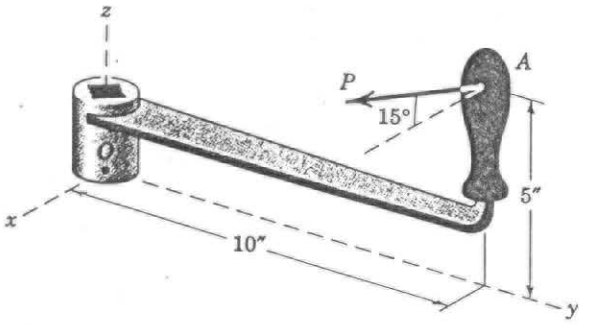
PROBLEMS

Introductory Problems

1 A force of magnitude $P = 40$ lb is applied to the stationary machine handle as shown. Write the force and moment reactions at O as vectors. Neglect the weight of the handle assembly.

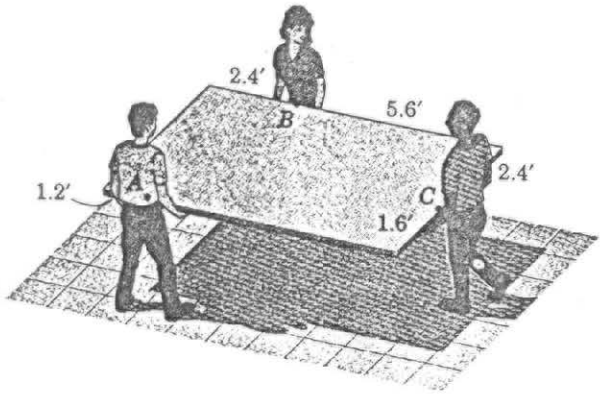
Ans. $\mathbf{R} = -38.6\mathbf{i} - 10.35\mathbf{k}$ lb

$\mathbf{M} = -103.5\mathbf{i} - 193.2\mathbf{j} + 386\mathbf{k}$ lb-in.



Problem 1

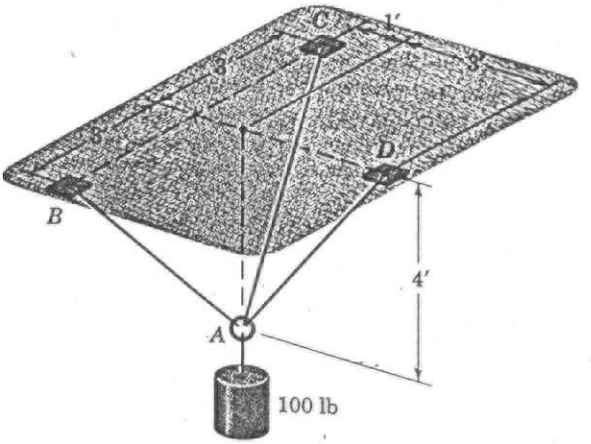
2 Three workers are carrying a 4-ft by 8-ft panel in the horizontal position shown. If the homogeneous panel weighs 100 lb, estimate the lifting force exerted by each worker.



Problem 2

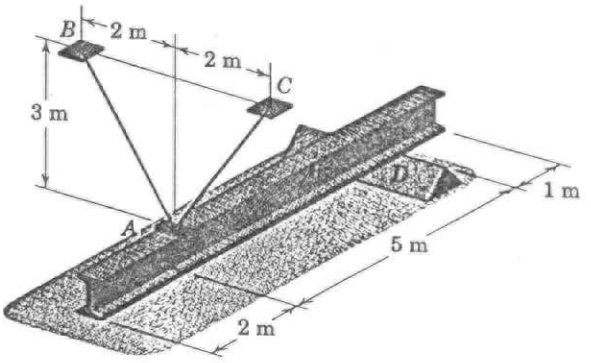
3 Determine the tensions in cables AB, AC, and AD.

Ans. $T_{AB} = 47.8$ lb, $T_{AC} = 47.8$ lb, $T_{AD} = 31.2$ lb



Problem 3

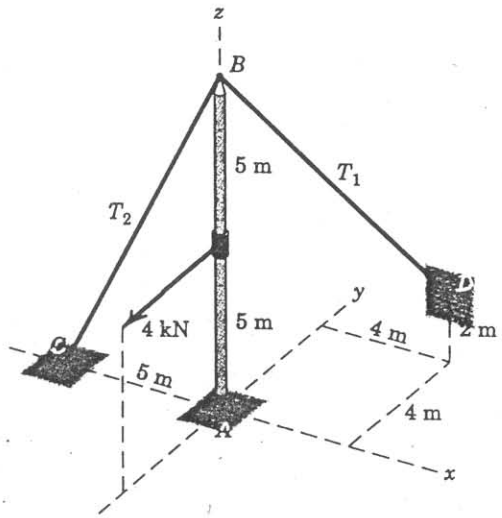
4 The uniform I-beam has a mass of 60 kg per meter of its length. Determine the tension in the two supporting cables and the reaction at D.



Problem 4

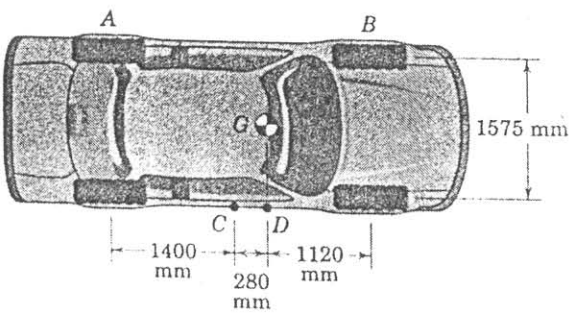
5 The vertical mast supports the 4-kN force and is constrained by the two fixed cables BC and BD and by a ball-and-socket connection at A. Calculate the tension T_1 in BD. Can this be accomplished by using only one equation of equilibrium?

Ans. $T_1 = 4.90$ kN



Problem 5

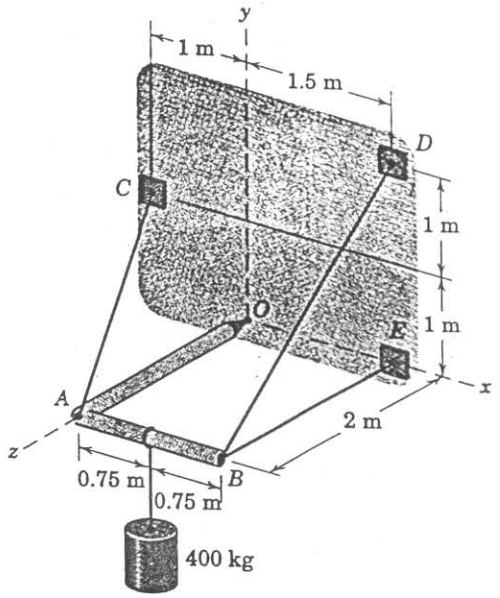
6 An overhead view of a car is shown in the figure. Two different locations C and D are considered for a single jack. In each case, the entire right side of the car is lifted just off the ground. Determine the normal reaction forces at A and B and the vertical jacking force required for the case of each jacking location. Consider the 1600-kg car to be rigid. The mass center G is on the midline of the car.



Problem 6

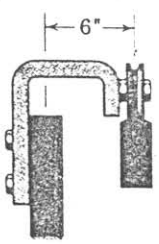
7 The light right-angle boom which supports the 400-kg cylinder is supported by three cables and a ball-and-socket joint at O attached to the vertical x-y surface. Determine the reactions at O and the cable tensions.

Ans. $O_x = 1962$ N, $O_y = 0$, $O_z = 6540$ N
$T_{AC} = 4810$ N, $T_{BD} = 2770$ N, $T_{BE} = 654$ N

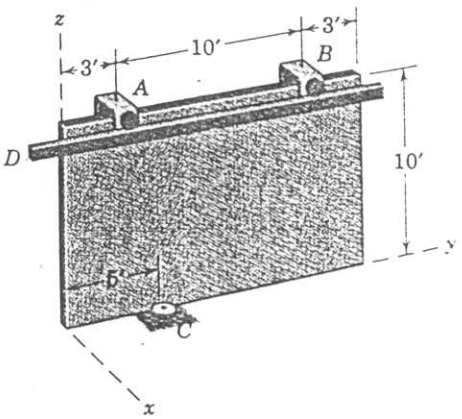


Problem 7

8 The industrial door is a uniform rectangular panel weighing 1200 lb and rolls along the fixed rail D on its hanger-mounted wheels A and B. The door is maintained in a vertical plane by the floor-mounted guide roller C, which bears against the bottom edge. For the position shown compute the horizontal side thrust on each of the wheels A and B, which must be accounted for in the design of the brackets.



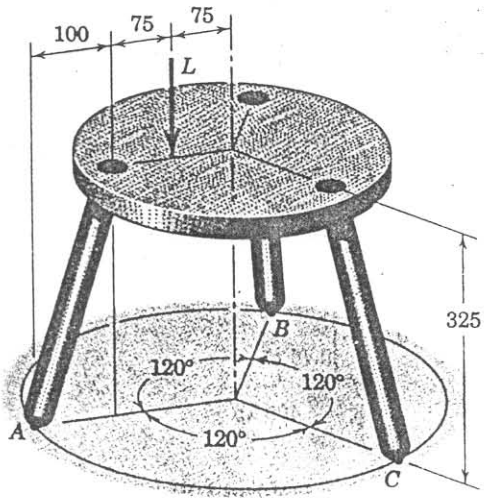
Detail of door hanger



Problem 8

9 A three-legged stool is subjected to the load L as shown. Determine the vertical force reaction under each leg. Neglect the weight of the stool.

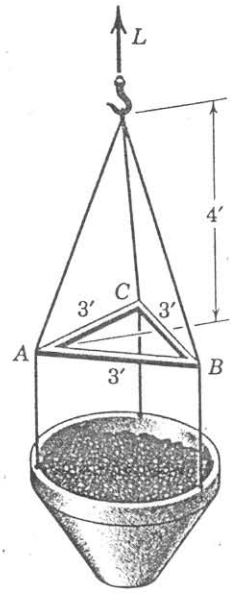
Ans. $N_A = 0.533L, N_B = N_C = 0.233L$



Dimensions in millimeters

Problem 9

10 Calculate the compression P in each leg of the equilateral spreader frame ABC, which ensures the application of equal vertical forces to the rim of the concrete hopper. The total load L is 840 lb. Note that determination of P would be a first step in the design of the frame.

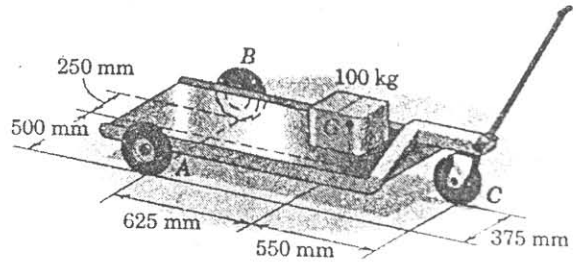


Problem 10

Representative Problems

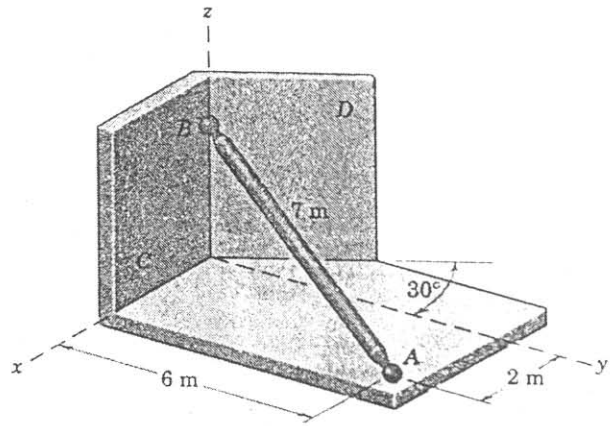
11 The three-wheel truck is used to carry the 100-kg box as shown. Calculate the changes in the normal force reactions at the three wheels due to the weight of the box.

Ans. $\Delta N_A = 66.1$ N, $\Delta N_B = 393$ N
$\Delta N_C = 522$ N



Problem 11

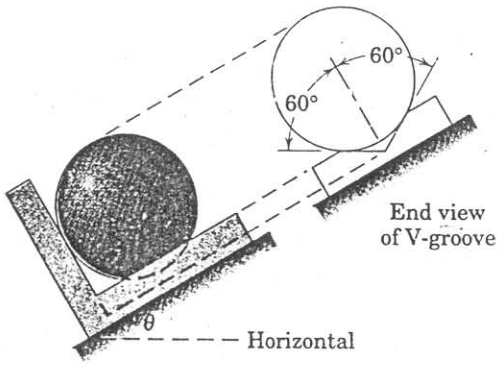
12 One of the vertical walls supporting end B of the 200-kg uniform shaft of Sample Problem 3/5 is turned through a 30° angle as shown here. End A is still supported by the ball-and-socket connection in the horizontal x-y plane. Calculate the magnitudes of the forces **P** and **R** exerted on the ball end B of the shaft by the vertical walls C and D, respectively.



Problem 12

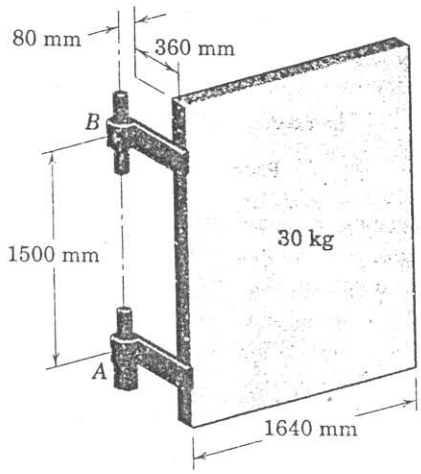
13 The smooth homogeneous sphere rests in the 120° groove and bears against the end plate which is normal to the direction of the groove. Determine the angle θ, measured from the horizontal, for which the reaction on each side of the groove equals the force supported by the end plate.

Ans. $\theta = 30°$



Problem 13

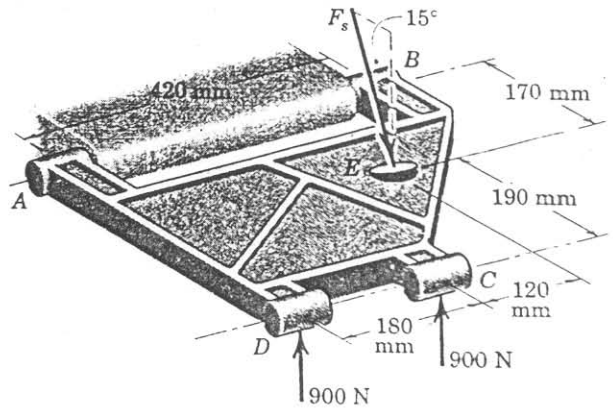
14 The mass center of the 30-kg door is in the center of the panel. If the weight of the door is supported entirely by the lower hinge A, calculate the magnitude of the total force supported by the hinge at B.



Problem 14

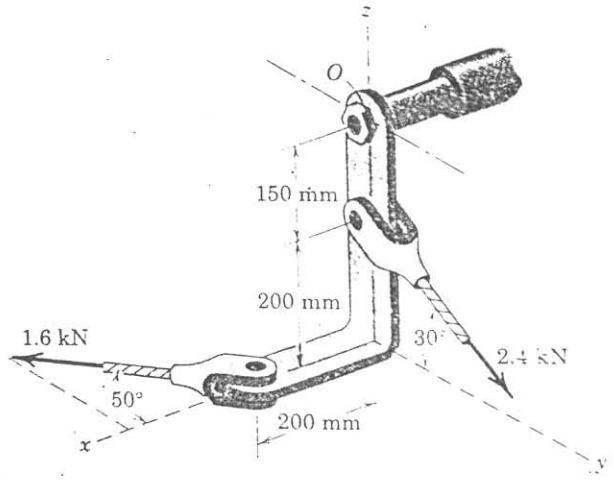
15 As part of a check on its design, a lower A-arm (part of an automobile suspension) is supported by bearings at A and B and subjected to the pair of 900-N forces at C and D. The suspension spring, not shown for clarity, exerts a force F_S at E as shown, where E is in plane $ABCD$. Determine the magnitude F_S of the spring force and the magnitudes F_A and F_B of the bearing forces at A and B which are perpendicular to the hinge axis AB.

Ans. $F_S = 3950$ N, $F_A = 437$ N, $F_B = 2450$ N



Problem 15

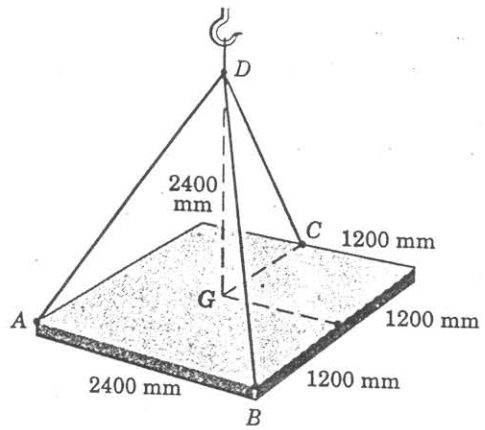
16 Determine the magnitudes of the force **R** and couple **M** exerted by the nut and bolt on the loaded bracket at O to maintain equilibrium.



Problem 16

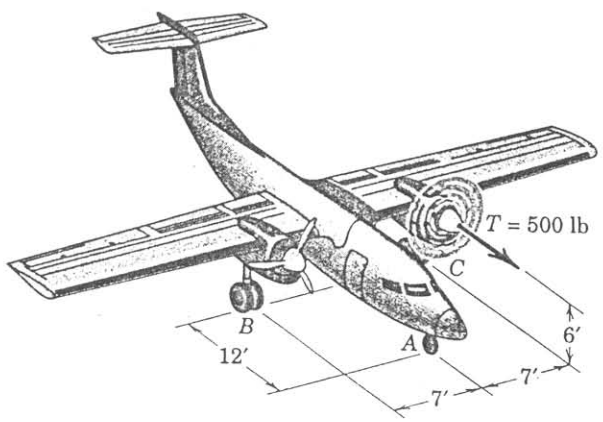
17 The square steel plate has a mass of 1800 kg with mass center at its center G. Calculate the tension in each of the three cables with which the plate is lifted while remaining horizontal.

Ans. $T_A = T_B = 5.41$ kN, $T_C = 9.87$ kN



Problem 17

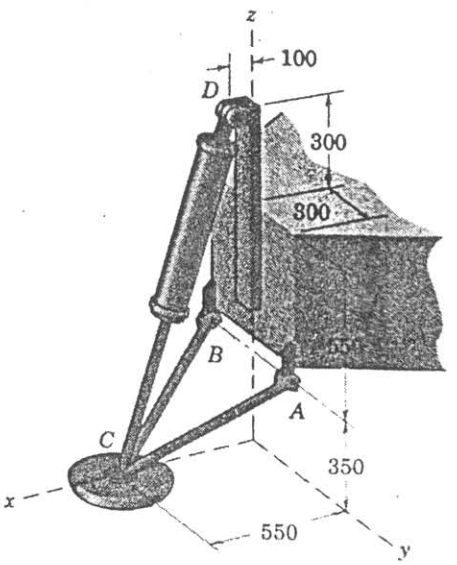
18 During a test, the left engine of the twin-engine airplane is revved up and a 500-lb thrust is generated. The main wheels at B and C are braked in order to prevent motion. Determine the change (compared with the nominal values with both engines off) in the normal reaction forces at A, B, and C.



Problem 18

19 One of the three landing pads for a proposed Mars lander is shown in the figure. As part of a design check on the distribution of force in the landing struts, compute the force in each of the struts AC, BC, and CD when the lander is resting on a horizontal surface on Mars. The arrangement is symmetical with respect to the x-z plane. The mass of the lander is 600 kg. (Assume equal support by the pads and consult Table D/2 in Appendix D as needed.)

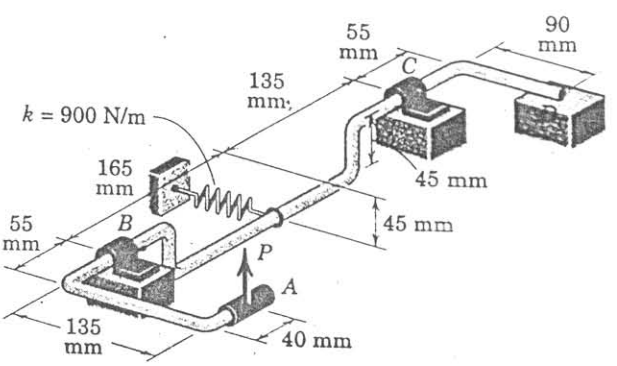
Ans. $F_{AC} = F_{CB} = 240$ N tension
$F_{CD} = 1046$ N compression



Dimensions in millimeters

Problem 19

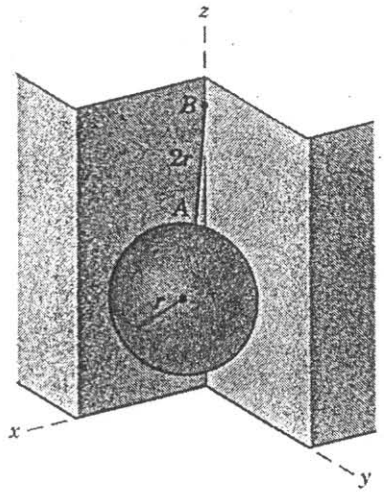
20 The spring of modulus $k = 900$ N/m is stretched a distance $\delta = 60$ mm when the mechanism is in the position shown. Calculate the force P_{min} required to initiate rotation about the hinge axis BC, and determine the corresponding magnitudes of the bearing forces which are perpendicular to BC. What is the normal reaction force at D if $P = P_{min}/2$?



Problem 20

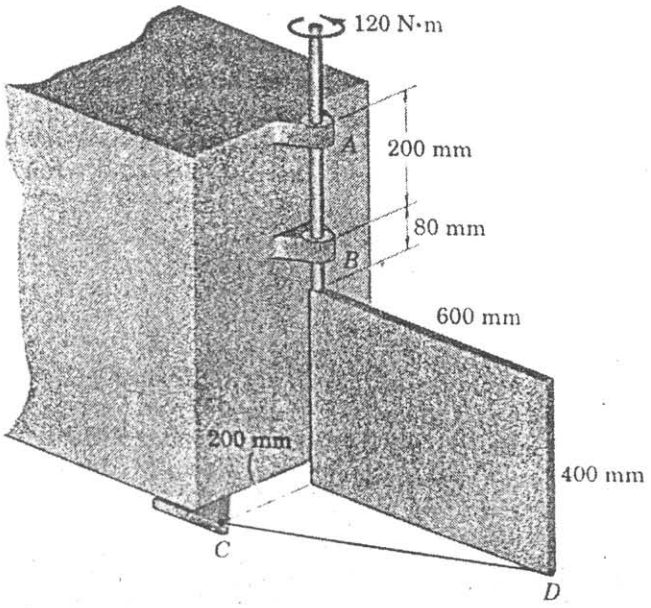
21 A smooth homogeneous sphere of mass m and radius r is suspended by a wire AB of length $2r$ from point B on the line of intersection of the two smooth vertical walls at right angles to one another. Determine the reaction R of each wall against the sphere.

Ans. $R = mg/\sqrt{7}$



Problem 21

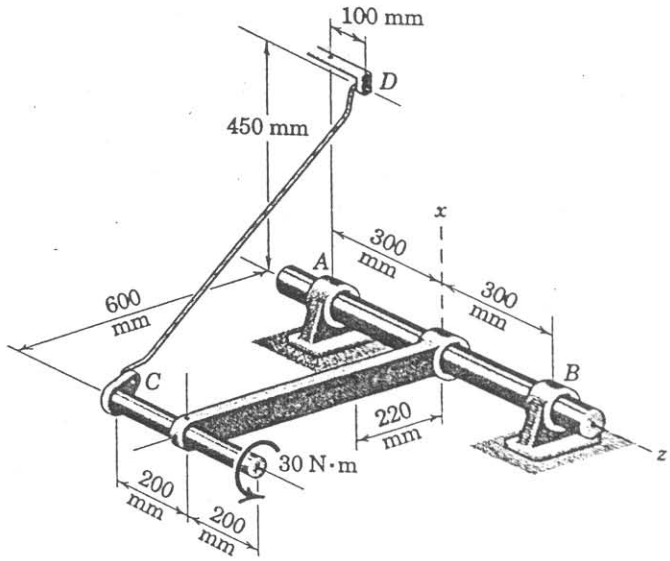
22 The uniform 15-kg plate is welded to the vertical shaft, which is supported by bearings A and B. Calculate the magnitude of the force supported by bearing B during application of the 120-N·m couple to the shaft. The cable from C to D prevents the plate and shaft from turning, and the weight of the assembly is carried entirely by bearing A.



Problem 22

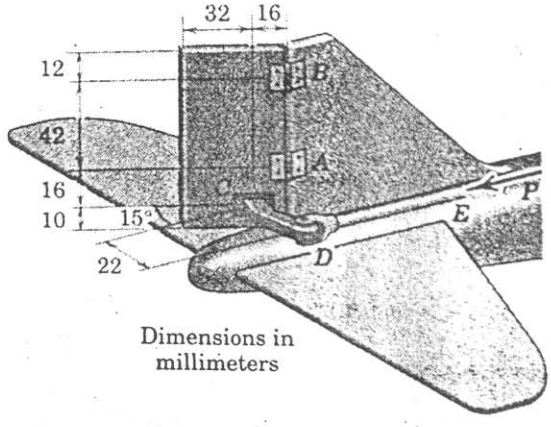
23 The shaft, lever, and handle are welded together and constitute a single rigid body. Their combined mass is 28 kg with mass center at G. The assembly is mounted in bearings A and B, and rotation is prevented by link CD. Determine the forces exerted on the shaft by bearings A and B while the 30-N·m couple is applied to the handle as shown. Would these forces change if the couple were applied to the shaft AB rather than to the handle?

Ans. $A = 167.9$ N, $B = 117.1$ N



Problem 23

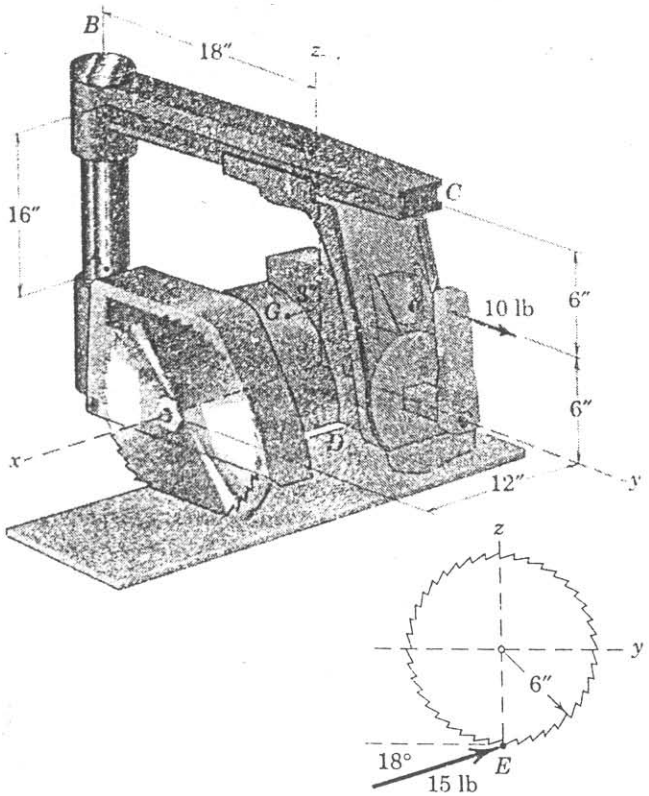
24 Consider the rudder assembly of a radio-controlled model airplane. For the 15° position shown in the figure, the net pressure acting on the left side of the rectangular rudder area is $p = 4(10^{-5})$ N/mm^2. Determine the required force P in the control rod DE and the horizontal components of the reactions at hinges A and B which are parallel to the rudder surface. Assume the aerodynamic pressure to be uniform.



Problem 24

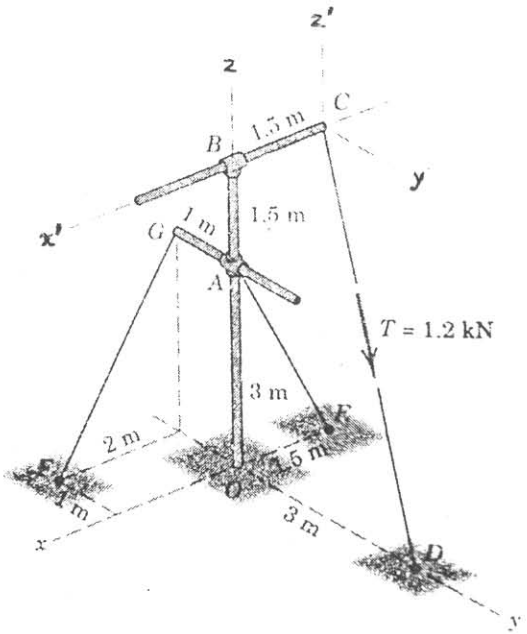
25 The unit *ABCD* of the radial-arm saw weighs 40 lb with center of gravity at *G*. If a horizontal 10-lb force is applied to the control handle in sawing the board, calculate the corresponding bending moment acting on the column at *A* (total moment about a horizontal axis through *A*). The reaction of the wood on the saw teeth is 15 lb in the direction shown, and to a close approximation, its point of application may be taken as *E*. What justification exists for treating the saw as being in equilibrium?

Ans. $M = 711$ lb-in.



Problem 25

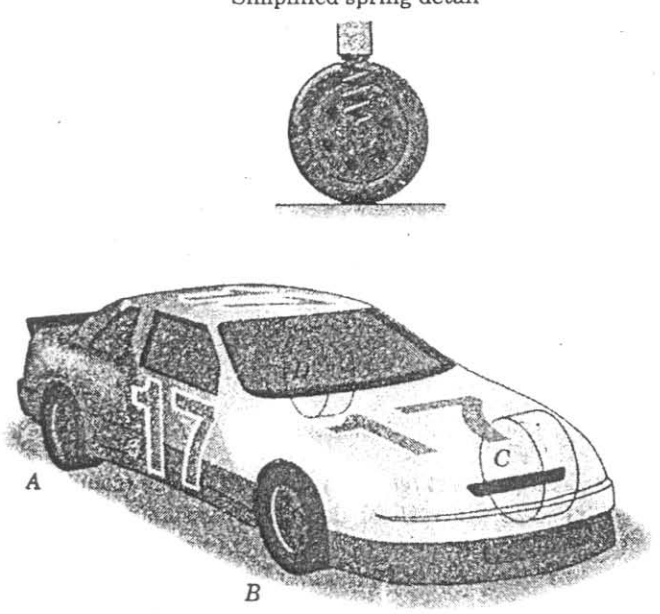
26 The rigid pole and cross-arms are shown here. Determine the tensions T_{AE} and T_{GF} in the two supporting cables resulting from the 1.2-kN tension in cable *CD*. Assume the absence of any resisting moments on the base of the pole at *O* about the *x*- and *y*-axes, but not about the *z*-axis.



Problem 26

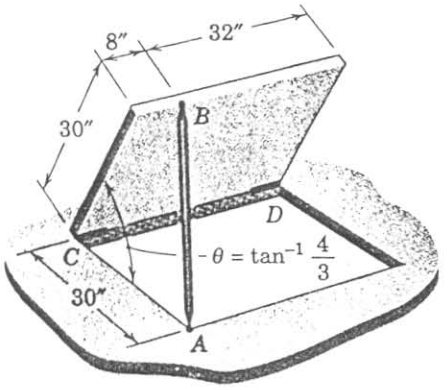
27 The upper ends of the vertical coil springs in the stock racecar can be moved up and down by means of a screw mechanism not shown. This adjustment permits a change in the downward force at each wheel as an optimum handling setup is sought. Initially, scales indicate the normal forces to be 800 lb, 800 lb, 1000 lb, and 1000 lb at *A*, *B*, *C*, and *D*, respectively. If the top of the right rear spring at *A* is lowered so that the scale at *A* reads an additional 100 lb, determine the corresponding changes in the normal forces at *B*, *C*, and *D*. Neglect the effects of the small attitude changes (pitch and roll angles) caused by the spring adjustment. The front wheels are the same distance apart as the rear wheels.

Ans. $\Delta N_B = -100$ lb, $\Delta N_C = 100$ lb
$\Delta N_D = -100$ lb



Problem 27

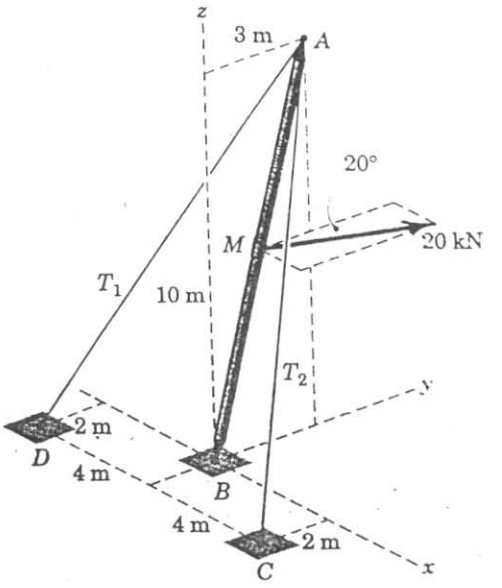
28 The uniform 30- by 40-in. trap door weighs 200 lb and is propped open by the light strut AB at the angle $\theta = \tan^{-1}(4/3)$. Calculate the compression F_B in the strut and the force supported by the hinge D normal to the hinge axis. Assume that the hinges act at the extreme ends of the lower edge.



Problem 28

29 The boom AB lies in the vertical y-z plane and is supported by a ball-and-socket joint at B and by the two cables at A. Calculate the tension in each cable resulting from the 20-kN force acting in the horizontal plane and applied at the midpoint M of the boom. Neglect the weight of the boom.

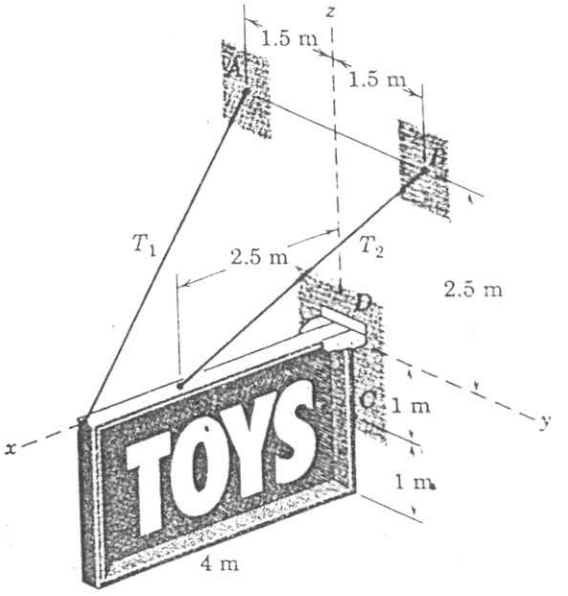
Ans. $T_1 = 33.0$ kN, $T_2 = 22.8$ kN



Problem 29

30 A rectangular sign over a store has a mass of 100 kg, with the center of mass in the center of the rectangle. The support against the wall at point C may be treated as a ball-and-socket joint. At corner D support is provided in the y-direction only. Calculate the tensions T_1 and T_2 in the supporting wires, the total force supported at C, and the lateral force R supported at D.

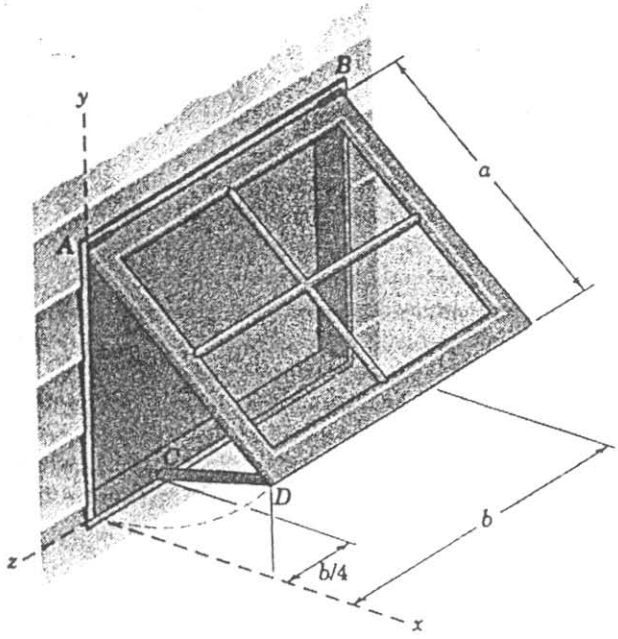
Ans. $T_1 = 347$ N, $T_2 = 431$ N
$R = 63.1$ N, $C = 768$ N



Problem 30

31 The awning window is temporarily held open in the 50° position shown by a wooden prop CD until a crank-type opening mechanism can be installed. If $a = 0.8$ m and $b = 1.2$ m and the mass of the window is 50 kg with mass center at its geometric center, determine the compressive force F_{CD} in the prop and all components of the forces exerted by the hinges A and B on the window. Assume that A is a thrust-bearing hinge but that hinge B is not.

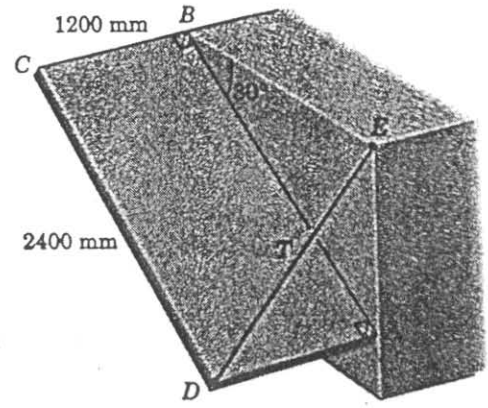
Ans. $A_x = -140.9$ N, $A_y = 118.2$ N, $A_z = -92.0$ N
$B_x = -47.0$ N, $B_y = 285$ N, $F_{CD} = 227$ N



Problem 31

32 The uniform rectangular panel $ABCD$ has a mass of 40 kg and is hinged at its corners A and B to the fixed vertical surface. A wire from E to D keeps edges BC and AD horizontal. Hinge A can support thrust along the hinge axis AB, whereas hinge B supports force normal to the hinge axis only. Find the tension T in the wire and the magnitude B of the force supported by hinge B.

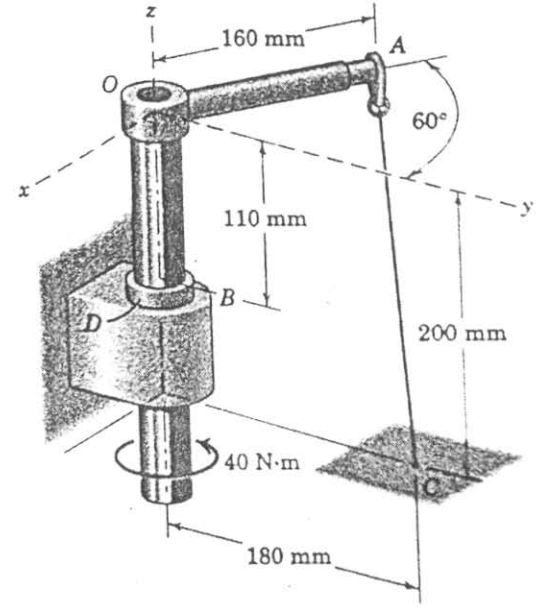
Ans. $T = 277$ N, $B = 169.9$ N



Problem 32

33 Under the action of the 40-N·m torque (couple) applied to the vertical shaft, the restraining cable AC limits the rotation of the arm OA and attached shaft to an angle of 60° measured from the y-axis. The collar D fastened to the shaft prevents downward motion of the shaft in its bearing. Calculate the bending moment M, the compression P, and the shear force V in the shaft at section B. (*Note:* Bending moment, expressed as a vector, is normal to the shaft axis, and shear force is also normal to the shaft axis.)

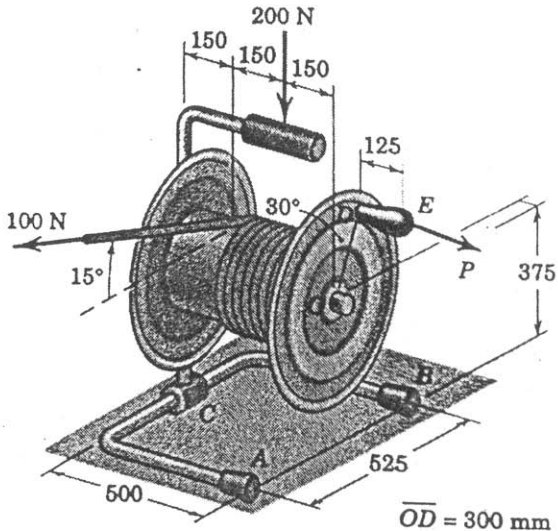
Ans. $M = 47.7$ N·m, $P = 320$ N, $V = 274$ N



Problem 33

34 The portable reel is used to wind up and store an air hose. The tension in the hose is 100 N and a vertical 200-N force is applied to the handle in order to steady the reel frame. Determine the minimum force P which must be applied perpendicular to the handle DE and the vertical components of the force reactions at the feet A, B, and C. The diameter of the coil of reeled hose is 300 mm, and the weight of the loaded reel and its frame may be neglected. State any assumptions.

Ans. $P = 50$ N, $N_A = 108.6$ N
$N_B = 32.4$ N, $N_C = 58.1$ N



Dimensions in millimeters

Problem 3 4