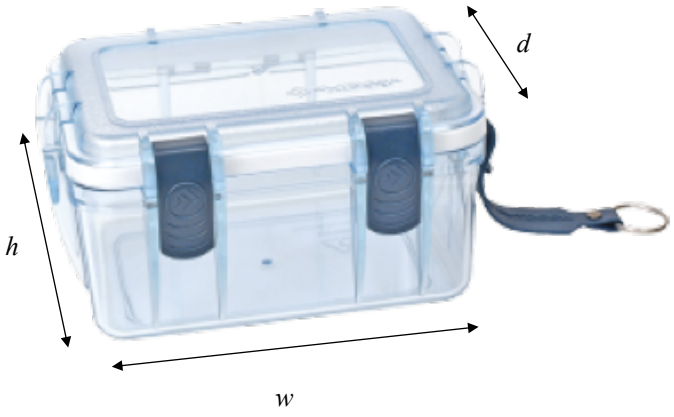
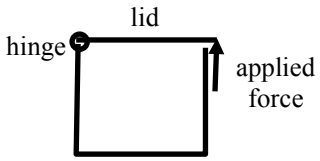
Your professor purchased a watertight box to hold his camera while traveling to Ft. Myers Beach, FL during winter break. The box's dimensions are shown in the photograph. During the flight, he opened the box and then re-sealed it. Upon reaching his destination, he found that he had significant difficulty trying to open the box.

a. Why was opening the box such a challenge?
b. Estimate the force required to open the box if the force is applied at the front of the box. Note that the box is hinged at the back.

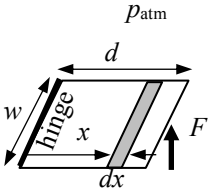


$w = 6.46$ in
$d = 5.11$ in
$h = 3.25$ in



SOLUTION:

The box was difficult to open because the air in the interior of the box was at the cabin pressure of the aircraft (required to be pressurized to a maximum altitude of 8000 ft altitude[1]) and the air outside the box was at the local atmospheric pressure (Ft. Myers Beach, FL which is at sea level). This pressure difference resulted in a net pressure force acting to hold the lid shut.



Sum moments about the lid's hinge,

$$\sum M_{hinge} = 0 = Fd - \int_{x=0}^{x=d} \underbrace{x}_{\text{moment arm}} \underbrace{\left(p_{atm} - p_{box}\right)}_{\text{pressure difference}} \underbrace{wdx}_{=dA}, \tag{1}$$

$$Fd = \left(p_{atm} - p_{box}\right)\frac{1}{2}wd^2, \tag{2}$$

$$\boxed{F = \left(p_{atm} - p_{box}\right)\frac{1}{2}wd}. \tag{3}$$

where

$p_{FMB} = p_{sea\ level} = 14.7$ psia (using a U.S. Standard Atmosphere)
$p_{cabin} = p_{8000\ ft\ altitude} = 10.9$ psia (using a U.S. Standard Atmosphere)
$A_{lid} = wd = (6.46\text{ in})\,(5.11\text{ in}) = 33.0\text{ in}^2$
$\Rightarrow$ $\boxed{F_{lid} = 62.5\text{ lb}_f!}$

[1] https://en.wikipedia.org/wiki/Cabin_pressurization