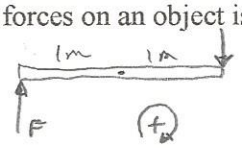
23 FEB 15

KEY

Physics: Principle and Applications, 7e (Giancoli)
Chapter 9 Static Equilibrium; Elasticity and Fracture ALL

9.1 Conceptual Questions

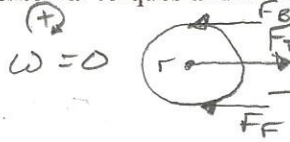
1) If the sum of the external forces on an object is zero, then the sum of the external torques on it must also be zero.
A) True
B) False
Answer: B; Var: 1



$\Sigma F = F_y - F_y = 0$

$\Sigma \tau = F(1m) + F(1m) = 2F(m)$

3) If the sum of both the external torques and the external forces on an object is zero, then the object must be at rest.
A) True
B) False
Answer: B; Var: 1



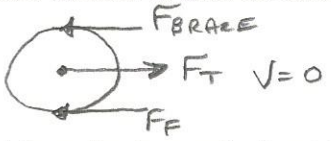
$F_T - F_{BRAKE} - F_F = 0$

...BUT MAG TIRE WILL TRANSLATE (SLIPS OR SKIDS)

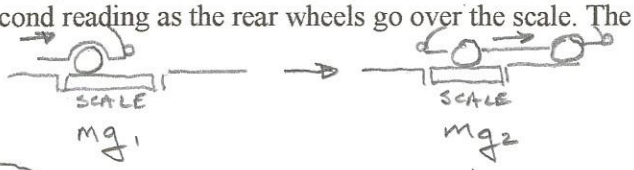
$\Sigma \tau = F_F r - (F_{BRAKE}) r - F_T r = 0$

4) If an object remains at rest, then the sum of both the external torques and the external forces on the object must be zero.
A) True
B) False
Answer: A; Var: 1

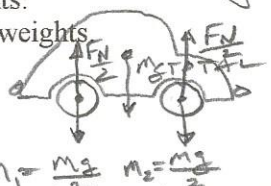
SAME SCENARIO APPLIED @ REST



5) When a car is weighed, it is driven slowly on a horizontal floor over a scale that records a reading as the front wheels go over the scale, and then records a second reading as the rear wheels go over the scale. The weight of the car is equal to
A) the weight under the front wheels.
B) the weight under the rear wheels.
C) the average of the two weights.
D) the sum of the two weights.
E) the difference of the two weights.
Answer: D; Var: 1

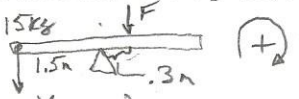


$mg_1 + mg_2 =$ WEIGHT TOTAL



9.2 Problems

1) A 15-kg child is sitting on a playground teeter-totter, 1.5 m from the pivot. What is the magnitude of the minimum force, applied 0.30 m on the other side of the pivot, that is needed to make the child lift off the ground?
A) 75 N
B) 740 N
C) 23 N
D) 44 N
E) 66 N
Answer: B; Var: 1

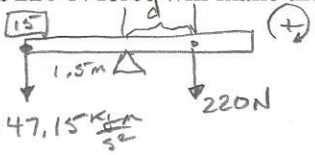


$F_g = (15kg)(9.81\frac{m}{s^2}) = 147.15\frac{kg\cdot m}{s^2}$

$\Sigma \tau = -F_g(1.5m) + F(.3m) = 0$

$F = \frac{(147.15\frac{kg\cdot m}{s^2})(1.5m)}{.3m} = 735.75N$

2) A 15-kg child is sitting on a playground teeter-totter, 1.5 m from the pivot. What is the minimum distance, on the other side of the pivot, such that a 220-N force will make the child lift off the ground?
A) 1.0 m
B) 1.5 m
C) 0.10 m
D) 9.8 m
E) 2.4 m
Answer: A; Var: 1

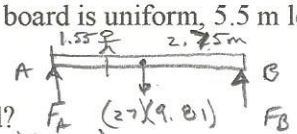


$F_g = 147.15\frac{kg\cdot m}{s^2}$

$\Sigma \tau = F_g(1.5m) + d(220N) = 0$

$d = \frac{(147.15\frac{kg\cdot m}{s^2})(1.5m)}{220N} = 1.0m$

3) An 82-kg painter stands on a long horizontal board 1.55 m from one end. This 27-kg board is uniform, 5.5 m long, and supported at each end by vertical posts.
(a) What is the magnitude of the *total* force provided by *both* posts?
(b) With what force does the post that is closest to the painter push upward on the board?
Answer: (a) 1100 N (b) 710 N; Var: 1



$\Sigma F = F_A + F_B - (82)(9.81) - (27)(9.81) = 0$

(b) $\Sigma \tau_B = -(2.75m)(27)(9.81) - (82)(9.81)(3.95m) + (F_A)(5.5m)$

$2\tau_B = 0 = -728.4Nm - 3177.5Nm + (5.5m)(F_A)$

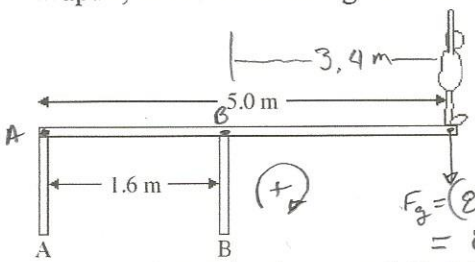
$-F_A = \frac{-3905.9N\cdot m}{5.5m} \Rightarrow F_A = 710.16N\cdot m$

$F_A + F_B =$ TOTAL $F = 804.4N + 264.9N$

$F_{TOT} = 1069.3N$

2 SIG FIGS $1100N$

4) An 82-kg diver stands at the edge of a light 5.0-m diving board, which is supported by two vertical pillars that are 1.6 m apart, as shown in the figure. Find the magnitude and direction of the force exerted by each pillar.



$m_{BOARD} = 0$ kg

$\Sigma \tau_B = F_A(1.6m) + (3.4m)(804.4N) = 0$

$F_A = -1709.35N (\downarrow)$

$F_g = (82kg)(9.81 \frac{m}{s^2}) = 804.4N$

$\Sigma \tau_A = F_B(1.6m) + (5.0m)(804.4N) = 0$

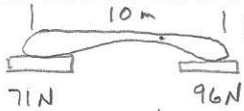
$F_B = -2513.75N (\uparrow)$

Answer: A: 1.7 kN downward, B: 2.5 kN upward; Var: 1

5) An irregularly shaped object that is 10 m long is placed with each end on a scale. If the scale on the right reads 96 N while the scale on the left reads 71 N, how far from the left end is the center of gravity of this object?

A) 5.7 m
B) 7.4 m
C) 4.3 m
D) 14 m

Answer: A; Var: 50+



FIND: d_{cm} FROM LEFT SCALE

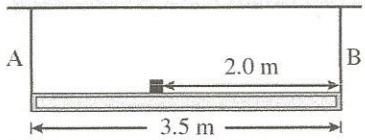
① $\Sigma \tau_{cm} = (71N)x + (96N)(y) = 0$

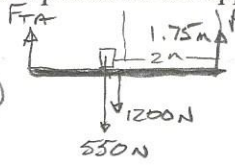
② $y = 10 - x$ *

$96N\ y = 71N\ x$

$.7396x = 10 - x \Rightarrow 1.7396x = 10$ $\quad x = 5.75m$ $\quad y = \frac{71N}{96N} x = .7396x$ *

6) A uniform 1200-N piece of medical apparatus that is 3.5 m long is suspended horizontally by two vertical wires at its ends. A small but dense 550-N weight is placed on the apparatus 2.0 m from one end, as shown in the figure. What are the tensions, *A* and *B*, in the two wires?





FIND: F_{TA} ; F_{TB}

$\Sigma F = F_{T\,TOTAL} = -1200N + 550N = -1750N$

A) $A = 880$ N, $B = 880$ N
B) $A = 840$ N, $B = 910$ N
C) $A = 9000$ N, $B = 8200$ N
D) $A = 910$ N, $B = 840$ N
E) $A = 8200$ N, $B = 9000$ N

Answer: D; Var: 1

A] $\Sigma \tau_B = F_{TA}(3.5m) - (550N)(2m) - (1200N)(1.75m) = 0$

$F_{TA}(3.5m) = 1100Nm + 2100N \cdot m = 3200N \cdot m$

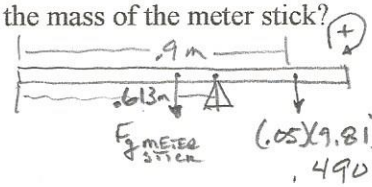
$F_{TA} = \frac{3200Nm}{3.5m} = 914.3N \approx 910N$

B] $F_{T\,TOTAL} = 914.3N \Rightarrow F_{TB} = 835.7N \approx 840N$

7) A meter stick balances at the 50.0-cm mark. If a mass of 50.0 g is placed at the 90.0-cm mark, the stick balances at the 61.3-cm mark. What is the mass of the meter stick?

A) 127 g
B) 178 g
C) 89.7 g
D) 32.6 g
E) 73.4 g

Answer: A; Var: 1



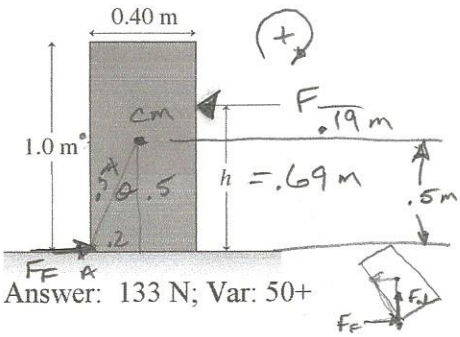
$m_1 = .05kg$ $\quad d = .90m$ $\quad r_1 = .9 - .613 = .287m$

$0 = \Sigma \tau_{cm} = F_g(.113m) + (.287m)(.05kg)(g) = .613 - .5 = .113m$

$(.287m)(.05kg)(g) = mg(.113m)$

$m = .127kg = 127g$

8) As shown in the figure, a uniform rectangular crate 0.40 m wide and 1.0 m tall sits on a horizontal surface. The crate weighs 460 N, and its center of gravity is at its geometric center. A horizontal force of magnitude *F* is applied at a distance *h* above the floor. Friction at the floor is great enough to prevent the crate from sliding. If $h = 0.69$ m, what minimum value of *F* is required to make the crate start to tip over?



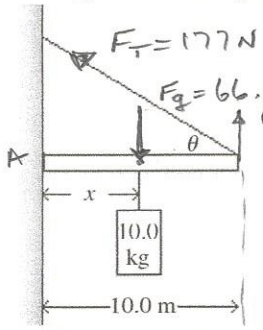
$W = 460N$ $\quad F = F_F$ $\quad r_{cm} = .2m$

$\Sigma \tau_A = +(.2m)(460N) - F_F(0) - F(.69m) = 0$

$F = \frac{92Nm}{.69m} = \boxed{133\ N}$

Answer: 133 N; Var: 50+

9) As shown in the figure, a 10.0 m long bar is attached by a frictionless hinge to a wall and held horizontal by a light rope that makes an angle $\theta = 49°$ with the bar. The bar is uniform and weighs 66.5 N. What distance x from the hinge should a 10.0 kg mass be suspended for the tension in the rope to be 177 N?



$F_{Ty} = F_T \sin 49°$

$F_{Ty} = (177N)(.755)$

$= 133.64N$

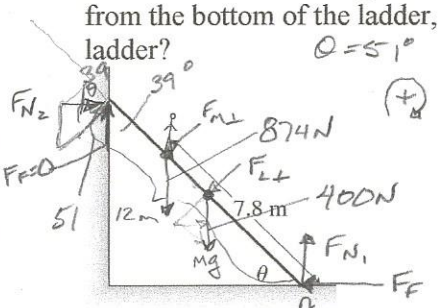
$\Sigma \tau_A = F_g x - (F_{Ty})\,10m + (66.5N)(5.0m) = 0$

$= (10kg)(9.81\frac{m}{s^2})x - 1336.4Nm + 332.5Nm = 0$

$x = \frac{1336.4Nm - 332.5Nm}{(10kg)(9.81\frac{m}{s^2})} = \boxed{10.23m}$

Answer: 10 m; Var: 50+

10) A uniform ladder 12 meters long rests against a vertical frictionless wall, as shown in the figure. The ladder weighs 400 N and makes an angle $\theta = 51°$ with the floor. A man weighing 874 N climbs slowly up the ladder. When he is 7.8 m from the bottom of the ladder, it just starts to slip. What is the coefficient of static friction between the floor and the ladder?



$\Sigma \tau_A = -(6m)(\cos 51)(400N) - (7.8m)(\cos 51)(874N) + (12m)F_{N2} = 0$

$-1510.4\ Nm - 4290.2Nm + 12m\,F_{N2} = 0$

$F_{N2L} = 483.4N$

$F_{N2} = (\cos 39)483.4N = 375.7N$

$\Sigma F_x = F_{N2} - F_{Fx} = 0$

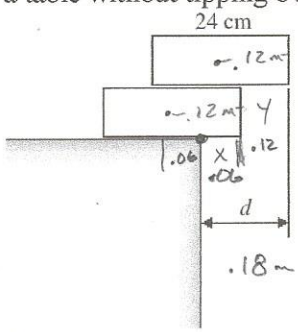
$F_{N2} = F_{Fx} = \mu F_{N1} \Rightarrow \mu = \frac{F_{N2}}{F_{N1}}$

$\mu = .295$

Answer: 0.49; Var: 50+

$\Sigma F_y = F_{N1} - F_L - F_m + F_{F2} = 0 \Rightarrow F_{N1} = +874N + 400N = +1274N$

11) A child is trying to stack two uniform bricks, each 24 cm long, so they will protrude as far as possible over the edge of a table without tipping over, as shown in the figure. What is the maximum possible overhang distance d?



$\Sigma \tau = (.06m)W - (.06m)(W) = 0$

$(.06m)W = (.06m)W$ ✓

ONCE THE CM EXTENDS BEYOND THE EDGE THE BRICK TIPS SO $.06m + .12m = .18m$

$X + Y = d$

$X = d - Y$

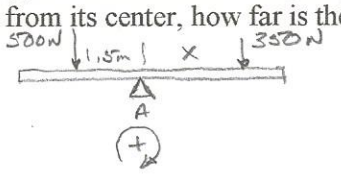
MAX $Y = .12m$

$X = d - .12m$

A) 10 cm
B) 12 cm
C) 14 cm
D) 16 cm

E) 18 cm
Answer: E; Var: 1

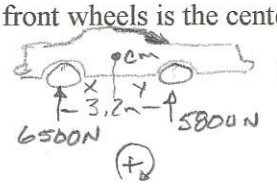
12) A uniform 40-N board supports two children weighing 500 N and 350 N. If the support is at the center of the board and the 500-N child is 1.5 m from its center, how far is the 350-N child from the center?
A) 1.1 m
B) 1.5 m
C) 2.1 m
D) 2.7 m
Answer: C; Var: 1



$\Sigma \tau_A = (1.5m)(500N) + X(350N) = 0$

$X = \frac{(1.5m)(500N)}{350N} = 2.14m$

13) To determine the location of the center of mass (or center of gravity) of a car, the car is driven over a scale on a horizontal floor. When the front wheels are over the scale, the weight recorded by the scale is 5800 N, and when the rear wheels are over the scale, the scale reads 6500 N. The distance between the front and rear wheels is measured to be 3.20 m. How far behind the front wheels is the center of mass located?
A) 0.845 m
B) 1.50 m
C) 1.59 m
D) 1.69 m
E) 1.72 m
Answer: D; Var: 1



$X + Y = 3.2m$

$0 = \Sigma \tau_{cm} = X(6500N) - Y(5800N)$ $\quad X = 3.2m - Y$

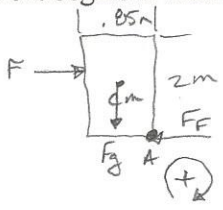
$Y = 3.2m - X = 1.69m$

$= X(6500N) - (3.2m - X)(5800N)$

$= (6500N)X - 18560Nm + (5800N)X = 0$

$12300X = 18560Nm \Rightarrow X = 1.51m$

14) A 120-kg refrigerator that is 2.0 m tall and 85 cm wide has its center of mass at its geometrical center. You are attempting to slide it along the floor by pushing horizontally on the side of the refrigerator. The coefficient of static friction between the floor and the refrigerator is 0.30. Depending on where you push, the refrigerator may start to tip over before it starts to slide along the floor. What is the highest distance above the floor that you can push the refrigerator so that it will not tip before it begins to slide?
A) 0.71 m
B) 1.0 m
C) 1.2 m
D) 1.4 m
E) 1.6 m
Answer: D; Var: 1



$\mu = .30$ $\quad F_g = (120kg)(9.81\frac{m}{s^2}) = 1177.2N$

[THEN DETERMINE HOW HIGH TO APPLY] $\quad \Sigma F = F - F_F = 0$

$\Sigma \tau_A = Fx - F_g(\frac{.85m}{2}) + F_F(0) = 0$ $\quad F = F_F = (.30)(1177.2N) = 353.16N$

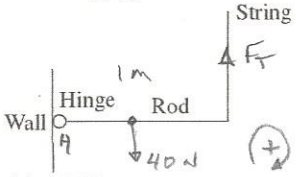
[SOLVE FOR MIN FORCE TO SLIDE]

$F \cdot x = (1177.2N)(.425m)$

$(353.16N)x = 500.31Nm$

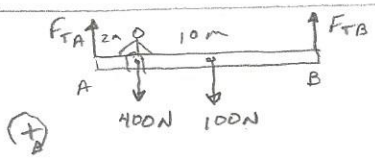
$x = 1.42m$

15) A uniform rod weighs 40 N and is 1.0 m long. It is hinged to a wall at the left end, and held in a horizontal position at the right end by a vertical string of negligible weight, as shown in the figure. What is the magnitude of the torque due to the string about a horizontal axis that passes through the hinge and is perpendicular to the rod? The hinge is very small with negligible friction.
A) 40 N · m
B) 10 N · m
C) 5.0 N · m
D) 20 N · m
E) 30 N · m
Answer: D; Var: 1



$\Sigma \tau_H = 0 = (.5m)(40N) - F_T(1m)$ $\quad \tau_T$

$\tau_T = (.5m)(40N) = 20N \cdot m$



$\Sigma F = 0 = (F_{TA} + F_{TB}) - 400N - 100N$ $\quad F_{TTOTAL}$

$F_{TTOTAL} = +500N$

16) A 10-m uniform beam weighing 100 N is supported by two vertical ropes at its ends. If a 400-N person sits at a point 2.0 m from the left end of the beam, what is the tension in each rope?
Answer: 370 N (left rope), 130 N (right rope); Var: 1

$\Sigma \tau_B = -(5m)(100N) - (8m)(400N) + F_{TA}(10m) = 0$

$F_{TA} = \frac{500Nm + 3200Nm}{10m} = 370N$

$F_{TB} = F_{TTOTAL} - F_{TA} = 130N$

19

(2) $\Sigma\tau = 0 = (3g)(4cm) = m_3\ 3cm$

$m_3 = \frac{12g\,cm}{3cm} = \boxed{4g}$

(4) $\Sigma\tau = 0 = (8cm)(6g) = (6cm)(8g)$ ✓

(3)

(1) $m_1 + m_2 = 3g$

$m_1 = 3g - m_2$

$m_1 = 3g - 2g = \boxed{1g}$

$\Sigma\tau = 0 = (2cm)m_1 = (1cm)(m_2)$

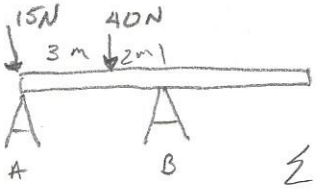
$(2cm)(3g - m_2) = (1cm)(m_2)$

$(2cm)(3g) - 2cm\,m_2 = 1cm\,m_2$

$2cm(3g) = 3cm\,m_2$

$m_2 = \frac{2cm\,3g}{3cm} = \boxed{2g}$

? (18)



$\Sigma F = -15N - 40N + F_A + F_B = 0$

$F_A + F_B = F_{SHTOTAL} = 55N$

$\Sigma\tau_B = (-5m)(15N) - (2m)(40N) + F_A\,5m = 0$

$-75Nm - 80Nm = -F_A\,5m$

$F_A = \frac{-155Nm}{-5m} = 31N$

17) A light board that is 10 m long is supported by two sawhorses, one at one end of the board and a second at the midpoint. A 40-N weight is placed between the two sawhorses, 3.0 m from the end and 2.0 m from the center. What magnitude forces do the sawhorses exert on the board?
Answer: 16 N at the end, 24 N at the midpoint; Var: 1

$\Sigma F = 0 = -F_{g\,BOARD} - F_{gW} + F_{SHTOTAL} = 0$

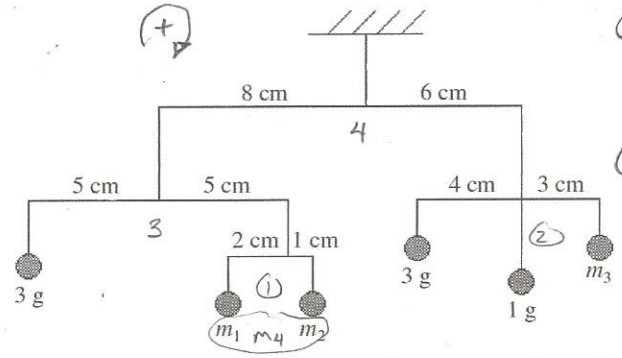
$F_{SHTOTAL} = F_{gW} = 40N$ || $\Sigma \tau_A = (3m)40N - (5m)F_{SHB} = 0$

$F_{SHB} = \frac{120Nm}{5m} = 24N$

$F_{SHA} = F_{SHTOTAL} - F_{SHB} = 40N - 24N = 16N$

18) A light board that is 10 m long is supported by two sawhorses, one at one end of the board and a second at the midpoint. A 40-N object is placed between the two sawhorses, 3.0 m from the end and 2.0 m from the center. A second object, with a weight of 15 N, is placed on the supported end. What magnitude forces do the sawhorses exert on the board?
SEE PRECEEDING PAGE
Answer: 1.0 N at the end, 54 N at the midpoint; Var: 1

19) The mobile shown in the figure is perfectly balanced, and the horizontal supports have insignificant masses. What must be the masses of the suspended objects m_1, m_2, and m_3 to maintain balance?



② $\Sigma \tau = 0 = (3g)(4cm) = m_3(3cm)$

$m_3 = \frac{12\,g\,cm}{3\,cm} = 4g$

① $m_1 + m_2 = 3g$

$m_1 = 3g - m_2$ → SUBSTITUTE

$m_1 = 3g - 2g = 1g$

$\Sigma \tau = 0 = (2cm)m_1 = (1cm)m_2$

$(2cm)(3g - m_2) = 1cm\,m_2$

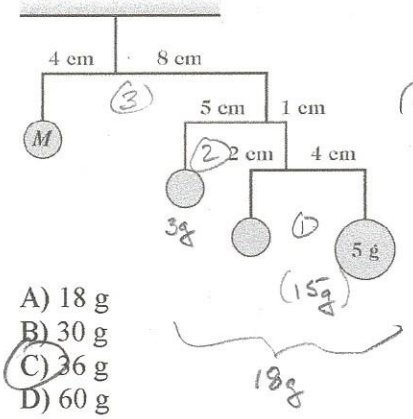
$6cm\,g - (2cm)m_2 = 1cm\,m_2$

$6cm\,g = 3cm\,m_2$

$m_2 = \frac{6cm\,g}{3cm} = 2g$

Answer: $m_1 = 1$ g, $m_2 = 2$ g, and $m_3 = 4$ g; Var: 1

20) A mobile is shown in the figure. The horizontal supports have negligible mass. Assume that all the numbers given in the figure are accurate to two significant figures. What mass M is required to balance the mobile?



① $\Sigma \tau = 0 \Rightarrow (4cm)(5g) = 2cm\,m_1$

$m_1 = 10g$

② $\Sigma \tau = 0 \Rightarrow (5cm)m_2 = 1cm(15g)$

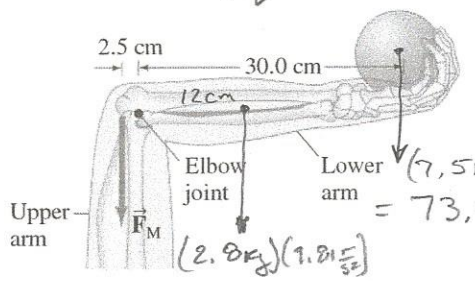
$m_2 = 3g$

③ $\Sigma \tau = 0 \Rightarrow 4cm\,M = (8cm)(18g)$

$M = 36g$

A) 18 g
B) 30 g
C) 36 g
D) 60 g
E) 90 g
Answer: C; Var: 1

21) An athlete holds a 7.5-kg shot put in his hand with his lower arm horizontal, as shown in the figure. His lower arm has a mass of 2.8 kg and its center of gravity (or center of mass) is 12 cm from the elbow-joint pivot. How much force must the extensor muscle (which is $\vec{F}_M$ in the figure) in the upper arm exert on the lower arm?



$(7.5\text{kg})(9.81\frac{m}{s^2}) = 73.575\text{kg}\frac{m}{s^2}$

$(2.8\text{kg})(9.81\frac{m}{s^2}) = 27.468\text{N}$

FIND: F_m ASSUME STATIC.

$\therefore \Sigma\tau = -F_m(.025\text{m}) + (.12\text{m})(27.468\text{N}) + (.30\text{m})(73.575\text{N}) = 0$

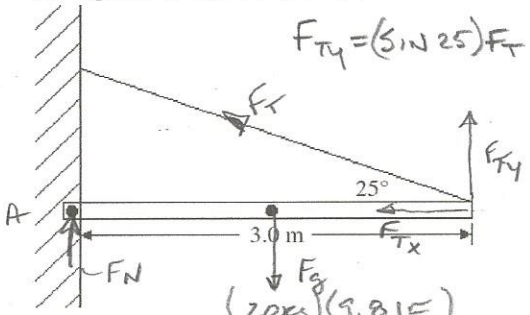
$0 = -F_m(.025\text{m}) + 3.296\text{Nm} + 22.07\text{Nm}$

$F_m = 1014.74\text{N}$

2 SIG FIGS $\underline{1000\text{N}}$

A) 100 N
B) 500 N
C) 1000 N
D) 1500 N
Answer: C; Var: 1

22) A store's sign has a mass of 20 kg and is 3.0 m long. It is uniform, so its center of gravity is at the center of the sign. It is supported horizontally by a small loose bolt attached to the wall at one end and by a wire at the other end, as shown in the figure. What is the tension in the wire?



$F_{Ty} = (\sin 25)F_T$ $\quad \Sigma F_y = F_N - F_g + F_{Ty} = 0$

THIS DOES NOT HELP MUCH BUT SELECT THE HINGE AS PIVOT AND SUM τ

$(20\text{kg})(9.81\frac{m}{s^2}) = 196.2\text{N}$

$\Sigma\tau_A = (+F_g)(1.5\text{m}) - (3\text{m})F_{Ty} = 0$

$\frac{(196.2\text{N})(1.5\text{m})}{3\text{m}} = F_{Ty}$

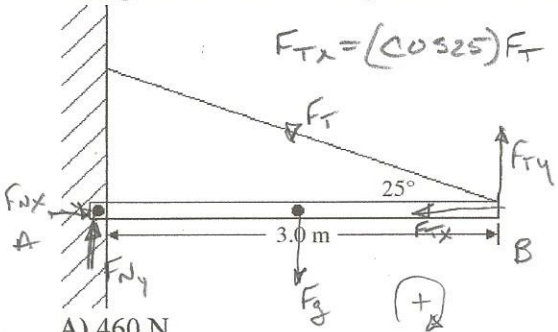
$F_{Ty} = 98.1\text{N}$

$F_{Ty} = (\sin 25)(F_T) = 98.1\text{N}$

$F_T = 232.12\text{N}$ 2SIGFIGS = 230N

A) 460 N
B) 230 N
C) 120 N
D) 200 N
E) 300 N
Answer: B; Var: 1

23) A store's sign has a mass of 20 kg and is 3.0 m long. It is uniform, so its center of gravity is at the center of the sign. It is supported horizontally by a small loose bolt attached to the wall at one end and by a wire at the other end, as shown in the figure. What is the magnitude of the *net* force that the bolt exerts on the sign?



$F_{Tx} = (\cos 25)F_T$ $\quad \Sigma F_y = F_{Ny} - F_g + F_{Ty} = 0$ $\quad F_T = 232.12$ FROM 22

$\Sigma F_x = F_{Nx} - F_{Tx} = 0$

$\Sigma\tau_B = -(1.5\text{m})(20\text{kg})(9.81\frac{m}{s^2}) + (3\text{m})F_{Ny} + F_{Ty}(0) = 0$

$F_{Ny} = \frac{294.3\text{Nm}}{3\text{m}} = 98.1\text{N}$

$F_{Tx} = (\cos 25)(232.12\text{N}) = 210.4\text{N} = F_{Nx}$

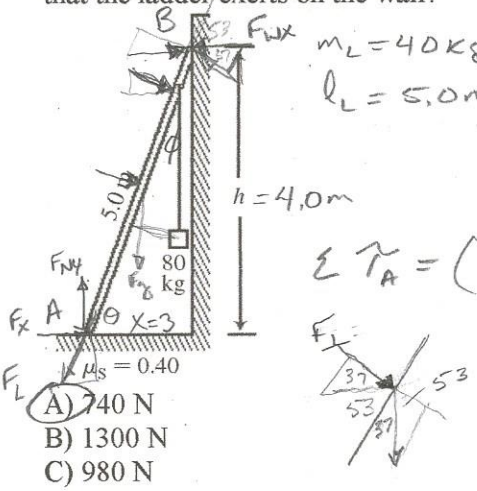
$F_{NNET} = \sqrt{(98.1\text{N})^2 + (210.4\text{N})^2} = \sqrt{9623.61 + 44268.16}$

$F_{NNET} = 232.15\text{N}$ 2SIGFIGS = 230N

A) 460 N
B) 230 N
C) 200 N
D) 120 N
E) 300 N
Answer: B
Var: 1

24) A 40-kg uniform ladder that is 5.0 m long is placed against a smooth wall at a height of $h = 4.0$ m, as shown in the

figure. The base of the ladder rests on a rough horizontal surface whose coefficient of static friction with the ladder is 0.40. An 80-kg bucket is suspended from the top rung of the ladder, just at the wall. What is the magnitude of the force that the ladder exerts on the wall?



$m_D = 80\,kg$ $\quad 5^2 = 4^2 + x^2 \Rightarrow x = 3$

$\sin\theta = \frac{4}{5}$ $\quad \theta = 53°$ $\quad \phi = 37°$

$\Sigma F_y = F_{Ny} - (40)(9.81) - (80)(9.81) = 0$

$\Sigma F_x = F_{Nx} - F_{Wx} = 0$

$F_{Nx} = F_{Wx}$

$\Sigma \tau_A = (\sin 37)(40\,kg)(9.81\,\frac{m}{s^2})(2.5m) + (\sin 37)(80\,kg)(9.81\,\frac{m}{s^2})(5m) - (F_{W\perp})(5m) = 0$

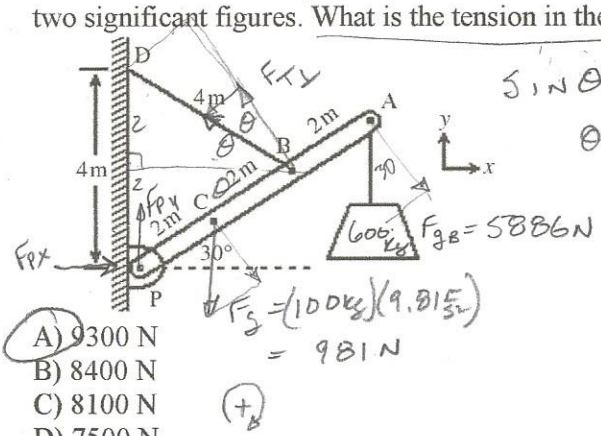
$590.4\,Nm + 2361.5\,Nm - F_{W\perp}\,5m = 0$

$F_{W\perp} = \frac{2951.9\,Nm}{5m} = 590.38N$

$F_{W\perp} = (\cos 37)F_{Wx} \Rightarrow F_{Wx} = \frac{F_{W\perp}}{\cos 37} = \frac{590.38N}{.7986} = 739.2N$

A) 740 N
B) 1300 N
C) 980 N
D) 900 N
E) 1100 N
Answer: A; Var: 50+

25) A 100-kg nonuniform boom that is 6.0 m long is loosely pinned at the pivot at P. A 600-kg concrete block is suspended from the end of the boom at A, as shown in the figure. The boom forms a 30° angle above the horizontal, and is supported by a 4.0-m cable between points D and B. Point B is 4.0 m from P, and point D is 4.0 m above P. The center of mass of the boom is at point C, which is 2.0 m from P. Assume that all the quantities shown in the figure are accurate to two significant figures. What is the tension in the cable connected between points B and D?



$\sin\theta = \frac{2}{4}$ $\quad \theta = 30$

$\Sigma \tau_P = 0 = (\cos 30)(981N)(2m) - (4m)(\cos 30)F_T + (\cos 30)(5886N)(6m) = 0$

$0 = 1699.1\,Nm - 3.46\,m\,F_T + 30584.6N$

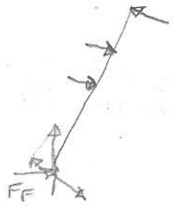
$F_T = \frac{32283.7\,Nm}{3.46m} = 9330.5N$

2 SIG FIGS $9300N$

A) 9300 N
B) 8400 N
C) 8100 N
D) 7500 N
E) 6900 N
Answer: A; Var: 7

26) In the figure, 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 the ladder and the floor is 0.50. What is the maximum value of x for which the ladder will not slip?

(26)



$$\Sigma F_y = F_{Ay} - 600N - 200N = 0$$

$$F_{Ay} = 800\,N$$

$$F_F = \mu F_N = (.5)(800N) = 400N$$

$$\Sigma F_x = F_F - F_{Wx} = 0$$

$$F_F = F_{Wx}$$

$$F_{Wx} = 400N \Rightarrow F_{W\perp} = F_{Wx}(\cos 40) = 306.4N$$

$$0 = \Sigma \tau_A = (+\cos 50)(200N)(5m) + (\cos 50)(600N)x - (306.4N)10m$$

$$0 = 642.8Nm + 385.7N(x) - 3064Nm$$

$$x = \frac{3064Nm - 642.8Nm}{385.7N} = \underline{6.28m}$$

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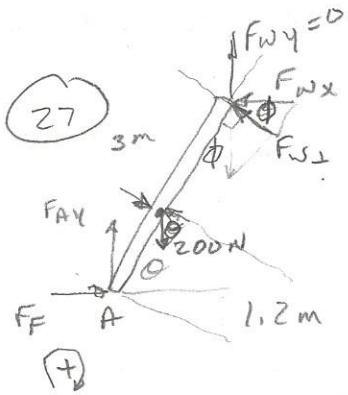
(27)



$\theta = 70.5°$ $\quad \phi = 19.5°$

$$\Sigma F_x = F_F - F_{Wx} = 0 \qquad F_N = F_{Ay} = 200N$$

$$F_F = F_{Wx}$$

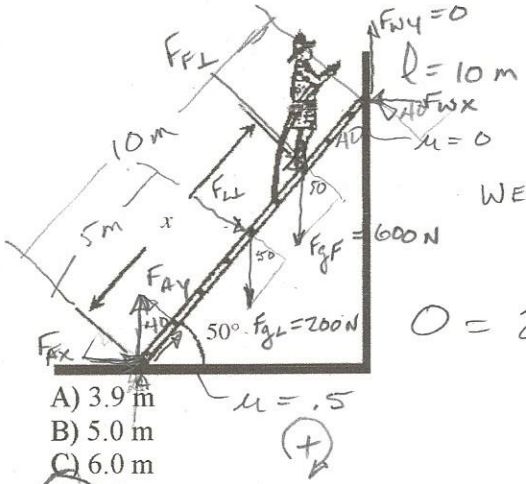
$$F_F = \mu F_N = F_{Wx} \Rightarrow F_{Wx} = \mu\, 200N$$

$$F_{W\perp} = \cos\phi\, F_{Wx} =$$

$$\Sigma \tau_A = (\cos 70.5)(200N)(1.2m) - F_{W\perp}(3m) = 0$$

$$80.1Nm - \cos(19.5)(F_{Wx})\,3m = 0$$

$$F_{Wx} = \frac{80.1Nm}{(\cos 19.5)(3m)} = \underline{28.3N}$$



F_{WX}: X_{MAX}

WEIGHT = 800N

$\Sigma F_y = F_{AY} - 200N - 600N = 0$

$F_{AY} = 800N = F_N$

$F_F = \mu F_N = (.5)(800N) = 400N$

$\Sigma F_x = F_F - F_{WX} = 0$

$F_F = 400N = F_{WX}$

$F_{W\perp} = F_{WX}(\cos 40) = (400N)(.766) = 306.4\,N$

$0 = \Sigma \tau_A = (\cos 50)(200N)(5m) + (\cos 50)(600N)x - (F_{W\perp})10m$

$0 = 642.8\,Nm + 385.7\,N(x) - 3064\,Nm$

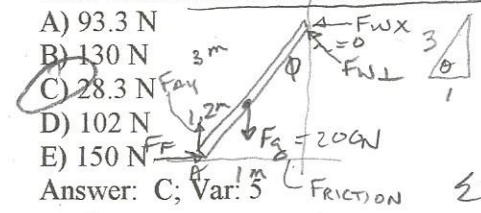
$x = \dfrac{3064Nm - 642Nm}{385.7N} = 6.28\,m$

2 SIG FIGS 6.3 m

A) 3.9 m
B) 5.0 m
C) 6.0 m
D) 6.3 m
E) 8.4 m
Answer: D; Var: 1

SIMPLER VERSION OF 26

27) A 3.00-m-long ladder, weighing 200 N, leans against a smooth vertical wall with its base on a horizontal rough floor, a distance of 1.00 m away from the wall. The ladder is not completely uniform, so its center of gravity is 1.20 m from its base. What force of friction must the floor exert on the base of the ladder to prevent the ladder from sliding down?



$\cos\theta = \frac{1}{3}$ (3, 1, θ)

$\theta = 70.5°$

$\phi = 19.5°$

$\Sigma F_x = F_F - F_{WX} = 0$

$F_F = F_{WX}$

$F_N = F_{AY} = 200N$

$F_F = \mu F_N = F_{WX} \Rightarrow F_{WX} = \mu 200N$

$F_{W\perp} = \cos\phi\, F_{WX}$

$\Sigma \tau_A = (\cos 70.5)(200N)(1.2m) - F_{W\perp}(3m) = 80.1Nm - (\cos 19.5)(F_{WX})3m = 0$

$F_{WX} = \dfrac{80.1Nm}{(\cos 19.5)3m} = 28.3\,N$

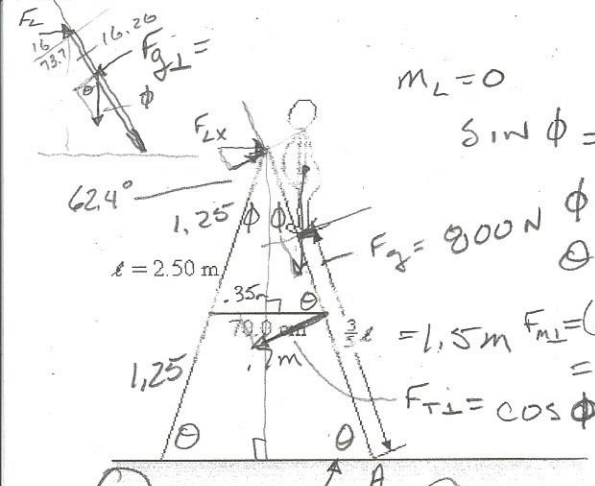
A) 93.3 N
B) 130 N
C) 28.3 N
D) 102 N
E) 150 N
Answer: C; Var: 5

28) A 5.00-m-long uniform ladder, weighing 200 N, rests against a smooth vertical wall with its base on a horizontal rough floor, a distance of 1.20 m away from the wall. The coefficient of static friction between the ladder and the floor is 0.200. How far up the ladder, measured along the ladder, can a 600-N person climb before the ladder begins to slip?

SAME AS 26

A) 1.50 m
B) 1.26 m
C) 1.05 m
D) 3.95 m
E) 4.56 m
Answer: E; Var: 5

29) A stepladder consists of two halves that are hinged at the top and connected by a tie rod which keeps the two halves from spreading apart. In this particular instance, the two halves are 2.5 m long, the tie rod is connected to the center of each half and is 70 cm long. An 800-N person stands 3/5 of the way up the stepladder, as shown in the figure. The ladder is light enough that we can neglect its weight, and it rests on an extremely smooth floor. What is the tension in the tie rod? (*Note:* To solve this problem, it is helpful to imagine cutting the ladder in half vertically and consider the forces and torques acting on each half of the ladder.)



A) 140 N
B) 240 N
C) 280 N
D) 360 N
E) 560 N
Answer: A; Var: 1

FIND: F_T

$m_L = 0$

$\sin\phi = \frac{.35}{1.25}$

$\phi = 16.26°$

$\theta = 73.74°$

$F_g = 800\,N$

$\ell = 1.5m$ $F_{\perp} = (\cos\theta)\,800\,N$

$= 224\,N$

$F_{T\perp} = \cos\phi\, F_{TX}$

$\sum \tau_A = (F_{L\perp})(2.5m) - (F_{m\perp})(1.5m) - F_{T\perp}(1.25m) = 0$

$(\cos 73.74°)F_{LX} - (224\,N)(1.5m)(\cos 73.74) - (\cos 16.26°)F_T = 0$

$\cos 73.74\, F_{LX} - 94.1\,Nm - (.96)F_{TX} = 0$

$\cos 73.74\, F_{TX} - 94.1\,Nm - .96F_{TX} = 0$

$-.68F_{TX} = 94.1\,Nm$

$F_{TX} = 138.4\,N$

$2\,SIG\,FIGS = 140\,N$

$u = 0$ (+)

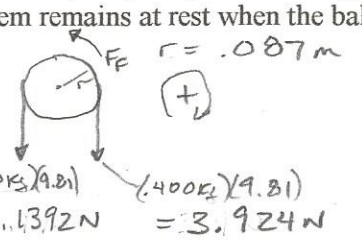
$F_{L\perp} = (\cos\phi)F_{LX}$

$\sum F_X = F_{LX} - F_{TX} = 0$

$F_{LX} = F_{TX}$

30) A 320-g ball and a 400-g ball are attached to the two ends of a string that goes over a pulley with a radius of 8.7 cm. Because of friction in its axle, the pulley does not begin to rotate. What is the magnitude of the frictional torque at the axle of the pulley if the system remains at rest when the balls are released?

A) 0.068 N · m
B) 0.61 N · m
C) 0.079 N · m
D) 0.063 N · m
E) 0.00070 N · m
Answer: A; Var: 1



$r = .087\,m$ (+)

$(.320\,kg)(9.81) = 3.1392\,N$

$(.400\,kg)(9.81) = 3.924\,N$

$\sum \tau = (3.924N)(.087m) - (3.139N)(.087m) - \tau_F = 0$

$= .3414\,Nm - .2731\,Nm = \tau_F$

$\tau_F = .0683\,Nm$

35) When a 125-kg piece of equipment is hung from a steel wire of diameter 6.00 mm, it stretches the wire by 4.00 mm. If instead the wire had a diameter of 3.00 mm, but all else were the same, by what distance would the same equipment stretch the wire?

A) 16.0 mm
B) 8.00 mm
C) 4.00 mm
D) 2.00 mm
E) 1.00 mm
Answer: A; Var: 1

36) When a 125-kg piece of equipment is hung from a steel wire of length 75 cm, it stretches the wire by 4.00 mm. If instead the wire had a length of 150 cm, but all else were the same, by what distance would the same equipment stretch the wire?

A) 16.0 mm
B) 8.00 mm
C) 4.00 mm
D) 2.00 mm
E) 1.00 mm
Answer: B; Var: 1