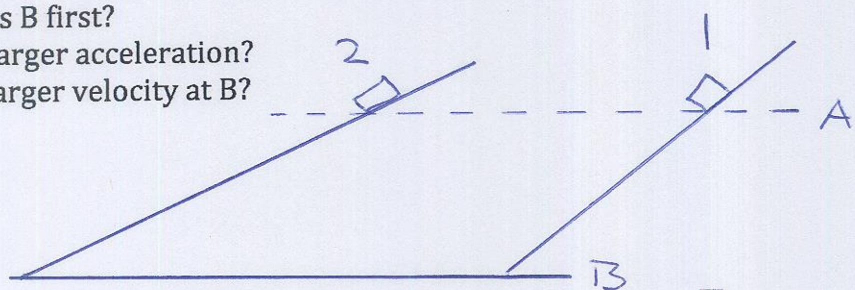
Review Problems Unit 3

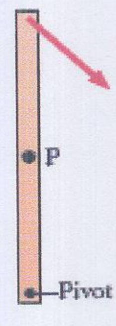
This unit covers ideas of torque, work and energy. You will be graded by your communication of the reasoning and problem solving methods you show.

- show all equations used in symbol form before adding numerical values.
- your picture should clearly show your choices of such factors as pivot point and any coordinate systems used.
- any problem solved entirely by methods from previous units will receive zero points. Newton's laws and kinetics may be needed to solve parts of a problem, but not to solve the problem in its entirety.

1. Boxes 1 and 2 sit on frictionless ramps, as shown. Each starts from rest at point A and is allowed to slide down to point B. The mass of 1 is greater than the mass of 2.
   a. which if either reaches B first?
   b. which if either has a larger acceleration?
   c. which if either has a larger velocity at B?



2. A rod is pivoted and has one force acting on it, as shown. Draw this three times and on each picture, draw in one force acting at P that will keep the rod in total static equilibrium. Explain why three very different forces all achieve the same result.

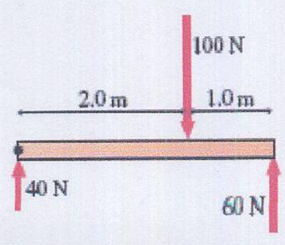


3. Student A has a mass of 75 kg and student B has a mass of 57 kg. They sit in identical wheeled chairs. Student A places his feet on the knees of student B and suddenly pushes outward with his feet, causing both chairs to move.
   a. During the push, which student if either exerts a greater force on the other?
   b. Consider the work done by the push on each student. Which if either has more work done?

4. Three forces with the magnitudes shown act on the object below. There are no other forces acting.

This object will experience:

____rotational acceleration only
____linear acceleration only
____both linear and rotational acceleration
____neither linear nor rotational acceleration

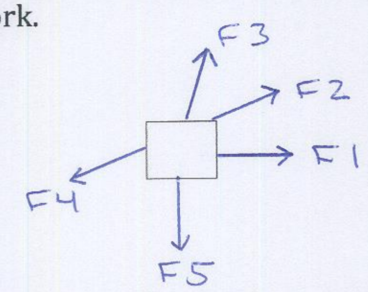


5. Stand on one leg and let your other leg swing. Notice that your leg has a certain natural rate of swinging back and forth (which is why your walking speed is what it is!). Now force your leg to swing at twice that rate. What do you observe yourself doing? Explain in physics terms why these changes help you swing the leg faster.

6. The particle shown moves a distance d to the right on this page as the forces shown act on it. All the forces have equal magnitudes.

a. make a series of pictures showing the angle θ for each force.

b. rank the work done by each force, from largest to smallest. Rank positive work higher than negative work.



7. Andy and Bill have the same weight and wear identical shoes. When they both stand with their backs against the wall and start leaning over, Andy can lean forward farther than Bill before falling over. Whose center of gravity is closer to the ground when they are standing upright?

8. Two identical metersticks are pinned to a level frictionless tabletop. A pivots around one end, and B pivots around its center. The same magnitude of force F pushes at right angles to each meterstick, at one end. Which if either experiences a higher rotational acceleration, and how many times greater is it?

9. What energy transformations happen in each of the following systems?

a. a pendulum bob moves from the bottom of its swing to the top.

b. a skier slides down a gentle slope at constant speed.

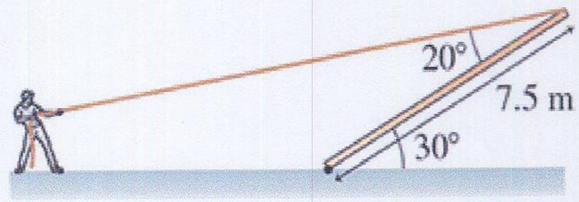
10. A car is traveling at 22.2 m/s along a road which is angled upward 10^0 from the horizontal. The driver suddenly slams on the brakes to avoid hitting a moose 60 m away. The coefficient of kinetic friction between tires and road is 0.27.

a. sketch the situation. Show and label all forces acting on the car.

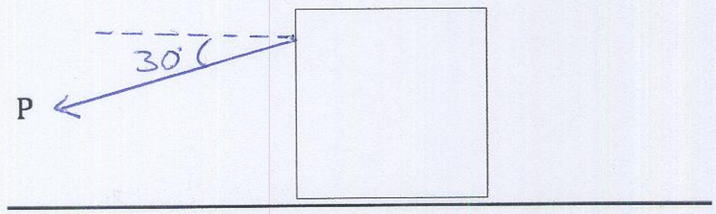
b. state what you are including in your system.

c. does the moose get hit?

11. In the picture below, the man is pulling on the rope attached to the top of a telephone pole (mass = 28 kg) with a constant tension of 650 N. Is the pole being raised, lowered, or held still? If the pole is rotating, find its angular acceleration.



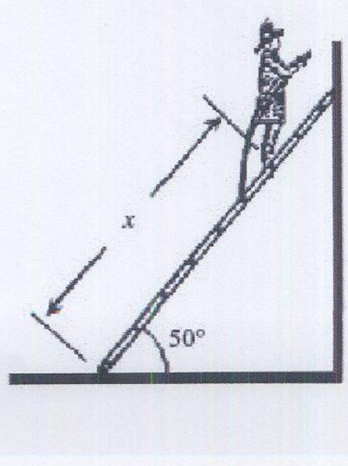
12. A 100 kg crate is being pushed at constant speed across a horizontal floor by a force P that makes an angle of 300 below the horizontal. The coefficient of kinetic friction is 0.20. Find the magnitude of P.



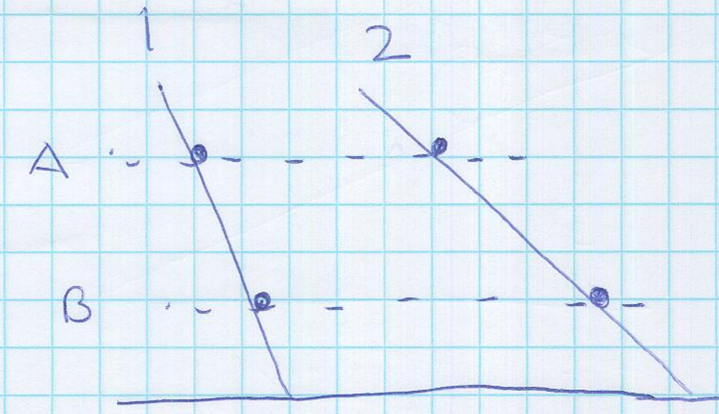
13. A 0.10 kg meterstick hangs from the ceiling by a string attached at its 40 cm mark. A 0.70 kg object hangs from the 5.0 cm mark. An object of mass M hangs somewhere on the stick, such that the meterstick hangs horizontally and is in equilibrium. The tension in the string attached to the ceiling is 19.6 N.

a. sketch the situation, including all forces acting on the meterstick.
b. find the value of M and the location where it is hung.

14. A uniform ladder of weight 200 N and length 10 m leans against a perfectly smooth wall. A firefighter of weight 600 N climbs a distance x up the ladder. The coefficient of static friction between ladder and floor is 0.50. What is the maximum value of x for which the ladder will not slip?



1. System:
Everything.



For either box equation will look like

$$K_F + U_{gF} + \Delta E_{TH} = K_0 + U_{g0} + W$$

$$\frac{1}{2} m v_F^2 + mgh_B + 0 = 0 + mgh_A + 0$$

$$\frac{m}{2} v_F^2 = mgh_A - mgh_B$$

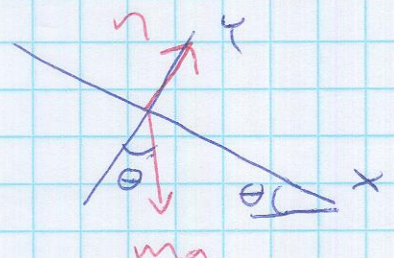
$$m v_F^2 = 2mg(h_A - h_B)$$

$$v_F = \sqrt{2g(h_A - h_B)}$$

m cancels: the different masses are irrelevant.

Both have same $h_A - h_B$

So both have same v_F.

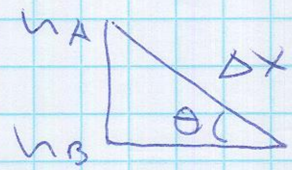


Check with Forces + Kinematics:

$$\Sigma F_x = m a_x$$

$$mg\sin\theta = m a_x$$

$$a_x = g\sin\theta$$



$$v_F^2 = v_0^2 + 2a\Delta x$$

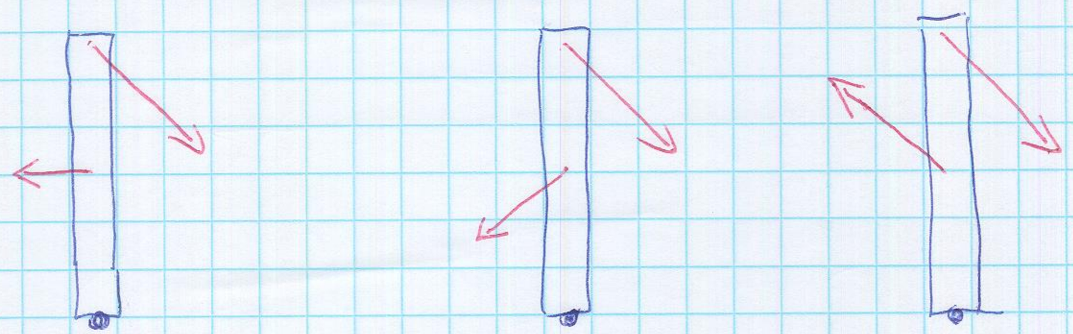
$$v_F^2 = 0 + 2(g\sin\theta)\left(\frac{h_A - h_B}{\sin\theta}\right)$$

$$v_F^2 = 2g(h_A - h_B)$$

$$\sin\theta = \frac{h_A - h_B}{\Delta x}$$

$$\Delta x = \frac{h_A - h_B}{\sin\theta}$$

2.



Original Force creates a certain (−) τ. New force needs to be same magnitude τ, but (+).

Since $\tau = Fr\sin\phi$, if we vary ϕ we can use different magnitudes of F.

3. F ← A   B → F   Forces equal. 3^{rd} law pair.

$$W = Fd\cos\theta.$$

Same F + θ.

Which moves larger d while they push off?

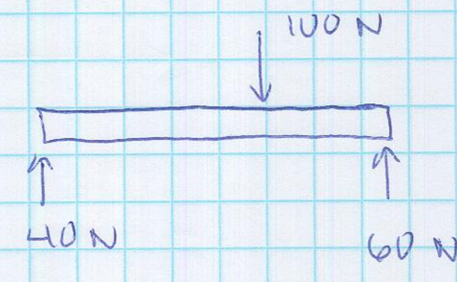
$a = \frac{F}{m}$ so B has larger accel. and moves farther.

$$W_B > W_A$$

4. $\Sigma F = ma$

$40 + 60 - 100 = ma$

$a = 0$ so linear accel $= 0$



$\Sigma \tau = I\alpha$ if $\alpha = 0$, it $= 0$ around any pivot. Pick one and try.

Around left end:

$(-100\text{ N})(2.0\text{ m}) + (60\text{ N})(3\text{ m}) = -20\text{ Nm}$

Right end:

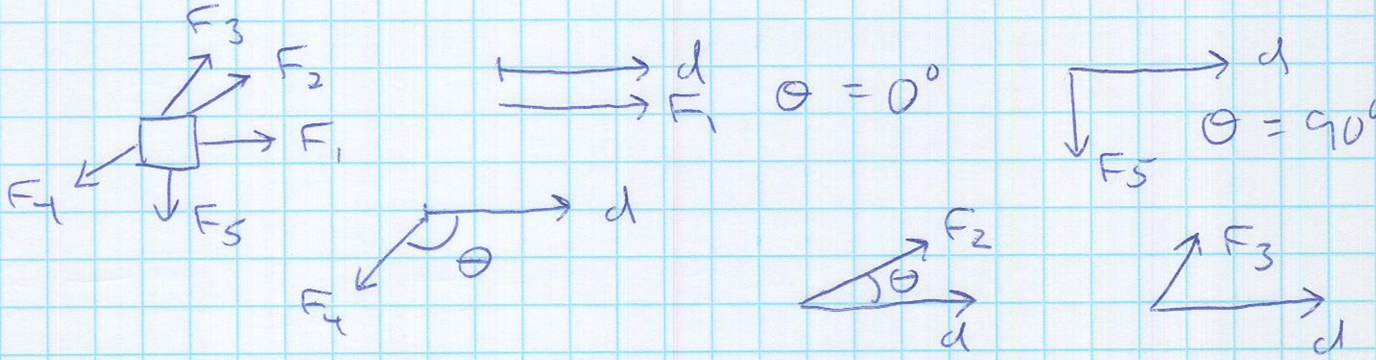
$(+100\text{ N})(1\text{ m}) - (40\text{ N})(3\text{ m}) = -20\text{ Nm}$

has α in (−) dir. Rotates CW.

5. I use more muscle power: more muscle force creates higher τ.
<u>And</u> I bend my leg at knee. This changes leg's I.
More mass closer to hip, so I decreases.

$$\alpha = \frac{\Sigma\tau \text{ — Increased}}{I \text{ — decreased}} \Bigg\} \text{ so more rotational acceleration.}$$

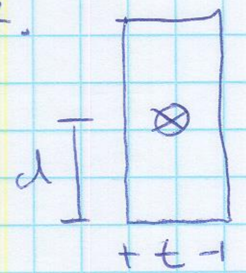
6.



$$W = \underbrace{Fd}_{\text{same for all}} \cos\theta$$

so $\underset{(+)}{W_1} > \underset{(+)}{W_2} > \underset{(+)}{W_3} > \underset{(\emptyset)}{W_5} > \underset{(-)}{W_4}$

7.



Stability depends on track base + d to CG.

Same shoes → same track

$$\theta_c = \arctan\left(\frac{t/2}{h}\right)$$

as h gets larger, θ_c gets smaller.

Small θ_c means easy to tip over.

Andy tips <u>less</u> easily, so his CG is closer to floor.

8.

$$\Sigma \tau = I\alpha$$

$$Fr\sin\varphi = I\alpha$$

$$A:\ r = L,\ \varphi = 90^\circ,\ I = \tfrac{1}{3} mL^2$$

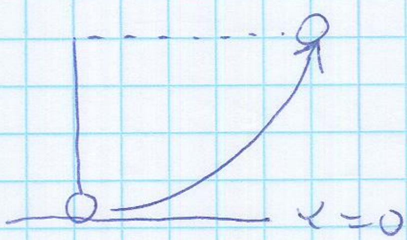
$$B:\ r = \tfrac{L}{2},\ \varphi = 90^\circ,\ I = \tfrac{1}{12} mL^2$$

$$\alpha_A = \frac{FL(1)}{1/3\, mL^2} = \frac{3F}{mL}$$

$$\alpha_B = \frac{F\left(\frac{L}{2}\right)(1)}{\frac{1}{12} mL^2} = \frac{6F}{mL}$$

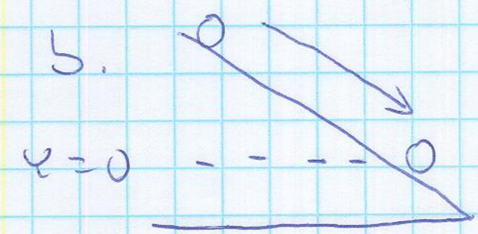
$$\alpha_B = 2\alpha_A$$

9. a.



$K \to U_g$

b.

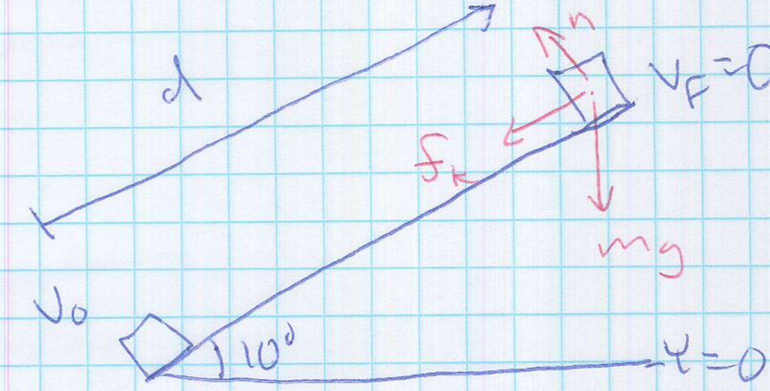


$U_g \to \Delta E_{TH}$

(not into K. Speed is constant)

10. My system is Everything.

Work: None.

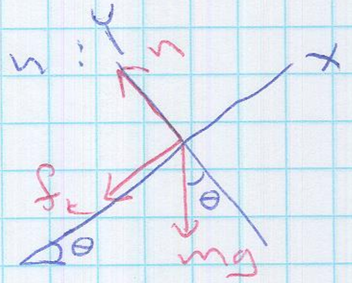


$$K_F + U_{gF} + \Delta E_{TH} = K_0 + U_{g0} + W$$

$$0 + mgy_F + f\Delta x = \frac{1}{2}mv_0^2 + 0 + 0$$

$$mgy_F + \mu n \Delta x = \frac{1}{2}mv_0^2$$

Need n:



$$\Sigma F_y = ma_y$$

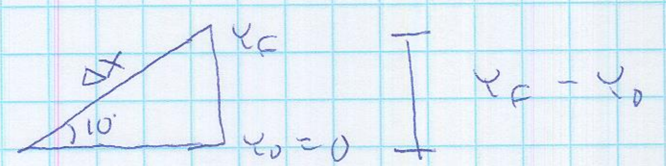
$$n - mg\cos 10° = 0$$

$$n = mg\cos 10°$$

$$mgy_F + \mu(mg\cos 10°)\Delta x = \frac{1}{2}mv_0^2$$

$$gy_F + (\mu g\cos 10°)\Delta x = \frac{1}{2}v_0^2$$

↳ need y_F.



$$\sin 10° = \frac{y_F - 0}{\Delta x}$$

$$y_F = \Delta x \sin 10°$$

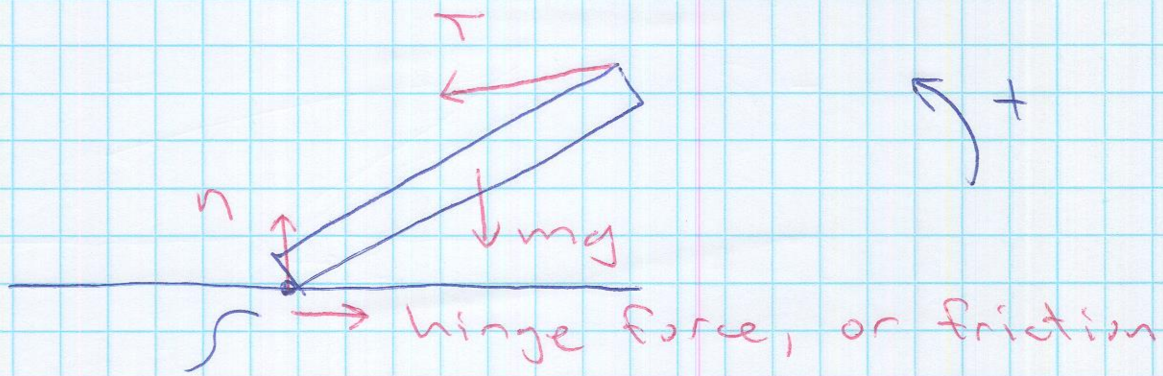
$$g\Delta x \sin 10° + \mu g\cos 10° \Delta x = \frac{1}{2}v_0^2$$

$$\Delta x[g\sin 10° + \mu g\cos 10°] = \frac{1}{2}v_0^2$$

$$\Delta x[9.8\sin 10° + 0.27(9.8)\cos 10°] = \frac{1}{2}(22.2)^2$$

$$\Delta x = 57.2 \text{ m}$$

11.



pivot. This is point it could possibly be rotating around.

$$\tau = F r \sin\varphi$$

$$\tau_T = T L \sin 20^\circ$$

$$\tau_{mg} = (mg)\left(\tfrac{L}{2}\right)\sin 60^\circ$$

$$\left.\begin{array}{l} \tau_n = 0 \\ \tau_f = 0 \end{array}\right\}$$ Line of force goes through pivot. No lever arm.

$$\Sigma \tau = I\alpha$$

$$^{+}TL\sin 20^\circ + {}^{-}mg\left(\tfrac{L}{2}\right)\sin 60^\circ + 0 + 0 = I\alpha$$

$$(650\ \text{N})(7.5\ \text{m})\sin 20^\circ - (28\ \text{kg})(9.8\ \tfrac{\text{m}}{\text{s}^2})(3.75\ \text{m})\sin 60^\circ = I\alpha$$

$$I\alpha = {}^{+}776\ \overbrace{\left(\tfrac{\text{rad}}{\text{s}^2}\right)(\text{kg m}^2)}^{\text{or N m}}$$

Rod about one end: $I = \frac{1}{3}ML^2$

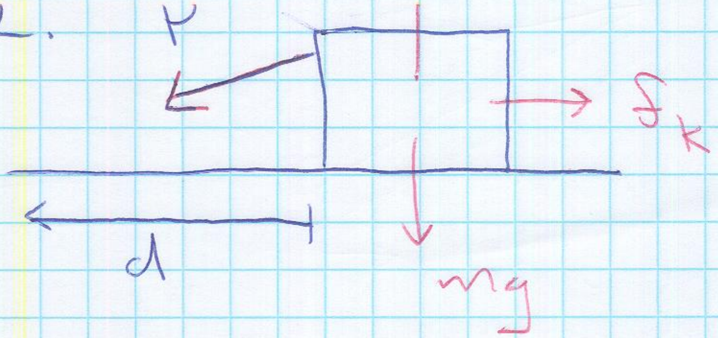
$$I = \tfrac{1}{3}(28\ \text{kg})(7.5\ \text{m})^2 = 525\ \text{kg m}^2$$

$$\alpha = \frac{\Sigma\tau}{I} = \frac{^{+}776}{525}$$

$$\alpha = {}^{+}1.5\ \text{rad/s}^2$$

Positive, so accelerating CCW. Raising.

12.



Dont know value for d, but must be moving to left across floor.

I choose to use $W_{TOTAL} = \Delta K$

System: Crate.
Work: by all forces acting.

$$\left.\begin{array}{l} W_n = 0 \\ W_{mg} = 0 \end{array}\right\} \cos 90° = 0$$

$$W_{f_k} = f_k d \cos 180° = -(\mu_k n) d$$

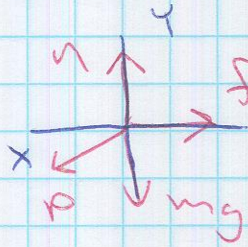
$$W_P = P d \cos 30°$$

v = constant, so $\Delta K = 0$.

$$\cancel{f_k d} \; -(\mu_k n) d + P d \cos 30° = 0$$

need n:

$$\Sigma F_y = m a_y$$
$$n - P \sin 30 - mg = 0$$
$$n = mg + P \sin 30$$



$$-\mu_k (mg + P \sin 30) d + P d \cos 30 = 0$$

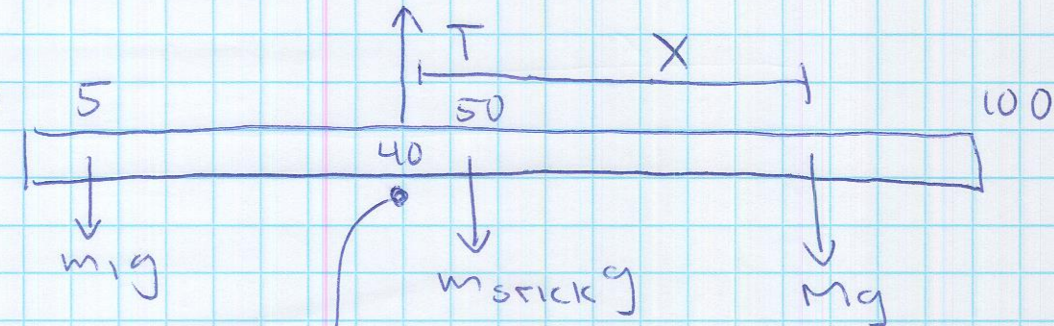
$$P \cancel{d} \cos 30 - (\mu_k P \sin 30) \cancel{d} = \mu_k mg \cancel{d}$$

$$P [\cos 30 - \mu_k \sin 30] = \mu_k mg$$

$$P [\cos 30 - 0.2 \sin 30] = (0.2)(100)(9.8)$$

$$P = 256 \text{ N}$$

13.



M must be off to right to have any chance of $\Sigma\tau = 0$.

I pick pivot at 40 cm mark.

$\tau_1 = m_1 g (0.35\,m) \sin 90 = (0.70)(0.35) g$

$\tau_T = 0$

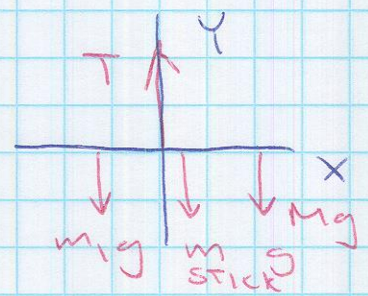
$\tau_{stick} = (0.10\,kg)\, g\, (0.10\,m) \sin 90$

$\tau_M = M g x \sin 90$

$+(0.70)(0.35)\cancel{g} - (0.10)(0.10)\cancel{g} - M\cancel{g}x = 0$

$Mx = 0.234\ kg \cdot m$

$\Sigma F_y = m a_y$



$T - m_1 g - m_s g - M g = 0$

$\frac{T}{g} = m_1 + m_s + M$

$\frac{19.6\,N}{9.8\,m/s^2} = \underset{kg}{0.70} + \underset{kg}{0.10} + M$

$M = 1.2\ kg$

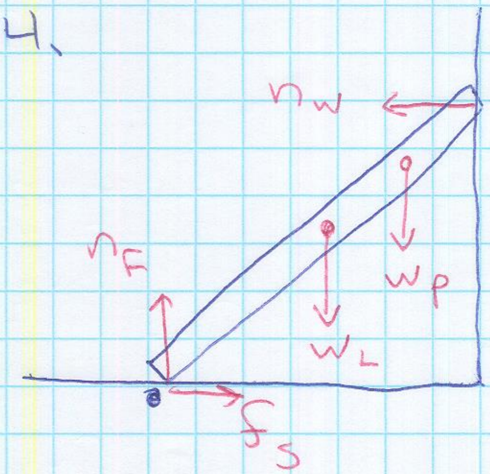
and $M \cdot x = 0.234$

$1.2\,x = 0.234$

$x = 0.195\ m$ from pivot

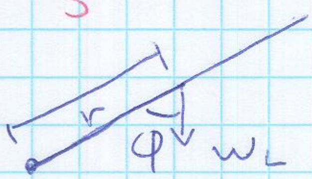
which is the $0.40 + 0.195 =$
$0.595\ m$ mark
$59.5\ cm$ mark

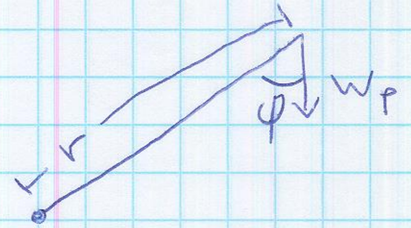
14.

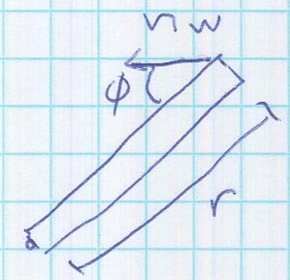


I pick pivot at floor. Ladder does not slip so any pivot is correct.

$$\left.\begin{aligned}\tau_{n_F} &= 0\\ \tau_{f_s} &= 0\end{aligned}\right\}\text{ no lever arm}$$







$$\tau_{w_L} = w_L\left(\frac{L}{2}\right)\sin 40^\circ$$

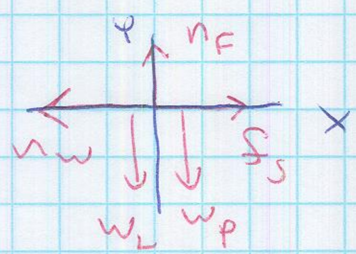
$$\tau_{w_p} = w_p(x)\sin 40^\circ$$

$$\tau_{n_w} = n_w(L)\sin 50^\circ$$

$$\Sigma\tau = I\alpha$$

$$-(200N)\left(\frac{10m}{2}\right)\sin 40^\circ + -(600N)(x)\sin 40^\circ + n_{WALL}(10m)\sin 50^\circ = 0$$

need n_{WALL}.



$\Sigma F_x = ma_x$ $\qquad$ $\Sigma F_y = ma_y$

$n_w - f_s = 0$ $\qquad$ $n_F - w_L - w_p = 0$

$n_w = \mu n_F$ and $n_F = w_L + w_p = 800N$

$n_w = (0.5)(800N)$

$= 400N$

$$-(200N)(5m)\sin 40 - (600N)x\sin 40 + (400N)(10m)\sin 50 = 0$$

$$-643 + 3064 = 386x$$

$$x = 6.3\text{ m}$$