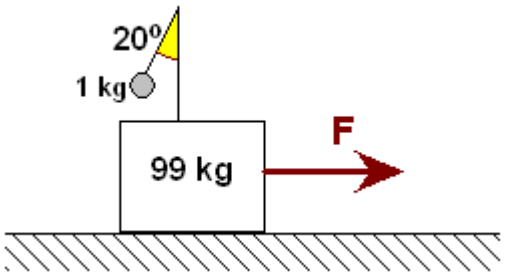
Classical Mechanics

Friction

Problem 1.- A crate that has a mass of 99kg is pushed with a force F. A pendulum mounted on the crate has a mass of 1kg and hangs at an angle $\theta = 20^\circ$ off the vertical. Calculate the force F if the coefficient of friction between the crate and the floor is $\mu_k = 0.25$



Solution: The angle $\theta = 20^\circ$ off the vertical indicates that the acceleration of the 1kg pendulum (and the whole system) is:

$$a = g \tan\theta$$

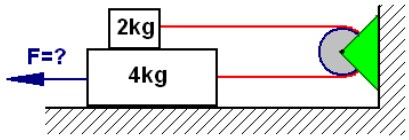
Now, the normal force is equal to the total weight of the crate plus pendulum, so:

$$F_N = mg = 100 \times 9.8 = 980N \rightarrow F_{friction} = \mu_K F_N = 0.25 \times 980N = 245N$$

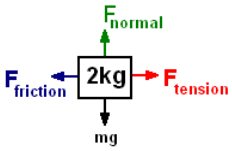
Newton's second law:

$$F - F_{friction} = ma \rightarrow F = F_{friction} + ma = 245 + 100 \times 9.8 \tan 20^\circ = \mathbf{600\ N}$$

Problem 2.- Calculate the force necessary to move the 4kg-box at constant velocity to the left. Notice that the coefficient of friction between the boxes, as well as between the 4kg-box and the ground, is $\mu_k = 0.25$. Assume the string has negligible mass and ignore friction in the pulley.



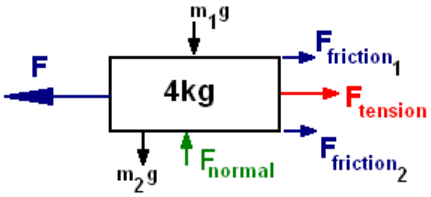
Solution: Since there is no acceleration, the only forces necessary will be against friction.



The tension in the string is equal to the friction force on the small mass, so:

$$F_{Tension} = F_{friction} = \mu_k F_{normal} = \mu_k m_1 g$$

There are 7 forces acting on the 4kg mass:



In the horizontal direction:

$$F = F_{friction1} + F_{friction2} + F_{Tension}$$

$$F = \mu_k m_1 g + \mu_k (m_1 + m_2) g + \mu_k m_1 g = \mu_k g (m_2 + 3m_1) = 0.25 \times 9.8(4 + 3 \times 2) = \mathbf{24.5\ N}$$