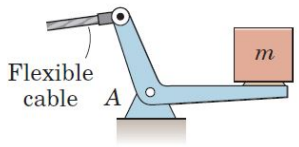
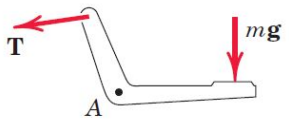
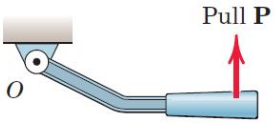
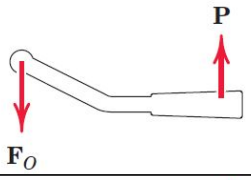
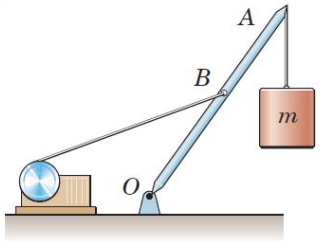
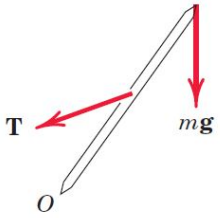
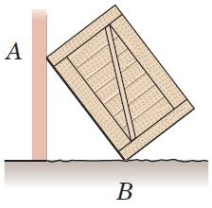
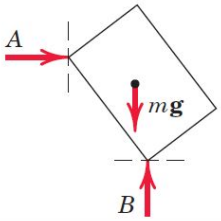
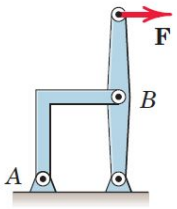
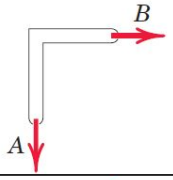
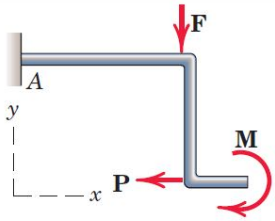
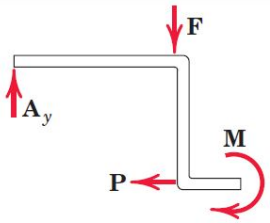
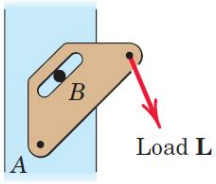
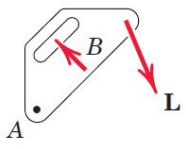
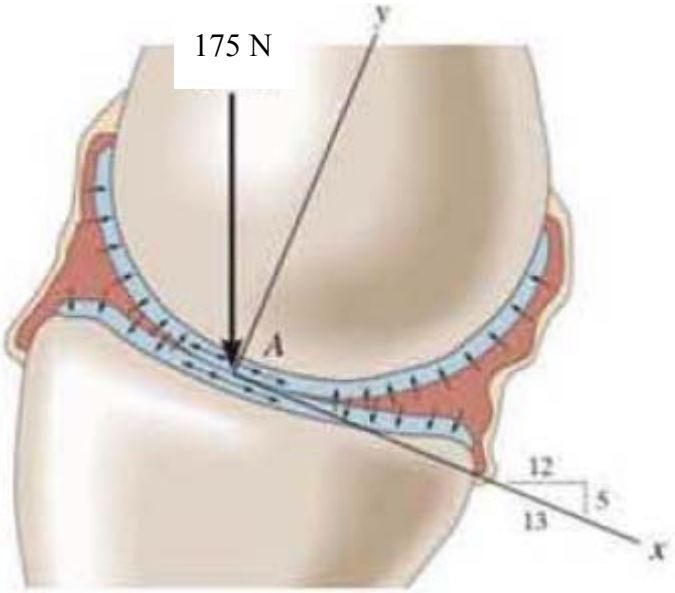
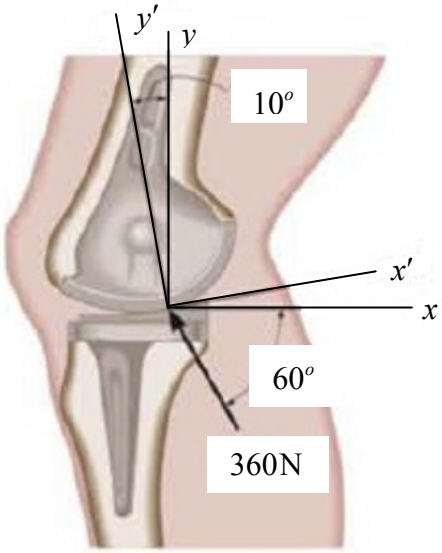
STATIC PROBLEMS

	Body	Incomplete FBD
1. Bell crank supporting mass m with pin support at A.		
2. Control lever applying torque to shaft at O.		
3. Boom OA, of negligible mass compared with mass m. Boom hinged at O and supported by hoisting cable at B.		
4. Uniform crate of mass m leaning against smooth vertical wall and supported on a rough horizontal surface.		
4. Supporting angle bracket for frame; pin joints.		
5. Bent rod welded to support at A and subjected to two forces and couple.		
5. Loaded bracket supported by pin connection at A and fixed pin in smooth slot at B.		

Problem 1. In each of the following examples, the body to be isolated is shown in the left-hand diagram, and an incomplete free-body diagram (FBD) of the isolated body is shown on the right. Add whatever forces are necessary in each case to form a complete free-body diagram. The weights of the bodies are negligible unless otherwise indicated. Dimensions and numerical values are omitted for simplicity (Meriam&Kraige, 2006).

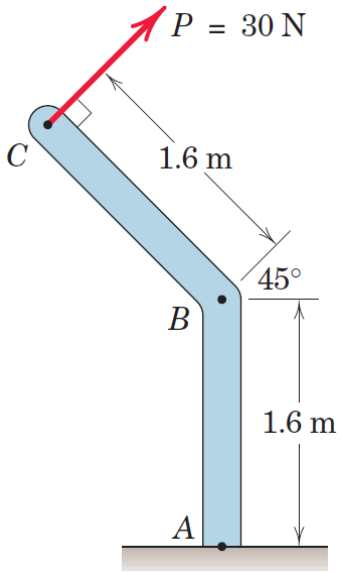


Problem 2. The contact point between the femur and tibia bones of the leg is at *A*. If a vertical force of 175 N is applied at this point, determine the components along the *x* and *y* axes. Note that the *y* component represents the normal force on the load-bearing region of the bones. Both the *x* and *y* components of this force cause synovial fluid to be squeezed out of the bearing space.

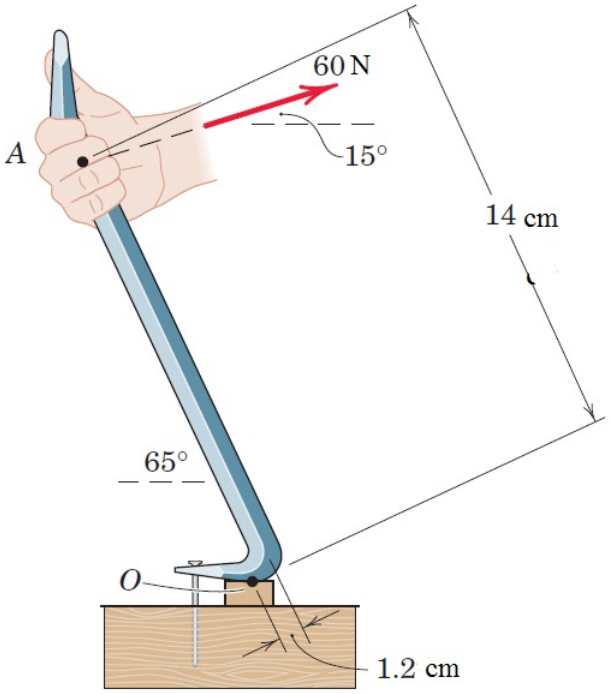


Problem 3. Find the components of force ***F***=360 N along the *x′* and y axes.

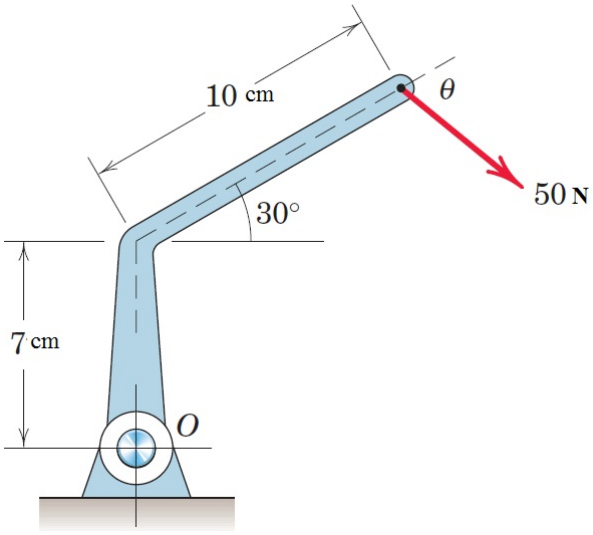
Şekildeki diz protezine gelen kuvvet 360 N'dur. Bu kuvvetin x′ ve y eksenlerindeki bileşke kuvvetlerini hesaplayınız.



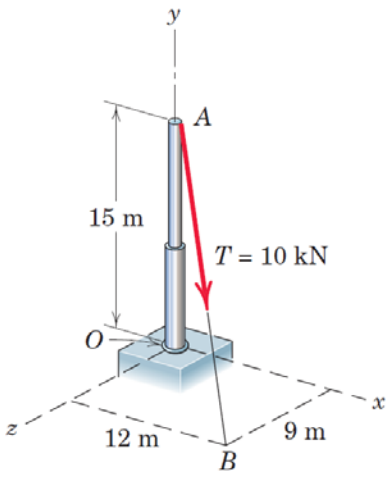
Problem 4. The 30N force **P** is applied perpendicular to the portion *BC* of the bent bar. Determine the moment of **P** about point *B* and about point *A*. Meriam and Craige, Ans: Mb 48 Nm Ma: 81.9 Nm



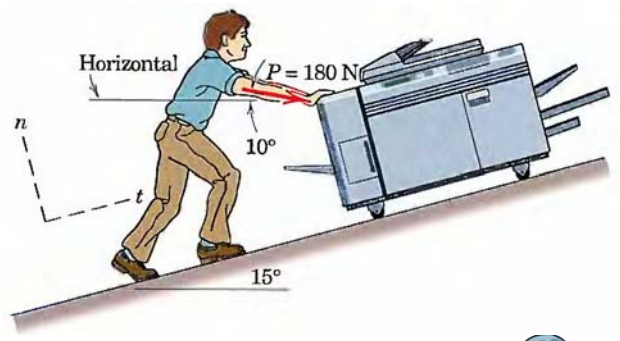
Problem 5. A prybar is used to remove a nail as shown. Determine the moment of the 60N force about the point *O* of contact between the prybar and the small support block (Meriam and Kraige, Statics).



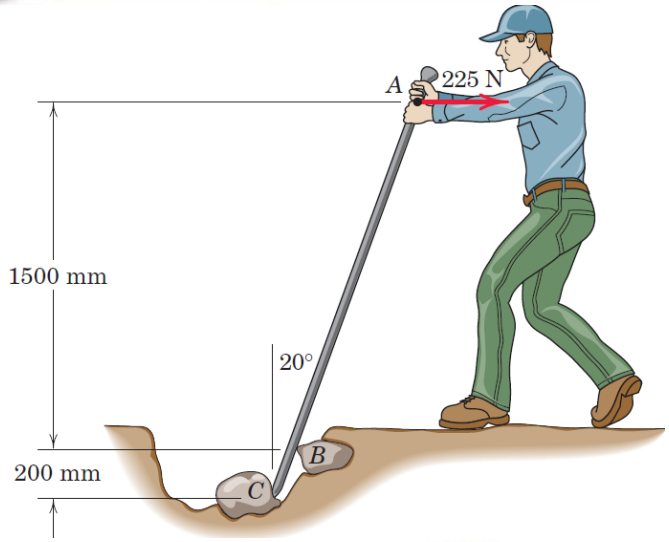
Problem 6. Determine the angle which will maximize the moment *Mo* of the 50N force about the shaft axis at *O*. Also compute *Mo*. (Meriam and Kraige, Statics).



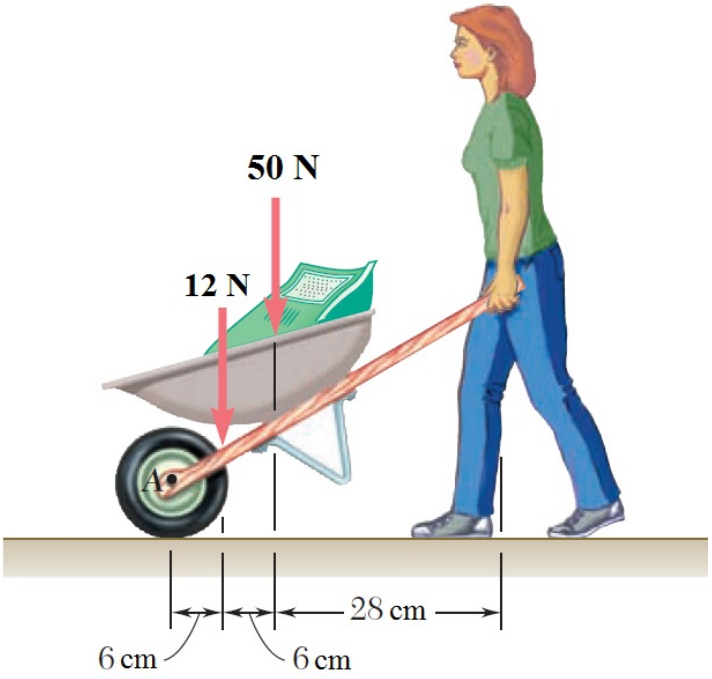
Problem 7. A tension ***T*** of magnitude 10 kN is applied to the cable attached to the top *A* of the rigid mast and secured to the ground at *B*. Determine the moment *Mz* of ***T*** about the *z*-axis passing through the base *O*. Answer: -84.9 kNm (Meriam and Kraige, p.79)



Problem 8. While steadily pushing the machine up an incline, a person exerts a 180 N force *P* as shown. Determine the components of *P* which are parallel and perpendicular to the incline.

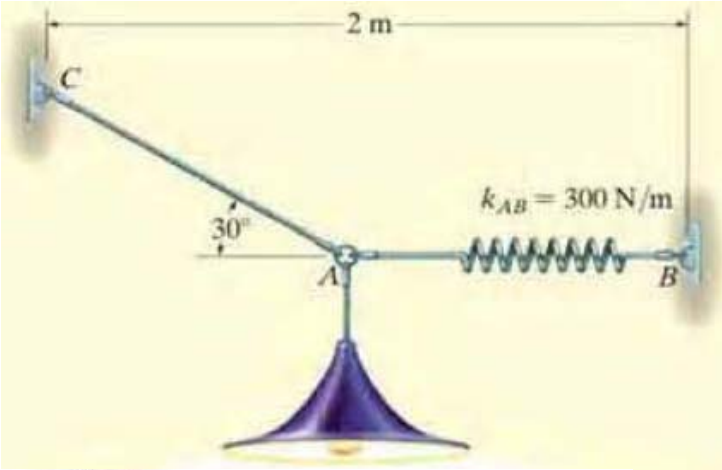


Problem 9. While digging a small hole prior to planting a tree, a homeowner encounters rocks. If he exerts a horizontal 225N force on the prybar as shown, what is the horizontal force exerted on rock *C*? Note that a small ledge on rock *C* supports a vertical force reaction there. Neglect friction at *B*. Complete solutions (*a*) including and (*b*) excluding the weight of the uniform 18-kg prybar. Meriam and Craige, Ans: (a) 1705 N, (b) 1464 N

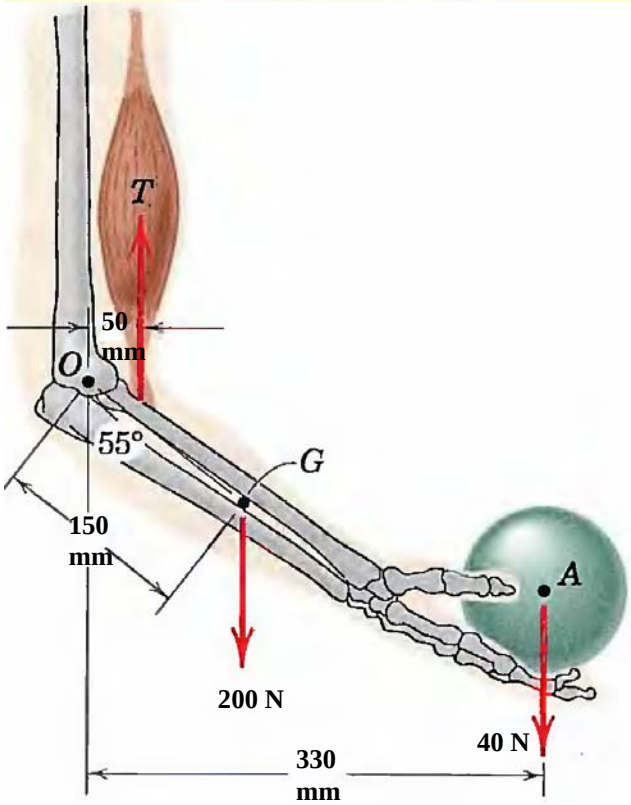


Problem 10. A gardener uses a 12N wheelbarrow to transport a 50N bag of fertilizer. What force must the gardener exert on each handle ? (Ans. 8.4 N) (Beer et al., 2009)

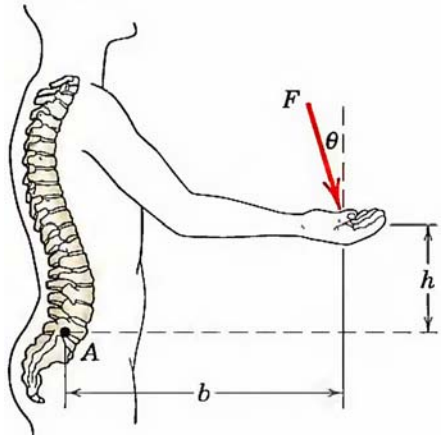
Şekildeki 50N ve 12N ağırlığındaki toprağı taşımak için el arabasının her bir koluna uygulanması gereken kuvvet ne kadardır ?



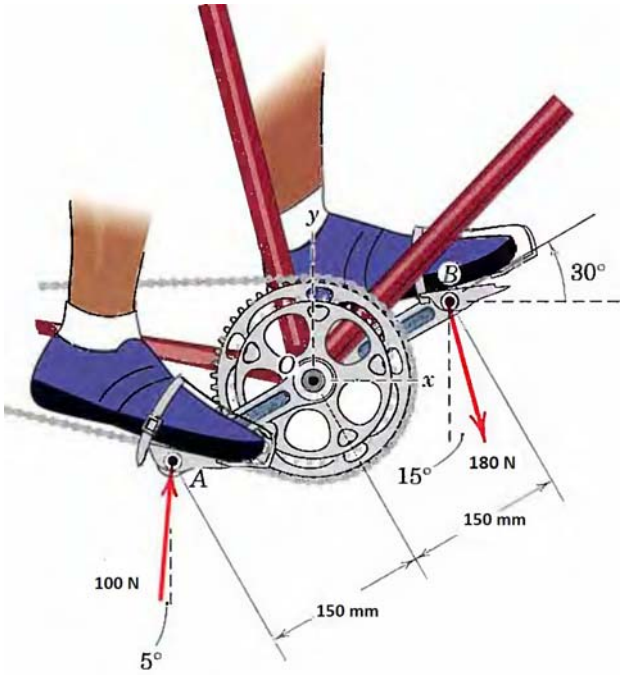
Problem 11. Determine the required length of cord AC so that the 8-kg lamp can be suspended in the position shown. The undeformed length of the spring AB is l_{AB} = 0.4 m, and the spring has a stiffness of k_{AB} = 300 N/m.



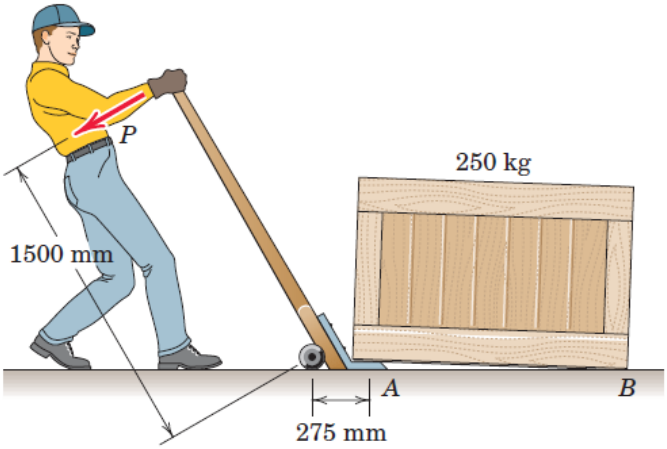
Problem 12. Elements of the lower arm are shown in the figure. The weight of the forearm is 20 N with mass center at *G*. Determine the combined moment about the elbow pivot *O* of the weights of the forearm and the sphere. What must the biceps tension force so that the overall moment about *O* is zero?



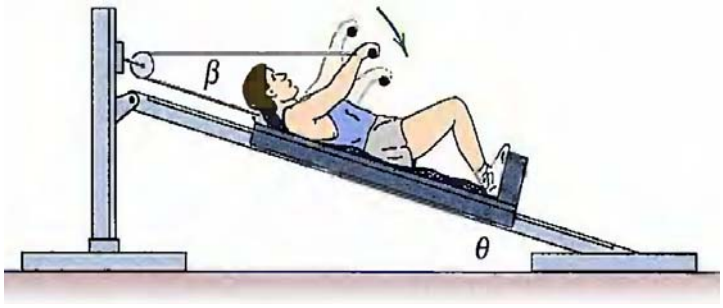
Problem 13. The lower lumber region *A* of the spine is the part of the spinal column most susceptible to abuse while resisting excessive bending caused by the moment about *A* of a force *F*. For given values of *F*, *b*, and *h*, determine the angle θ which causes the most severe bending strain. In order to maintain this static position, determine the reaction effects, which must be occurred at A, while assuming the A is a fixed support.



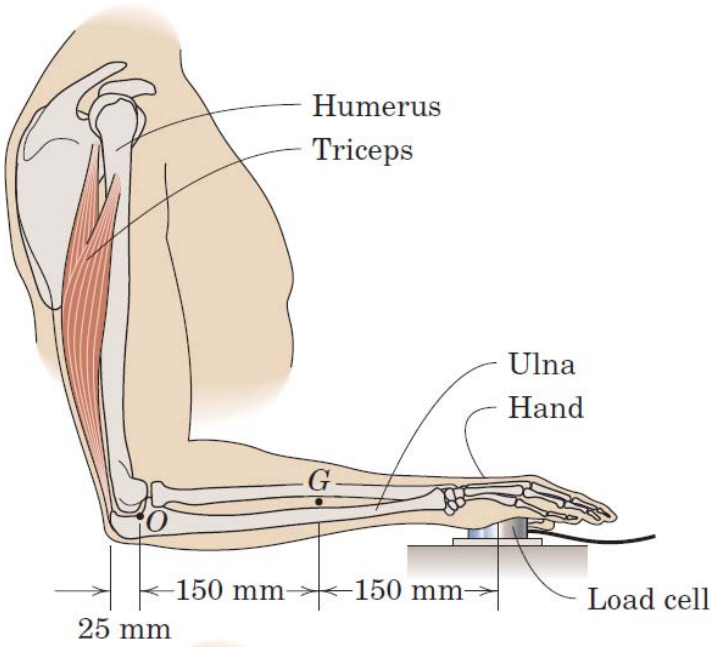
Problem 14. The pedal-chainwheel unit of a bicycle is shown in the figure. The left foot of the rider exerts the 180 N force, while the use of toe clips allows the right foot to exert the nearly upward 100 N force. Determine the equivalent force-couple system at point O. Also determine the equation of the line of action of the system resultant treated as a single force *R*. Treat the problem as two dimensional.



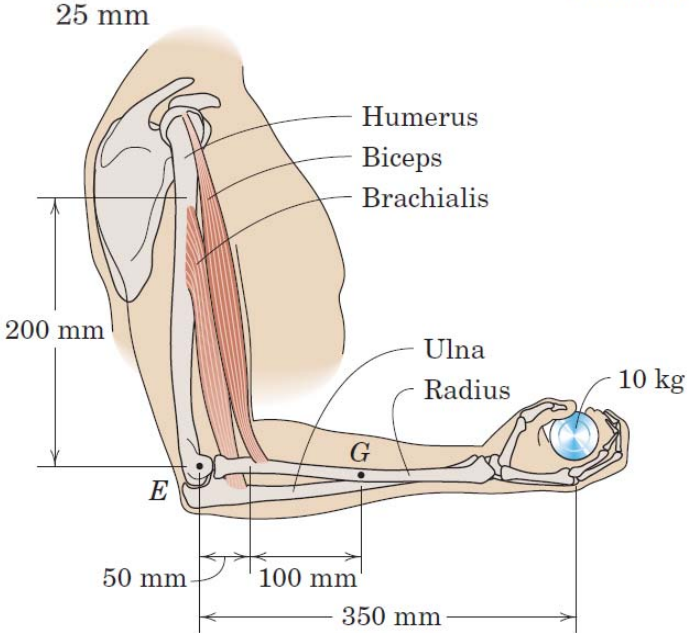
Problem 15. Determine the force magnitude *P* required to lift one end of the 250-kg crate with the lever dolly as shown (Ans: 225 N).



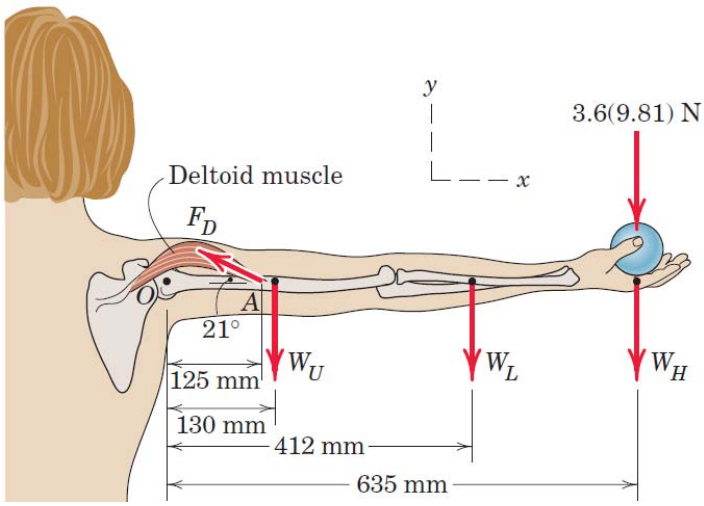
Problem 16. The exercise is designed with a lightweight cart which is mounted on small rollers so that it is free to move along the inclined ramp. Two cables are attached to the cart-one for each hand. If the hands are together so that the cables are parallel and if each cable lies essentially in a vertical 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 70kg, the ramp angle θ is 15^o, and the angle β is 18^o. In addition, calculate the force *R* which the ramp exerts on the cart (Ans. *P*=45.5N; *R*=691N).



Problem 17. 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. What are the reaction forces of the elbow joint? (Ans: F=1832 N)

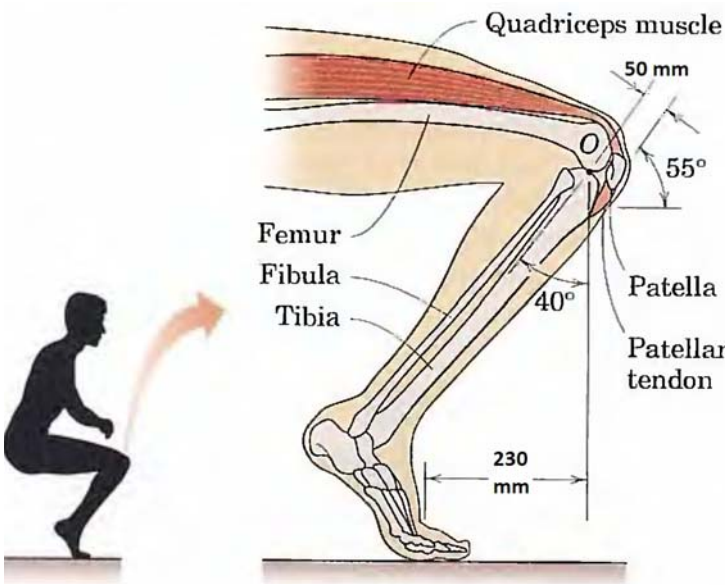


Problem 18. A person is performing slow arm curls with a 10-kg weight as indicated in the figure. The brachialis muscle group (consisting of the biceps and brachialis muscles) is the major factor in this exercise. Determine the magnitude F of the brachialis muscle group force and the magnitude E of the 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. (Ans: F=753 N, E=644 N)

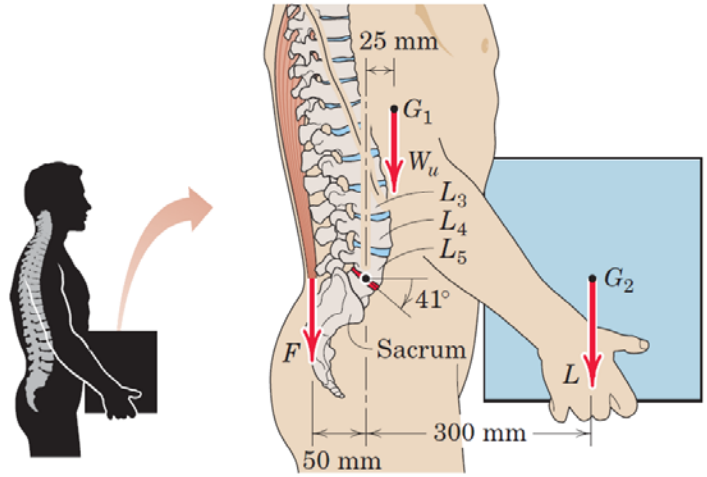


Problem 19. A woman is holding a 3.6-kg sphere in her hand with the entire arm held horizontally as shown in the figure. A tensile force in the deltoid muscle prevents the arm from rotating about the shoulder joint O; this force acts at the angle shown. Determine the force exerted by the deltoid muscle 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

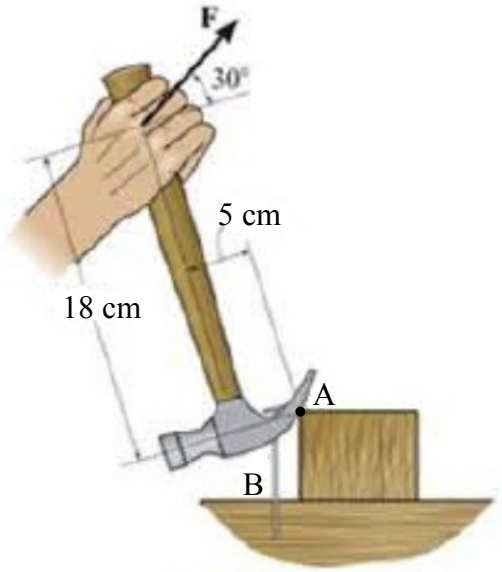
weights act at the locations shown in the figure. (Ans: F_D=710 N, O_x= 662 N, O_y=185.6 N)



Problem 20. 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.

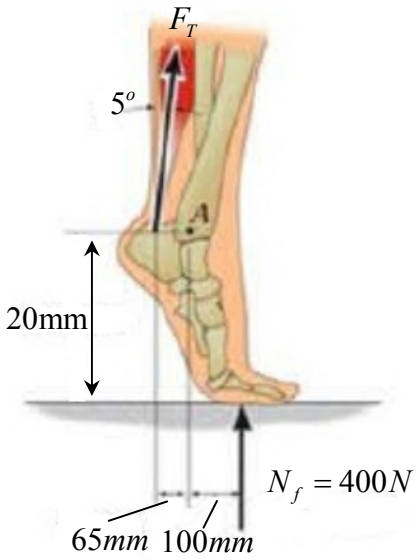


Problem 21. The lumbar portion of the human spine supports the entire weight of the upper torso and the force load imposed on it. We consider here the disk (shaded red) between the lowest vertebra of the lumbar region (L_5) and the uppermost vertebra of the sacrum region. (a) For the case $\boldsymbol{L}$=0, 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. (b) Repeat for the case when the person holds a weight of magnitude L=W/3. State any assumption (Ans: a) S=0.669W, C=0.770W b) S= 2.20W, C=2.53W).



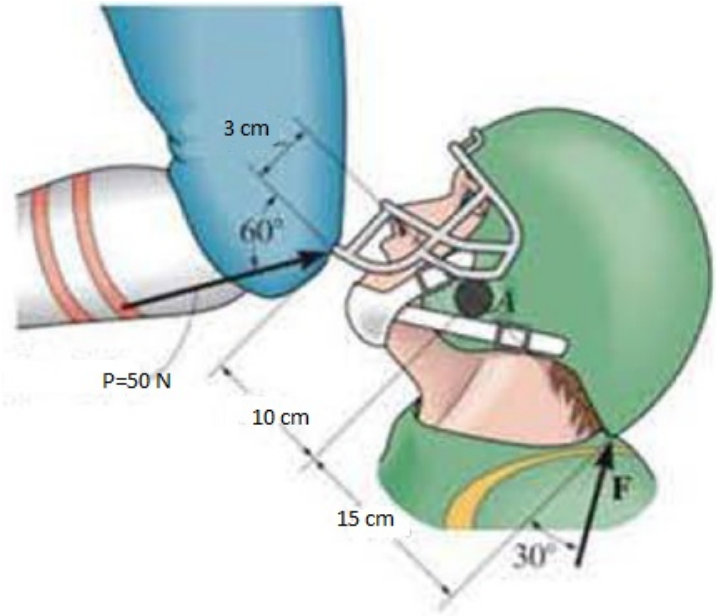
Problem 22. In order to pull the nail at B, the force **F** exerted on the handle of the hammer must produce a clockwise moment of 500 Ncm about point A. Determine the required magnitude of F.

B'deki çiviyi çıkarabilmek için elin A noktası çevresinde saat yönünün tersinde uygulaması gereken moment değeri 500 Ncm'dir. F kuvvetinin değerini hesaplayınız.

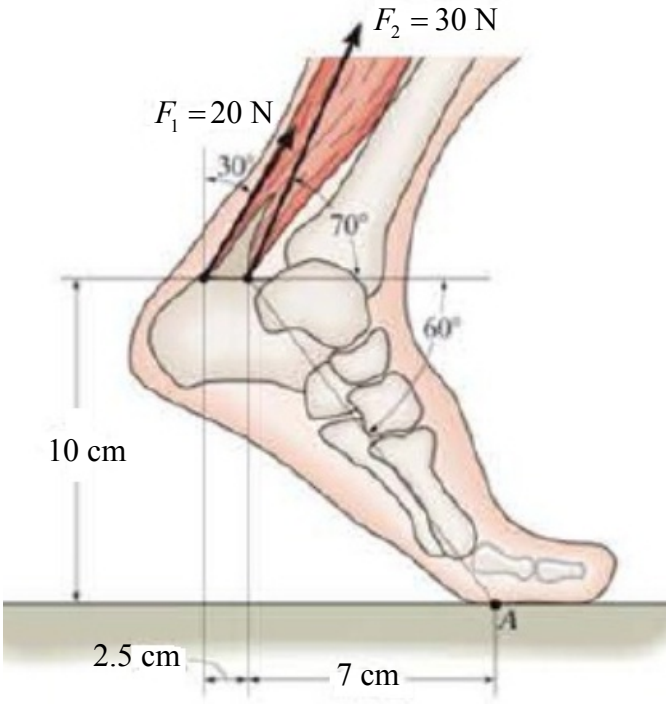


Problem 23. The Achilles tendon force $\boldsymbol{F_T}$ is mobilized when the man tries to stand on his toes. As this is done, each of his feet is subjected to a reactive force of N_f = 400N. If the resultant moment produced by forces $\boldsymbol{F_T}$ and N_f about the ankle joint A is required to be zero, determine the magnitude of $\boldsymbol{F_T}$.

Şekildeki insan vücudu ayak ucunun üzerinde doğrulduğu zaman Achilles tendonunun üzerinde şekildeki gibi bir F_T kuvveti oluşmaktadır. Bu sırada 400 N'luk bir tepki kuvveti N_f ortaya çıkmaktadır. Eğer F_T ve N_f kuvvetlerinin bilekte (A noktası) oluşturdukları moment sıfıra eşitse F_T kuvvetini hesaplayınız.

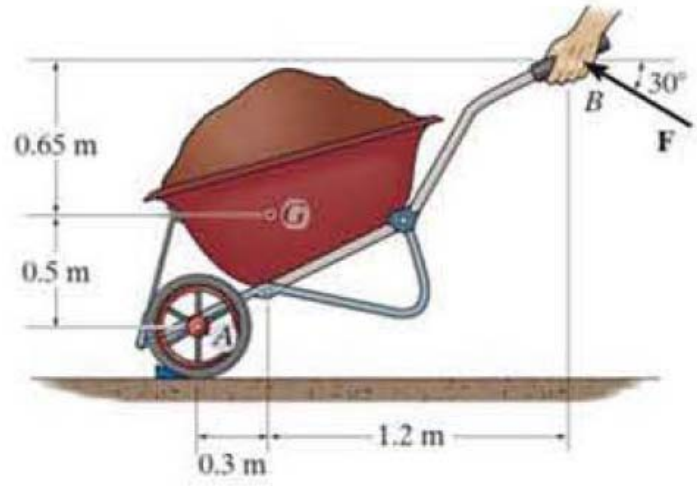


Problem 24. Serious neck injuries can occur when a football player is struck in the face guard of his helmet in the manner shown, giving rise to a guillotine mechanism. Determine the moment of the knee force P = 50N about point A. What would be the magnitude of the neck force ***F*** so that it gives the counterbalance moment about A?

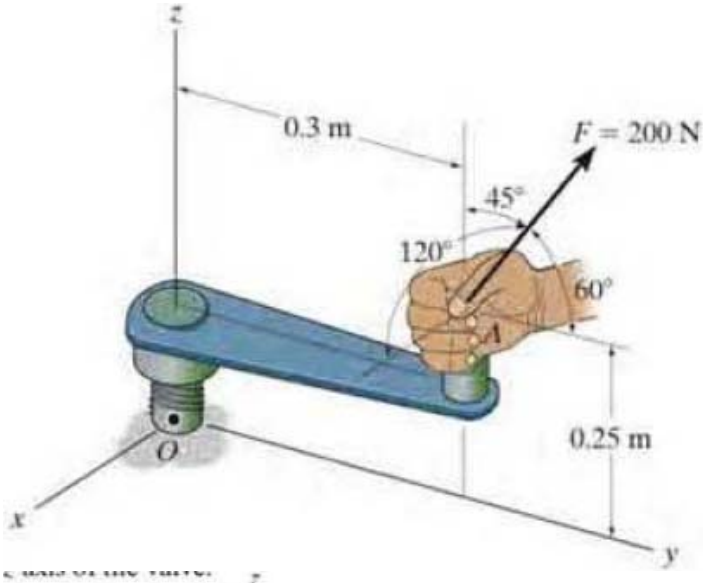


Problem 25. The foot segment is subjected to the pull of the two plantarflexor muscles. Determine the moment of each force about the point of contact A on the ground.

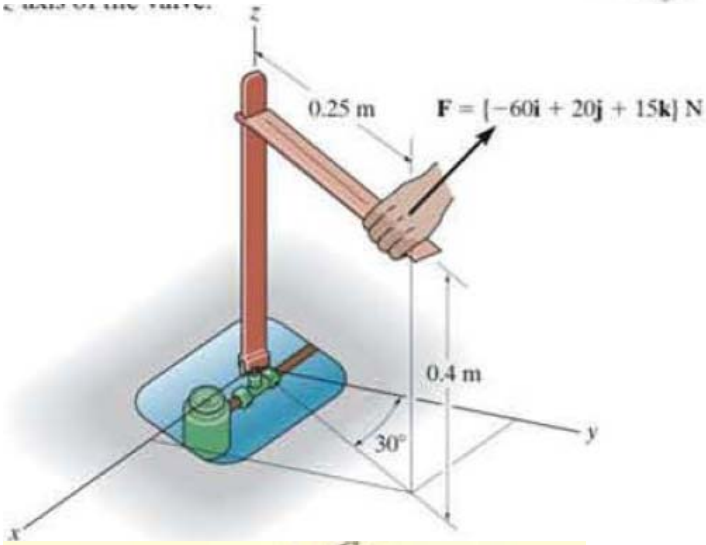
Şekildeki ayak, iki tane plantarfleksor kasın çekme kuvvetine maruz kalmaktadır. Her bir kas kuvvetinin (F_1 ve F_2), ayağın yere temas ettiği A noktası etrafında oluşturdukları momenti hesaplayınız.



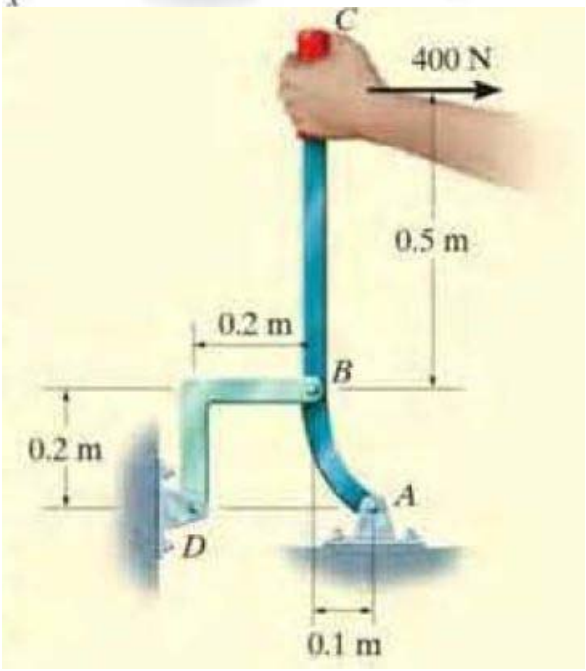
Problem 26. The wheelbarrow and its contents have a center of mass at *G*. If ***F*** = 100 N and the resultant moment produced by force ***F*** and the weight about the ankle at A is zero, determine the mass of the wheelbarrow and its contents.



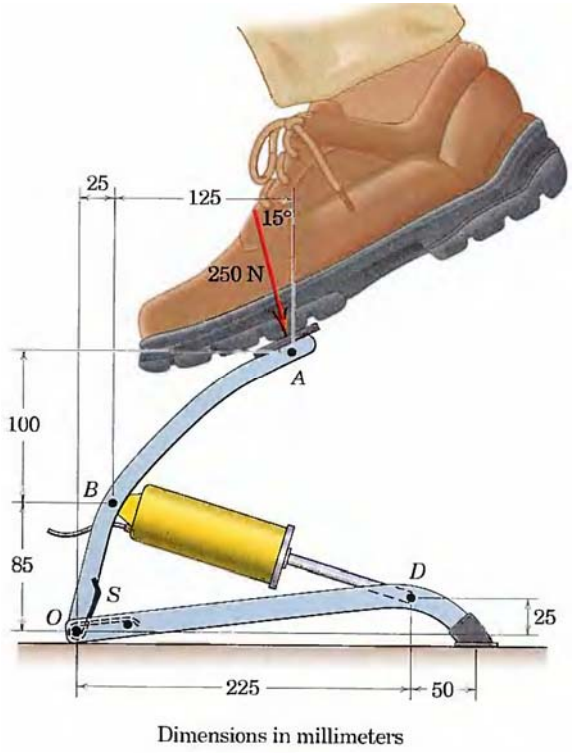
Problem 27. Determine the magnitude of the moment of the 200-N force about the *x* axis.



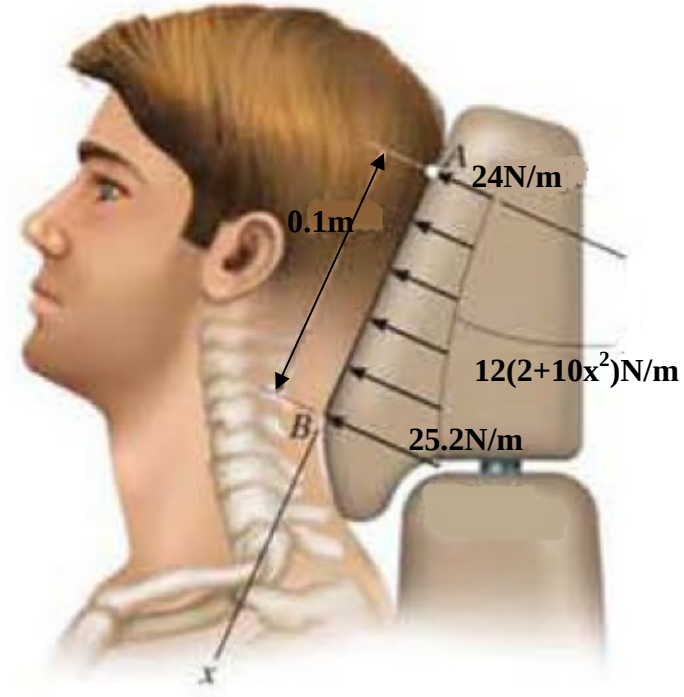
Problem 27. The tool is used to shut off gas valves that are difficult to access. If the force ***F*** is applied to the handle, determine the component of the moment creeated about the *z* axis of the valve.



Problem 28. The lever *ABC* is supported at *A* and connected to a short link *BD* as shown in figure. If the weight of the members is negligible, determine the force of the pin on the lever at *A*.(Ans. F_A=1.07 kN) *Hint: There are two and three force members in the system.*

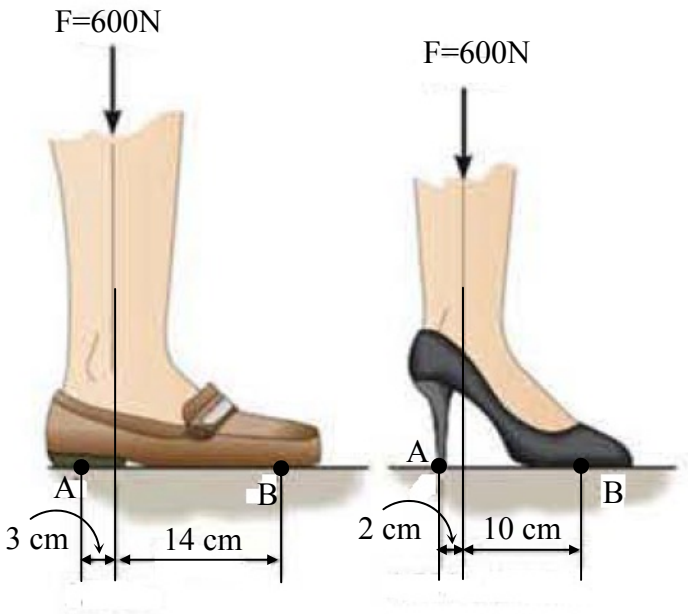


Problem 29. A 250 N force is applied to the foot-operated air pump. The return spring *S* exerts a 3Nm moment on member OBA for this position. Determine the corresponding compression force F_C in the cylinder BD. If the diameter of the piston in the cylinder is 45 mm, estimate the air pressure generated for these conditions. State any assumptions (Ans. F_C = 510 N, p = 321 kPa)

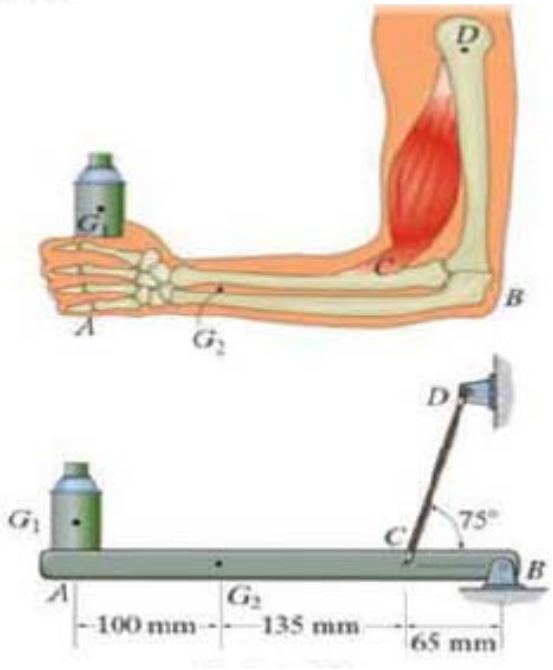


Problem 30. Currently 85% of all neck injuries are caused by rear-end car collisions. To alleviate this problem, an automobile seat restraint has been developed that provides additional pressure contact with the cranium. During dynamic tests the distribution of load on the cranium has been plotted and shown to be parabolic. Determine the equivalent resultant force and its location, measured from point A.

1.

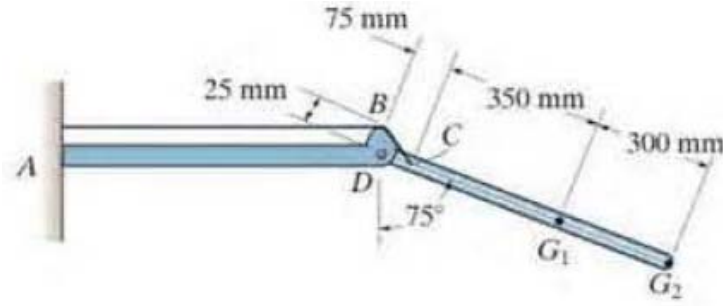


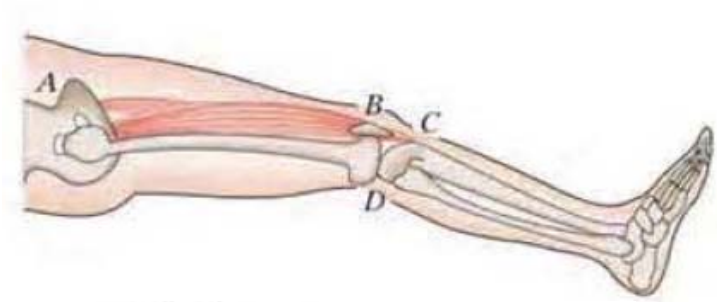
Problem 31. Compare the force exerted on the toe and heel of a 600N woman when she is wearing regular shoes and stiletto heels. Assume all her weight is placed on one foot and the reactions occur at points A and B as shown.



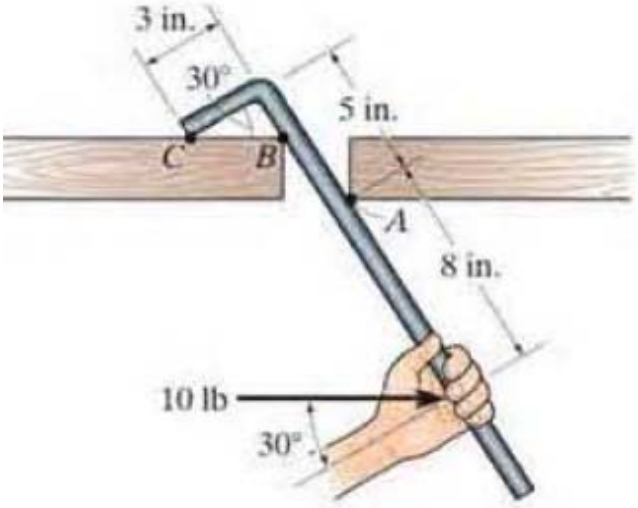
Problem 32. A skeletal diagram of a hand holding a load is shown in the upper figure. If the load and the forearm have masses of 2 kg and 1.2kg, respectively, and their centers of mass are located at G_1 and G_2, determine the force developed in the biceps CD and the horizontal and vertical components of reaction at the elbow joint *B*. The forearm supporting system can be modeled as the structural system shown in the lower figure.

Yük ve ön kolun kütleleri sırasıyla 2 kg ve 1.2 kg'dır ve ağırlık merkezleri G_1 ve G_2 ile gösterilmektedir. Biceps kasının uyguladığı kuvvet ile B noktasındaki reaksiyon kuvvetinin yatay ve düşey eksenlerdeki bileşenlerini hesaplayınız.

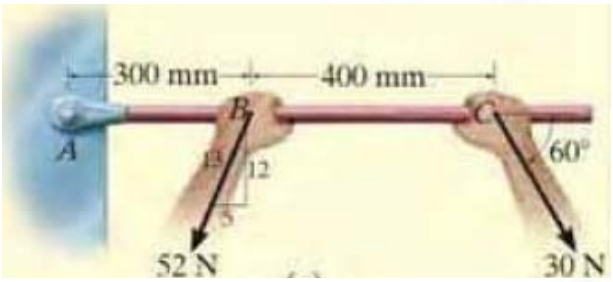




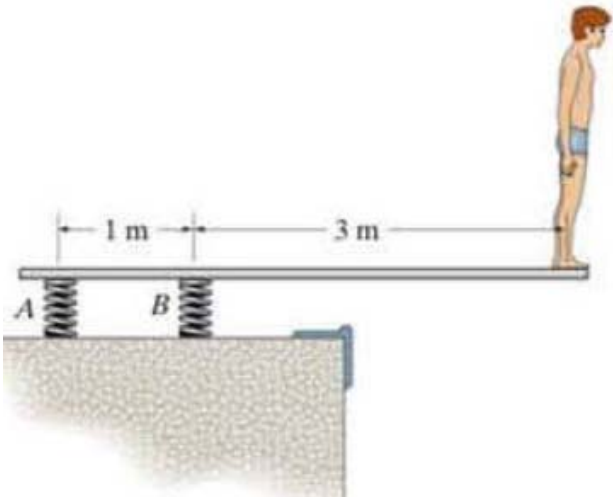
Problem 33. A skeletal diagram of the lower leg is shown in the figure. Here it can be noted that this portion of the led is lifted by the quadriceps muscle attached to the hip at *A* and to the patella bone at *B*. This bone slides freely over cartilage at the knee joint. The quadriceps is further extended and attached to the tibia at *C*. Using the mechanical system shown in the figure to model the lower leg, determine the tension in the quadriceps at *C* and the magnitude of the resultant force at the femur (pin), *D*, in order to hold the lower leg in the position shown. The lower leg has a mass of 3.2 kg and mass center at G_1; the foot has a mass of 1.6 kg and a mass center at G_2.



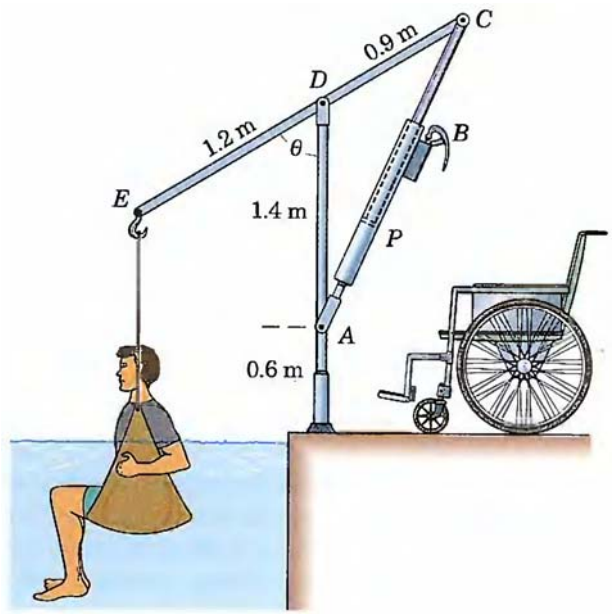
Problem 34. Draw the free-body diagram of the bar, which has a negligible thickness and smooth points of contact at A, B, and C.



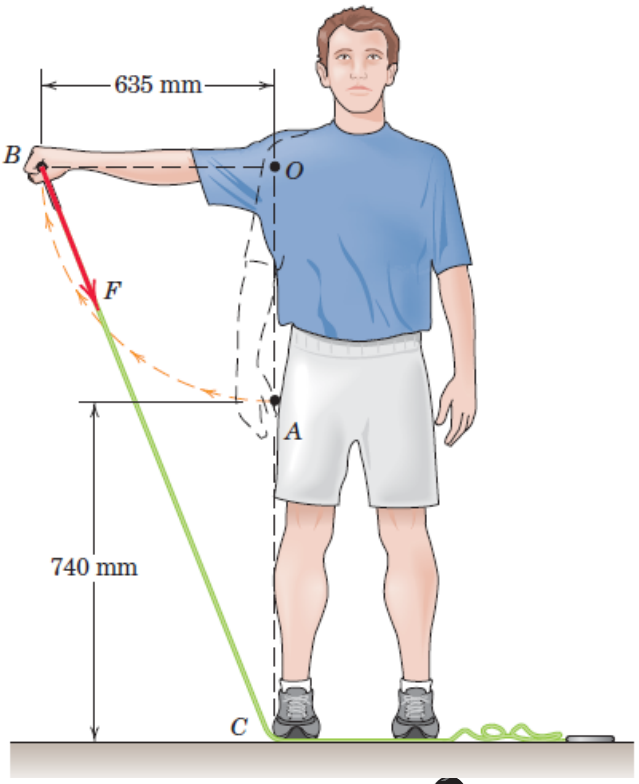
Problem 35. The box wrench is used to tighten the bolt at *A*. If the wrench does not turn when the load is applied to the handle, determine the torque or moment applied to the bolt and the force for of the wrench on the bolt.



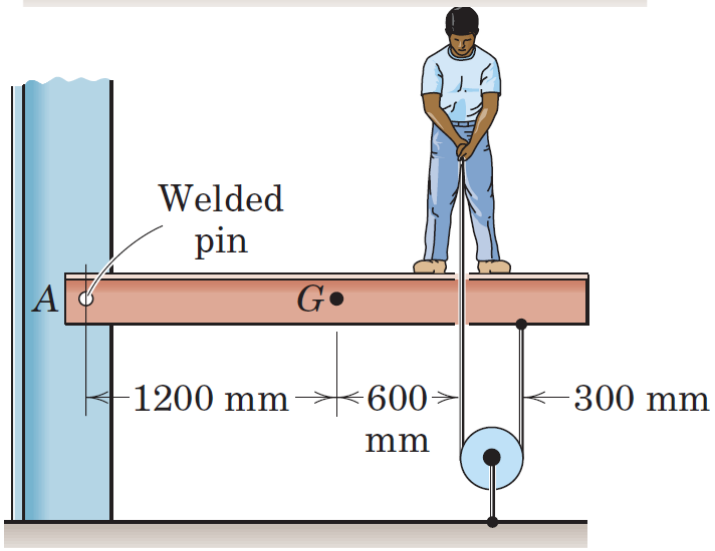
Problem 36. A man stands out at the end of the diving board, which is supported by two springs *A* and *B*, each having a stiffness of k=15 kN/m. In the position shown the board is horizontal. If the man has a mass of 40 kg, determine the angle of tilt which the board makes with the horizontal after he jumps off. Neglect the weight of the board and assume it is rigid (Ans: 10.3^o).



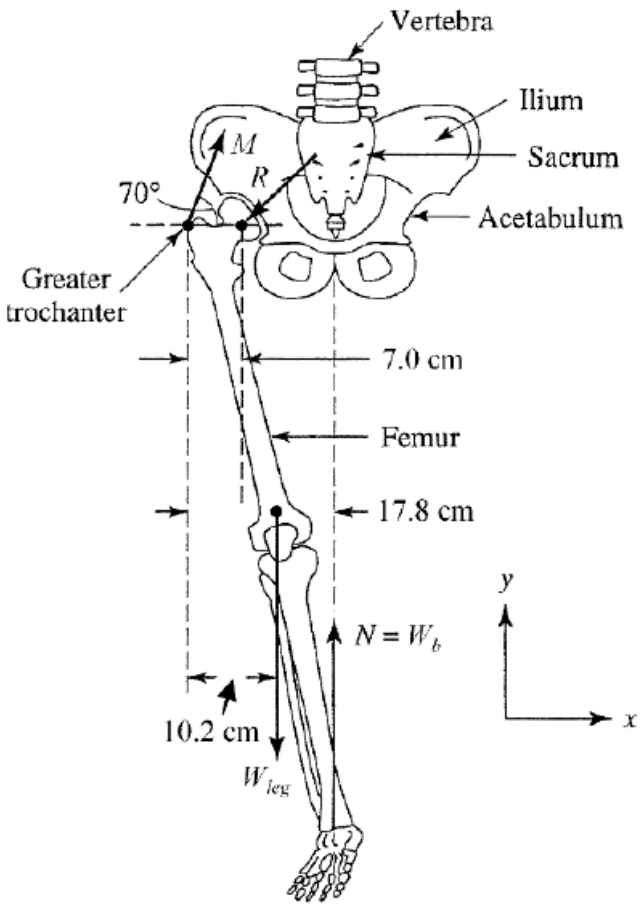
Problem 37. The frame shown enables transfer of a 75kg disabled person to and from a wheelchair and a fresh-water swimming pool. A small hand pump at *B* pressurizes the upper end of the cylinder to control the tension and length of link *AC*. For the position $\theta = 60^{o}$, link *AC* is under a tension of 670N. Calculate the volume of the submerged portion of the person. Neglect the weight of the frame assemby. Recall thath the density of fresh water is 1000 kg/m^3.



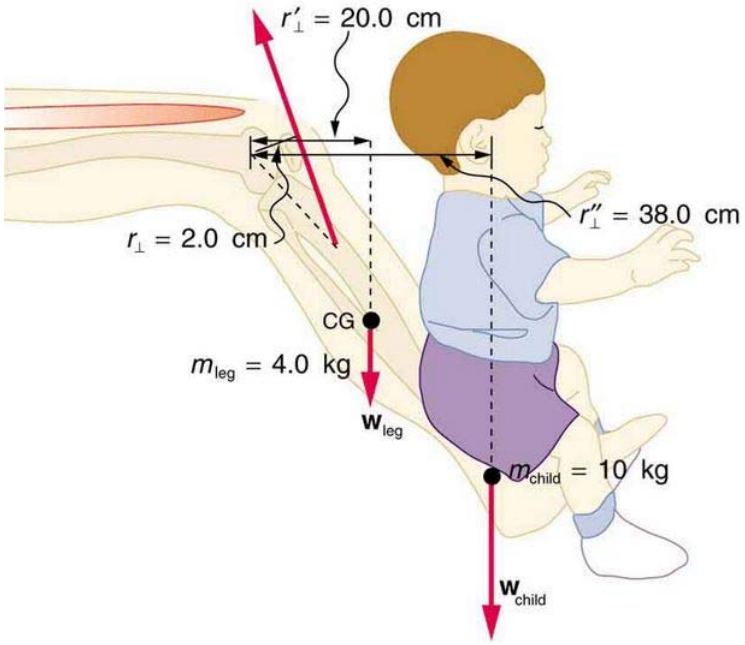
Problem 38. An exerciser begins with his arm in the relaxed vertical position *OA*, at which the elastic band is outstretched. He then rotates his arm to the horizontal position *OB*. The elastic modulus (stiffness) of the hand is k = 60N/m; that is, 60 N of force is required to stretcht the band each additional meter of elongation. Determine the moment about *O* of the force which the band exerts on the hand *B* (Ans: 26.8 Nm).



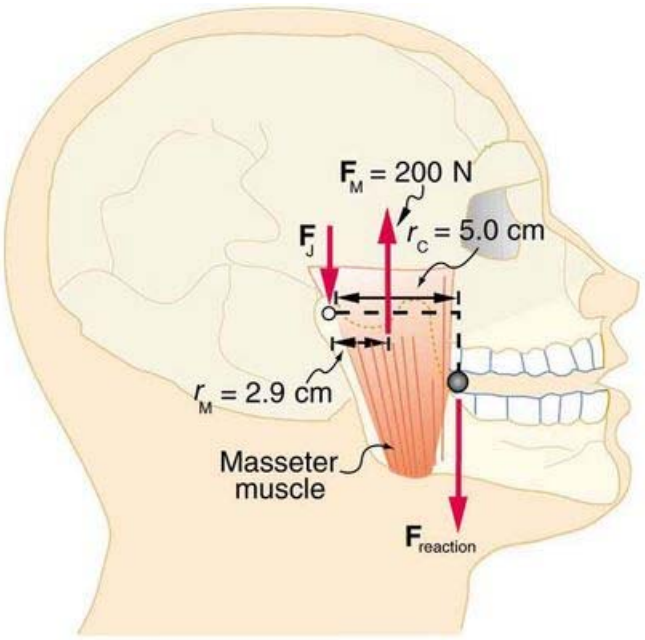
Problem 39. The pin *A*, which connects the 200-kg steel beam with center of gravity at *G* to the vertical column, is welded both to the beam and to the column. To test the weld, the 80-kg man loads the beam by exerting a 300-N force on the rope which passes through a hole in the beam as shown. Calculate the torque (couple) *M* supported by the pin. (Ans: *M*=4,94kNm) (Meriam&Kraige, 2006)



Problem 40. Anatomical diagram of the leg and hip for someone with mass 90 kg standing on one leg, or during slow walking, showing the forces on them and relevant dimensions, including the force exerted on the head of the femur by the acetabulum ***R*** and the net force exerted by the hip abductor muscles. W_{leg} is the weight of the leg and equals to $0.16W_b$. It acts as if it were applied at the center of mass of the leg, which is approximately halfway down the leg. ***R*** is the reaction force on the leg from the hip, and it is normal to the hip socket. ***M*** is the force due to the hip abductor muscles. There are actually three muscles involved here: the tensor fascia latae, gluteus minimus, and the gluteus medius (the gluteus maximus muscle is what I am sitting on as I am typing this). The hip abductor muscle structure we consider is a composite of the three muscles. Determine the forces ***R***, ***M***, $\boldsymbol{W_b}$, $\boldsymbol{W_{leg}}$.



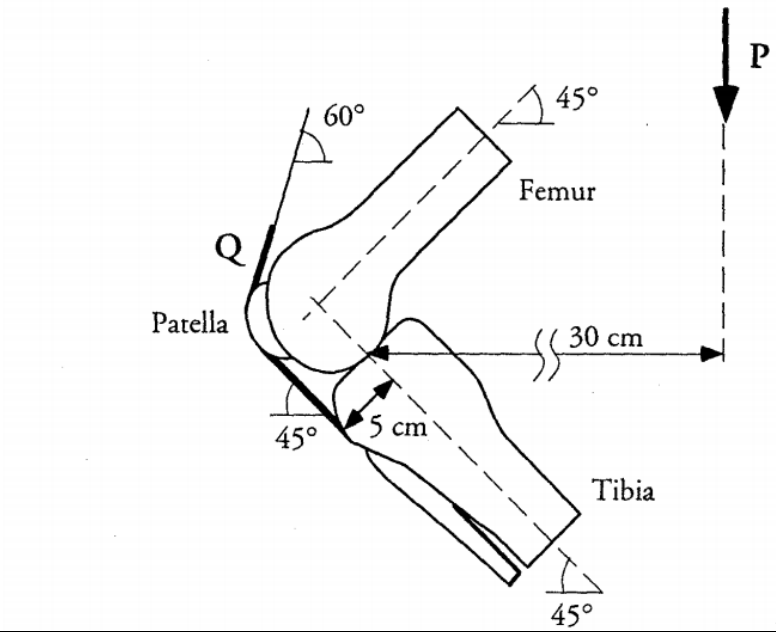
Problem 41. A father lifts his child as shown in the figure. What force should the upper leg muscle exert to lift the child at a constant speed?



Problem 42. Unlike most of the other muscles in our bodies, the masseter muscle in the jaw, as illustrated in figure, is attached relatively far from the joint, enabling large forces to be exerted by the back teeth. (a) Using the information in the figure, calculate the force exerted by the teeth on the bullet. (b) Calculate the force on the joint.

Problem 43.

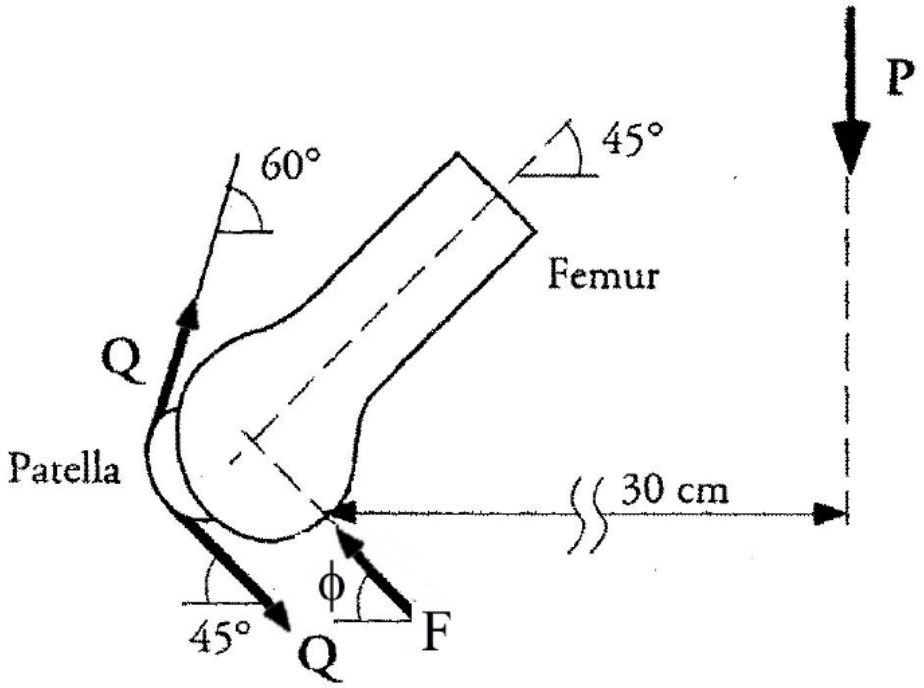
Knee Geometry at 90° Flexion during Squatting (Sagittal View)



People often complain about knee pain during squatting. Consider a knee of an individual in a squatting stance, as shown in the accompanying figure. In this position, the quadriceps muscle (Q) is the only active muscle to support this person's weight.

While considering only static forces that act in the sagittal plane, **determine the bone on-bone contact forces that occur at the tibio-femoral interface and express your answer in terms of body weight (W)**. Assume that the moment arm between the quadriceps muscle (Q) and the contact point between the femur and tibia (tibio-femoral interface) is 9 cm. Note that the quadriceps muscle terminates into the patellar tendon as it wraps around the patella which acts as a pulley. Also, the lower extremities account for approximately 14% of an individual's body weight (i.e. $P = 0.43W$, since the weight is distributed between both legs).

Free Body Diagram of the Femur



$(+\text{cw})\sum M_o = 0$:

$$9Q + 30P - 5Q = 0$$

$$Q = -\frac{30}{4}P$$

$$Q = -\frac{30}{4}(0.43BW)$$

$$\therefore Q = -3.23BW$$

$(+\uparrow)\sum F_y = 0$:

$$Q\sin 60° - Q\sin 45° + F\sin\phi - P = 0$$

$$F\sin\phi = P + Q(\sin 45° - \sin 60°) \qquad \text{(eq.}$$

$$(+\rightarrow)\sum F_x = 0:$$

$$Q\cos 60^\circ + Q\cos 45^\circ - F\cos\phi = 0$$

$$F\cos\phi = Q(\cos 60^\circ + \cos 45^\circ) \qquad \text{(eq.}$$

dividing (eq.1) by (eq.2):

$$\tan\phi = \frac{P + Q(\sin 45^\circ - \sin 60^\circ)}{Q(\cos 60^\circ + \cos 45^\circ)}$$

$$\tan\phi = \frac{0.43BW - 3.23BW(\sin 45^\circ - \sin 60^\circ)}{-3.23BW(\cos 60^\circ + \cos 45^\circ)}$$

$$\therefore \phi = -13.6^\circ$$

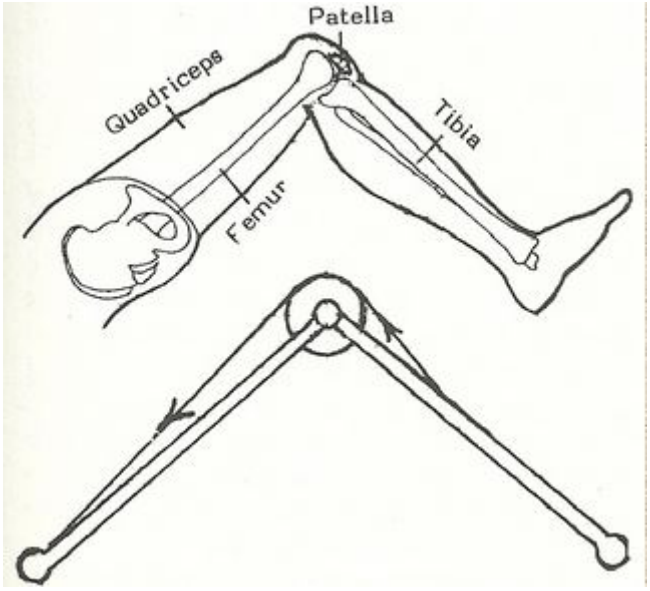
substituting into (eq.2) yields:

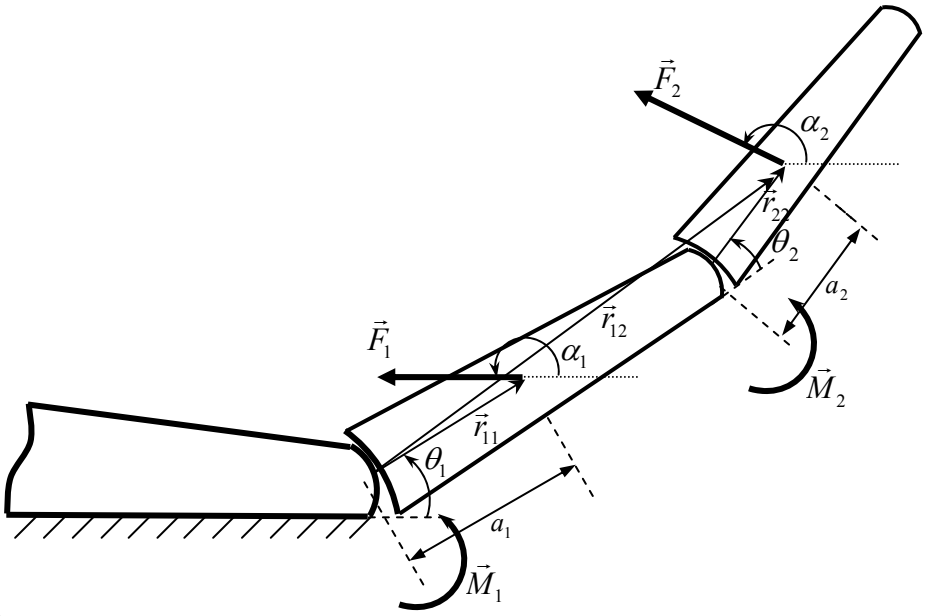
$$F = \frac{Q(\cos 60^\circ + \cos 45^\circ)}{\cos\phi}$$

$$F = \frac{-3.23BW(\cos 60^\circ + \cos 45^\circ)}{\cos(-13.6^\circ)}$$

$$\therefore F = -4.01BW$$

There is 4 times body weight being transmitted through each knee in this particular squatting position!





Problem 44.

Determine the joint moments M_1 and M_2 in terms of parameters of the physical system shown in the figure. Length of the first and second links are l_1 and l_2.