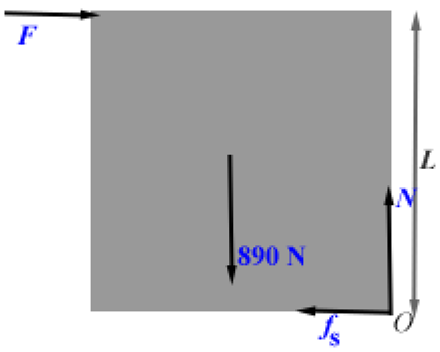
48.

Problem 13.43P (HRW)

A cubical box is filled with sand and weighs 890 N. *we wish to "roll" the box by pushing horizontally on one of the upper edges.* (a) *What minimum force is required?* (b) *What minimum coefficient of static friction between box and floor is required?* (c) *Is there a more efficient way to roll the box? If so find the smallest possible force that would have to be applied directly to the box to roll it.*

Solution:

As we wish to roll the box by pushing horizontally on one of the upper edges, the normal force on the box will act at the bottom edge about which the box is intended to roll. The free-body diagram of the box will be as shown.



Minimum force F that will roll the box about the edge perpendicular to the plane of the diagram and passing through O is determined by requiring that the torque is zero. This condition gives the relation

$$F \times L = 890\ \mathrm{N} \times \mathrm{L}/2.$$

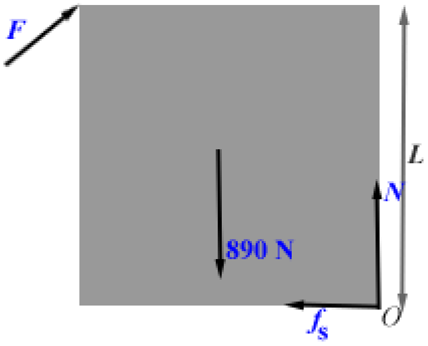
From this we find that the minimum force required for rolling the box by pushing it horizontally on one of the upper edges is

$$F = 450\ \mathrm{N}.$$

Minimum coefficient of static friction between box and floor that is required is

$$\mu_s = \frac{F}{N} = 0.5, \text{ as } N = 890\ \mathrm{N}.$$

A more efficient way to roll the box will be to maximise the rotational arm of F. When the force F is applied at right-angles to the line joining the point O and the point of application of F, then same magnitude of torque can be obtained by reducing the magnitude of F. The maximum rotational arm will be the diagonal length $\sqrt{2}L$.



This gives

$$F_{\min} \times \sqrt{2}L = 890\ \text{N} \times L/2,$$

or,

$$F_{\min} = 318\ \text{N}.$$