10-83)
There is no slipping for either the cylinder or the wheel, so for each, the velocity of the hanging block is equal to $r\omega$ and the acceleration of the block is $r\alpha$:
Since we are looking for an acceleration, forces and acceleration, torques and angular acceleration is the way to go. We can do this with conservatin of mechanical energy, but it is a longer solution.
Let's let downward be positive for the hanging mass and to the right be positive for the rollng cylinder. To match signs, we'll let clockwise rotation be positive for both the cylinder and disc. Also note that teh tensions will NOT be the same in each part of the string.
Write NII for each object:
Hanging mass:
$gM - T_1 = Ma$
NII for the wheel:
$+RT_1 - RT_2 = I_{WHEEL}\,\alpha_{WHEEL} = {}^1/_2MR^2(a/R)$
$T_1 - T_2 = {}^1/_2Ma$
This cylinder does not translate, and we're not too interested in NII for it.
NII for rolling cylinder:
y: $N - gM = Ma_y = 0$
x: $T_2 - F_f = Ma_x = Ma$
Note that we can NOT say that $F_f = \mu_S N$, since we don't know how close to slipping the interface is. So the y equation we just wrote is not too useful.
Pick the center of the cylinder as the pivot for torque calculation
Rot: $0{*}T_2 + 0{*}N + 0{*}gM + F_f{*}(2R) = I_{CYLINDER}\,\alpha_{CYLINDER} = {}^1/_2M(2R)^2(a/2R)$
$F_f = {}^1/_2Ma$
Now just add all four of the equations:
$gM - T_1 + T_1 - T_2 + T_2 - F_f + F_f = Ma + {}^1/_2Ma + Ma + {}^1/_2Ma$
$g = 3a$
$a = g/3$.