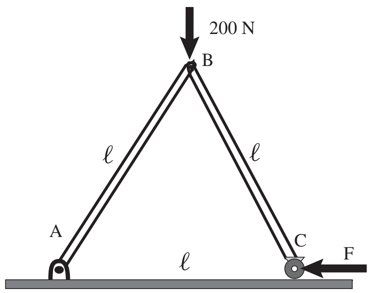
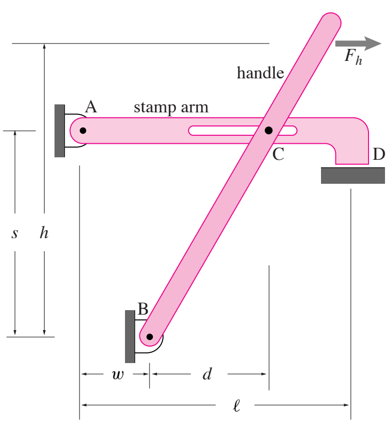
7.3 Machines

7.3.1 A simply supported two bar mechanism supports a load of 200 N at joint B with the help of a horizontal force F applied at joint C. Find F.



Problem 7.3.1

7.3.2 Pulling on the handle causes the stamp arm to press down at D. Neglect gravity and assume that the hinges at A and B, as well as the roller at C, are frictionless. Find the force N that the stamp machine causes on the support at D in terms of some or all of F_h, w, d, ℓ, h, and s. *



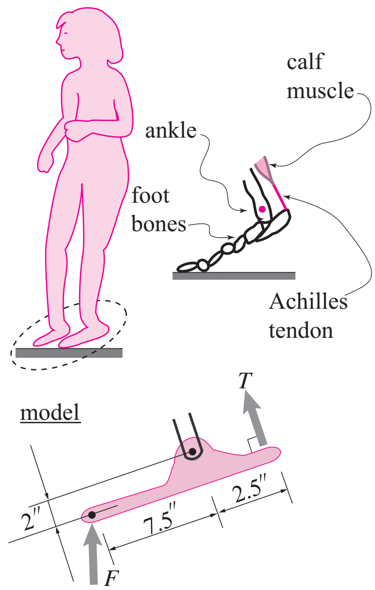
Problem 7.3.2

More-Involved Problems

7.3.3 See Problem 5.2.17 on page 305. A person who weighs W stands on tiptoes on one foot. Assume the weight of the foot is negligible.

a) Draw a free-body diagram of the whole person and find the force of the ground on the foot front.

b) Draw a free-body diagram of the foot and find the force of the calf on the foot at the ankle and the tension in the Achilles tendon.

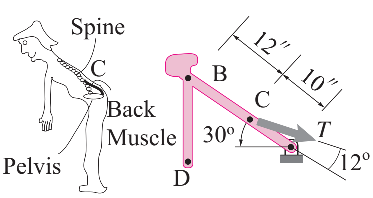


Problem 7.3.3

7.3.4 See Problem 5.2.17 on page 305. A person with weight $W = 140$ lbf has an upper body with weight $0.7W$ with center of mass at C. The back muscles are idealized as a single muscle with one end (the muscle *origin* also at C. Use the idealization and geometry shown.

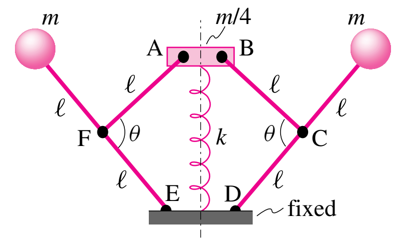
a) Find the back-muscle tension and the force of the lower body on the upper body at the hips.

b) Repeat the problem but assume that the person is lifting a 30 lbf load at D.



Problem 7.3.4

7.3.5 In the flyball governor shown, the mass of each ball is $m = 5$ kg, and the length of each link is $\ell = 0.25$ m. There are frictionless hinges at points A, B, C, D, E, F where the links are connected. The central collar has mass $m/4$. Assuming that the spring of constant $k = 500$ N/m is uncompressed when $\theta = \pi$ radians, what is the compression of the spring?

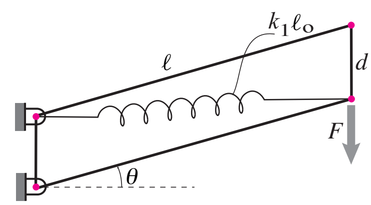


Problem 7.3.5

7.3.6

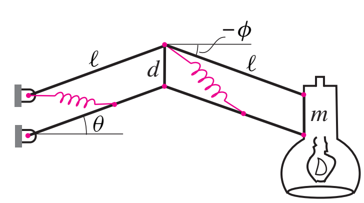
a) Find F for equilibrium for the parallelogram structure shown assuming the rest length of the spring is zero.

b) Comment on how your answer above depends on θ.



Problem 7.3.6

7.3.7 A common lamp design is shown. In principle, the lamp should be in equilibrium in all positions. According to the original patent from the 1930s, it can be in equilibrium, even with no friction in the joints. Unfortunately, the recent manufacturers of this lamp seem to have lost the wisdom of the original patent. Show how to place the springs so this lamp is in equilibrium for all $\theta < \pi/2$ and $\phi < \pi/2$. [Hint: use springs with zero rest length.]

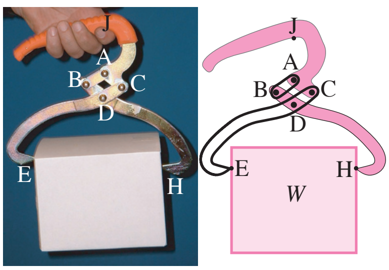


Problem 7.3.7: Lamp.

7.3.8 Log carrier. This self-locking scissors-mechanism gadget is used to pick up logs and blocks of ice. The 5 cm wide and 3 cm high diamond arrangement of hinges ABCD makes up a 4-bar linkage. The grips E and H are 16 cm apart and 9 cm below D. The block weighs 250 N. Neglect the weight of the mechanism.

a) What is the horizontal component of the force on the block at E?

b) What is the minimum coefficient of friction μ for which this device self locks?



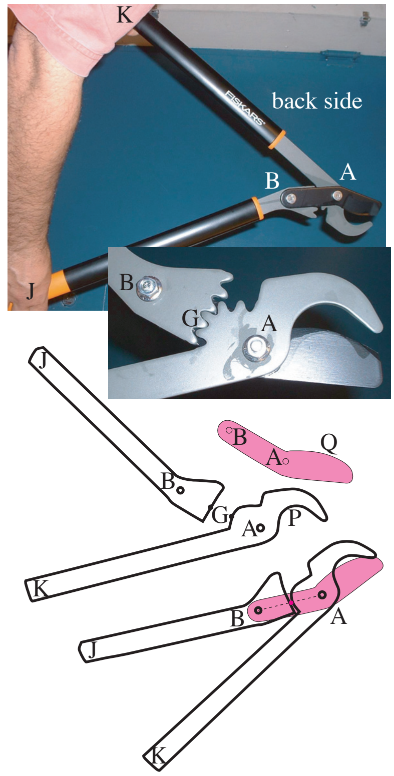
Problem 7.3.8

7.3.9 Gear teeth on handle JB mesh with teeth on handle-and-blade KAP at point G midway between hinges A and B. Assume that in the configuration of interest J, B and A are co-linear, that K, A and Q are co-linear and that the cutting contact points Q and P are effectively coincident, that angle JAK = 20°, $JB = 40$ cm, $BA = 6$ cm, $KA = 46$ cm, $AP = AQ = 3$ cm, and that the co-linear squeezing forces at J and K are 100 N.

a) Find the cutting force at Q and P.

b) Replace this design with one that has no tooth engagement at G. But instead handle JB and blade BAQ are welded together as one piece. Assuming the same geometry as before, what then is the cutting force at Q and P?

c) Without detailed calculations, explain the ratio of the two answers above. *



Problem 7.3.9

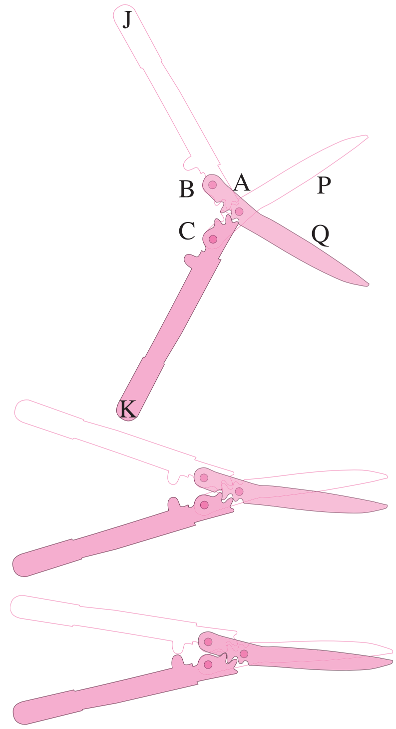
7.3.10 These 4-piece shears use the mechanism in problem 7.3.9 twice over. Co-linear hand forces F_{JK} are applied to handles JB and KC at J and K. Handle JB is hinged to blade BAQ at B. Handle KC is hinged to blade CAP at C. The blades are hinged to each other at A. Handle JB is effectively hinged to CAP, by means of gear teeth, at G, a point on the line segment AB. Similarly KC is effectively hinged to BAQ at point G' on the segment AC. The cut object presses with colinear forces F_{PQ} on the blades at P and Q. See box 7.6 on page 419 for more pictures of these shears.

Assume $F_{JK} = 100$ N, $JB = KC = 30$ cm, $AB = AC = 6$ cm, $AG = AG' = 3$ cm, and $AP = AQ = 20$ cm. Assume AB, BJ, AC,and CK all make angles of ±20° with a horizontal line. Assume P and Q are coincident and on a horizontal line extending from A.

a) Find F_{PQ}.

b) Replace this design with one where JB is welded to BAQ at B, KC is welded to CAP at C, and there are no contacting gears. In this same geometry what is F_{PQ}?

c) Give a quantitative estimate, but not a detailed calculation that tells you the ratio of the forces in the above two problems? *



Problem 7.3.10

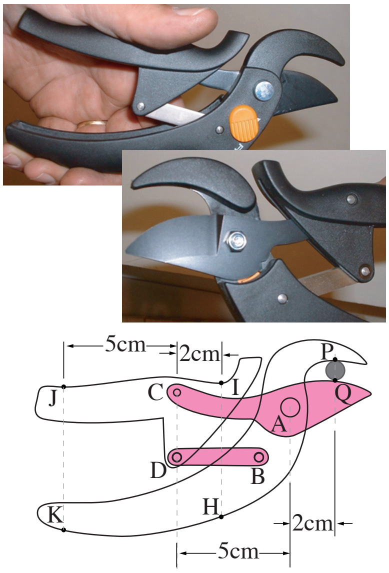
7.3.11 The garden cutters shown are a 4-bar linkage. Estimate the locations of points, as needed, using the given dimensions as a scale (the drawn clippers are shrunk slightly from reality to simplify the numbers).

a) If the handle is squeezed with a pair of 50 N forces at J and K what is the cutting force at P and Q? *

b) If the handle is squeezed with a pair of 50 N forces at I and H what is the cutting force at P and Q? *

c) If this design was changed by eliminating link DB and welding handle JCDI to the blade CAQ, what would be the answers to the two questions above. *

d) Describe in words, the reasons for the similarities and differences between the answers above. *



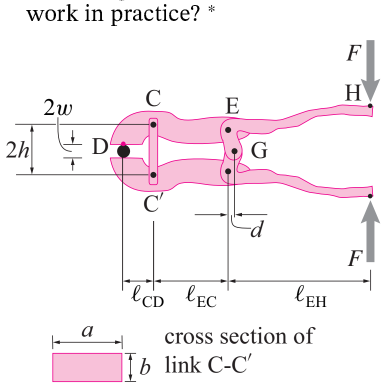
Problem 7.3.11

7.3.12 The pliers shown are made of five pieces modeled as rigid: HEG and its mirror image, DCE and its mirror image, and link CC'. You may assume that the geometry is symmetric about a horizontal line (the top is a mirror image of the bottom). The load F and dimensions shown are given. (See also similar problem 7.2.6)

a) Find the force squeezing the piece at D; *

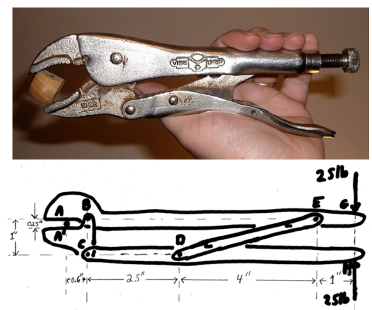
b) Find the tension in CC'; *

c) What happens to the squeezing force if d is made smaller, approaching zero? Why can't this work in practice? *



Problem 7.3.12

7.3.13 For simplicity the vice grips shown in the photo are approximated as in the drawing. Round piece AA' is gripped between the upper handle/jaw ABEG and the lower jaw A'BC. The upper handle ABEG is pinned to the lower jaw A'BC at B. Handle CDH is pinned to the lower jaw at C and to the bar DE at D. Bar DE is pinned to the upper handle ABEG at E. The 25 lbf forces act at G and H as shown. Dimensions are as shown. What is the magnitude of the force at A? *



Problem 7.3.13

7.3.14 Pipe wrench. A wrench is used to turn a pipe as shown in the figure. Neglecting the weight of the pipe, find

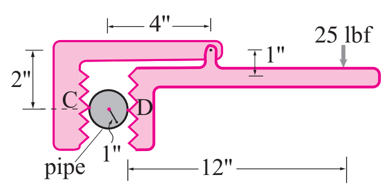
a) the torque of the pipe wrench forces about the center of the pipe

b) the forces on the pipe at C and D

c) the needed friction coefficient between the wrench and pipe for the wrench not to slip.

d) what design change would reduce this needed coefficient of friction (what change of dimensions)? *

e) given that the design change above is possible, why isn't it used? [hint: implement the design change and calculate the forces on the pipe.] *

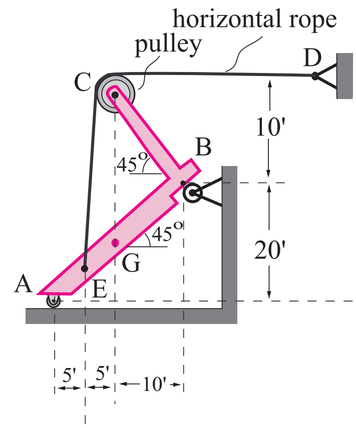


Problem 7.3.14

7.3.15 The center of mass of 200 pound structure AEGBC is at G. It is held by rollers at A and B as well as with the rope which starts at E, wraps around the pulley at C, and ends at D. You can assume the pulley at C has negligible size.

a) Find the force of the ground on the structure at A. *

b) Find the tension in the rope. *



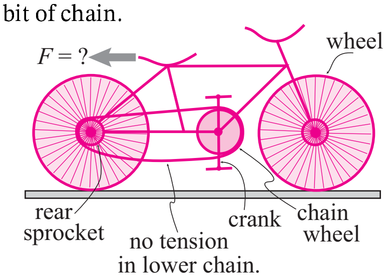
Problem 7.3.15

7.3.16 Consider a bike on level ground that is held from falling sideways with forces that don't push it forward or back. Assume that all the bearings are ideal and that the wheels don't slip.
R_r = radius of rear wheel,
R_s = radius of rear sprocket,
R_p = crank length from crank-axle to pedal, and
R_c = radius of chain wheel (front sprocket).
What backwards force F on the seat is required to keep the bike from going forward (*i.e.,* to maintain static equilibrium) if

a) A person sits on the bike and pushes back on the bottom pedal with a force F_p? (is $F > 0$?)

b) A person standing next to the bike pushes back on the pedal with force F_p? (is $F > 0$?)

Your answer should be in terms of some or all of R_r, R_s, R_p, R_c, and F_p. Of great interest is whether F is bigger or less than zero. So pay close attention to signs.
To solve this problem you have to draw several free-body diagrams: 1) of the whole bike and rider (if the rider is on the bike), 2) of the crank-pedal-chain-wheel system, with a little bit of chain, 3) The rear wheel and rear sprocket, with a little bit of chain.



Problem 7.3.16

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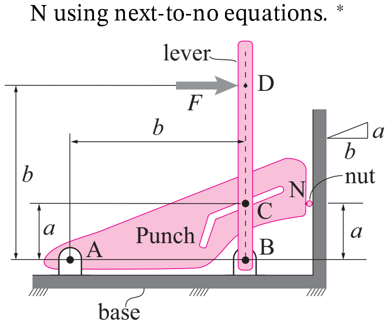
7.3.17 The proposed nutcracker design consists of two moving parts: a lever hinged to the fixed base at B and a punch hinged to the fixed base at A. All joints and slots are assumed to have negligible friction.

Mechanism and geometry clarifications: The vertical lever has a pin at C and a horizontal force F applied at D. The punch has a slot in which the lever pin slides at C. The slot is parallel to the line AC. The spherical nut is cracked by being squeezed between the vertical surface of the punch at N and the vertical surface attached to the base. Point N at the left edge of the nut is level with the sliding pin at C. The horizontal distance from C to N does not enter the solution, but assume it is c if you need it for an intermediate calculation.

Quantities: $F = 10\,\text{lbf}$, $a = 2\,\text{in}$, $b = 10\,\text{in}$.

a) Find the force acting on the nut at N. A number is desired (i.e., so many lbf force). [Hint: Only substitute in numbers when you have a formula for your answer in terms of a, b and F.] *

b) The answer to (a) is conspicuous in its being either much smaller than F, very similar to F, or much bigger than F. Which is it? Explain, in words, why. The best possible answer will generate an approximate formula for the force at N using next-to-no equations. *



Problem 7.3.17