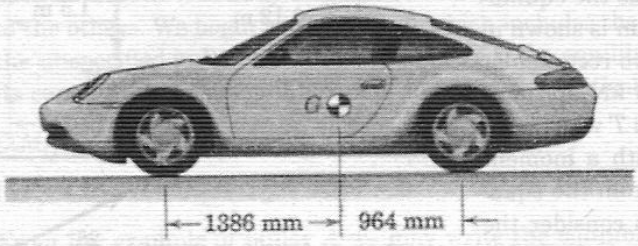
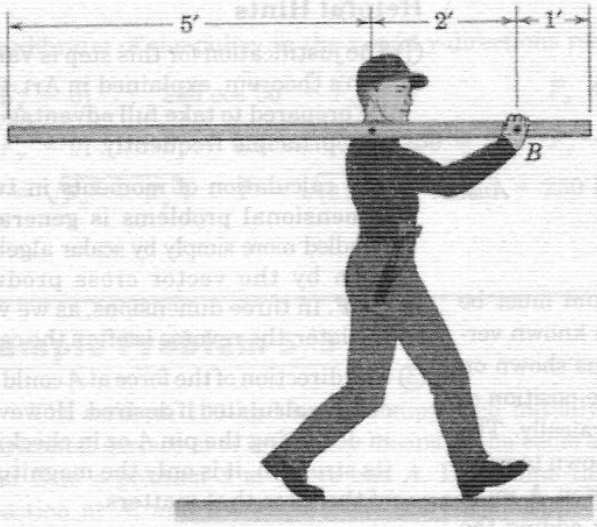
1 The mass center G of the 1400-kg rear-engine car is located as shown in the figure. Determine the normal force under each tire when the car is in equilibrium. State any assumptions.

Ans. $N_f = 2820$ N, $N_r = 4050$ N



Problem 1

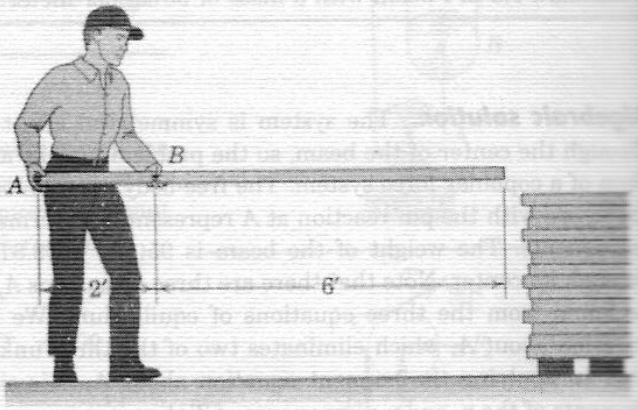
2 A carpenter carries a 12-lb 2-in. by 4-in. board as shown. What downward force does he feel on his shoulder at A?



Problem 2

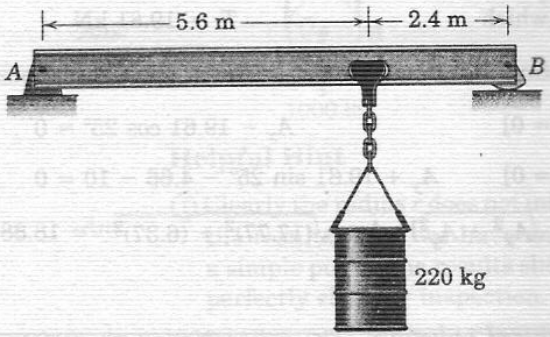
3 A carpenter holds a 12-lb 2-in. by 4-in. board as shown. If he exerts vertical forces on the board, determine the forces at A and B.

Ans. $N_A = 12$ lb down, $N_B = 24$ lb up



Problem 3

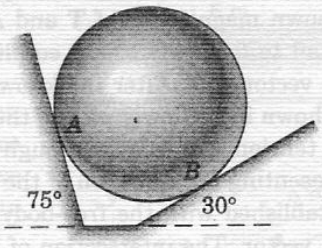
4 The 450-kg uniform I-beam supports the load shown. Determine the reactions at the supports.



Problem 4

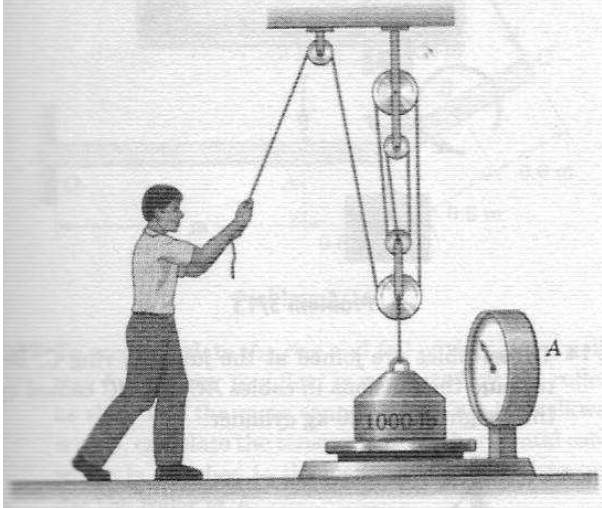
5 The 20-kg homogeneous smooth sphere rests on the two inclines as shown. Determine the contact forces at A and B.

Ans. $N_A = 101.6$ N, $N_B = 196.2$ N



Problem 5

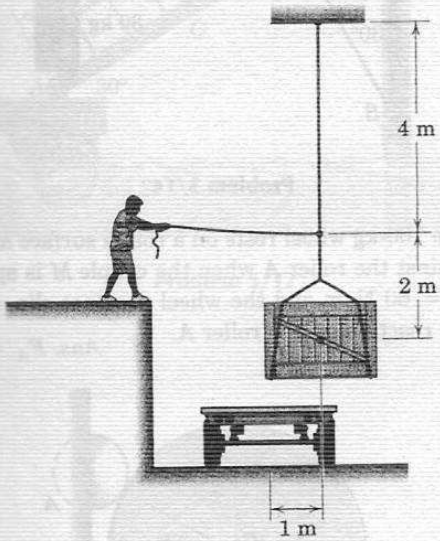
6 With what force magnitude T must the person pull on the cable in order to cause the scale A to read 500 lb? The weights of the pulleys and cables are negligible. State any assumptions.



Problem 6

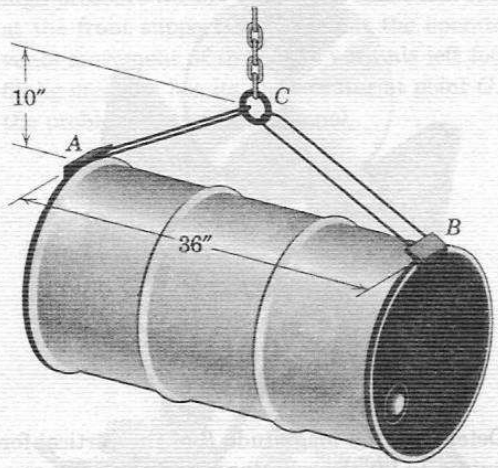
7 What horizontal force P must a worker exert on the rope to position the 50-kg crate directly over the trailer?

Ans. $P = 126.6$ N



Problem 7

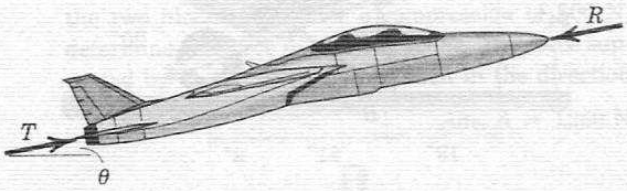
8 The 600-lb drum is being hoisted by the lifting device which hooks over the end lips of the drum. Determine the tension T in each of the equal-length rods which form the two U-shaped members of the device.



Problem 8

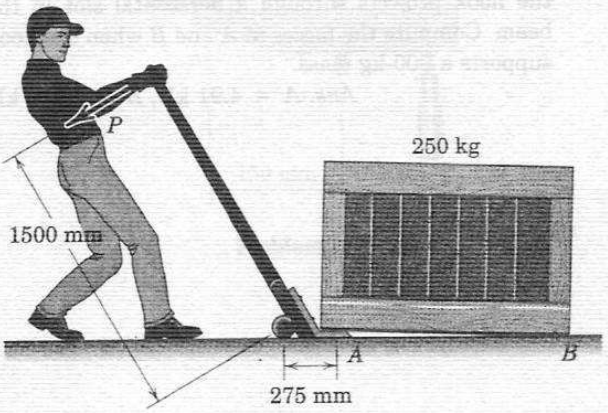
9 What fraction n of the weight W of a jet airplane is the net thrust (nozzle thrust T minus air resistance R) in order for the airplane to climb with a constant speed at an angle θ with the horizontal?

Ans. $n = \sin\theta$



Problem 9

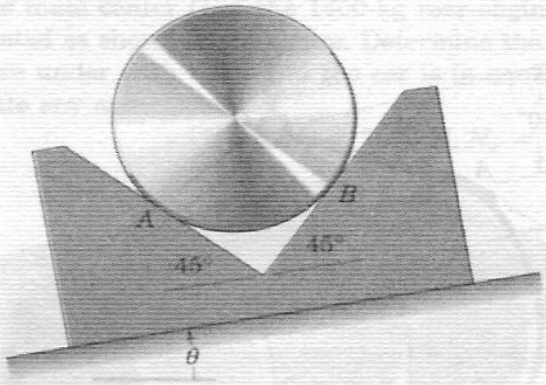
10 Determine the force magnitude P required to lift one end of the 250-kg crate with the lever dolly as shown. State any assumptions.



Problem 10

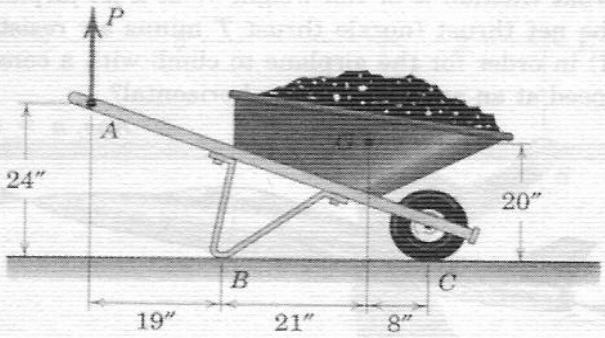
11 Find the angle of tilt θ with the horizontal so that the contact force at B will be one-half that at A for the smooth cylinder.

Ans. $\theta = 18.43°$



Problem 11

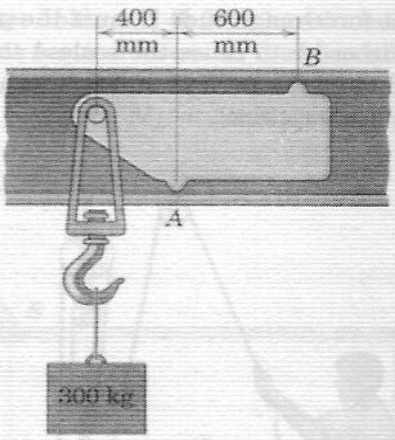
12 Determine the magnitude P of the vertical force required to lift the wheelbarrow free of the ground at point B. The combined weight of the wheelbarrow and its load is 240 lb with center of gravity at G.



Problem 12

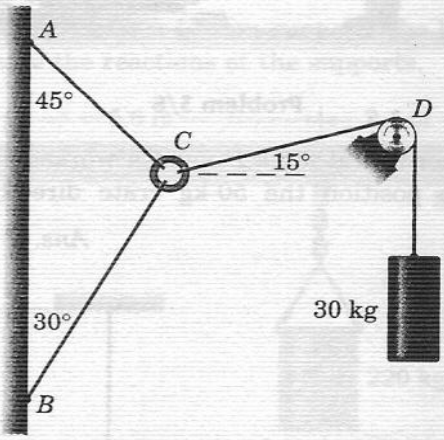
13 To facilitate shifting the position of a lifting hook when it is not under load, the sliding hanger shown is used. The projections at A and B engage the flanges of a box beam when a load is supported, and the hook projects through a horizontal slot in the beam. Compute the forces at A and B when the hook supports a 300-kg mass.

Ans. $A = 4.91$ kN, $B = 1.962$ kN



Problem 13

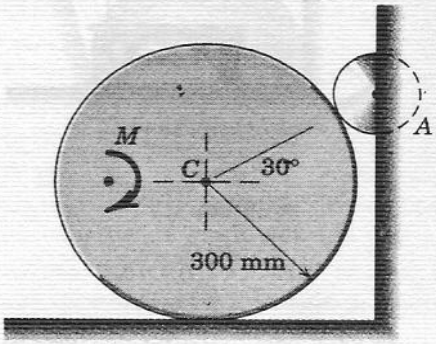
14 Three cables are joined at the junction ring C. Determine the tensions in cables AC and BC caused by the weight of the 30-kg cylinder.



Problem 14

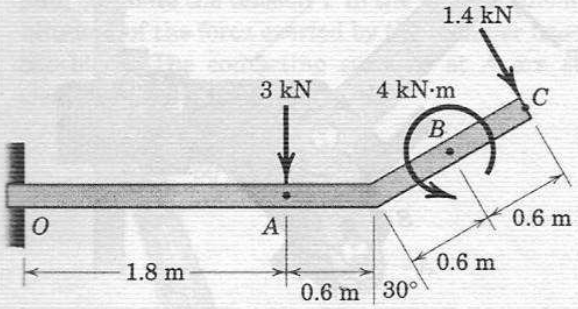
15 The 100-kg wheel rests on a rough surface and bears against the roller A when the couple M is applied. If $M = 60$ N·m and the wheel does not slip, compute the reaction on the roller A.

Ans. $F_A = 231$ N



Problem 15

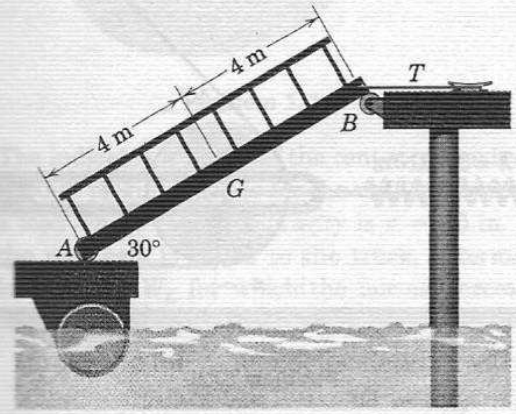
16 The uniform beam has a mass of 50 kg per meter of length. Compute the reactions at the support O. The force loads shown lie in a vertical plane.



Problem 16

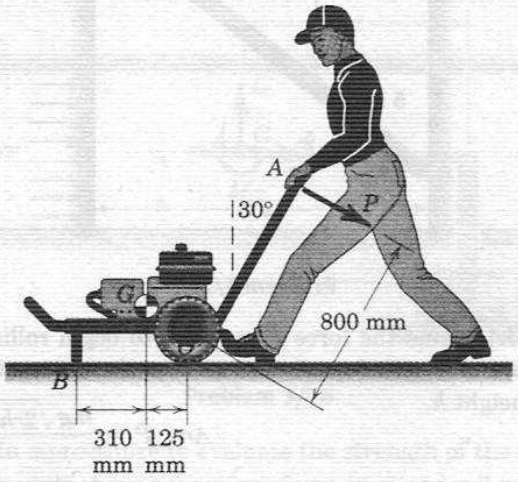
17 To accommodate the rise and fall of the tide, a walkway from a pier to a float is supported by two rollers as shown. If the mass center of the 300-kg walkway is at G, calculate the tension T in the horizontal cable which is attached to the cleat and find the force under the roller at A.

Ans. $T = 850$ N, $A = 1472$ N



Problem 17

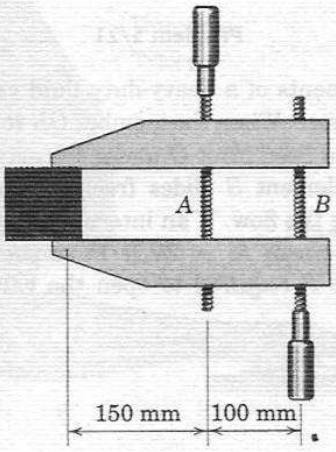
18 Determine the magnitude P of the force which the man must exert perpendicular to the handle of the high-pressure washer in order to cause loss of contact at the front support B. Note that the operator prevents movement of the wheel with his left foot. The 60-kg machine has its mass center at point G. Treat the problem as two-dimensional.



Problem 18

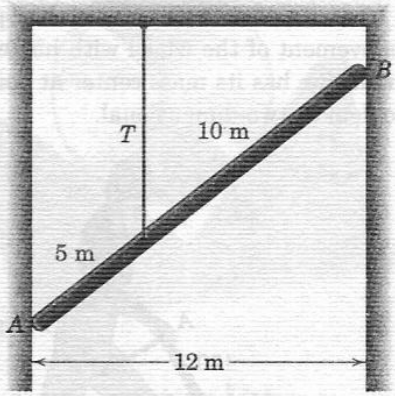
19 If the screw B of the wood clamp is tightened so that the two blocks are under a compression of 500 N, determine the force in screw A. (*Note:* The force supported by each screw may be taken in the direction of the screw.)

Ans. $A = 1250$ N



Problem 19

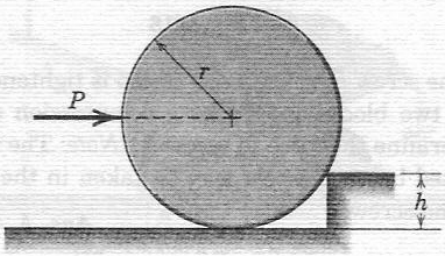
20 The uniform 15-m pole has a mass of 150 kg and is supported by its smooth ends against the vertical walls and by the tension T in the vertical cable. Compute the reactions at A and B.



Problem 20

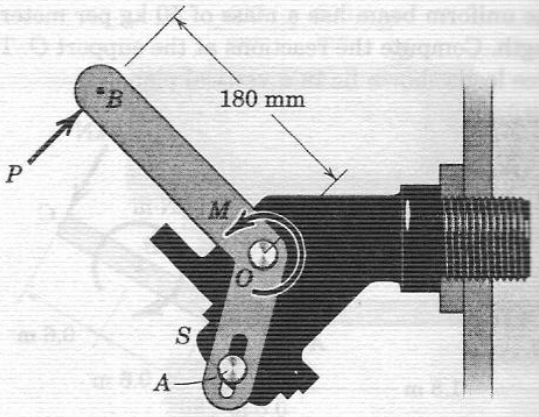
21 Determine the force P required to begin rolling the uniform cylinder of mass m over the obstruction of height h.

Ans. $P = \dfrac{mg\sqrt{2rh - h^2}}{r - h}$



Problem 21

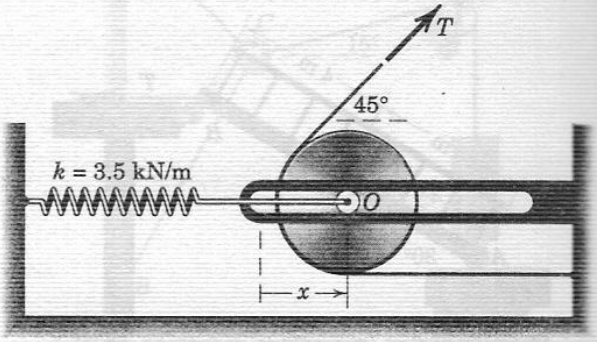
22 The elements of a heavy-duty fluid valve are shown in the figure. When the member OB rotates clockwise about the fixed pivot O under the action of the force P, the element S slides freely upward in its slot, releasing the flow. If an internal torsional spring exerts a moment $M = 20$ N·m as shown, determine the force P required to open the valve. Neglect all friction.



Problem 22

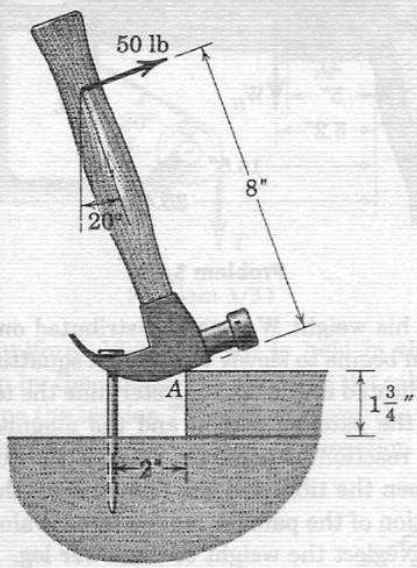
23 The spring of modulus $k = 3.5$ kN/m is stretched 10 mm when the disk center O is in the leftmost position $x = 0$. Determine the tension T required to position the disk center at $x = 150$ mm. At that position, what force N is exerted on the horizontal slotted guide? The mass of the disk is 3 kg.

Ans. $T = 328$ N, $N = 203$ N



Problem 23

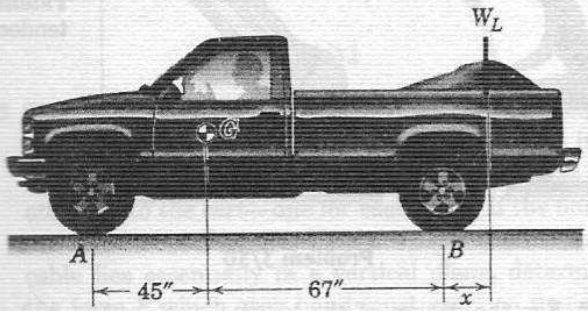
24 A block placed under the head of the claw hammer as shown greatly facilitates the extraction of the nail. If a 50-lb pull on the handle is required to pull the nail, calculate the tension T in the nail and the magnitude A of the force exerted by the hammer head on the block. The contacting surfaces at A are sufficiently rough to prevent slipping.



Problem 24

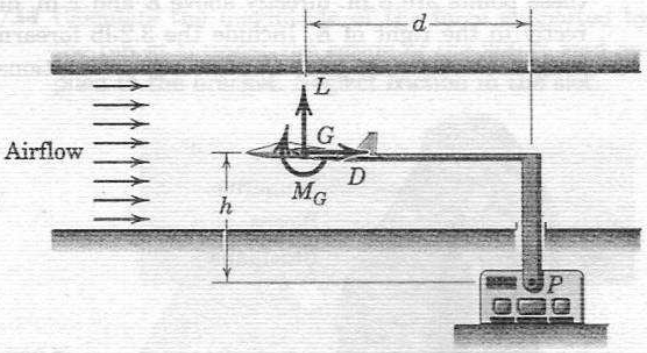
25 The indicated location of the center of gravity of the 3600-lb pickup truck is for the unladen condition. If a load whose center of gravity is $x = 16$ in. behind the rear axle is added to the truck, determine the load weight W_L for which the normal forces under the front and rear wheels are equal.

Ans. $W_L = 550$ lb



Problem 25

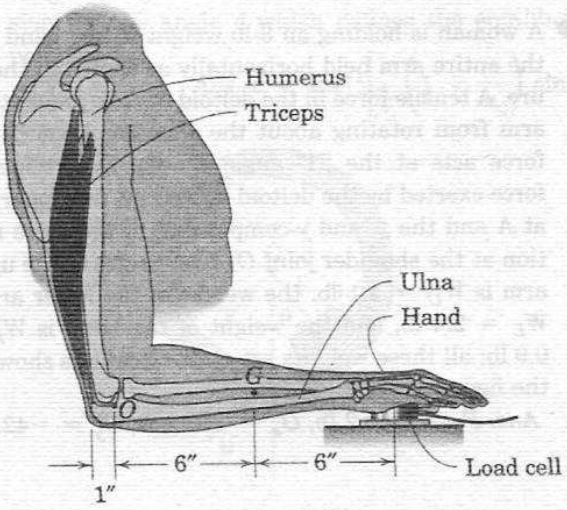
26 To test the validity of aerodynamic assumptions made in the design of the aircraft, its model is being tested in a wind tunnel. The support bracket is connected to a force and moment balance, which is zeroed when there is no airflow. Under test conditions, the lift L, drag D, and pitching moment M_G act as shown. The force balance records the lift, drag, and a moment M_P. Determine M_G in terms of L, D, and M_P.



Problem 26

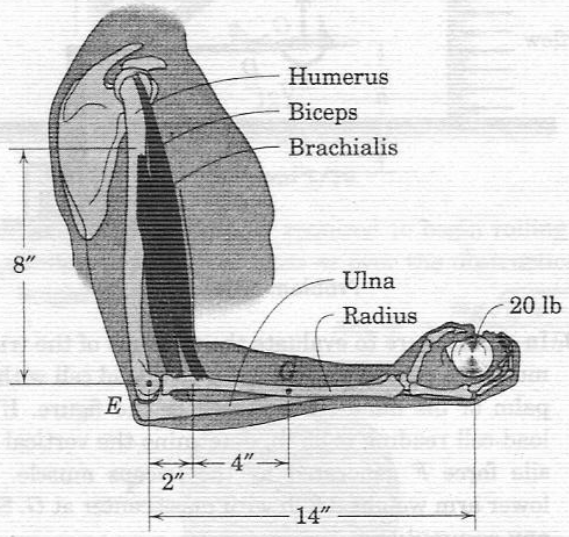
27 In a procedure to evaluate the strength of the triceps muscle, a person pushes down on a load cell with the palm of his hand as indicated in the figure. If the load-cell reading is 35 lb, determine the vertical tensile force F generated by the triceps muscle. The lower arm weighs 3.2 lb with mass center at G. State any assumptions.

Ans. $F = 401$ lb



Problem 27

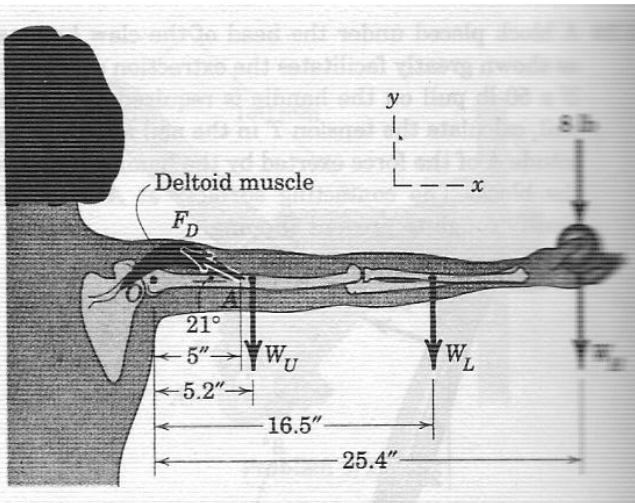
28 A person is performing slow arm curls with a 20-lb weight as indicated in the figure. The brachialis muscle group (consisting of the biceps and brachialis muscles) is the major factor in this exercise. Determine the magnitude F of the brachialis-muscle-group force and the magnitude E of the elbow joint reaction at point E for the forearm position shown in the figure. Take the dimensions shown to locate the effective points of application of the two muscle groups; these points are 8 in. directly above E and 2 in. directly to the right of E. Include the 3.2-lb forearm weight which acts at point G. State any assumptions.



Problem 28

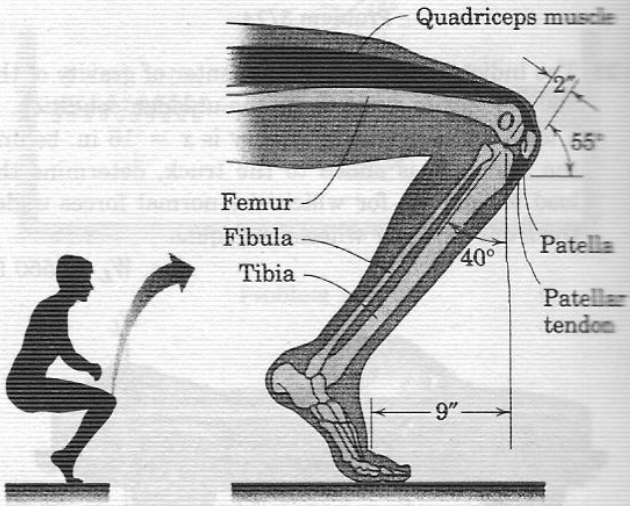
29 A woman is holding an 8-lb weight in her hand with the entire arm held horizontally as shown in the figure. A tensile force in the deltoid muscle prevents the arm from rotating about the shoulder joint O; this force acts at the 21° angle shown. Determine the force exerted by the deltoid muscle on the upper arm at A and the x- and y-components of the force reaction at the shoulder joint O. The weight of the upper arm is $W_U = 4.1$ lb, the weight of the lower arm is $W_L = 2.4$ lb, and the weight of the hand is $W_H = 0.9$ lb; all these weights act at the locations shown in the figure.

Ans. $F_D = 160.2$ lb, $O_x = 149.5$ lb, $O_y = -42.2$ lb



Problem 29

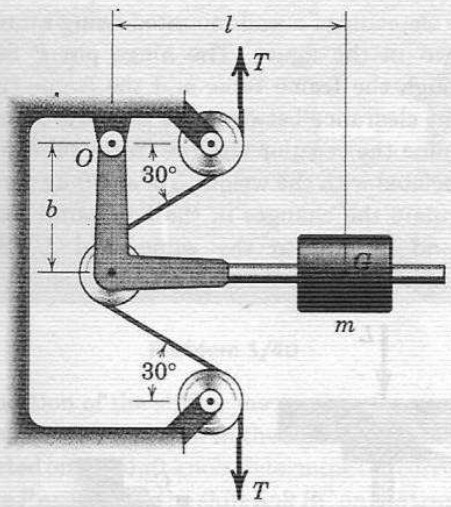
30 With his weight W equally distributed on both feet, a man begins to slowly rise from a squatting position as indicated in the figure. Determine the tensile force F in the patellar tendon and the magnitude of the force reaction at point O, which is the contact area between the tibia and the femur. Note that the line of action of the patellar tendon force is along its midline. Neglect the weight of the lower leg.



Problem 30

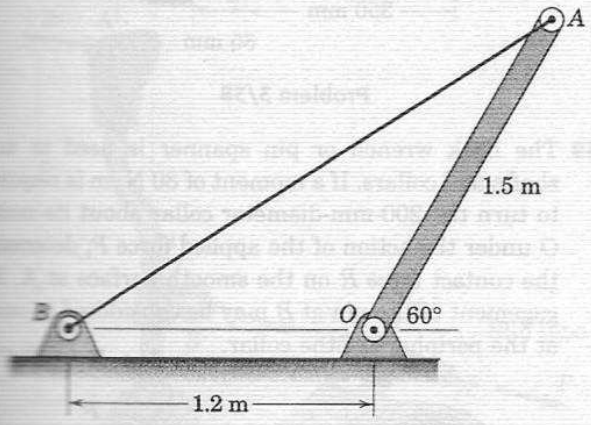
31 For the design of the belt-tensioning device, determine the dimension l if the mass m maintains a specified tension T in the belt for the position shown. Neglect the mass of the arm and central pulley compared with m. Also determine the magnitude R of the force supported by the pin at O.

Ans. $l = \dfrac{Tb\sqrt{3}}{mg}$, $R = \sqrt{3T^2 + m^2g^2}$



Problem 31

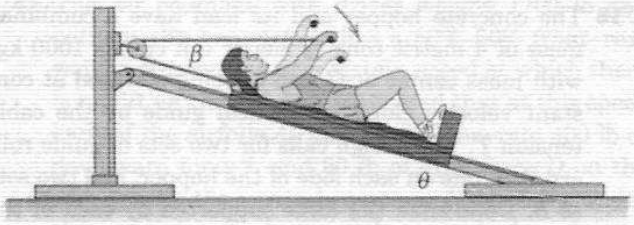
32 The uniform 18-kg bar OA is held in the position shown by the smooth pin at O and the cable AB. Determine the tension T in the cable and the magnitude and direction of the external pin reaction at O.



Problem 32

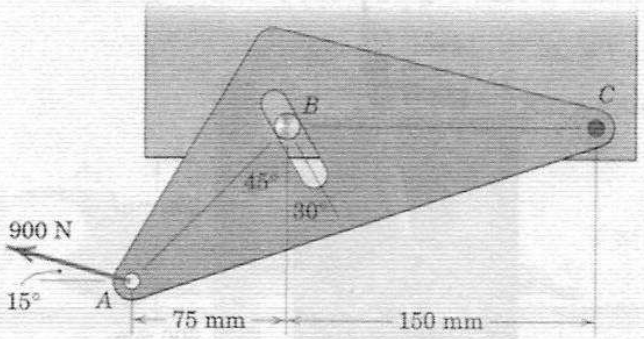
33 The exercise machine is designed with a lightweight cart which is mounted on small rollers so that it is free to move along the inclined ramp. Two cables are attached to the cart—one for each hand. If the hands are together so that the cables are parallel and if each cable lies essentially in a vertical plane, determine the force P which each hand must exert on its cable in order to maintain an equilibrium position. The mass of the person is 70 kg, the ramp angle θ is 15°, and the angle β is 18°. In addition, calculate the force R which the ramp exerts on the cart.

Ans. $P = 45.5$ N, $R = 691$ N



Problem 33

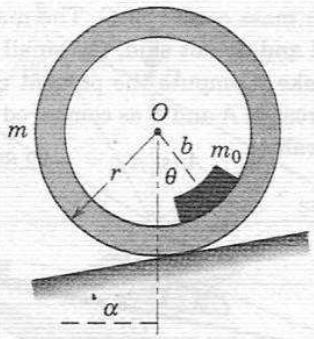
34 Calculate the magnitude of the force supported by the pin at C under the action of the 900-N load applied to the bracket. Neglect friction in the slot.



Problem 34

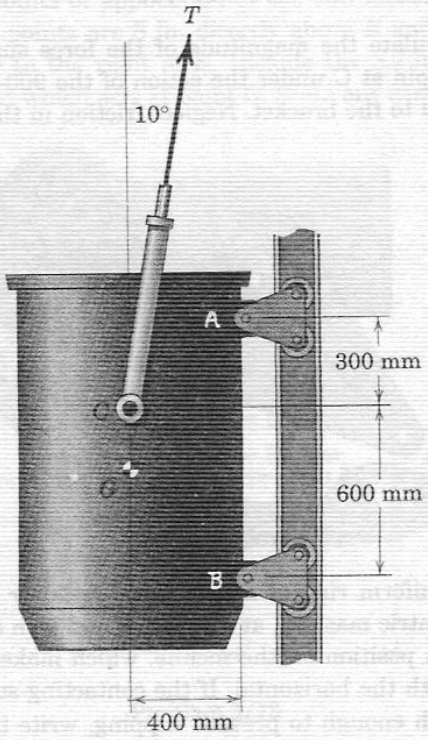
35 A uniform ring of mass m and radius r carries an eccentric mass m_0 at a radius b and is in an equilibrium position on the incline, which makes an angle α with the horizontal. If the contacting surfaces are rough enough to prevent slipping, write the expression for the angle θ which defines the equilibrium position.

Ans. $\theta = \sin^{-1}\left[\dfrac{r}{b}\left(1 + \dfrac{m}{m_0}\right)\sin\alpha\right]$



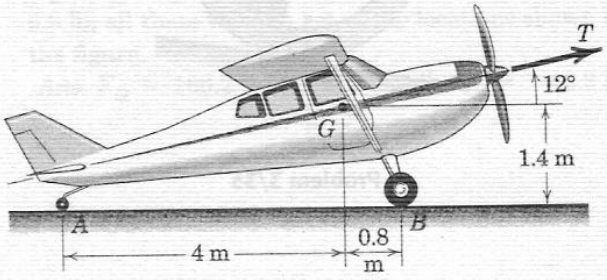
Problem 35

36 The concrete hopper and its load have a combined mass of 4 metric tons (1 metric ton equals 1000 kg) with mass center at G and is being elevated at constant velocity along its vertical guide by the cable tension T. The design calls for two sets of guide rollers at A, one on each side of the hopper, and two sets at B. Determine the force supported by each of the two pins at A and by each of the two pins at B.



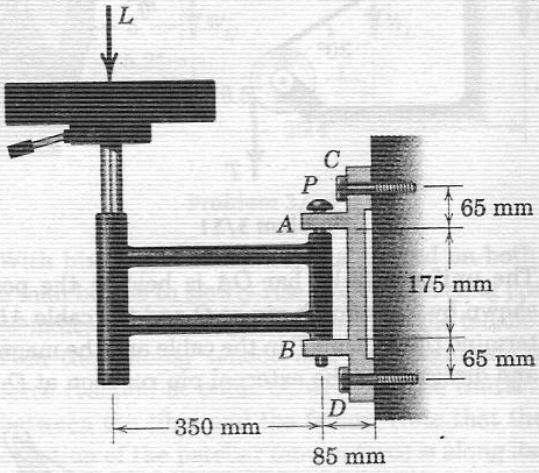
Problem 36

37 During an engine test on the ground, a propeller thrust $T = 3000$ N is generated on the 1800-kg airplane with mass center at G. The main wheels at B are locked and do not skid; the small tail wheel at A has no brake. Compute the percent change n in the normal forces at A and B as compared with their "engine-off" values. *Ans.* $n_A = -32.6\%$, $n_B = 2.28\%$



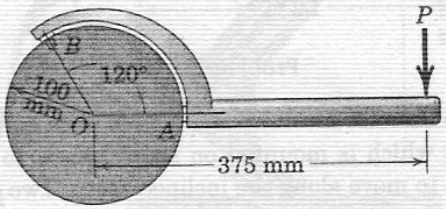
Problem 37

38 The elements of a wall-mounted swing-away stool are shown in the figure. The hinge pin P fits loosely through the frame tube, and the frame tube has a slight clearance between the supports A and B. Determine the reactions on the frame tube at A and B associated with the weight L of an 80-kg person. Also, calculate the changes in the horizontal reactions at C and D due to the same load L. State any assumptions.



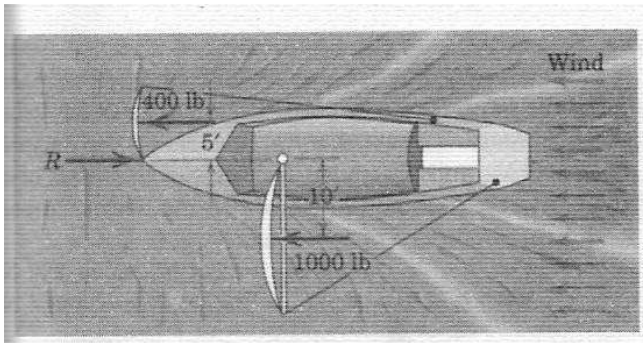
Problem 38

39 The hook wrench or pin spanner is used to turn shafts and collars. If a moment of 80 N · m is required to turn the 200-mm-diameter collar about its center O under the action of the applied force P, determine the contact force R on the smooth surface at A. Engagement of the pin at B may be considered to occur at the periphery of the collar. *Ans.* $R = 1047$ N



Problem 39

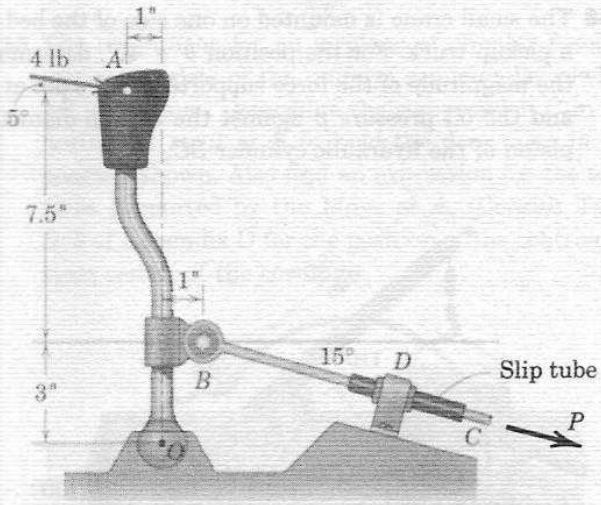
40 In sailing at a constant speed with the wind, the sailboat is driven by a 1000-lb force against its mainsail and a 400-lb force against its staysail as shown. The total resistance due to fluid friction through the water is the force R. Determine the resultant of the lateral forces perpendicular to motion applied to the hull by the water.



Problem 40

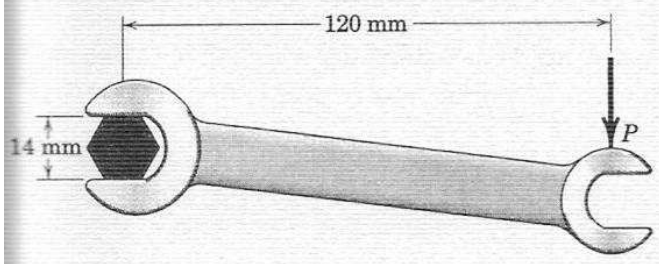
41 A portion of the shifter mechanism for a manual car transmission is shown in the figure. For the 4-lb force exerted on the shift knob, determine the corresponding force P exerted by the shift link BC on the transmission (not shown). Neglect friction in the ball-and- socket joint at O, in the joint at B, and in the slip tube near support D. Note that a soft rubber bushing at D allows the slip tube to self-align with link BC.

Ans. $P = 13.14$ lb



Problem 41

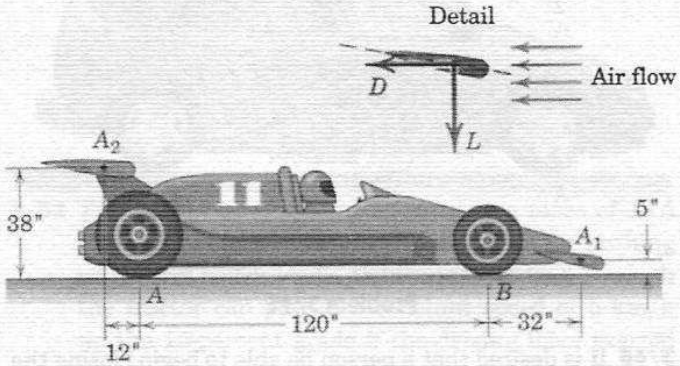
42 A torque (moment) of 24 N · m is required to turn the bolt about its axis. Determine P and the forces between the smooth hardened jaws of the wrench and the corners A and B of the hexagonal head. Assume that the wrench fits easily on the bolt so that contact is made at corners A and B only.



Problem 42

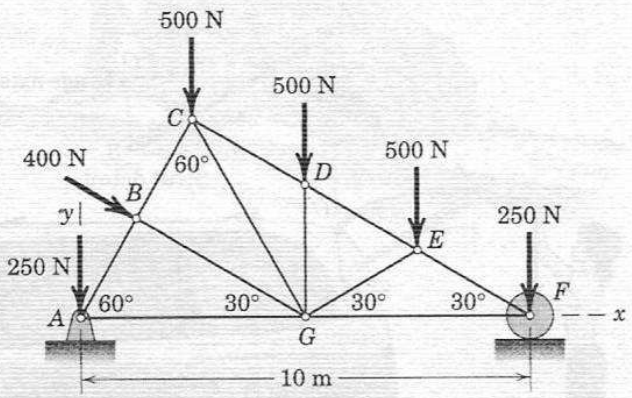
43 The car complete with driver weighs 1700 lb and without the two airfoils has a 50%–50% front–rear weight distribution at a certain speed at which there is no lift on the car. It is estimated that at this speed each of the airfoils A_1 and A_2 will generate 400 lb of downward force L and 50 lb of drag force D on the car. Specify the vertical reactions N_A and N_B under the two pairs of wheels at that speed when the airfoils are added. Assume that the addition of the airfoils does not affect the drag and zero-lift conditions of the car body itself and that the engine has sufficient power for equilibrium at that speed. The weight of the airfoils may be neglected.

Ans. $N_A = 1201$ lb (48.0%), $N_B = 1299$ lb (52.0%)



Problem 43

44 Determine the external reactions at A and F for the roof truss loaded as shown. The vertical loads represent the effect of the supported roofing materials, while the 400-N force represents a wind load.



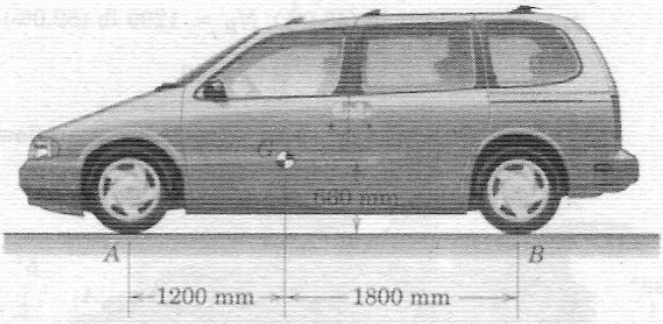
Problem 44

45 Calculate the normal forces associated with the front and rear wheel pairs of the 1600-kg front-wheel-drive van. Then repeat the calculations when the van (*a*) climbs a 10-percent grade and (*b*) descends a 10-percent grade, both at constant speed. Compute the percent changes n_A and n_B in the normal forces compared with the nominal values. Be sure to recognize that propulsive and braking forces are present for cases (*a*) and (*b*).

Ans. $N_A = 9420$ N, $N_B = 6280$ N

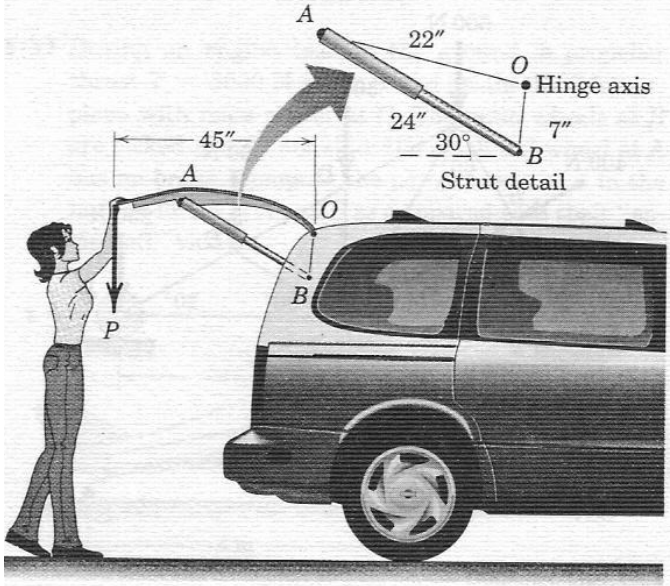
(*a*) $N_A = 9030$ N (−4.14%), $N_B = 6590$ N (+4.98%)

(*b*) $N_A = 9710$ N (+3.15%), $N_B = 5900$ N (−5.97%)



Problem 45

46 It is desired that a person be able to begin closing the van hatch from the open position shown with a 10-lb vertical force P. As a design exercise, determine the necessary force in each of the two hydraulic struts AB. The mass center of the 90-lb door is 1.5 in. directly below point A. Treat the problem as two-dimensional.

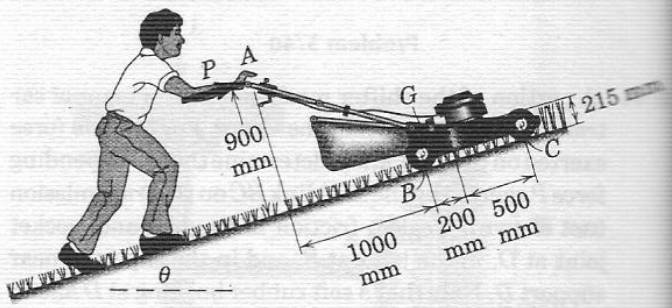


Problem 46

47 The man pushes the lawn mower at a steady speed with a force P that is parallel to the incline. The mass of the mower with attached grass bag is 50 kg with mass center at G. If $\theta = 15°$, determine the normal forces N_B and N_C under each pair of wheels B and C. Neglect friction. Compare with the normal forces for the conditions of $\theta = 0$ and $P = 0$.

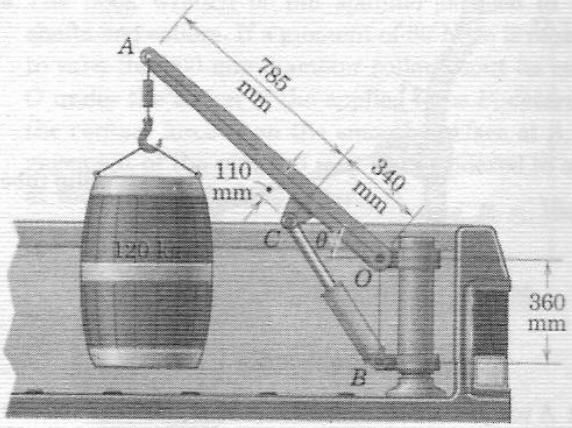
Ans. $N_B = 214$ N, $N_C = 260$ N

With $\theta = P = 0$: $N_B = 350$ N, $N_C = 140.1$ N



Problem 47

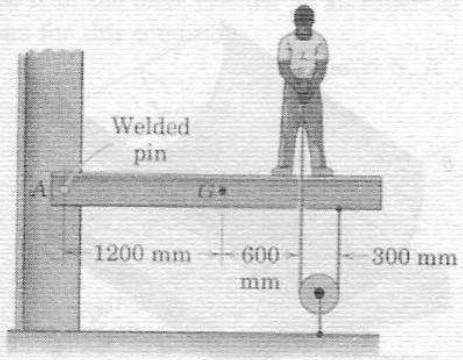
48 The small crane is mounted on one side of the bed of a pickup truck. For the position $\theta = 40°$, determine the magnitude of the force supported by the pin at O and the oil pressure p against the 50-mm-diameter piston of the hydraulic cylinder BC.



Problem 48

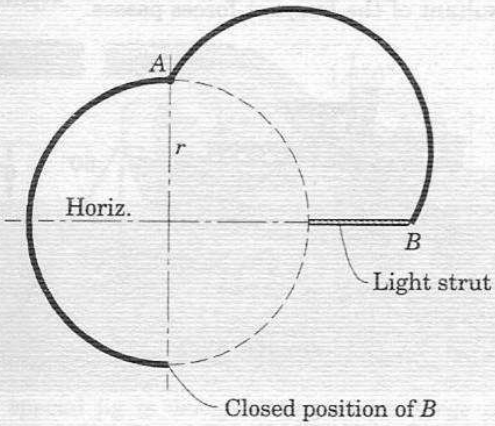
49 The pin A, which connects the 200-kg steel beam with center of gravity at G to the vertical column, is welded both to the beam and to the column. To test the weld, the 80-kg man loads the beam by exerting a 300-N force on the rope which passes through a hole in the beam as shown. Calculate the torque (couple) M supported by the pin.

Ans. $M = 4.94$ kN·m CCW



Problem 49

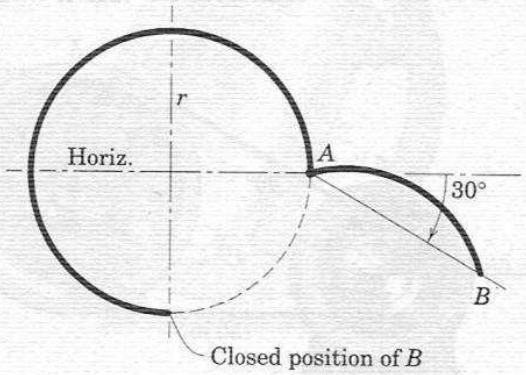
50 The cargo door for an airplane of circular fuselage section consists of the uniform semicircular cowling AB of mass m. Determine the compression C in the horizontal strut at B to hold the door open in the position shown. Also find an expression for the total force supported by the hinge at A. (Consult Table D/3 of Appendix D for the position of the centroid or mass center of the cowling.)



Problem 50

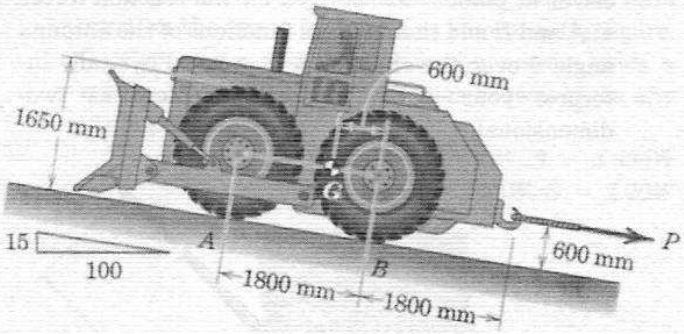
51 The cargo door for an airplane of circular fuselage section consists of the uniform quarter-circular segment AB of mass m. A detent in the hinge at A holds the door open in the position shown. Determine the moment exerted by the hinge on the door.

Ans. $M_A = 0.709mgr$ CCW



Problem 51

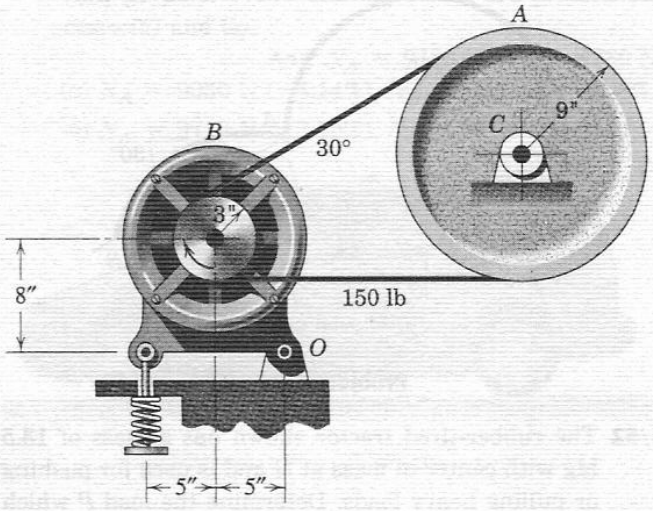
52 The rubber-tired tractor shown has a mass of 13.5 Mg with center of mass at G and is used for pushing or pulling heavy loads. Determine the load P which the tractor can pull at a constant speed of 5 km/h up the 15-percent grade if the driving force exerted by the ground on each of its four wheels is 80 percent of the normal force under that wheel. Also find the total normal reaction N_B under the rear pair of wheels at B.



Problem 52

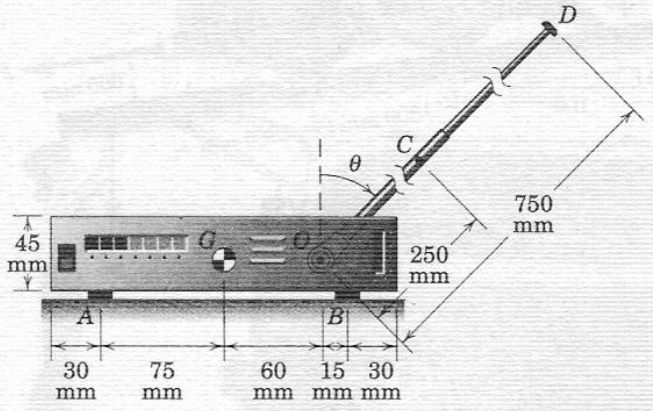
53 Pulley A delivers a steady torque (moment) of 900 lb-in. to a pump through its shaft at C. The tension in the lower side of the belt is 150 lb. The driving motor B weighs 200 lb and rotates clockwise. As a design consideration, determine the magnitude R of the force on the supporting pin at O.

Ans. $R = 287$ lb



Problem 53

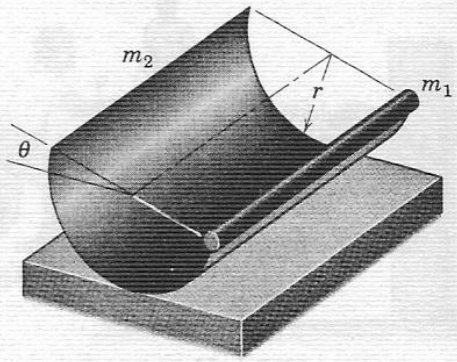
54 The receiving unit for a wireless microphone system, exclusive of the antenna, has a mass of 1100 grams with mass center at G. A single 375-g half-wave antenna with mass center at C is mounted to the receiver at point O as shown. Plot the reaction forces at A and B and their sum as functions of the antenna angle θ over the range $0 \le \theta \le 90°$. Physically interpret your plot. Treat the problem as two-dimensional.



Problem 54

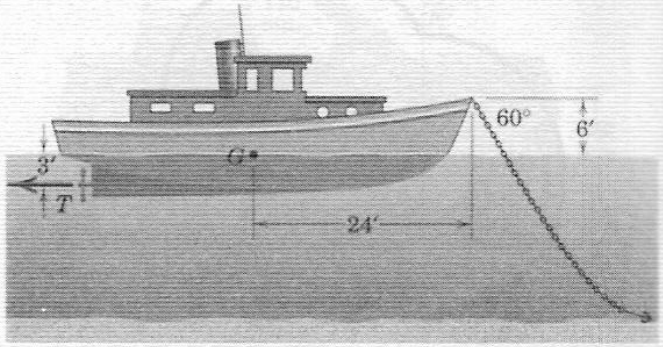
55 A slender rod of mass m_1 is welded to the horizontal edge of a uniform semicylindrical shell of mass m_2. Determine an expression for the angle θ with the horizontal made by the diameter of the shell through m_1. (Consult Table D/3 in Appendix D to locate the center of gravity of the semicircular section.)

Ans. $\theta = \tan^{-1}\dfrac{\pi m_1}{2m_2}$



Problem 55

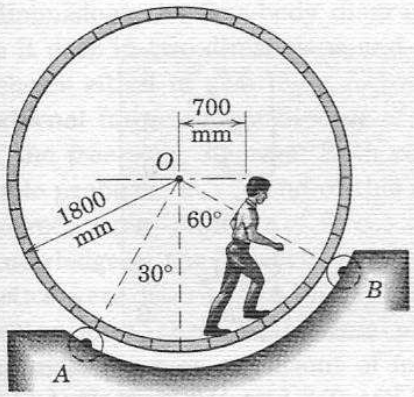
56 When setting the anchor so that it will dig into the sandy bottom, the engine of the 80,000-lb cruiser with center of gravity at G is run in reverse to produce a horizontal thrust T of 500 lb. If the anchor chain makes an angle of 60° with the horizontal, determine the forward shift b of the center of buoyancy from its position when the boat is floating free. The center of buoyancy is the point through which the resultant of the buoyant forces passes.



Problem 56

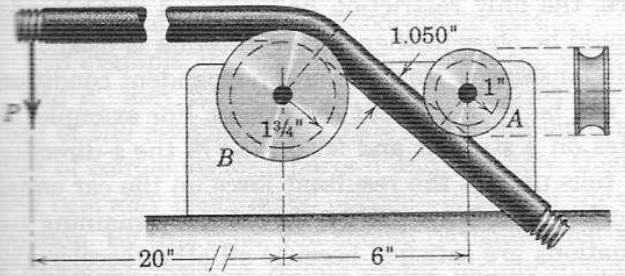
57 The uniform 400-kg drum is mounted on a line of rollers at A and a line of rollers at B. An 80-kg man moves slowly a distance of 700 mm from the vertical centerline before the drum begins to rotate. All rollers are perfectly free to rotate, except one of them at B which must overcome appreciable friction in its bearing. Calculate the friction force F exerted by that one roller tangent to the drum and find the magnitude R of the force exerted by all rollers at A on the drum for this condition.

Ans. $F = 305$ N, $R = 3770$ N



Problem 57

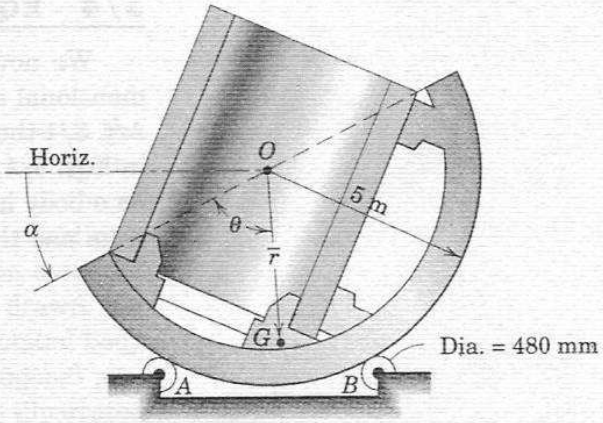
58 The pipe bender consists of two grooved pulleys mounted and free to turn on a fixed frame. The pipe is bent into the shape shown by a force $P = 60$ lb. Calculate the forces supported by the bearings of the pulleys.



Problem 58

59 A special jig is designed to position large concrete pipe sections (shown in gray) and consists of an 80-Mg sector mounted on a line of rollers at A and a line of rollers at B. One of the rollers at B is a gear which meshes with a ring of gear teeth on the sector so as to turn the sector about its geometric center O. When $\alpha = 0$, a counterclockwise torque of 2460 N·m must be applied to the gear at B to keep the assembly from rotating. When $\alpha = 30°$, a clockwise torque of 4680 N·m is required to prevent rotation. Locate the mass center G of the jig by calculating $\bar{r}$ and θ. Note that the mass center of the pipe section is at O.

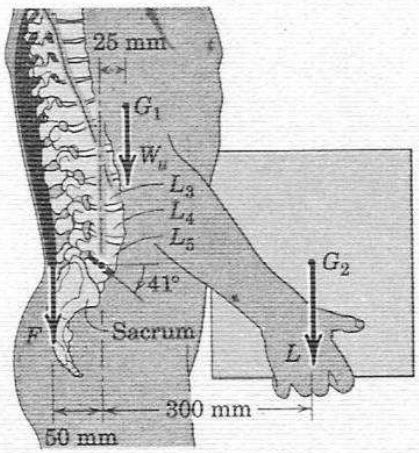
Ans. $\bar{r} = 367$ mm, $\theta = 79.8°$



Problem 59

60 The lumbar portion of the human spine supports the entire weight of the upper torso and the force load imposed on it. We consider here the disk (shaded red) between the lowest vertebra of the lumbar region (L_5) and the uppermost vertebra of the sacrum region. (*a*) For the case $L = 0$, determine the compressive force C and the shear force S supported by this disk in terms of the body weight W. The weight W_u of the upper torso (above the disk in question) is 68% of the total body weight W and acts at G_1. The vertical force F which the rectus muscles of the back exert on the upper torso acts as shown in the figure. (*b*) Repeat for the case when the person holds a weight of magnitude $L = W/3$ as shown. State any assumptions.

Ans. (*a*) $C = 0.770W$, $S = 0.669W$
(*b*) $C = 2.53W$, $S = 2.20W$



Problem 60