $V_F = mgy_F$

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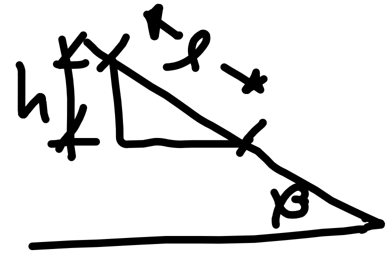

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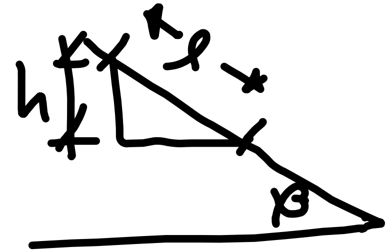
$T_I = \frac{1}{2}\bar{I}\omega_I^2 + \frac{1}{2}m\bar{v}_I^2$, $T_F = \frac{1}{2}\bar{I}\omega_F^2 + \frac{1}{2}m\bar{v}_F^2$, $V_I = mgy_I$ & $V_F = mgy_F$ & $T_I + V_I + U_{I\to F}^{NC} = T_F + V_F$

We have $wR(\sin\beta)\Delta\theta = \frac{1}{2} I_c (\omega_F^2 - \omega_I^2)$

The disk has rolled down the incline a distance $l = R\Delta\theta$



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But $\bar{v} = R\omega$ so $mgh = \frac{1}{2}\bar{I}(\omega_F^2 - \omega_I^2) + \frac{1}{2}M(\bar{v}_F^2 - \bar{v}_I^2)$

Now use conservation of energy:

$T_I = \frac{1}{2}\bar{I}\omega_I^2 + \frac{1}{2}m\bar{v}_I^2$, $T_F = \frac{1}{2}\bar{I}\omega_F^2 + \frac{1}{2}m\bar{v}_F^2$, $V_I = mgy_I$ & $V_F = mgy_F$ & $T_I + V_I + U^{NC}_{I\to F} = T_F + V_F \Rightarrow$

$$Mgh + U^{NC}_{I\to F} = \frac{1}{2}\bar{I}(\omega_F^2 - \omega_I^2) + \frac{1}{2}M(\bar{v}_F^2 - \bar{v}_I^2)$$

We have $\omega R(\sin\beta)\Delta\theta = \frac{1}{2} I_c (\omega_F^2 - \omega_I^2)$

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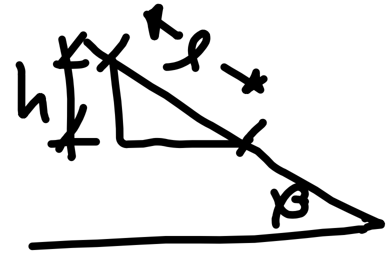

since $\sin\beta = \frac{l}{h}$ then $h = l\sin\beta$

$\Rightarrow \quad h = R\Delta\theta\sin\beta$

$$\boxed{mgh = \frac{1}{2}\bar{I}(\omega_F^2 - \omega_I^2) + \frac{mR^2}{2}(\omega_F^2 - \omega_I^2)}$$

Comparing these

$$\boxed{mgh + U^{NC}_{I\to F} = \frac{1}{2}\bar{I}(\omega_F^2 - \omega_I^2) + \frac{1}{2}m(\bar{v}_F^2 - \bar{v}_I^2)}$$

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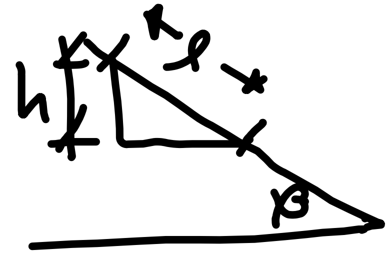

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MUST have $U^{NC}_{I\to F} = 0$

Comparing these

$$\boxed{mgh + \boxed{U^{NC}_{I\to F}} = \frac{1}{2}\bar{I}(\omega_F^2 - \omega_I^2) + \frac{1}{2}m(\bar{v}_F^2 - \bar{v}_I^2)}$$

So wheel rolling without slipping conserves energy such that $U^{NC}_{I\to F} = 0$.

$$\boxed{mgh = \frac{1}{2}\bar{I}(\omega_F^2 - \omega_I^2) + \frac{MR^2}{2}(\omega_F^2 - \omega_I^2)}$$

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$$\boxed{Mgh + \boxed{U^{NC}_{I\to F}} = \frac{1}{2}\bar{I}(\omega_F^2 - \omega_I^2) + \frac{1}{2}M(\bar{V}_F^2 - \bar{V}_I^2)}$$

So wheel rolling without slipping conserves energy such that $U^{NC}_{I \to F} = 0$.

No energy lost due to frictional force.

$$\boxed{mgh = \frac{1}{2}\bar{I}(\omega_F^2 - \omega_I^2) + \frac{mR^2}{2}(\omega_F^2 - \omega_I^2)}$$

MUST have $U^{NC}_{I \to F} = 0$

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We have a frictional force in the direction the wheel moves, but no energy lost due to that friction

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To figure out why this is true

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To figure out why this is true, we can look at the path of the contact point

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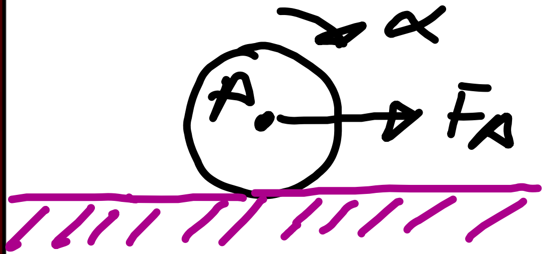
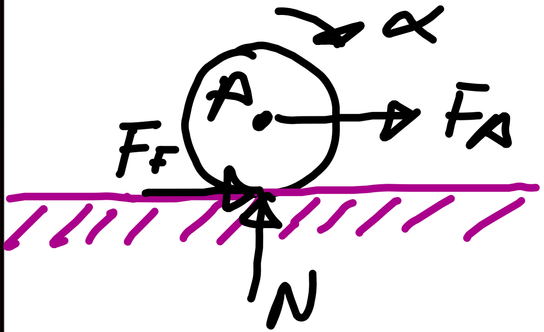
To figure out why this is true, we can look at the path of the contact point for a disk rolling without slipping

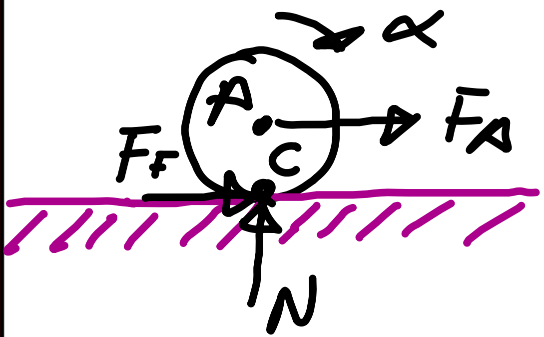
We have a frictional force in the direction the wheel moves, but no energy lost due to that friction ($U_{I \to F}^{NC} = 0$)

To figure out why this is true, we can look at the path of the contact point for a disk rolling without slipping that has force applied to the axel.

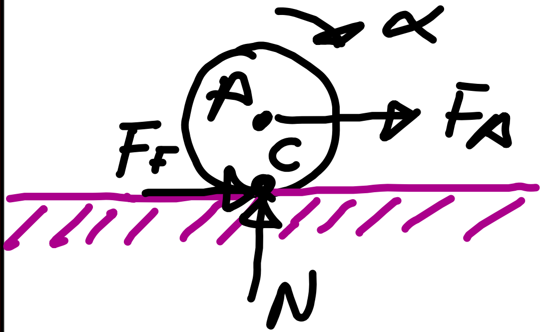

A


α
A
F_A

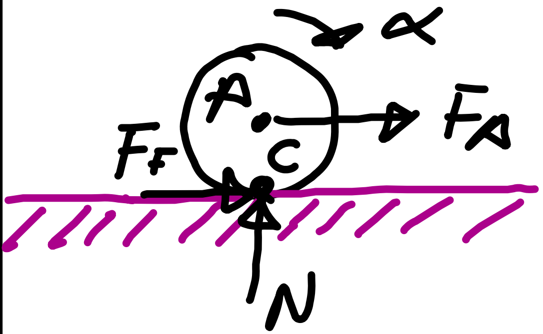

α
A
F_F
F_A
N



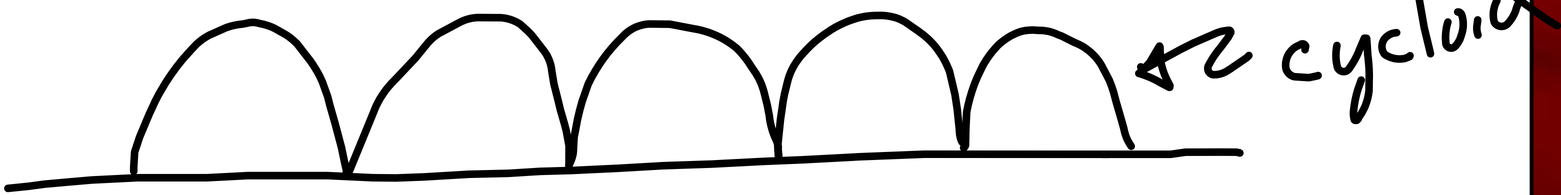
Frictional force applied at point C

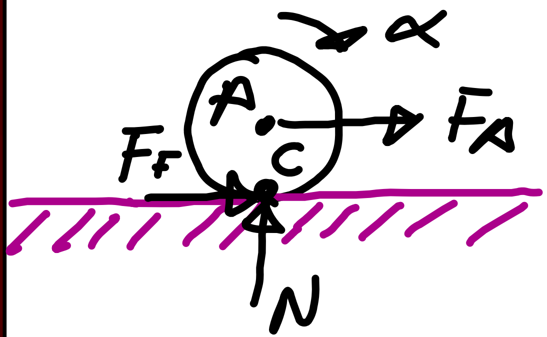


Frictional force applied at point c, but the path of point c is a cycloid

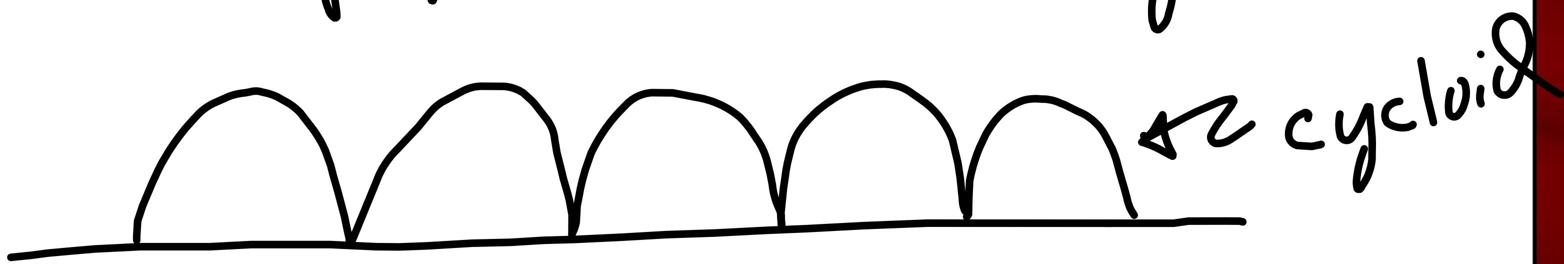


Frictional force applied at point C, but the path of point C is a cycloid

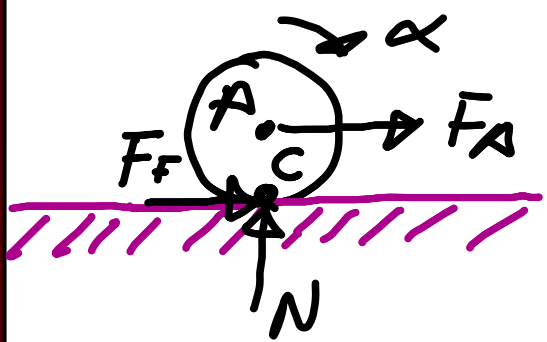




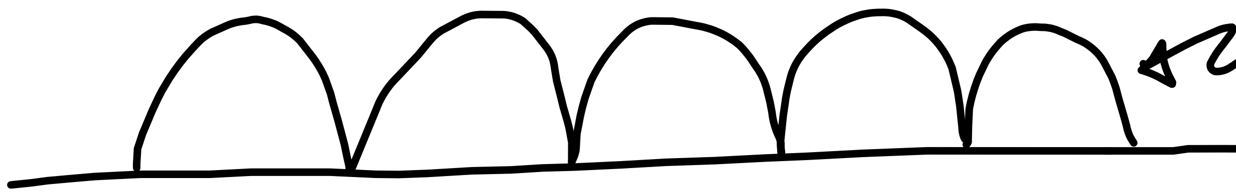
Frictional force applied at point C, but the path of point C is a cycloid



As point C touches the ground and F_F acts on that point.

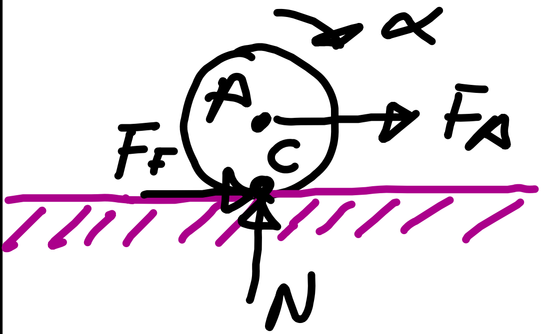


Frictional force applied at point C, but the path of point C is a cycloid

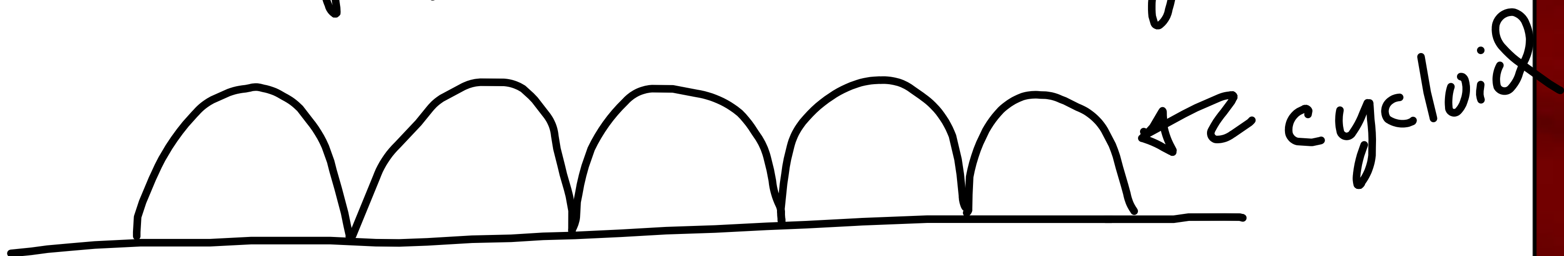


cycloid

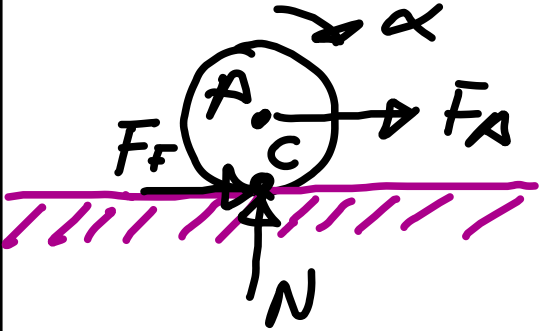
As point C touches the ground and F_F acts on that point, the product $\vec{F}_F \cdot d\vec{l}_C = 0$.



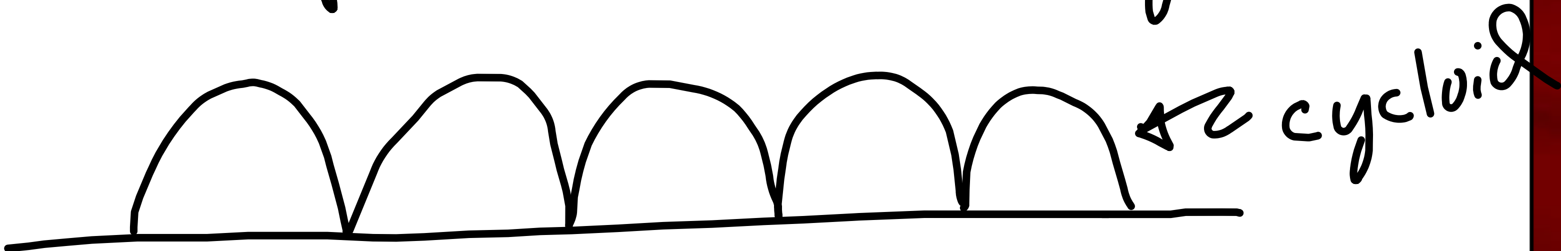
Frictional force applied at point C, but the path of point C is a cycloid



As point C touches the ground and F_F acts on that point, the product $\vec{F}_F \cdot d\vec{l}_c = 0$. In the past we found that $\vec{V}_c = 0$

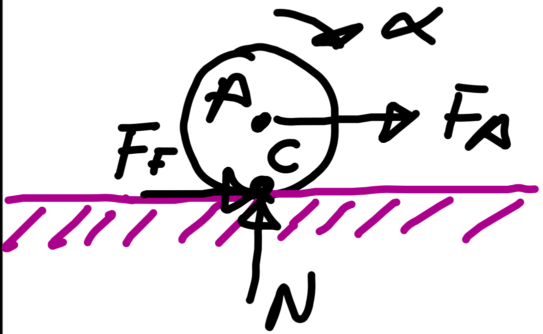


Frictional force applied at point C, but the path of point C is a cycloid

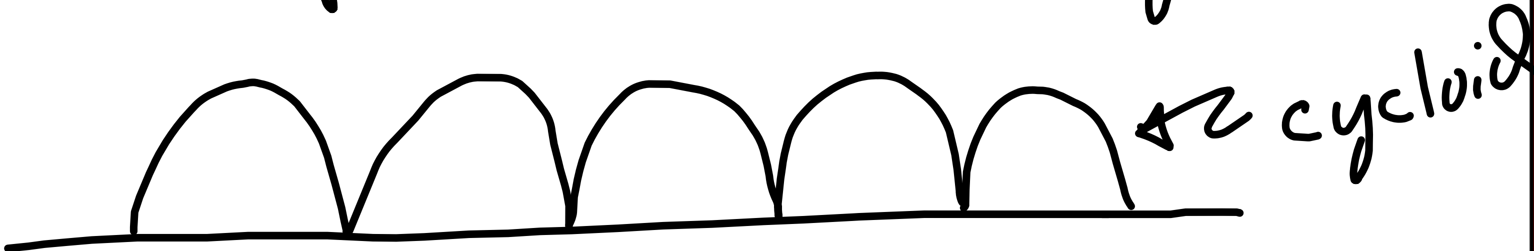


As point C touches the ground and F_F acts on that point, the product $\vec{F}_F \cdot d\vec{l}_c = 0$. In the past we found that $\vec{V}_c = 0$ but $\vec{V}_c = \frac{d\vec{l}_c}{dt}$

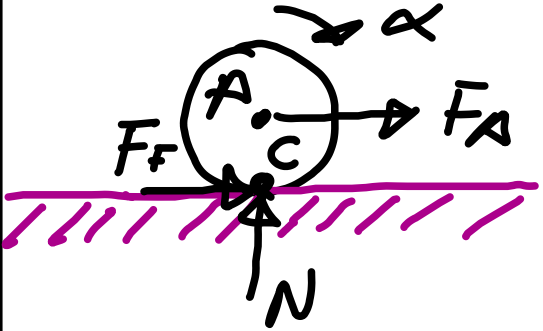
ASU



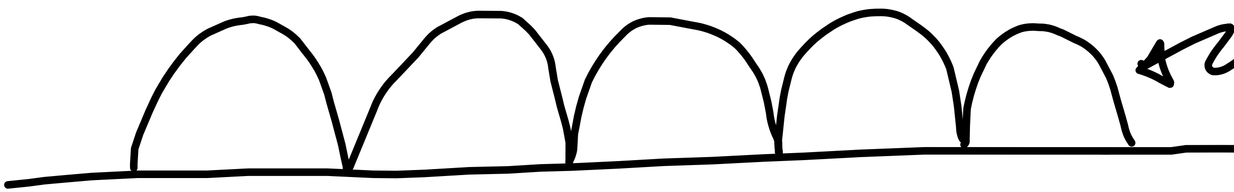
Frictional force applied at point C, but the path of point C is a cycloid



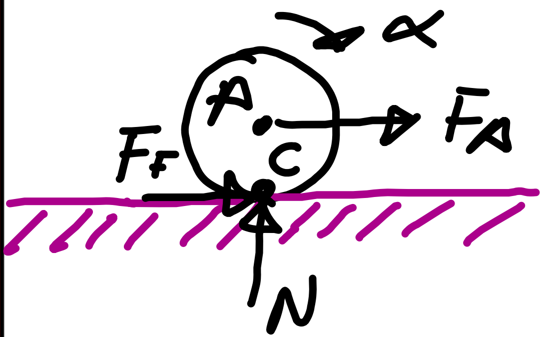
As point C touches the ground and F_F acts on that point, the product $\vec{F}_F \cdot d\vec{l}_C = 0$. In the past we found that $\vec{V}_C = 0$ but $\vec{V}_C = \frac{d\vec{l}_C}{dt} \Rightarrow d\vec{l} = \frac{d\vec{l}}{dt} dt$



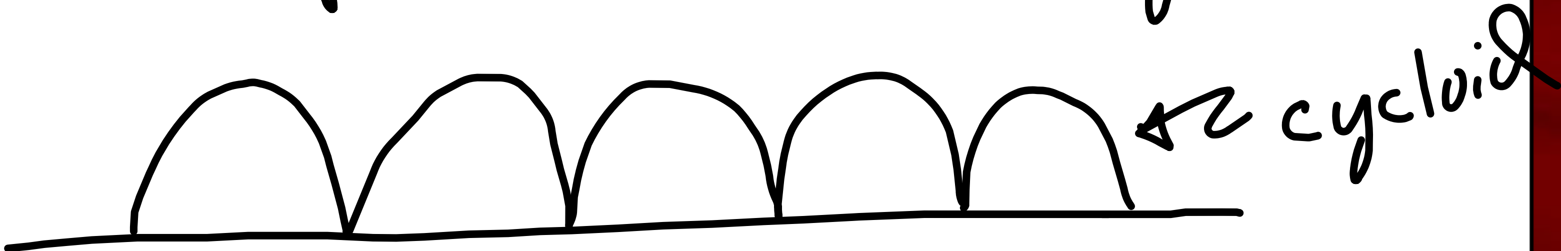
Frictional force applied at point C, but the path of point C is a cycloid



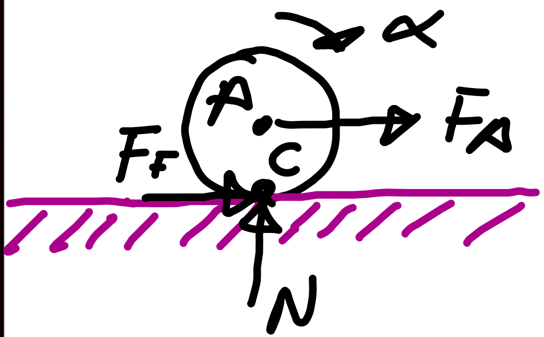
As point C touches the ground and F_F acts on that point, the product $\vec{F}_F \cdot d\vec{l}_c = 0$. In the past we found that $\vec{V}_c = 0$ but $\vec{V}_c = \frac{d\vec{l}_c}{dt} \Rightarrow d\vec{l} = \frac{d\vec{l}}{dt} dt$ so $\vec{F}_F \cdot d\vec{l}_c = \left(\vec{F}_F \cdot \frac{d\vec{l}_c}{dt}\right) dt = 0$.



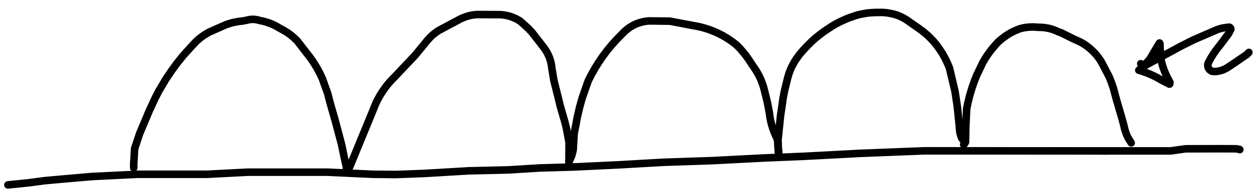
Frictional force applied at point C, but the path of point C is a cycloid



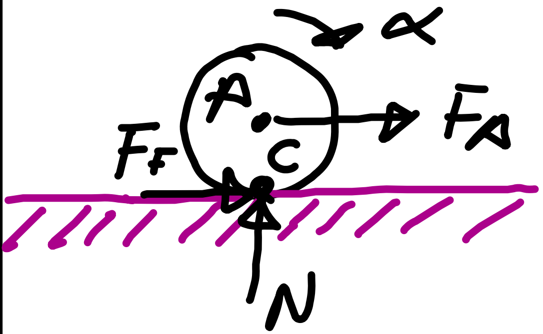
As point C touches the ground and F_F acts on that point, the product $\vec{F}_F \cdot d\vec{l}_c = 0$. In the past we found that $\vec{V}_c = 0$ but $\vec{V}_c = \frac{d\vec{l}_c}{dt} \Rightarrow d\vec{l} = \frac{d\vec{l}}{dt} dt$ so $\vec{F}_F \cdot d\vec{l}_c = \left(\vec{F}_F \cdot \frac{d\vec{l}_c}{dt}\right) dt = 0$.



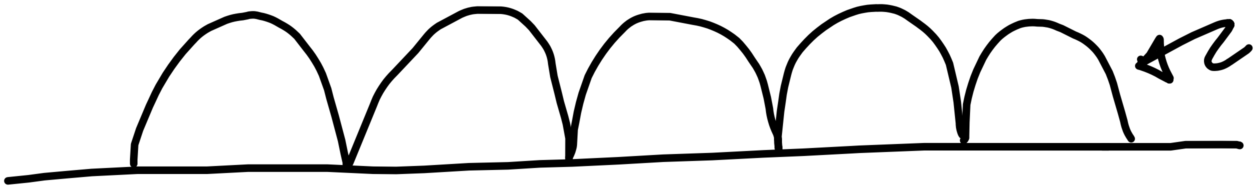
Frictional force applied at point c, but the path of point c is a cycloid



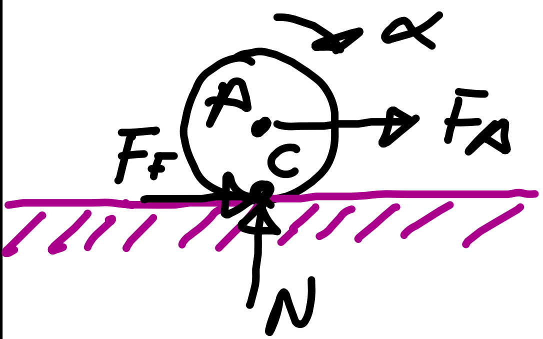
As point C touches the ground and F_F acts on that point, the product $\vec{F}_F \cdot d\vec{l}_c = 0$. In the past we found that $\vec{V}_c = 0$ but $\vec{V}_c = \frac{d\vec{l}_c}{dt} \Rightarrow d\vec{l} = \frac{d\vec{l}}{dt} dt$ so $\vec{F}_F \cdot d\vec{l}_c = \left(\vec{F}_F \cdot \frac{d\vec{l}_c}{dt}\right) dt = 0$. & No work done by this frictional force



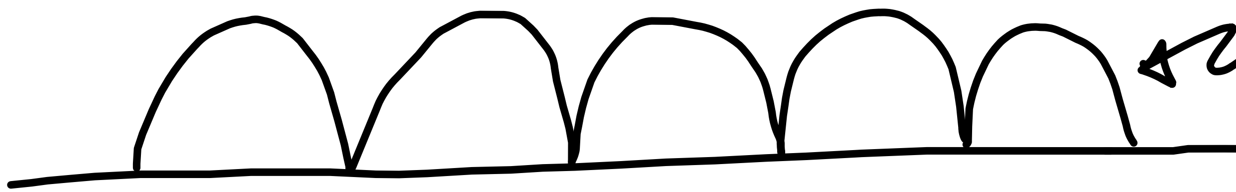
Frictional force applied at point C, but the path of point C is a cycloid



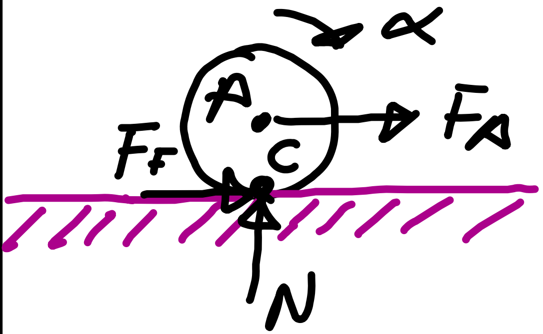
As point C touches the ground and F_F acts on that point, the product $\vec{F}_F \cdot d\vec{l}_c = 0$. In the past we found that $\vec{V}_c = 0$ but $\vec{V}_c = \frac{d\vec{l}_c}{dt} \Rightarrow d\vec{l} = \frac{d\vec{l}}{dt} dt$ so $\vec{F}_F \cdot d\vec{l}_c = \left(\vec{F}_F \cdot \frac{d\vec{l}_c}{dt}\right) dt = 0$. & No work done by this frictional force. However, if sliding,



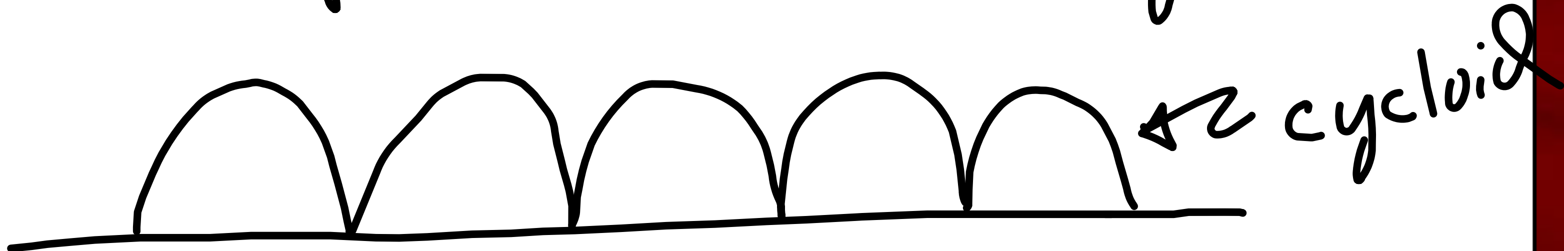
Frictional force applied at point C, but the path of point C is a cycloid



As point C touches the ground and F_F acts on that point, the product $\vec{F}_F \cdot d\vec{l}_c = 0$. In the past we found that $\vec{V}_c = 0$ but $\vec{V}_c = \frac{d\vec{l}_c}{dt} \Rightarrow d\vec{l} = \frac{d\vec{l}}{dt}dt$ so $\vec{F}_F \cdot d\vec{l}_c = \left(\vec{F}_F \cdot \frac{d\vec{l}_c}{dt}\right)dt = 0$. & No work done by this frictional force. However, if sliding, $W^{nc} \neq 0$



Frictional force applied at point C, but the path of point C is a cycloid



As point C touches the ground and F_F acts on that point, the product $\vec{F}_F \cdot d\vec{l}_c = 0$. In the past we found that $\vec{V}_c = 0$ but $\vec{V}_c = \frac{d\vec{l}_c}{dt} \Rightarrow d\vec{l} = \frac{d\vec{l}}{dt} dt$ so $\vec{F}_F \cdot d\vec{l}_c = \left(\vec{F}_F \cdot \frac{d\vec{l}_c}{dt}\right) dt = 0$. & No work done by this frictional force. However, if sliding, $W^{NC} \neq 0$ & work by that frictional force

For a disk rolling down an incline, starting at rest:

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$$Mgh = \frac{1}{2}\bar{I}\omega^2 + \frac{1}{2}M\bar{v}^2$$

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Potential energy converted into 2 kinds of K.E.

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Potential energy converted into 2 kinds of K.E.

Rotational K.E.

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We can write $\bar{I} = m\bar{k}^2$

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$$\underbrace{Mgh}_{\text{Potential energy converted into 2 kinds of K.E.}} = \underbrace{\tfrac{1}{2}\bar{I}\omega^2}_{\text{Rotational K.E.}} + \underbrace{\tfrac{1}{2}m\bar{v}^2}_{\text{Translational K.E.}}$$

We can write $\bar{I} = m\bar{k}^2 = m\left(\frac{\bar{k}^2}{r^2}\right)r^2$

For a disk rolling down an incline, starting at rest:

$$Mgh = \underbrace{\tfrac{1}{2}\bar{I}\omega^2}_{\text{Rotational K.E.}} + \underbrace{\tfrac{1}{2}M\bar{v}^2}_{\text{Translational K.E.}}$$

Potential energy converted into 2 kinds of K.E.

We can write $\bar{I} = m\bar{k}^2 = m\left(\frac{\bar{k}^2}{r^2}\right)r^2$, Let $\lambda \equiv \bar{k}^2/r^2$

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ASU

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$$\bar{v}^2 = \left(\frac{2gh}{\lambda + 1}\right)$$

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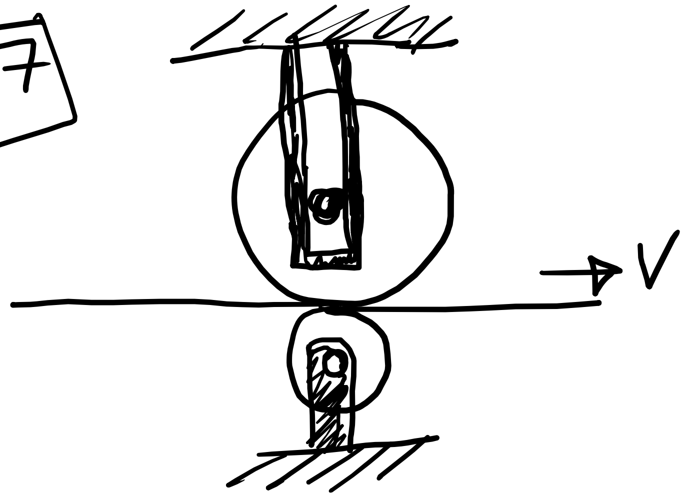
$\bar{v}^2 = \left(\frac{2gh}{\lambda+1}\right) \Rightarrow$ the smaller λ is, the greater the velocity of our wheel for a fixed amount of expended potential energy. So, for large $\bar{v}$ we want small $\frac{\bar{k}^2}{r^2} = \bar{I}/(mr^2)$

Notes on problems

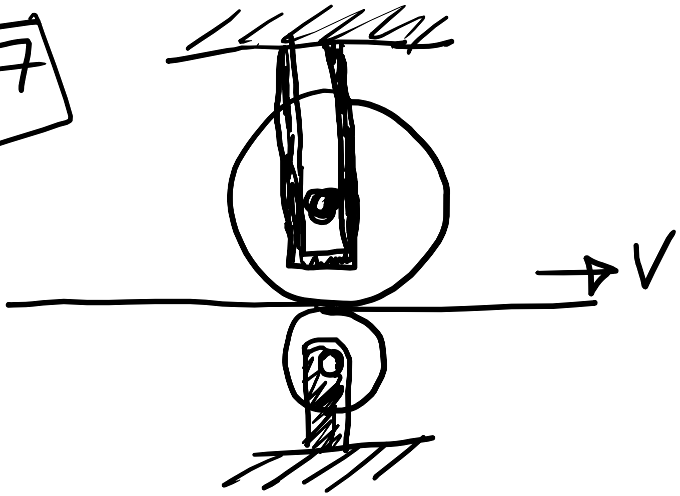
Notes on problems

17.7



Notes on problems

17.7

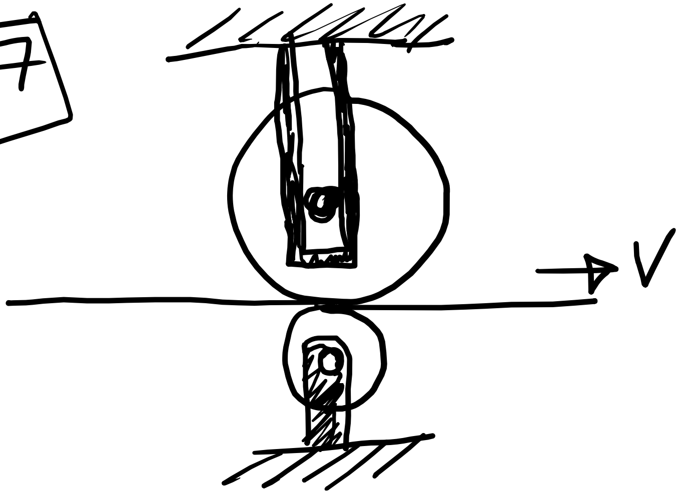


Given $W = 10\,lb$,

Notes on problems

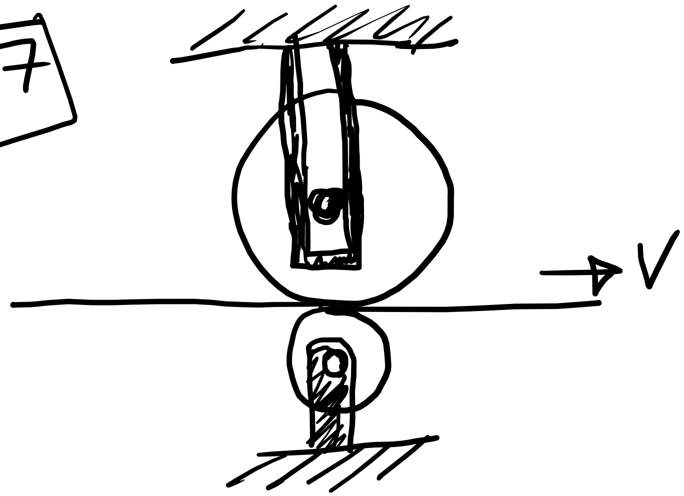
17.7

Given $W = 10\,lb$, $r = \frac{1}{2}\,ft$



Notes on problems

$\boxed{17.7}$

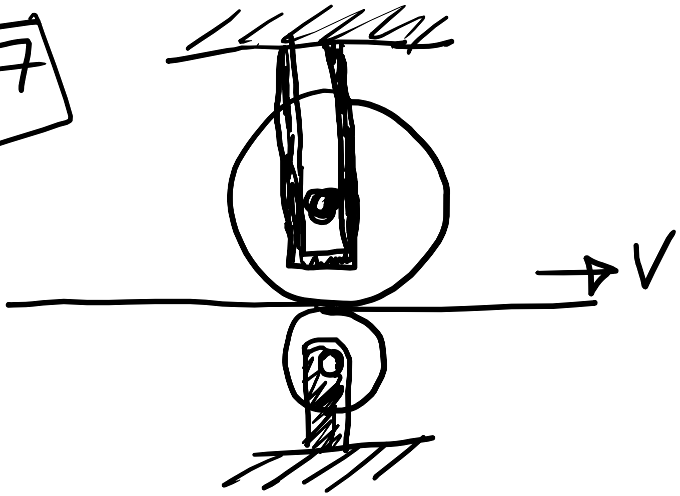


Given $W = 10\,lb$, $r = \frac{1}{2}\,ft$,

$\omega_1 = 0$,

Notes on problems

$\boxed{17.7}$

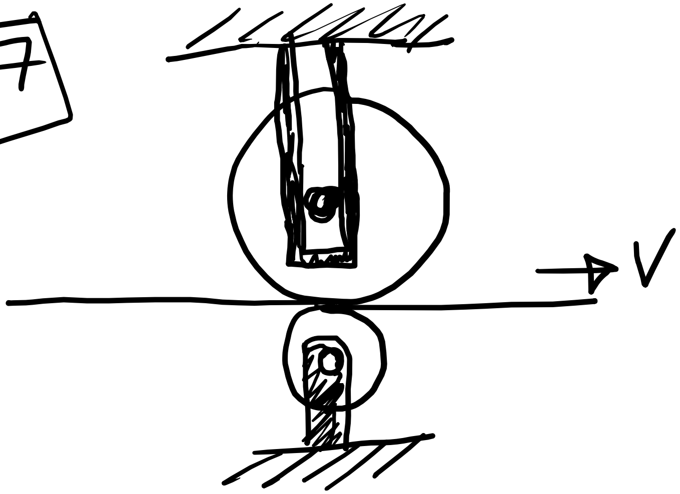


Given $W = 10\,lb$, $r = \frac{1}{2}\,ft$

$e\ell\ell_I = \cancel{\Theta}$, $V = 40\,ft/s$

Notes on problems

$\boxed{17.7}$



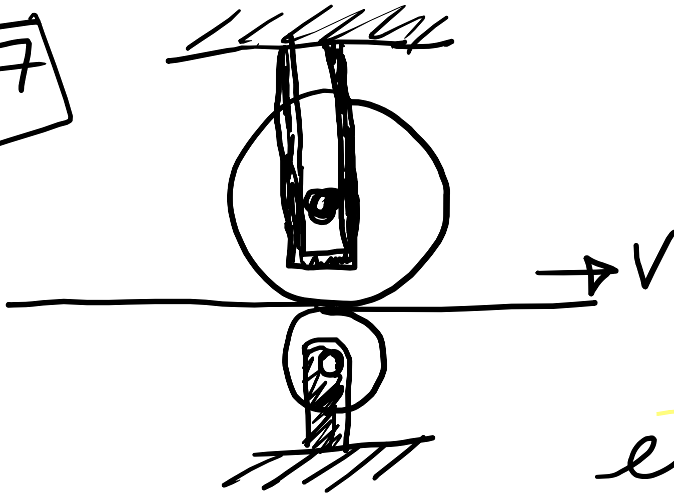
Given $W = 10\,lb$, $r = \frac{1}{2}\,ft$

$\omega_1 = 0$, $v = 40\,ft/s$,

$\mu_k = 0.2$

Notes on problems

$\boxed{17.7}$



Given $W = 10\,lb$, $r = \frac{1}{2}\,ft$

$\omega_I = \cancel{0}$, $v = 40\,ft/s$,

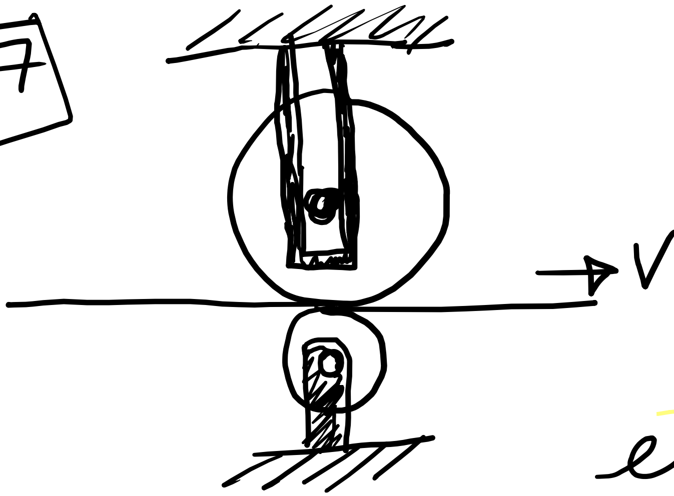
$\mu_k = 0.2$ Find #

of revolutions till

$\omega = const.$

Notes on problems

17.7

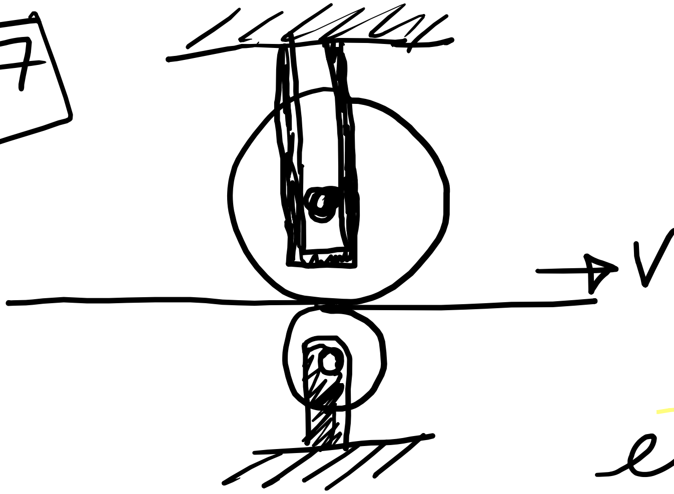


Given $W = 10\,lb$, $r = \frac{1}{2}\,ft$, $\omega_I = \cancel{0}$, $v = 40\,ft/s$, $\mu_k = 0.2$. Find # of revolutions till $\omega = const.$

$* \; \omega = const.$ when $\omega r = v$

Notes on problems

$\boxed{17.7}$



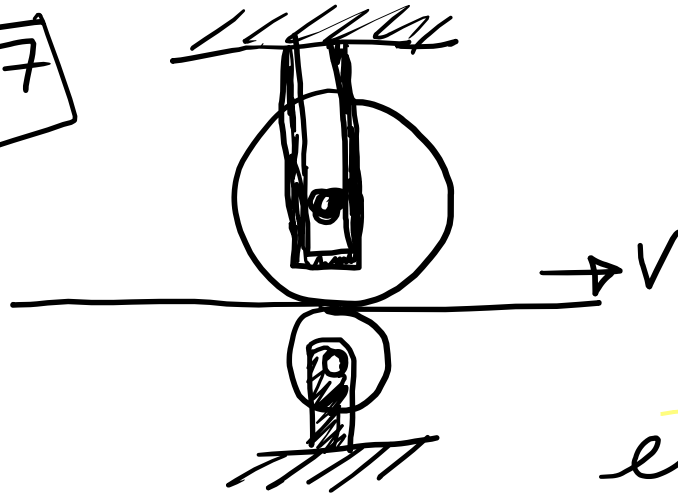
Given $W = 10\,lb$, $r = \frac{1}{2}\,ft$, $\omega_I = 0$, $v = 40\,ft/s$, $\mu_k = 0.2$ Find # of revolutions till $\omega = const.$

* $\omega = const.$ when $\omega r = V$ &

* $\#\,rev = \dfrac{\Delta\theta}{2\pi}$

Notes on problems

17.7



Given $W = 10\,lb$, $r = \frac{1}{2}\,ft$

$\omega_I = \cancel{0}$, $v = 40\,ft/s$,

$\mu_k = 0.2$ Find #

of revolutions till

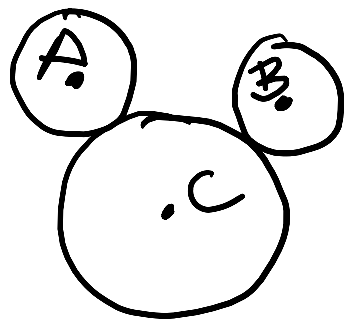
$\omega = $ const.

* $\omega = $ const. when $\omega r = v$ &

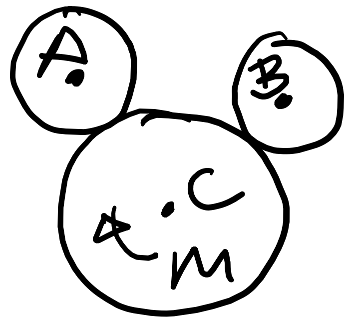
* # rev $= \frac{\Delta\theta}{2\pi}$ &

* $\int M\,d\theta = T_2 - T_1$

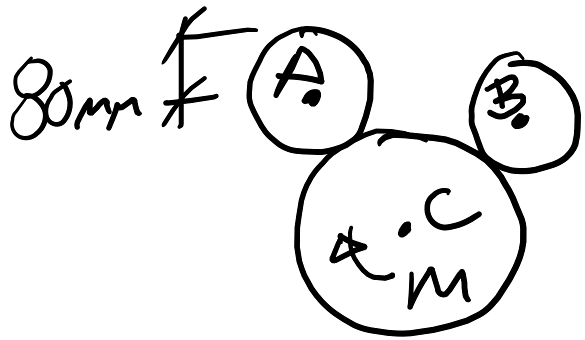
17.11a



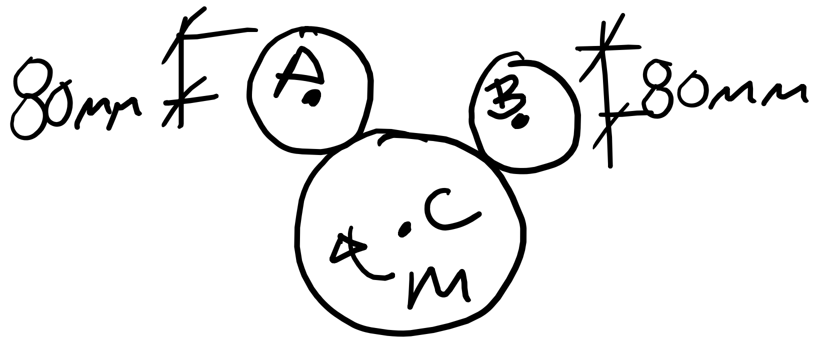
17.11a



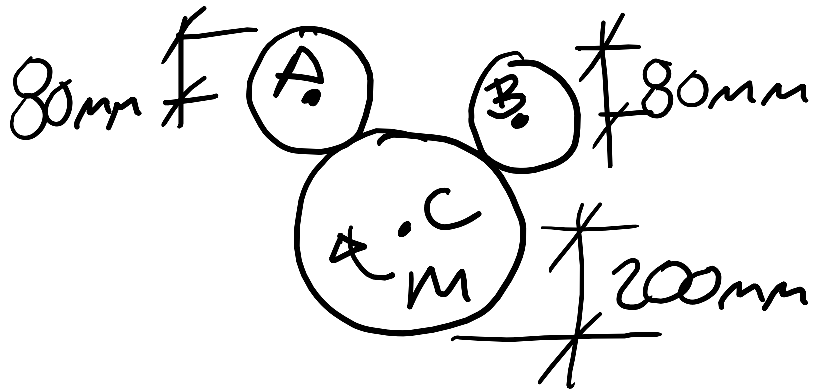
17.11a



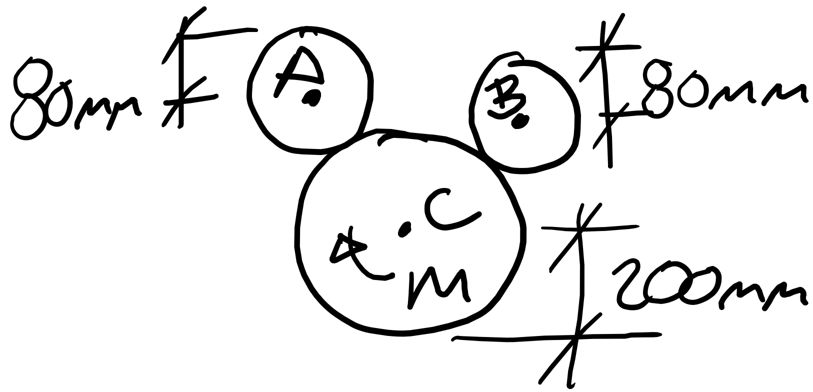
17.11a



17.11a

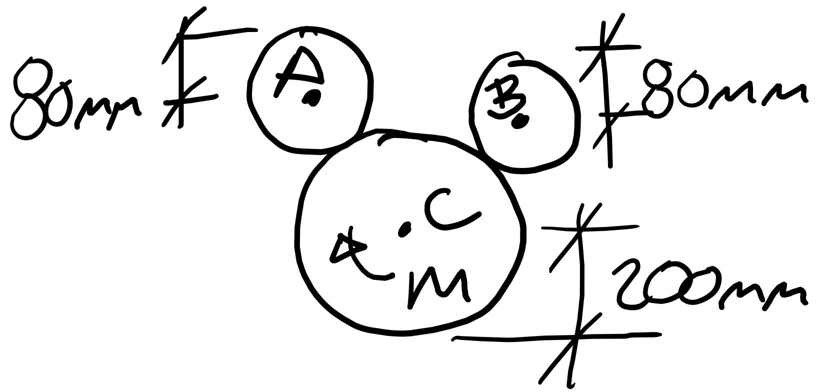


$\boxed{17.11a}$



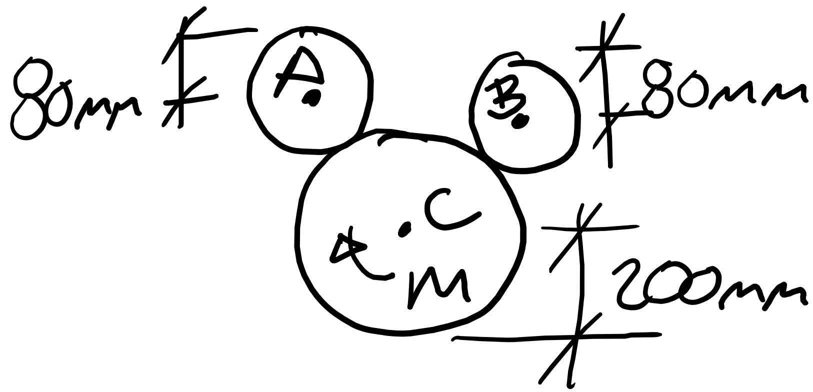
* Notice that $r_A \alpha_A = r_B \alpha_B$

17.11a



* Notice that $r_A \omega_A = r_B \omega_B = r_C \omega_C$

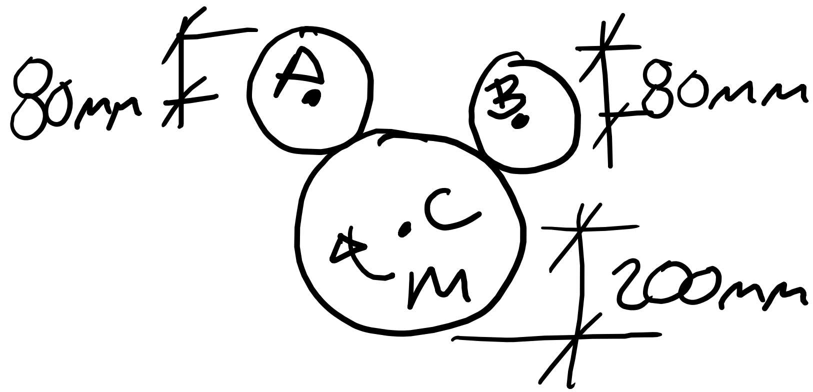
17.11a



* Notice that $r_A \omega_A = r_B \omega_B = r_C \omega_C$

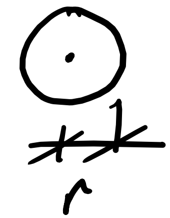
* $\int M_C \, d\theta_C = T_2 - T_1$

17.11a

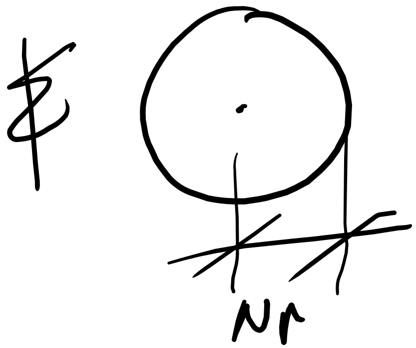


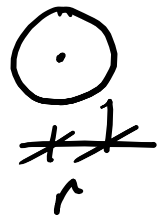
* Notice that $r_A \omega_A = r_B \omega_B = r_C \omega_C$
* $\int M_C \, d\theta_C = T_2 - T_1$, where T includes all 3 gears

$\boxed{17.13}$ Given two sized gears



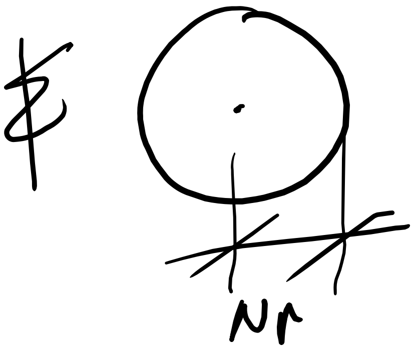
$\boxed{17.13}$ Given two sized gears

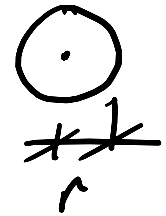




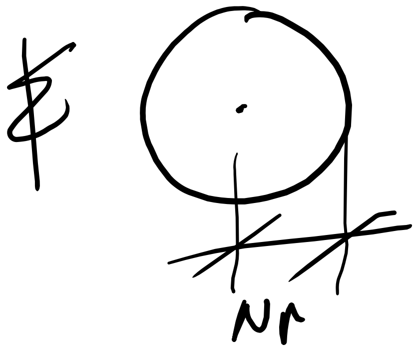
$\boxed{17.13}$

Given two sized gears and that the moment of inertia for gear of radius r is $\bar{I}_0$.

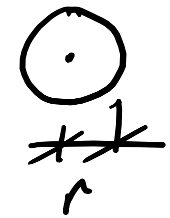




$\boxed{17.13}$

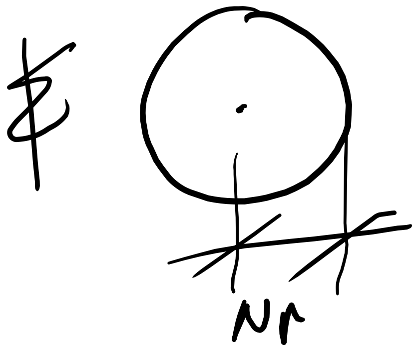


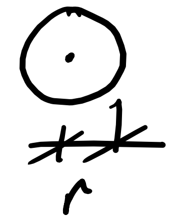
Given two sized gears and that the moment of inertia for gear of radius r is $\bar{I}_o$. You will need to figure out how



$\bar{I}_N$

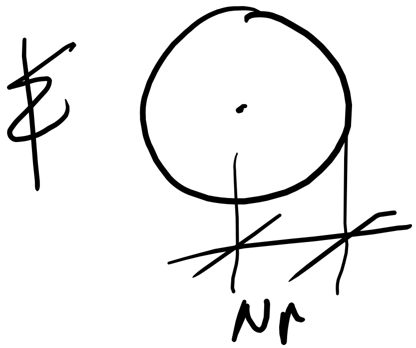
$\boxed{17.13}$



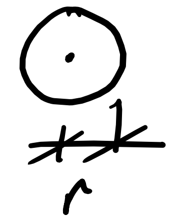


Given two sized gears and that the moment of inertia for gear of radius r is $\bar{I}_0$. You will need to figure out how $\bar{I}_N$ (moment of inertia for gear of radius=Nr)

$\boxed{17.13}$

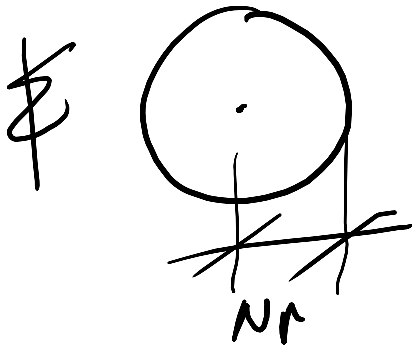


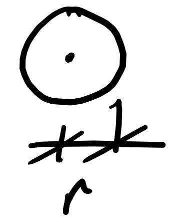
Given two sized gears and that the moment of inertia for gear of radius r is $\bar{I}_o$. You will need to figure out how $\bar{I}_N$ (moment of inertia for gear of radius $= Nr$) scales with $\bar{I}_o$.



$\boxed{17.13}$

Given two sized gears and that the moment of inertia for gear of radius r is $\bar{I}_o$. You will need to figure out how $\bar{I}_N$ (moment of inertia for gear of radius $= Nr$) scales with $\bar{I}_o$. Use disk as reference:





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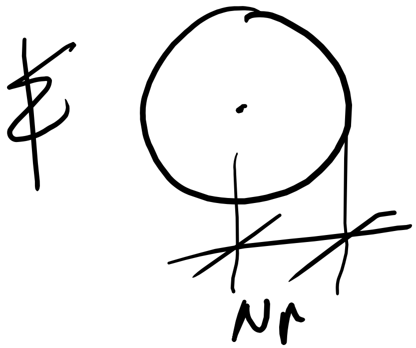
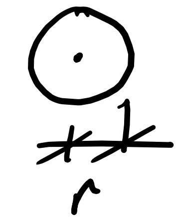
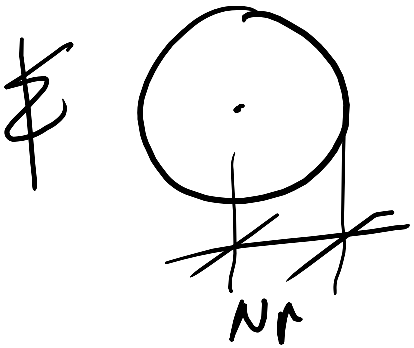


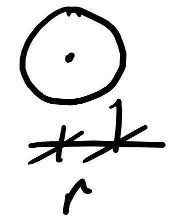


$\bar{I}_N$ (moment of inertia for gear of radius $= Nr$) scales with $\bar{I}_0$. Use disk as reference: $\bar{I}_{disk} = \frac{1}{2}Mr^2$

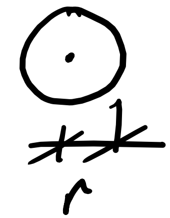
$\boxed{17.13}$

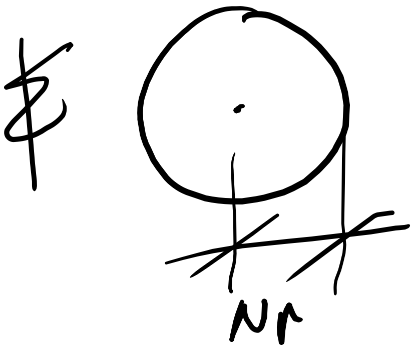


Given two sized gears and that the moment of inertia for gear of radius r is $\bar{I}_0$. You will need to figure out how $\bar{I}_N$ (moment of inertia for gear of radius $= Nr$) scales with $\bar{I}_0$. Use disk as reference: $\bar{I}_{disk} = \frac{1}{2}Mr^2$ so $r \to Nr$ implies $\bar{I}_{disk} \to \frac{1}{2}M'(Nr)^2$



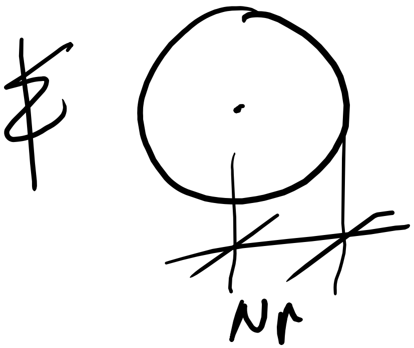
$\boxed{17.13}$ Given two sized gears and that the moment of inertia for gear of radius r is $\bar{I}_0$.

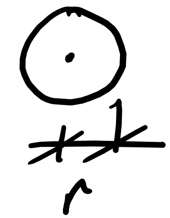




You will need to figure out how $\bar{I}_N$ (moment of inertia for gear of radius $= Nr$) scales with $\bar{I}_0$. Use disk as reference: $\bar{I}_{disk} = \frac{1}{2}Mr^2$ so $r \to Nr$ implies $\bar{I}_{disk} \to \frac{1}{2}M'(Nr)^2$ & since $M = \rho\pi r^2$,

$\boxed{17.13}$





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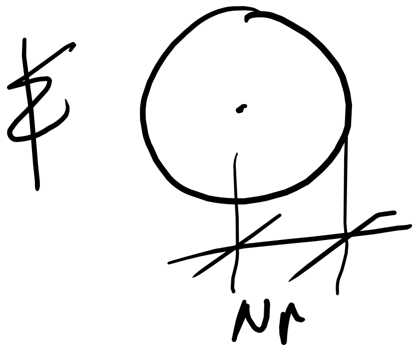
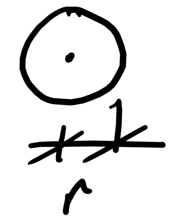
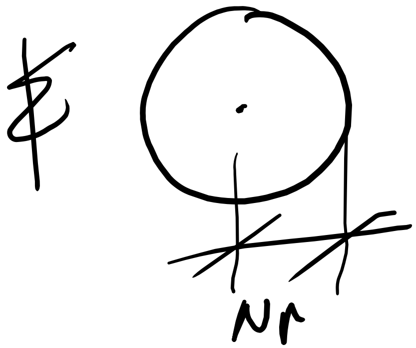
$\boxed{17.13}$

Given two sized gears and that the moment of inertia for gear of radius r is $\bar{I}_o$. You will need to figure out how $\bar{I}_N$ (moment of inertia for gear of radius $= Nr$) scales with $\bar{I}_o$. Use disk as reference: $\bar{I}_{disk} = \frac{1}{2}Mr^2$ so $r \to Nr$ implies $\bar{I}_{disk} \to \frac{1}{2}M'(Nr)^2$ & since $M = \rho\pi r^2$, where $\rho = \text{mass}/\text{Area}$ then $M' = \rho\pi(Nr^2)$





$\boxed{17.13}$



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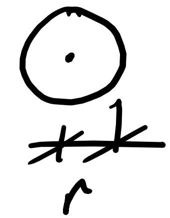

You will need to figure out how $\bar{I}_N$ (moment of inertia for gear of radius=Nr) scales with $\bar{I}_0$. Use disk as reference: $\bar{I}_{disk} = \frac{1}{2}Mr^2$ so $r \to Nr$ implies $\bar{I}_{disk} \to \frac{1}{2}M'(Nr)^2$ & since $M=\rho\pi r^2$, where $\rho = \text{mass}/\text{Area}$ then $M' = \rho\pi(Nr^2)$

$$\Rightarrow \quad \bar{I}_N = \bar{I}_0 N^4$$

$\boxed{17.16a} \rightarrow$ Conservation of energy

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$\boxed{17.17a}$ → Conserve energy, Find ω^2,

$\boxed{17.16a} \rightarrow$ Conservation of energy

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$$\frac{d\omega}{db} = 0$$

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$\boxed{17.17a}$ → Conserve energy, find ω^2, find value of b such that

$$\frac{\partial \omega}{\partial b} \cancel{= 0}$$

$\boxed{17.18}$ → Conserve energy,

$\boxed{17.16a} \rightarrow$ Conservation of energy

$\boxed{17.17a} \rightarrow$ Conserve energy, find ω^2, find value of b such that

$$\frac{\partial \omega}{\partial b} = 0$$

$\boxed{17.18} \rightarrow$ Conserve energy, remember that $L = L_0 + x$

$\boxed{17.16a}$ → Conservation of energy

$\boxed{17.17a}$ → Conserve energy, find ω^2, find value of b such that

$$\frac{\partial \omega}{\partial b} = 0$$

$\boxed{17.18}$ → Conserve energy, remember that $L = L_0 + x$, where

$L \equiv$ length of spring

$\boxed{17.16a}$ → Conservation of energy

$\boxed{17.17a}$ → Conserve energy, find ω^2, find value of b such that $\frac{\partial \omega}{\partial b} = 0$

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$\frac{\partial \omega}{\partial b} = 0$

$\boxed{17.18}$ → Conserve energy, remember that $L = L_0 + x$, where $L \equiv$ length of spring, $L_0 \equiv$ natural length of spring & $V = \frac{1}{2}kx^2$