1 rotation = 2π radians

1. $23.7 \text{ rotations} \left(\frac{2\pi \text{ radians}}{1 \text{ rotation}}\right) = 148.9 \text{ radians}$

2. $s = \theta r$ $\quad 0.64 m = 148.9 \text{ radians}(r)$

$r = 0.004298 m$

3. $\Delta\theta = \omega t + \frac{1}{2}\alpha t^2$

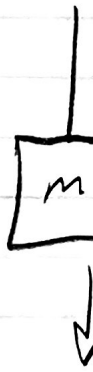
$148.9 \text{ rad} = 0 \text{ rad/s}(6s) + \frac{1}{2}\alpha(6s)^2$

$\alpha = 8.27 \text{ rad/s}^2$

4. $a = \alpha r$ $\quad a = 8.27 \text{ rad/s}^2 (0.004298 m)$

$a = 0.0356 \text{ m/s}^2$ downward

5.



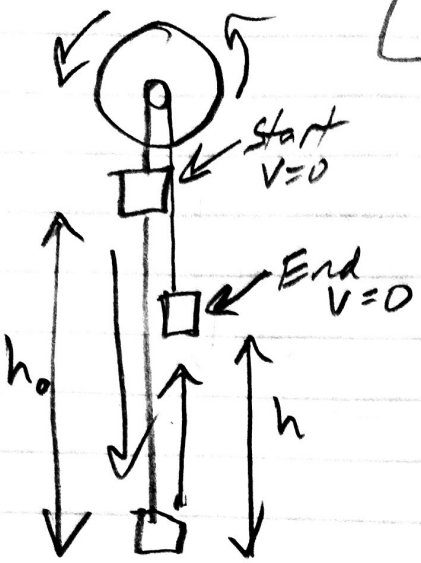
$\Sigma F = T - mg \Rightarrow T - mg = ma$

$\Sigma F = ma$ $\quad T = m(g + a)$

$T = 0.4 kg (9.8 m/s^2 - 0.0356 m/s^2)$

$T = 3.91 N$

acceleration is downward



$$PE_o + KE_o + W_{NC} = PE + KE$$

$$mgh_o + 0 + W_{NC} = mgh + 0$$

$$W_{NC} = mgh - mgh_o$$

$$W_{NC} = mg(h - h_o)$$

$$W_{NC} = 0.4kg(9.8m/s^2)(0.41m - 0.6$$

$$W_{NC} = -0.902\,J$$

$$s = \theta r$$

$$0.64m + 0.41m = \theta(0.004298m)$$

$$\theta = 244.3\,rad$$

$$Work = \tau\theta$$

$$-0.902J = \tau_{Friction}(244.3\,rad)$$

$$\tau_{Friction} = 3.69 \times 10^{-3}\,Nm$$

$$\tau = rF \qquad \tau = 0.004298m(3.91N)$$

$$\tau = 0.0168\,Nm$$

τ_{Net} = Sum of torques

10. $\tau_{Net} = \tau_{string} - \tau_{Friction}$

$\tau_{Net} = 0.0168\,Nm - 0.00369\,Nm$

$\tau_{Net} = 0.0131\,Nm$

11. $\tau_{Net} = I\alpha$

$0.0131\,Nm = I(8.27\,rad/s^2)$

$I_D = 1.58\times10^{-3}\,kgm^2$

12. $I_{Disk} = \frac{1}{2}mr^2 = \frac{1}{2}(0.0113\,kg)(0.0254\,m)^2$

$I_{wheel} = 3.65\times10^{-6}\,kgm^2$

13. $I_{axle} = \frac{1}{2}(0.034\,kg)(0.004\,m)^2$

$I_{axle} = 2.72\times10^{-7}\,kgm^2$

14. $I_{Front\ wheels + Axle} = 2(I_{wheel}) + I_{axle}$

$= 2(3.65\times10^{-6}\,kgm^2) + 2.72\times10^{-7}\,kgm^2$

$I_{W+A} = 7.57\times10^{-6}\,kgm^2$

$1s = 240 \text{ frames}$

15. $16 \text{ frames} \left(\frac{1 \text{ second}}{240 \text{ frames}} \right) = 0.0667 s = \Delta t$

16. $\omega = \frac{\Delta \theta}{\Delta t}$ $\omega = \frac{1 \text{ rotation}}{0.0667 s} \left(\frac{2\pi \text{ radians}}{1 \text{ rotation}} \right)$

$\omega = 94.2 \text{ rad/s}$

17. $KE_{rot} = \frac{1}{2} I \omega^2$

$KE_{\substack{\text{Rear} \\ \text{Wheel} + \\ \text{Axle}}} = \frac{1}{2} \left(1.58 \times 10^{-3} \text{ kgm}^2 \right) \left(94.2 \text{ rad/s} \right)^2$

$KE_{RW+A} = 7.03 J$

18. $S = \theta r$ $S = 15 \text{ rot} \left(\frac{2\pi \text{ rad}}{\text{rot}} \right) (0.12 m)$

$S = 11.3 m$

S = Distance rolled = Distance wound

θ = 15 rotations, in radians

r = Wheel radius

19. $\tau = rF = 0.0042m\,(30N)$

$\tau = 0.126\,Nm$

20. $\tau = rF \quad 0.126\,Nm = 0.12m\,(F_{Edge\ of\ wheel})$

$F_{Edge\ of\ wheel} = 1.05N$

21. $E_{Tot} = \frac{1}{2}mv^2 + \frac{1}{2}I_F\omega_F^2 + \frac{1}{2}I_D\omega_D^2$

$2(E_{Tot}) = mv^2 + I_F\frac{v^2}{r_F^2} + I_D\frac{v^2}{r_D^2}$

$2(E_{Tot}) = v^2\left(m + \frac{I_F}{r_F^2} + \frac{I_D}{r_D^2}\right)$

$v = \sqrt{\frac{2(E_{Tot})}{m + \frac{I_F}{r_F^2} + \frac{I_D}{r_D^2}}}$

$v = \sqrt{\frac{2(7.03J)}{0.4kg + \frac{7.57\times10^{-6}kgm^2}{(0.0254m)^2} + \frac{1.58\times10^{-3}kgm^2}{(0.12m)^2}}}$

$v = 5.19\,m/s$