

**Challenge Problem 9**

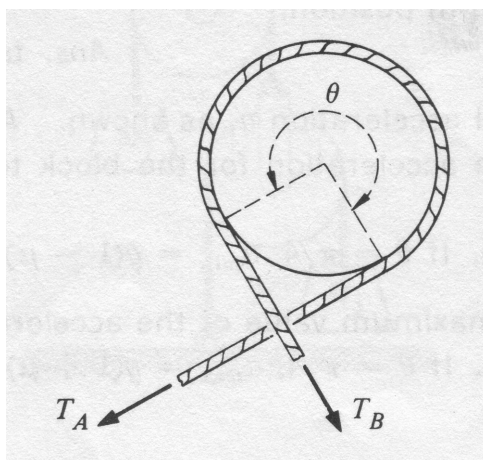
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A device called a capstan is used aboard ships to control a rope which is under great tension. The rope is rapped around a fixed drum, usually for several turns (the drawing shows about three-fourths of a turn). The load on the rope pulls it with a force  $T_A$ , and the sailor holds it with a much smaller force  $T_B$ .

(a) Show that

$$T_B = T_A e^{-\mu\theta}$$

where  $\mu$  is the coefficient of static friction of the drum's surface, and  $\theta$  is the total angle subtended by the rope on the drum.



(b) Alice can pull a rope with a force of magnitude 500 N. If the drum has a diameter of  $1/2$  m, the surface has coefficient of static friction  $1/2$ , and Alice has a 5 m length of rope, then by using the capstan, approximately what is the maximum load she can hold? Assume that all but 1 m of the rope will be wrapped around the drum.