STAEDTLER® No. 937 811E Engineer's Computation Pad

39 For the stepladder shown in Fig. 12-51, sides AC and CE are each 2.44 m long and hinged at C. Bar BD is a tie-rod 0.762 m long, halfway up. A man weighing 854 N climbs 1.80 m along the ladder. Assuming that the floor is frictionless and neglecting the mass of the ladder, find (a) the tension in the tie-rod and the magnitudes of the forces on the ladder from the floor at (b) A and (c) E. (*Hint:* Isolate parts of the ladder in applying the equilibrium conditions.)

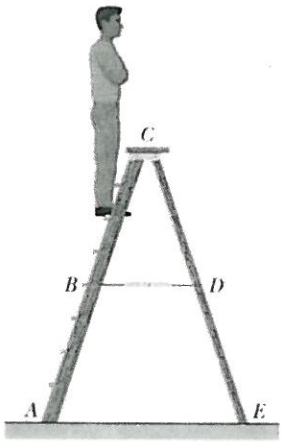


Fig. 12-51 Problem 39.

WE NEED TO FIND THE 3 UNKNOWNS, T, N_A, & N_E

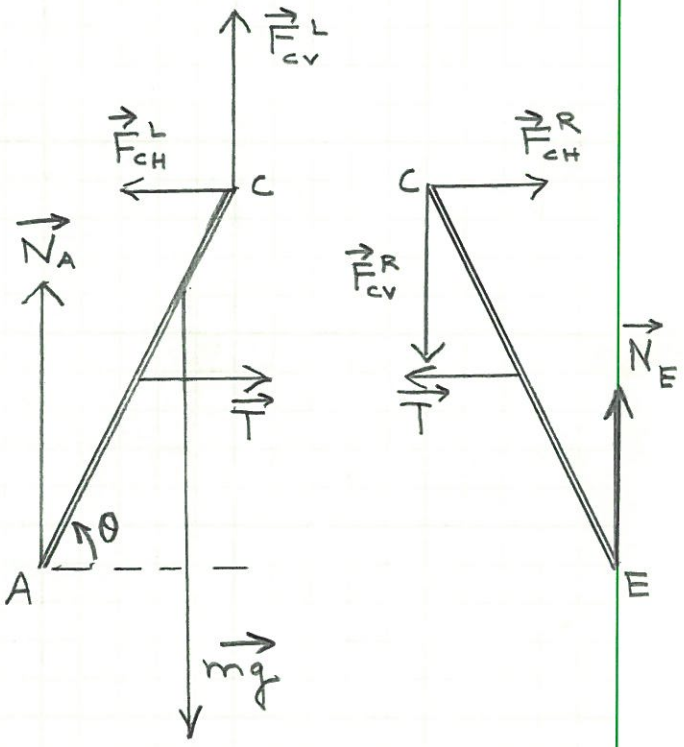
WE NEED 3 EQUATIONS WITH THESE 3 UNKNOWNS

TRANSLATIONAL EQUILIBRIUM OF THE LADDER $\Rightarrow$

$\vec{F}^{net}_{LADDER} \equiv 0 \Rightarrow N_A + N_E - mg = 0$ Eq^n *

APPLY $\tau^{net} \equiv 0$ TO BOTH THE LEFT & RIGHT SIDES OF THE LADDER AND CALCULATE TORQUES ABOUT POINT C

BECAUSE WE DO NOT KNOW THE FORCES ACTING AT THIS POINT,



LEFT SIDE OF LADDER

$\tau^{net}_{L\text{-SIDE}} \equiv 0$ CALCULATE TORQUES ABOUT POINT C

$T\frac{L}{2}\sin\theta + mg(L-d)\cos\theta - N_A L\cos\theta = 0$

RIGHT SIDE OF LADDER

$\tau^{net}_{R\text{-side}} \equiv 0$ CALCULATE TORQUES ABOUT POINT C

$N_E L\cos\theta - T\frac{L}{2}\sin\theta = 0$

ADD THE TORQUE EQUATIONS:

$mg(L-d)\cos\theta + (N_E - N_A)L\cos\theta = 0$

$\Rightarrow N_A - N_E = mg(L-d)/L$

ADD THIS TO Eq^n * (TRANS EQ)

$N_A = \left[mg\frac{(L-d)}{L} + mg\right]/2$

$N_A = mg(2L-d)/(2L)$

$* \Rightarrow N_E = mg - N_A = mgd/(2L)$

$\tau^{NET}_{R\text{-SIDE}} = 0 \Rightarrow T = 2N_E\frac{\cos\theta}{\sin\theta}$

$N_E = 854(1.80)/2(2.44) = 315\,N$

$N_A = mg - N_E = 854 - 315 = 539\,N$

$T = 2(315)\frac{\ell/L}{\sqrt{1-(\ell/L)^2}} = 207\,N$

L = Length of the Ladder

d = distance of Man along the Ladder

ℓ = Length of the Tie-rod

Tie Rod @ $L/2$ along Ladder

$\vec{F}^{\text{on Left by Right}}_{@C} = -\vec{F}^{\text{on Right by Left}}_{@C}$

with Horizontal & VERTICAL COMPONENTS of MAGNITUDES:

F_{CH} & F_{CV}