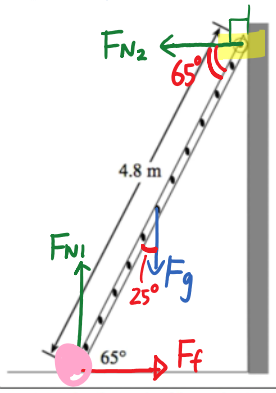
Equilibrium and Torque Extra Notes: Challenging Questions

1. A uniform 4.8 m long ladder of mass 16 kg leans against a frictionless vertical wall as shown in the diagram below.



What minimum force of friction is needed at the base of the ladder to keep it from sliding?

$\tau_{cw} = \tau_{ccw}$

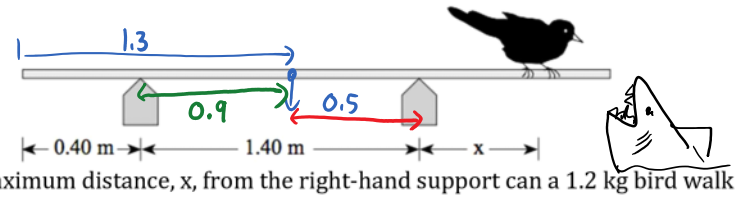
$F_g(2.4m)\sin(25) = F_{N2}(4.8m)\sin 65°$

16×9.8

$\therefore F_{N2} = 36.6\ N$

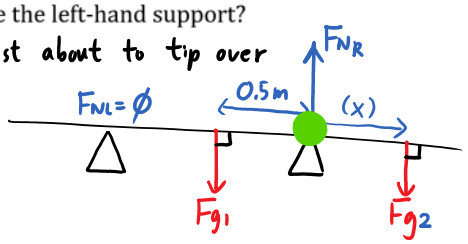
$\Sigma F_x = \emptyset$ $\quad F_f = F_{N2} = \boxed{36.6\ N}$

2. A 0.75 kg board of length 2.60 m initially rests on two supports as shown.



What maximum distance, x, from the right-hand support can a 1.2 kg bird walk before the board begins to leave the left-hand support?

Just about to tip over



$\tau_{cw} = \tau_{ccw}$

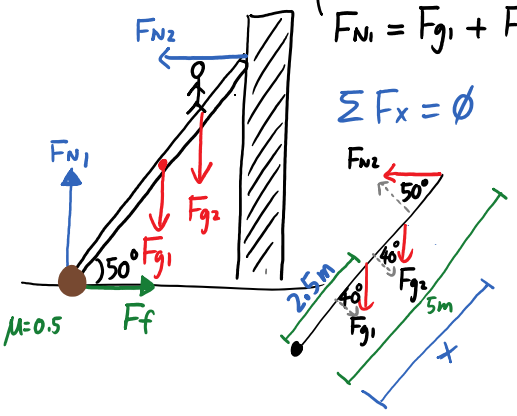
$F_{g_2}(x) = F_{g_1}(0.5m)$

$1.2(9.8)$ $\quad 0.75(9.8)$

$\boxed{X = 0.3125\ m}$

$\Sigma F_y = \emptyset$

3 A 20 kg ladder leans against a frictionless vertical wall at 50° to the ground. If the ladder is 5 m long and μ=0.5 on the ground How far up the ladder can a 80 kg person climb before the ladder starts sliding?



$F_{N_1} = F_{g_1} + F_{g_2} = 196 + 784 = 980\ N$ $\quad F_f = \mu F_{N_1} = 490$

$\Sigma F_x = \emptyset$ $\quad F_{N_2} = F_f = 490\ N$

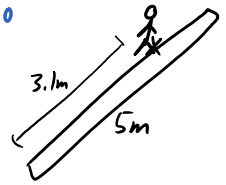
$\tau_{cw} = \tau_{ccw}$

$F_{g_1}(2.5m)\sin 40 + F_{g_2}(x)\sin 40 = F_{N_2}(5m)\sin 50$

196 $\quad$ 784 $\quad$ 490

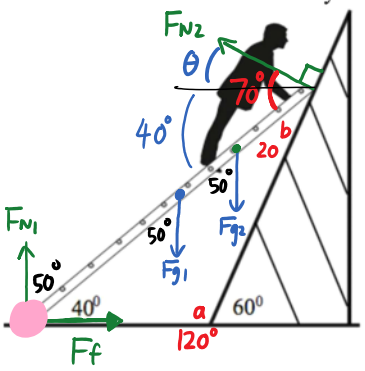
$\boxed{X = 3.1\ m}$

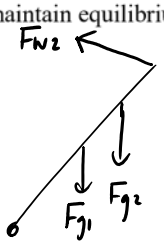
max height to climb.



Ladder = 4m

4 A 65 kg person is ¾ of the way up a 25 kg uniform ladder as shown in the diagram below. The ladder is leaning against a frictionless surface inclined at 60° to the horizontal. What is the minimum coefficient of friction between the ladder and the floor necessary to maintain equilibrium?



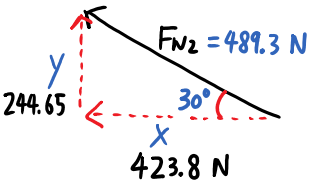


$\tau_{cw} = \tau_{ccw}$

$F_{g1}(2m)\sin 50° + F_{g2}(3m)\sin 50° = F_{N2}(4m)\sin 70°$

$25(9.8) \quad (65)9.8$

$\therefore F_{N2} = 489.3\ N$



$\Sigma F_x = \emptyset \quad F_f = F_{N2x}$

$F_f = 423.8\ N$

$\Sigma F_y = \emptyset \quad F_{N1} + F_{N2y} = F_{g1} + F_{g2}$

$F_{N1} + 224.65 = 245 + 637$

424 657

$F_{N1} = 657\ N$

$F_f = \mu F_N$

$\mu = 0.64$

Super challenging (for fun only)

A ladder is leant against the wall. The coefficient of the static friction μ_1 between the ladder and the wall is 0.3 and the coefficient of the static friction μ_2 between the ladder and the floor is 0.4. The center of mass of the ladder is in the middle of it. Find the **minimum angle** θ that the ladder can form with the floor not to slip down.

Hint 1: mass is not given on purpose because you don't need it
Hint 2: this trig identity is necessary **Sin(90-θ)= Cos(θ)**
Hint 3: with the magic of Physics you will end up with three main equations and a few side ones; only the magic of Maths/algebra can get you out of the mess that comes after.
Hint 4: Other than θ, μ_1 and μ_2, all other unknown can be cancelled out somehow.
Hint 5: the 2nd last step should be an equation that contains only three variables θ, μ_1 and μ_2 and some trig function.