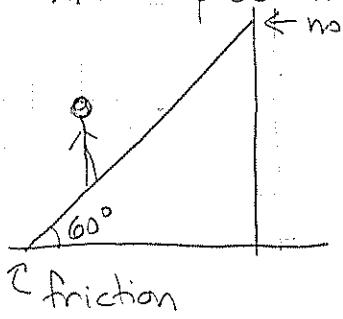
2. Ch. 12 problem 11

a)



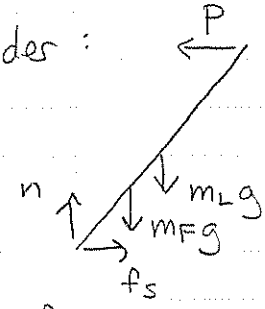
$L = 15.0$ m, $m_L g = 500$ N } ladder

halfway up, so 7.5 m from bottom

$m_F g = 800$ N } firefighter

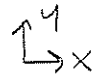
4 m from bottom

FBD of ladder:



3 unknowns: n, f_s, P

want to find f_s and n



choose horizontal + vertical axes

$\Sigma F_x = 0 \Rightarrow f_s - P = 0 \Rightarrow f_s = P$

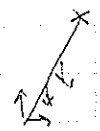
$\Sigma F_y = 0 \Rightarrow n - m_F g - m_L g \Rightarrow n = m_F g + m_L g = 1300$ N

$\Sigma \tau = 0$: choose axis at upper end of ladder to eliminate P

horizontal forces make angle $\phi = 60°$ with ladder

vertical forces make $\phi = 30°$

choose CCW torques as +



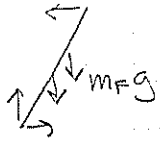
$\Sigma \tau_P = L f_s \sin 60 - L n \sin 30 + (L-4) m_F g \sin 30 + \frac{1}{2} m_L g \sin 30 = 0$

$(15) f_s \sin 60 = (15)(1300)\sin 30 - (11)(800)\sin 30 - (7.5)(500)\sin 30$

$\Rightarrow f_s = 268$ N

b) with firefighter 9 m from bottom, ladder on the verge of slipping

$\Rightarrow f_s = f_{s,max} = \mu_s n$



the only thing that changes is the torque:

$L f_s \sin 60 - L n \sin 30 + (L-9) m_F g \sin 30 + \frac{1}{2} m_L g \sin 30 = 0$

$\Rightarrow f_s = 421$ N

n still $= m_F g + m_L g = 1300$ N

so $\mu_s = \frac{f_s}{n} = \frac{421\text{ N}}{1300\text{ N}} = 0.324$