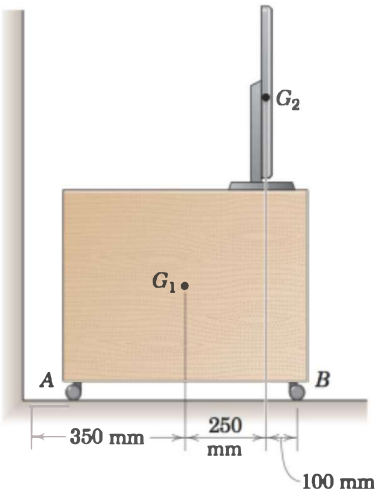
PROBLEMS

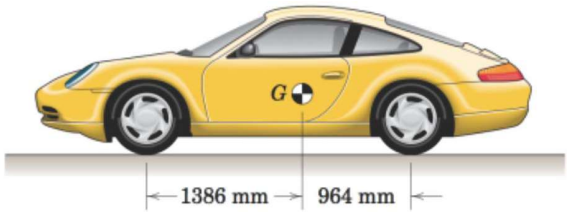
Introductory Problems

3/1 In the side view of a 25-kg flat-screen television resting on a 40-kg cabinet, the respective centers of mass are labeled G_2 and G_1. Assume symmetry into the paper and calculate the normal reaction force at each of the four casters.



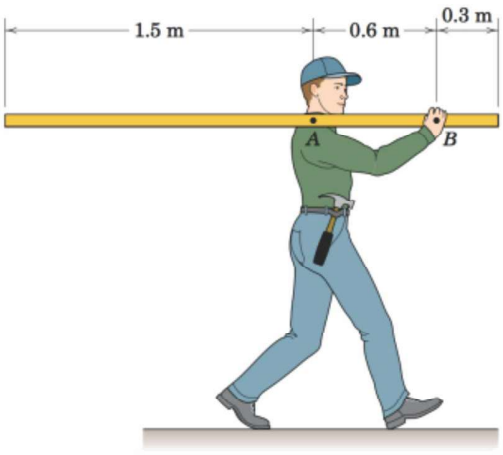
Problem 3/1

3/2 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.



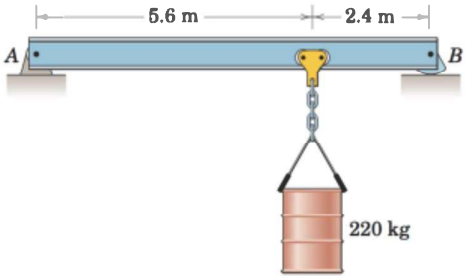
Problem 3/2

3/3 A carpenter carries a 6-kg uniform board as shown. What downward force does he feel on his shoulder at A?



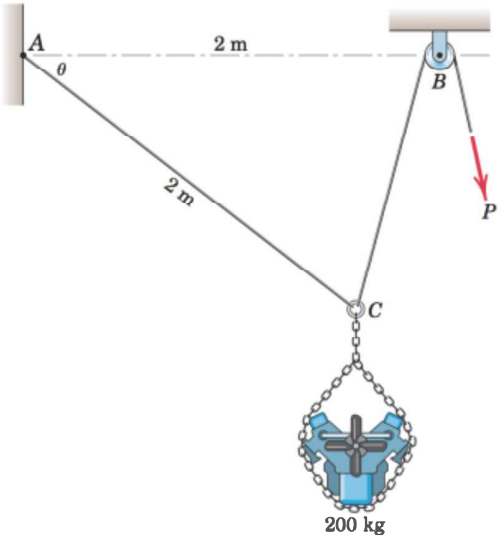
Problem 3/3

3/4 The 450-kg uniform I-beam supports the load shown. Determine the reactions at the supports.



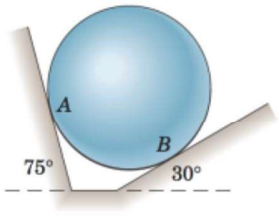
Problem 3/4

3/5 Determine the force P required to maintain the 200-kg engine in the position for which $\theta = 30°$. The diameter of the pulley at B is negligible.



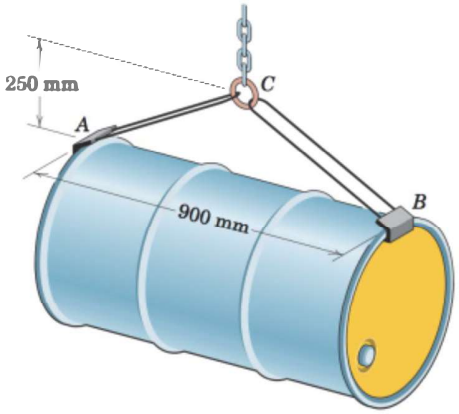
Problem 3/5

3/6 The 20-kg homogeneous smooth sphere rests on the two inclines as shown. Determine the contact forces at A and B.



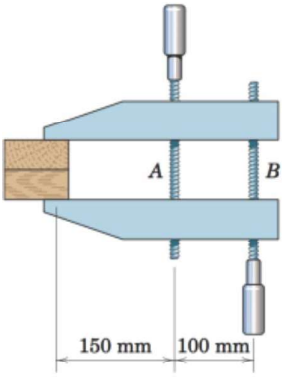
Problem 3/6

3/7 The 275-kg 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.



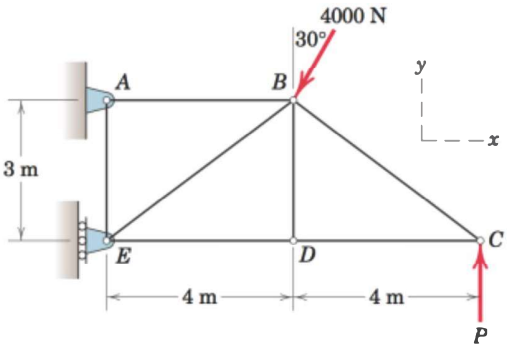
Problem 3/7

3/8 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.)



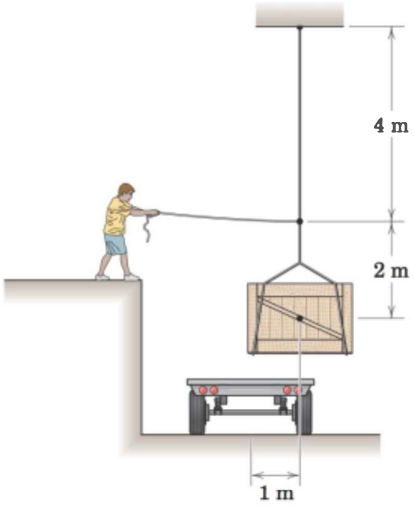
Problem 3/8

3/9 Determine the reactions at A and E if $P = 500$ N. What is the maximum value which P may have for static equilibrium? Neglect the weight of the structure compared with the applied loads.



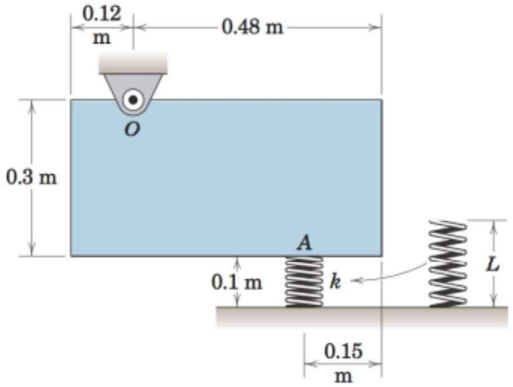
Problem 3/9

3/10 What horizontal force P must a worker exert on the rope to position the 50-kg crate directly over the trailer?



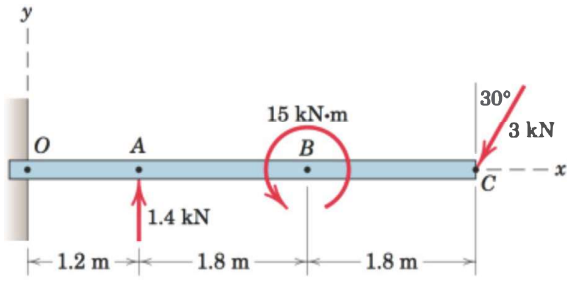
Problem 3/10

3/11 The 20-kg uniform rectangular plate is supported by an ideal pivot at O and a spring which must be compressed prior to being slipped into place at point A. If the modulus of the spring is $k = 2$ kN/m, what must be its undeformed length L?



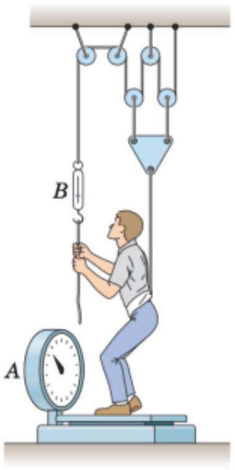
Problem 3/11

3/12 The 500-kg uniform beam is subjected to the three external loads shown. Compute the reactions at the support point O. The x-y plane is vertical.



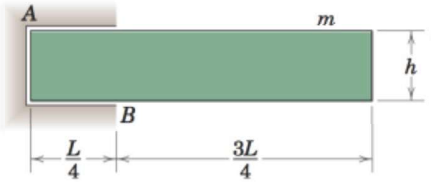
Problem 3/12

3/13 A former student of mechanics wishes to weigh himself but has access only to a scale A with capacity limited to 400 N and a small 80-N spring dynamometer B. With the rig shown he discovers that when he exerts a pull on the rope so that B registers 76 N, the scale A reads 268 N. What are his correct weight W and mass m?



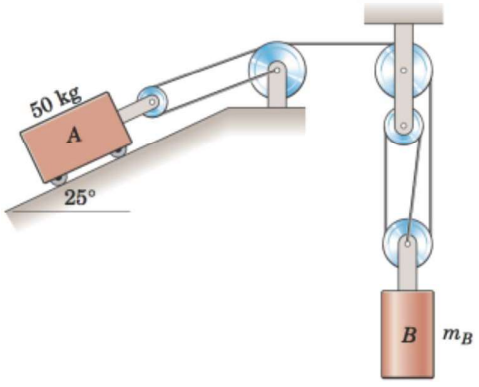
Problem 3/13

3/14 The uniform rectangular body of mass m is placed into a fixed opening with slight clearances as shown. Determine the forces at the contact points A and B. Do your results depend on the height h?



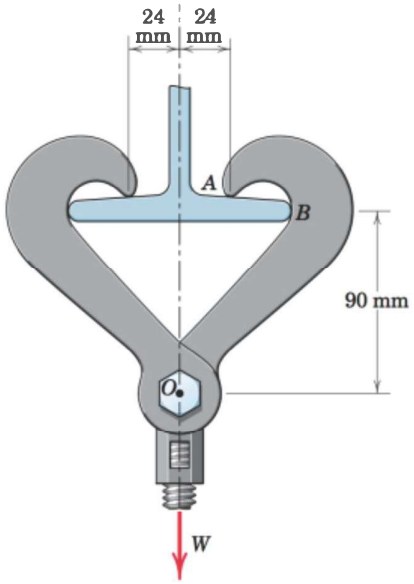
Problem 3/14

3/15 What mass m_B will cause the system to be in equilibrium? Neglect all friction, and state any other assumptions.



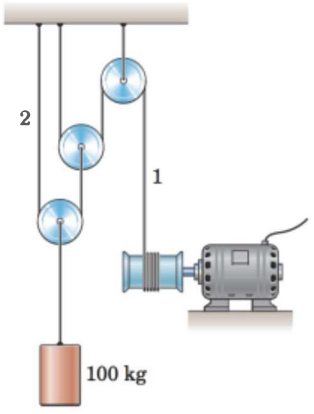
Problem 3/15

3/16 The pair of hooks is designed for the hanging of loads from horizontal I-beams. If the load $W = 5$ kN, estimate the contact forces at A and B. Neglect all friction.



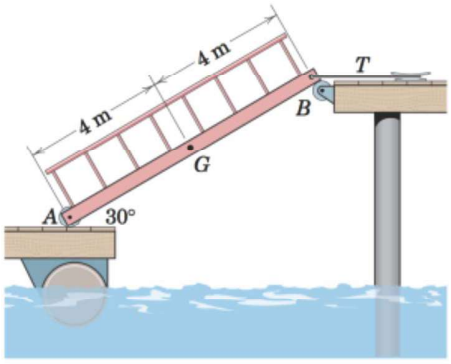
Problem 3/16

3/17 The winch takes in cable at the constant rate of 200 mm/s. If the cylinder mass is 100 kg, determine the tension in cable 1. Neglect all friction.



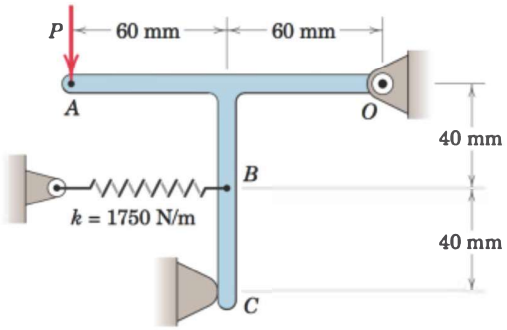
Problem 3/17

3/18 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.



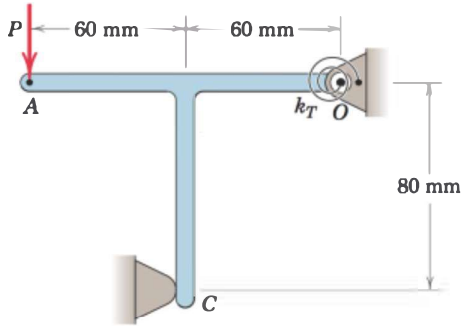
Problem 3/18

3/19 When the 0.05-kg body is in the position shown, the linear spring is stretched 10 mm. Determine the force P required to break contact at C. Complete solutions for (a) including the effect of the weight and (b) neglecting the weight.



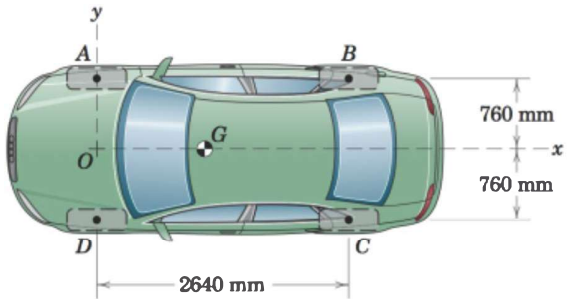
Problem 3/19

3/20 When the 0.05-kg body is in the position shown, the torsional spring at O is pretensioned so as to exert a 0.75-N·m clockwise moment on the body. Determine the force P required to break contact at C. Complete solutions for (a) including the effect of the weight and (b) neglecting the weight.



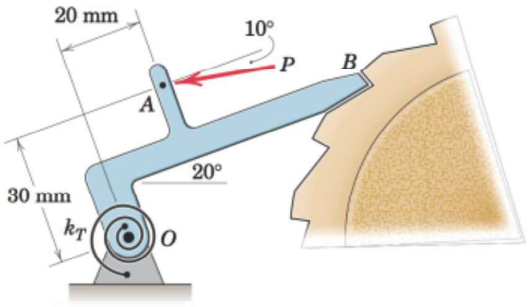
Problem 3/20

3/21 When on level ground, the car is placed on four individual scales—one under each tire. The scale readings are 4450 N at each front wheel and 2950 N at each rear wheel. Determine the x-coordinate of the mass center G and the mass of the car.



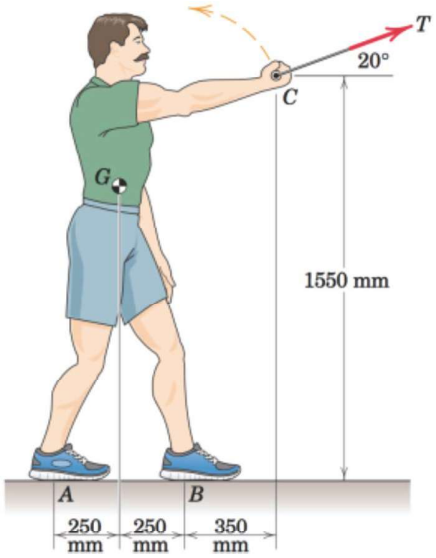
Problem 3/21

3/22 Determine the magnitude P of the force required to rotate the release pawl OB counterclockwise from its locked position. The torsional spring constant is $k_T = 3.4$ N·m/rad and the pawl end of the spring has been deflected 25° counterclockwise from the neutral position in the configuration shown. Neglect any forces at the contact point B.



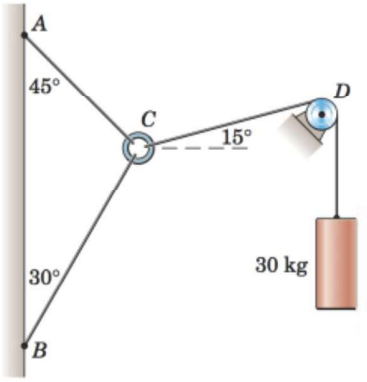
Problem 3/22

3/23 The 80-kg exerciser is beginning to execute some slow, steady bicep curls. As the tension $T = 65$ N is developed against an exercise machine (not shown), determine the normal reaction forces at the feet A and B. Friction is sufficient to prevent slipping, and the exerciser maintains the position shown with center of mass at G.



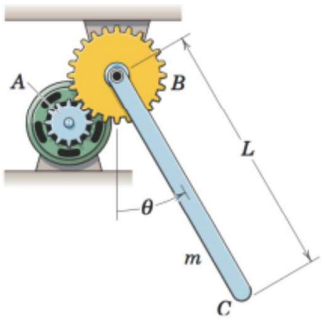
Problem 3/23

3/24 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.



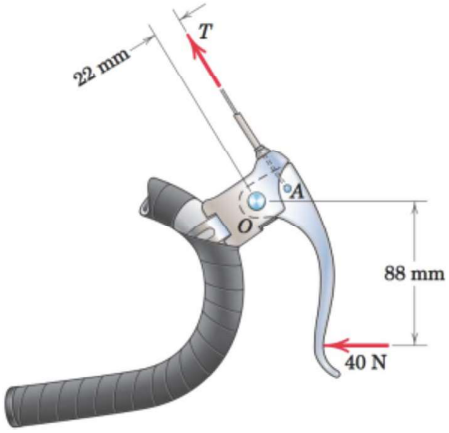
Problem 3/24

3/25 Determine the moment M which the motor must exert in order to position the uniform slender bar of mass m and length L in the arbitrary position θ. The ratio of the radius of the gear wheel B attached to the bar to that of the gear wheel A attached to the motor shaft is 2.



Problem 3/25

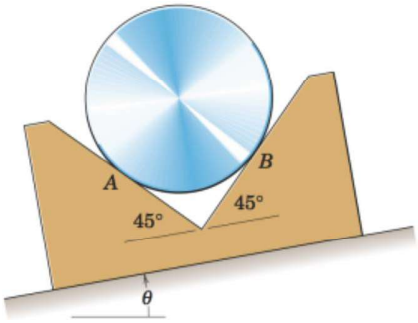
3/26 A bicyclist applies a 40-N force to the brake lever of her bicycle as shown. Determine the corresponding tension T transmitted to the brake cable. Neglect friction at the pivot O.



Problem 3/26

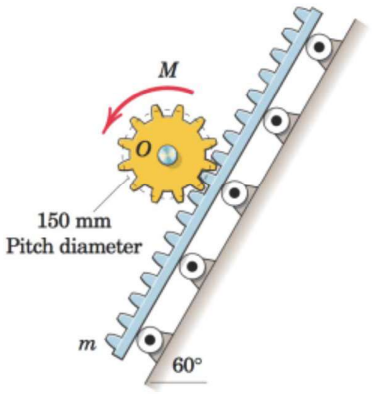
Representative Problems

3/27 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.



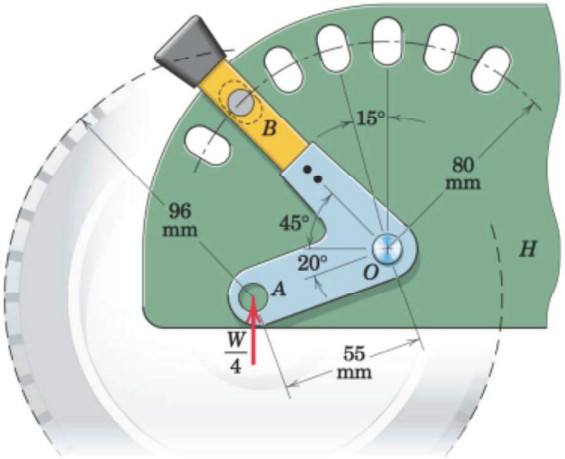
Problem 3/27

3/28 The rack has a mass $m = 75$ kg. What moment M must be exerted on the gear wheel by the motor in order to lower the rack at a slow steady speed down the 60° incline? Neglect all friction. The fixed motor which drives the gear wheel via the shaft at O is not shown.



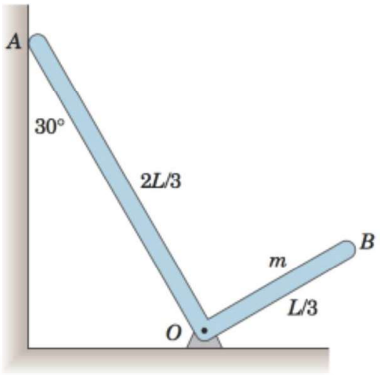
Problem 3/28

3/29 The elements of a wheel-height adjuster for a lawn mower are shown. The wheel (partial outline shown dashed for clarity) bolts through the hole at A, which goes through the bracket but not the housing H. A pin fixed to the back of the bracket at B fits into one of the seven elongated holes of the housing. For the position shown, determine the force at the pin B and the magnitude of the reaction at the pivot O. The wheel supports a force of magnitude $W/4$, where W is the weight of the entire mower.



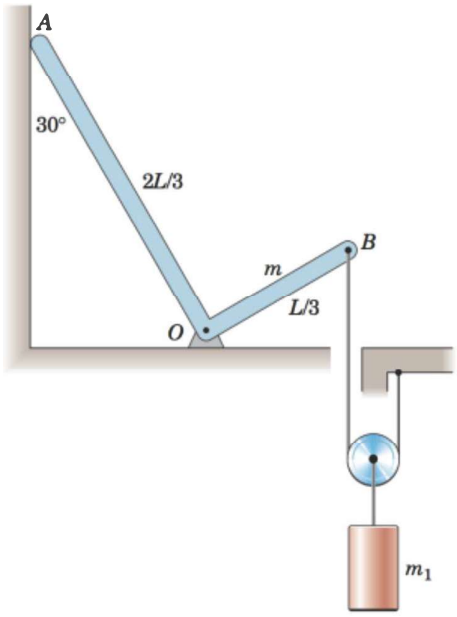
Problem 3/29

3/30 The right-angle uniform slender bar AOB has mass m. If friction at the pivot O is neglected, determine the magnitude of the normal force at A and the magnitude of the pin reaction at O.



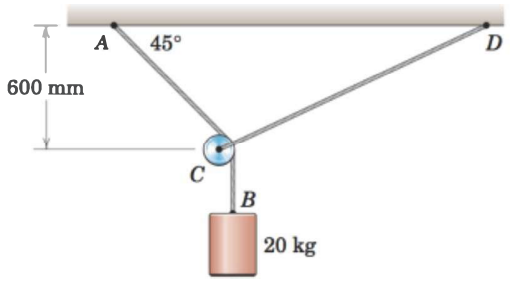
Problem 3/30

3/31 Determine the minimum cylinder mass m_1 required to cause loss of contact at A.



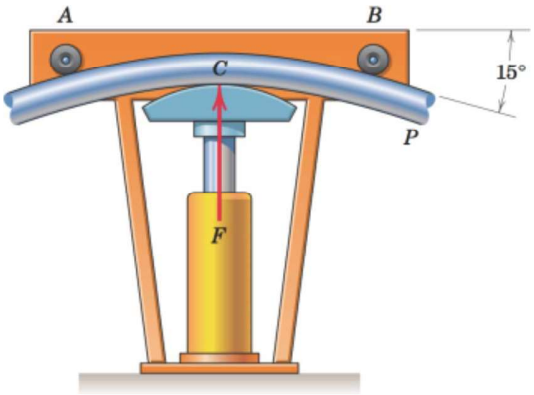
Problem 3/31

3/32 Cable AB passes over the small ideal pulley C without a change in its tension. What length of cable CD is required for static equilibrium in the position shown? What is the tension T in cable CD?



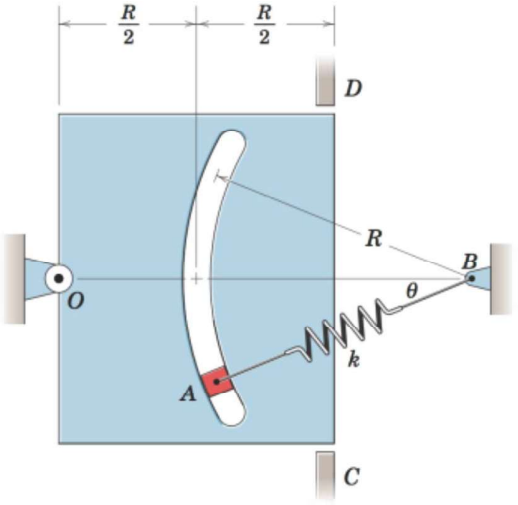
Problem 3/32

3/33 A pipe P is being bent by the pipe bender as shown. If the hydraulic cylinder applies a force of magnitude $F = 24$ kN to the pipe at C, determine the magnitude of the roller reactions at A and B.



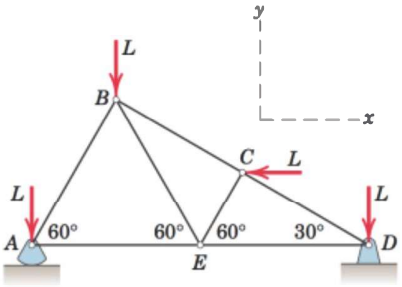
Problem 3/33

3/34 The small slider A is moved along the circular slot by a mechanism attached to the back side of the rectangular plate. For the slider position $\theta = 20°$ shown, determine the normal forces exerted at the small stops C and D. The unstretched length of the spring of constant $k = 1.6$ kN/m is $R/3$. The value of R is 25 mm, and the plate lies in a horizontal plane. Neglect all friction.



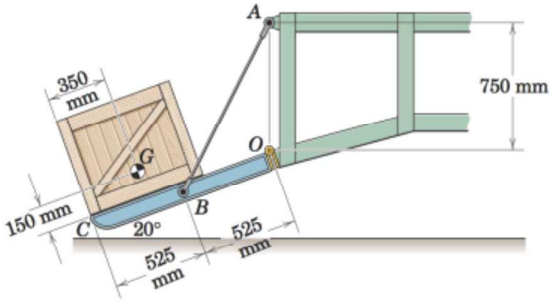
Problem 3/34

3/35 The asymmetric simple truss is loaded as shown. Determine the reactions at A and D. Neglect the weight of the structure compared with the applied loads. Is knowledge of the size of the structure necessary?



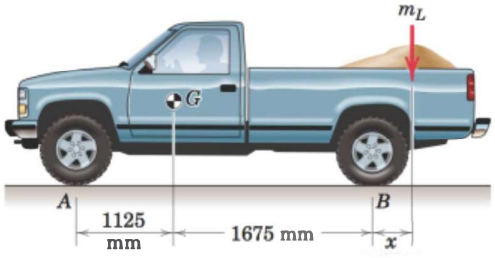
Problem 3/35

3/36 The tailgate OBC is attached to the rear of a trailer via hinges at O and two restraining cables AB. The 55-kg tailgate is 100 mm thick with center of mass at B, which is at midthickness. The crate is centered between the two cables and has a mass of 90 kg with center of mass at G. Determine the tension T in each cable.



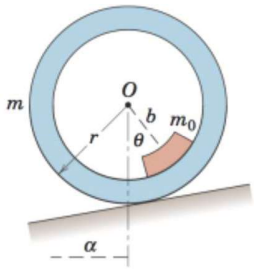
Problem 3/36

3/37 The indicated location of the center of mass of the 1600-kg pickup truck is for the unladen condition. If a load whose center of mass is $x = 400$ mm behind the rear axle is added to the truck, determine the load mass m_L for which the normal forces under the front and rear wheels are equal.



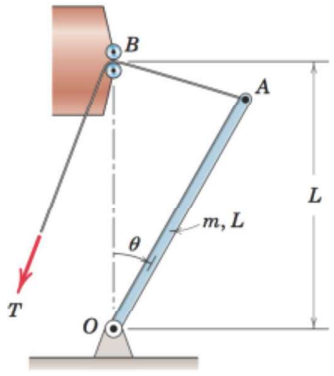
Problem 3/37

3/38 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.



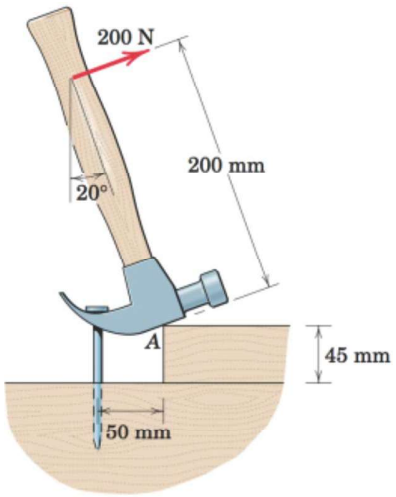
Problem 3/38

3/39 Determine the force T required to hold the uniform bar of mass m and length L in an arbitrary angular position θ. Plot your result over the range $0 \le \theta \le 90°$, and state the value of T for $\theta = 40°$.



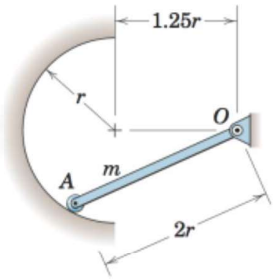
Problem 3/39

3/40 A block placed under the head of the claw hammer as shown greatly facilitates the extraction of the nail. If a 200-N 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.



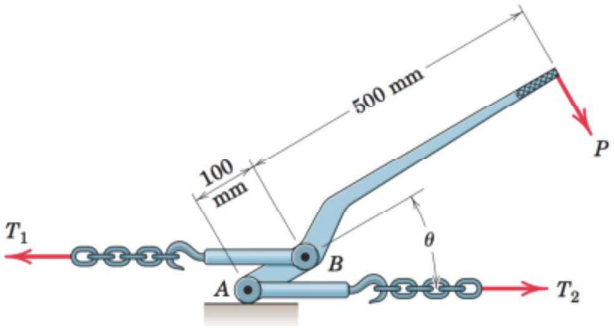
Problem 3/40

3/41 The uniform slender bar of length $2r$ and mass m rests against the circular surface as shown. Determine the normal force at the small roller A and the magnitude of the ideal pivot reaction at O.



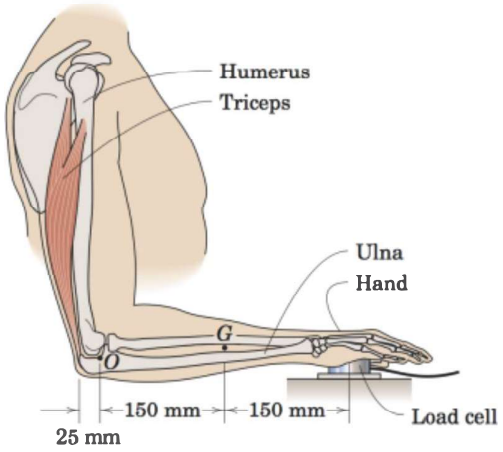
Problem 3/41

3/42 The chain binder is used to secure loads of logs, lumber, pipe, and the like. If the tension T_1 is 2 kN when $\theta = 30°$, determine the force P required on the lever and the corresponding tension T_2 for this position. Assume that the surface under A is perfectly smooth.



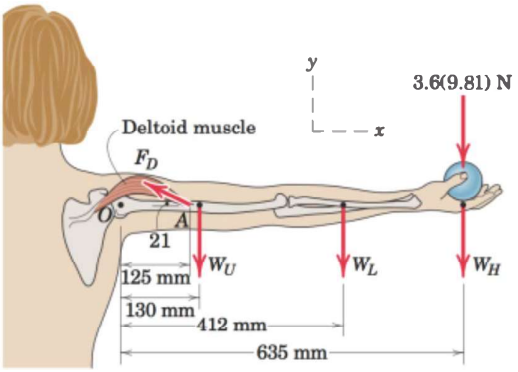
Problem 3/42

3/43 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 160 N, determine the vertical tensile force F generated by the triceps muscle. The mass of the lower arm is 1.5 kg with mass center at G. State any assumptions.



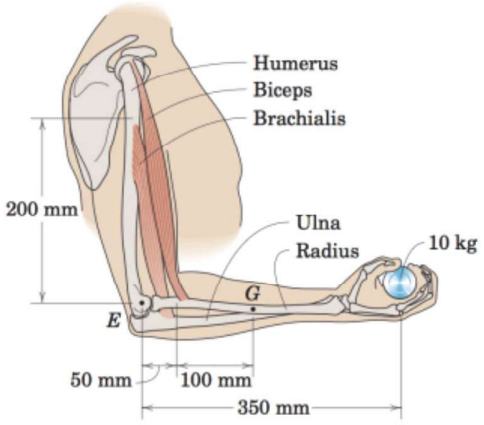
Problem 3/43

3/44 A woman is holding a 3.6-kg sphere 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 mass of the upper arm is $m_U = 1.9$ kg, the mass of the lower arm is $m_L = 1.1$ kg, and the mass of the hand is $m_H = 0.4$ kg; all the corresponding weights act at the locations shown in the figure.



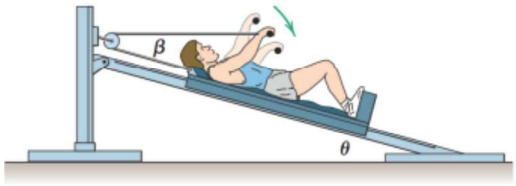
Problem 3/44

3/45 A person is performing slow arm curls with a 10-kg 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 200 mm directly above E and 50 mm directly to the right of E. Include the effect of the 1.5-kg forearm mass with mass center at point G. State any assumptions.



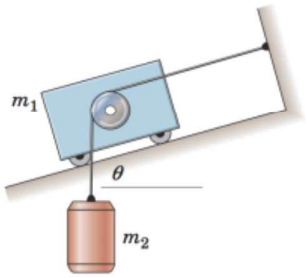
Problem 3/45

3/46 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.



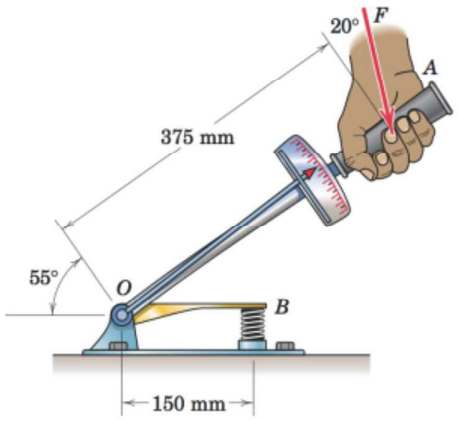
Problem 3/46

3/47 For a given value m_1 for the cart mass, determine the value m_2 for the cylinder mass which results in equilibrium of the system. Neglect all friction. Evaluate your expression for $\theta = 15°$, 45°, and 60°.



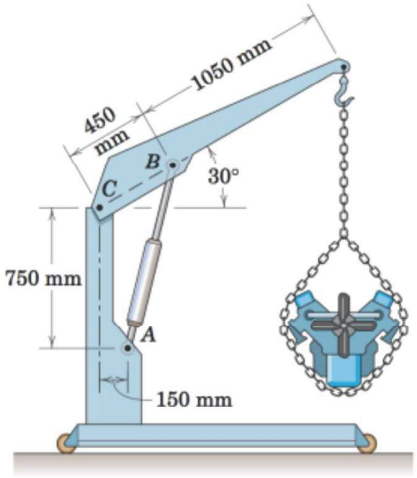
Problem 3/47

3/48 The device shown is used to test automobile-engine valve springs. The torque wrench is directly connected to arm OB. The specification for the automotive intake-valve spring is that 370 N of force should reduce its length from 50 mm (unstressed length) to 42 mm. What is the corresponding reading M on the torque wrench, and what force F exerted on the torque-wrench handle is required to produce this reading? Neglect the small effects of changes in the angular position of arm OB.



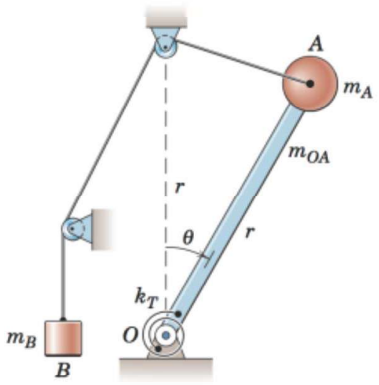
Problem 3/48

3/49 The portable floor crane in the automotive shop is lifting a 100-kg engine. For the position shown compute the magnitude of the force supported by the pin at C and the oil pressure p against the 80-mm-diameter piston of the hydraulic-cylinder unit AB.



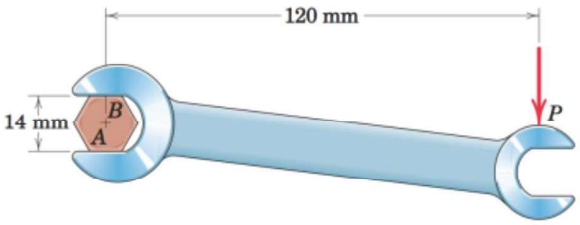
Problem 3/49

***3/50** The torsional spring of constant $k_T = 50$ N·m/rad is undeformed when $\theta = 0$. Determine the value(s) of θ over the range $0 \le \theta \le 180°$ for which equilibrium exists. Use the values $m_A = 10$ kg, $m_B = 1$ kg, $m_{OA} = 5$ kg, and $r = 0.8$ m. Assume that OA is a uniform slender rod with a particle A (negligible size) at its end, and neglect the effects of the small ideal rollers.



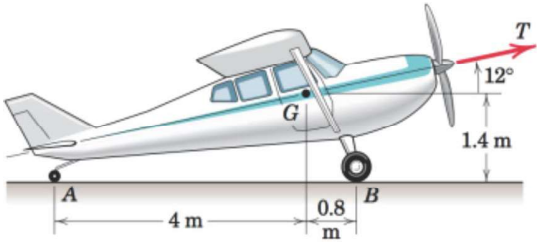
Problem 3/50

3/51 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.



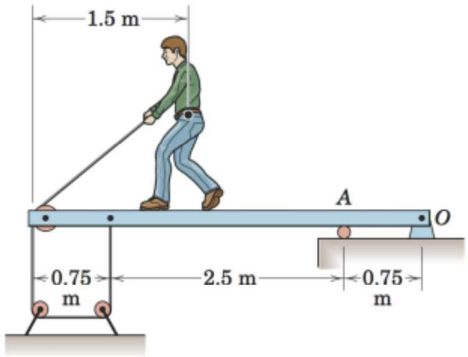
Problem 3/51

3/52 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.



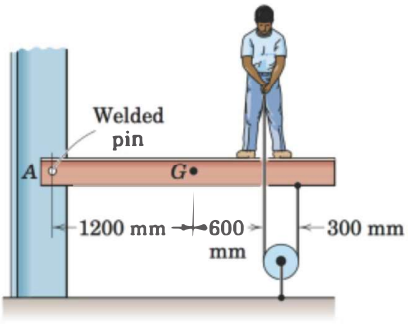
Problem 3/52

3/53 To test the deflection of the uniform 100-kg beam the 50-kg boy exerts a pull of 150 N on the rope rigged as shown. Compute the force supported by the pin at the hinge O.



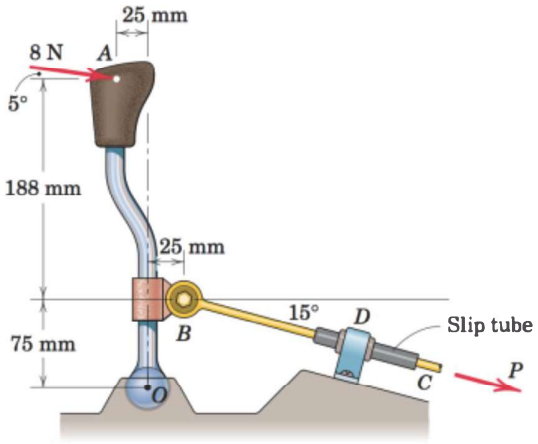
Problem 3/53

3/54 The pin A, which connects the 200-kg steel beam with center of mass 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.



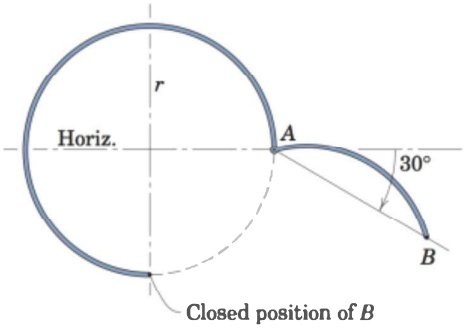
Problem 3/54

3/55 A portion of the shifter mechanism for a manual car transmission is shown in the figure. For the 8-N 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.



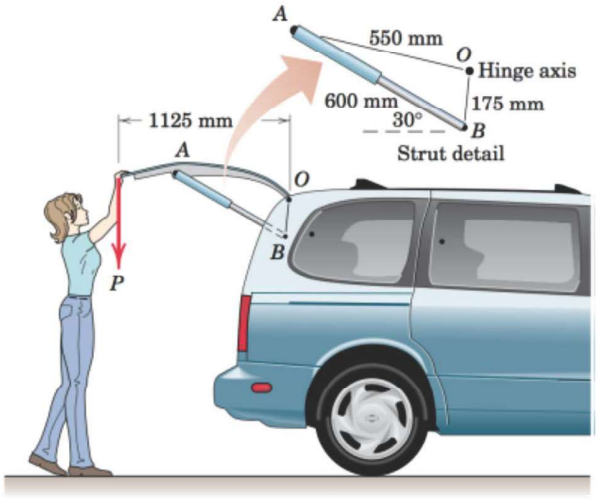
Problem 3/55

3/56 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.



Problem 3/56

3/57 It is desired that a person be able to begin closing the van hatch from the open position shown with a 40-N vertical force P. As a design exercise, determine the necessary force in each of the two hydraulic struts AB. The mass center of the 40-kg door is 37.5 mm directly below point A. Treat the problem as two-dimensional.



Problem 3/57