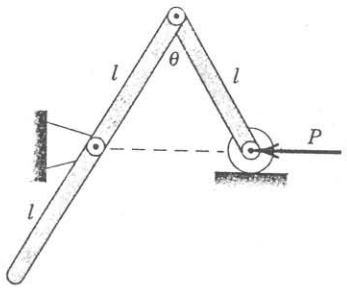
PROBLEMS

(Assume that the negative work of friction is negligible in the following problems unless otherwise indicated.)

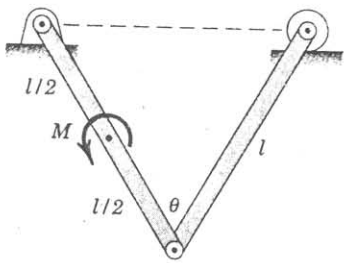
1 The mass of the uniform bar of length l is m while that of the uniform bar of length $2l$ is $2m$. For a given force P, determine the angle θ for equilibrium.

Ans. $\theta = 2 \tan^{-1}\left(\frac{4P}{mg}\right)$



Problem 1

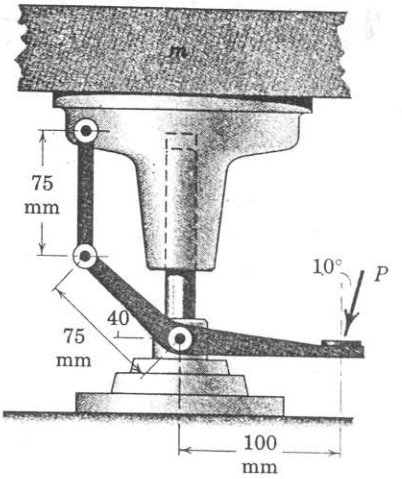
2 Determine the couple M required to maintain equilibrium at an angle θ. Each of the two uniform bars has mass m and length l.



Problem 2

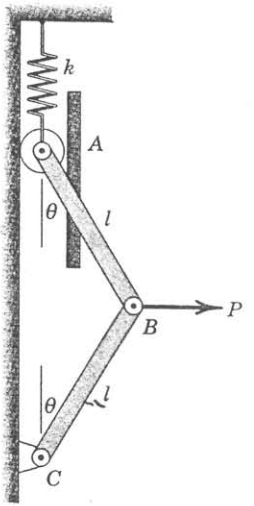
3 The foot-operated lift is used to raise a platform of mass m. Determine the necessary force P applied at the 10° angle to support the 80-kg load.

Ans. $P = 458$ N



Problem 3

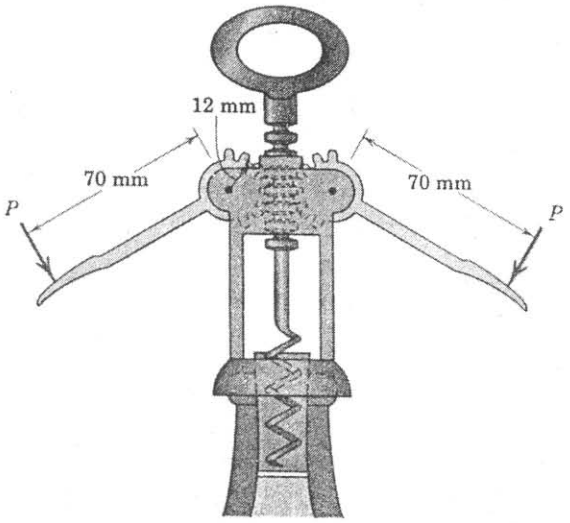
4 The spring of constant k is unstretched when $\theta = 0$. Derive an expression for the force P required to deflect the system to an angle θ. The mass of the bars is negligible.



Problem 4

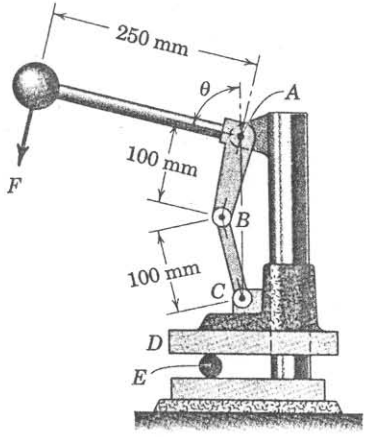
By means of a rack-and-pinion mechanism, large forces can be developed by the cork puller shown. If the mean radius of the pinion gears is 12 mm, determine the force R which is exerted on the cork for given forces P on the handles.

Ans. $R = 11.67P$



Problem 5

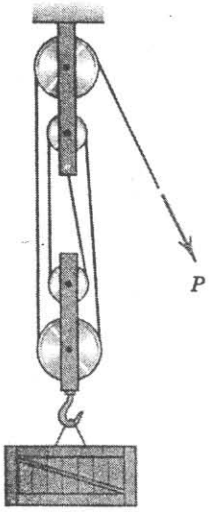
6 The upper jaw D of the toggle press slides with negligible frictional resistance along the fixed vertical column. Determine the required force F on the handle to produce a compression R on the roller for any given value of θ.



Problem 6

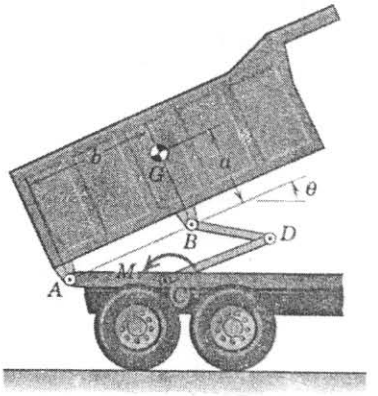
7 For each unit of movement of the free end of the rope in the direction of the applied force P, the 250-lb load moves one-fourth of a unit. If the mechanical efficiency e of the hoist is 0.75, calculate the force P required to raise the load and the force P' required to lower the load.

Ans. $P = 83.3$ lb, $P' = 46.9$ lb



Problem 7

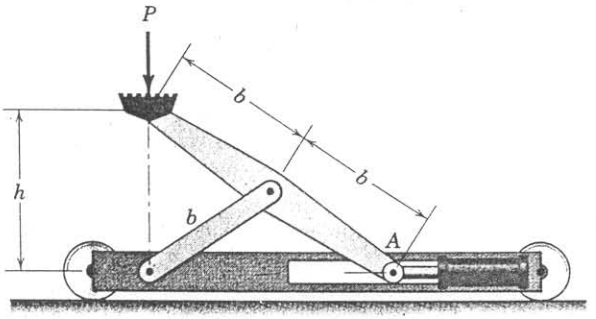
8 Determine the torque M on the activating lever of the dump truck necessary to balance the load of mass m with center of mass at G when the dump angle is θ. The polygon $ABDC$ is a parallelogram.



Problem 8

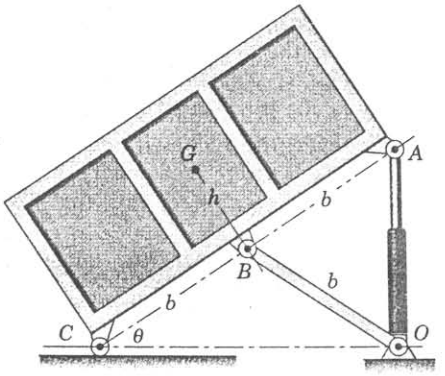
9 The portable car hoist is operated by the hydraulic cylinder which controls the horizontal movement of end A of the link in the horizontal slot. Determine the compression C in the piston rod of the cylinder to support the load P at a height h.

Ans. $C = P\sqrt{\left(\frac{2b}{h}\right)^2 - 1}$



Problem 9

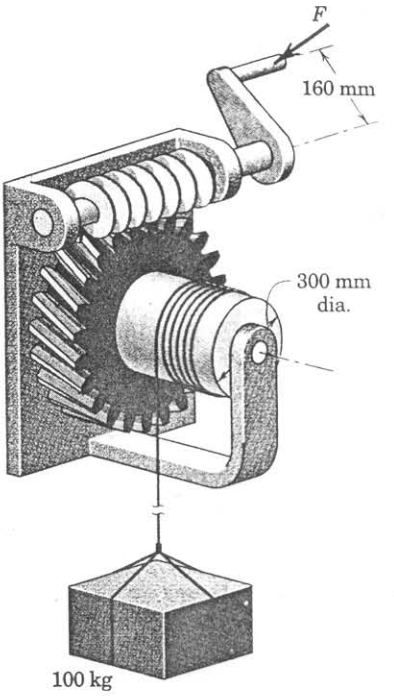
10 The hydraulic cylinder OA and link OB are arranged to control the tilt of the load which has a mass m and a center of mass at G. The lower corner C is free to roll horizontally as the cylinder linkage elongates. Determine the force P in the cylinder necessary to maintain equilibrium at a given angle θ.



Problem 10

11 The hand-operated hoist is designed to lift a 100-kg load where 25 turns of the handle on the worm shaft produce one revolution of the drum. Assuming a 40-percent loss of energy due to friction in the mechanism, calculate the force F normal to the handle arm required to lift the load.

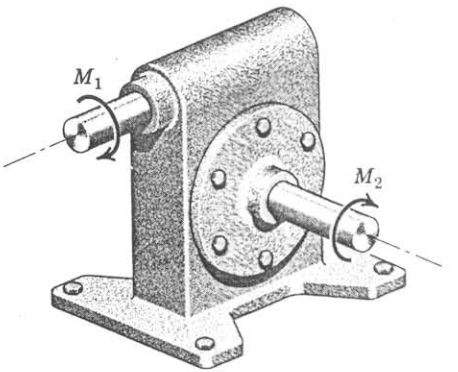
Ans. $F = 61.3$ N



Problem 11

Representative Problems

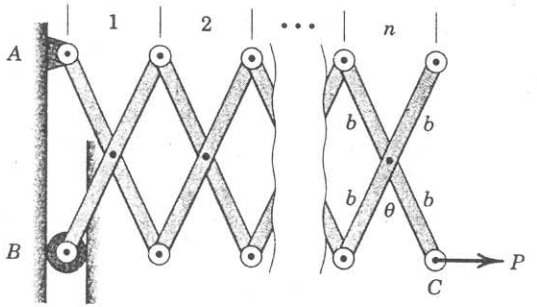
12 The speed reducer shown is designed with a gear ratio of 40:1. With an input torque $M_1 = 30$ N·m, the measured output torque is $M_2 = 1180$ N·m. Determine the mechanical efficiency e of the unit.



Problem 12

13 The folding linkage is composed of n identical sections, each of which consists of two identical bars of mass m each. Determine the horizontal force P necessary to maintain equilibrium in an arbitrary position characterized by the angle θ. Does P depend on the number n of sections present?

Ans. $P = mg \tan \frac{\theta}{2}$, no

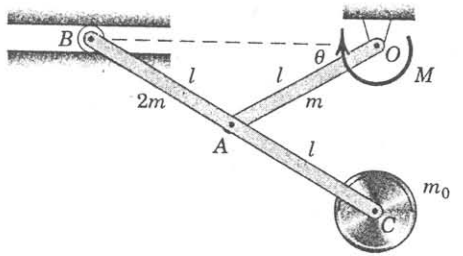


Problem 13

14 Replace the force P acting on the linkage of Prob. 13 by a couple M. Determine the moment M of the couple necessary to maintain equilibrium in an arbitrary position characterized by the angle θ. Does M depend on the number n of sections present?

15 Determine the couple M which must be applied at O in order to support the mechanism in the position $\theta = 30°$. The masses of the disk at C, bar OA, and bar BC are m_0, m, and $2m$, respectively.

Ans. $M = (\frac{5}{4}m + m_0)gl\sqrt{3}$



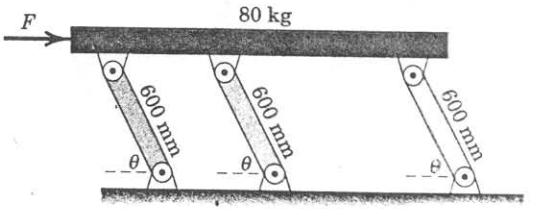
Problem 15

16 Determine the force F which the person must apply tangent to the rim of the handwheel of a wheelchair in order to roll up the incline of angle θ. The combined mass of the chair and person is m. (If s is the displacement of the center of the wheel measured along the incline and β the corresponding angle in radians through which the wheel turns, it is easily shown that $s = R\beta$ if the wheel rolls without slipping.)

Problem 16

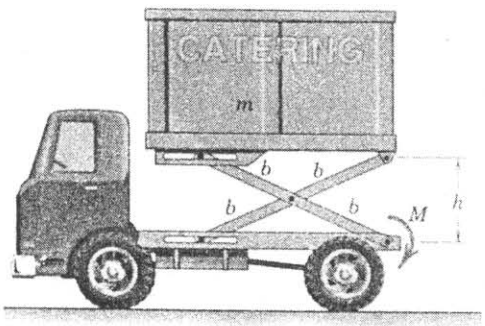
17 Specify the horizontal force F necessary to maintain equilibrium of the 80-kg platform in terms of the angle θ made by the supporting links with the horizontal. Each of the three uniform links has a mass of 10 kg. (Compare the solution by virtual work with a solution by force and moment equilibrium.)

Ans. $F = 932 \cot \theta$ N



Problem 17

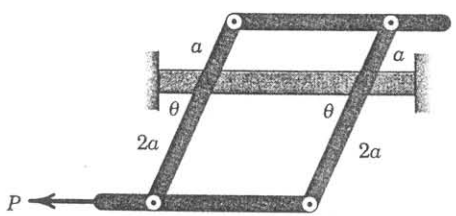
18 The cargo box of the food-delivery truck for aircraft servicing has a loaded mass m and is elevated by the application of a torque M on the lower end of the link which is hinged to the truck frame. The horizontal slots allow the linkage to unfold as the cargo box is elevated. Express M as a function of h.



Problem 18

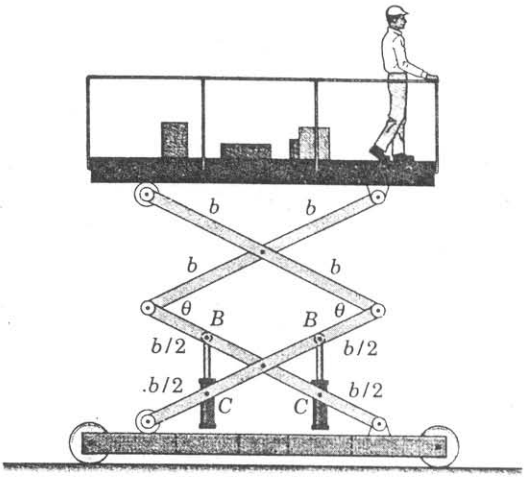
19 Each of the four uniform movable bars has a mass m, and their equilibrium position in the vertical plane is controlled by the force P applied to the end of the lower bar. For a given value of P, determine the equilibrium angle θ. Is it possible for the equilibrium position shown to be maintained by replacing the force P by a couple M applied to the end of the lower horizontal bar?

$$Ans.\ \theta = \tan^{-1}\frac{mg}{P},\ \text{no}$$



Problem 19

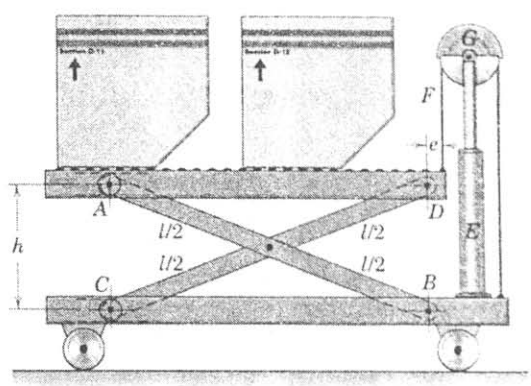
20 The portable work platform is elevated by means of the two hydraulic cylinders articulated at points C. Each cylinder is under a hydraulic pressure p and has a piston area A. Determine the pressure p required to support the platform and show that it is independent of θ. The platform, worker, and supplies have a combined mass m, and the masses of the links may be neglected.



Problem 19/20

21 The existing design of an aircraft cargo loader is under review. The platform AD of the loader is elevated to the proper height by the mechanism shown. There are two sets of linkages and hydraulic lifts, one set on each side. Cables F which lift the platform are controlled by the hydraulic cylinders E whose piston rods elevate the pulleys G. If the total weight of the platform and containers is W, determine the compressive force P in each of the two piston rods. Does P depend on the height h? What force Q is supported by each link at its center joint when W is centered between A and D?

$$Ans.\ P = W,\ \text{no};\ Q = \frac{W}{2}\left(1 + \frac{2e}{\sqrt{l^2 - h^2}}\right)$$



Problem 21