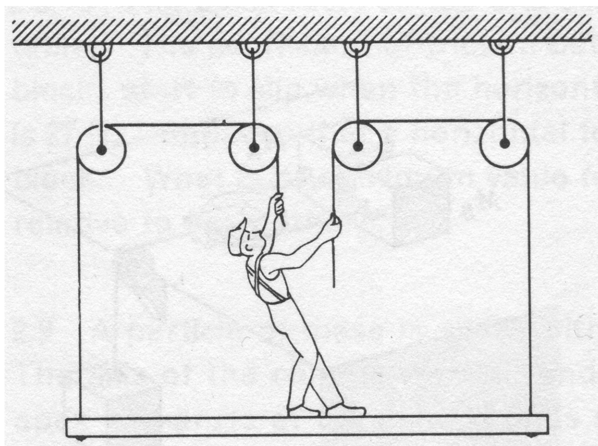
Physics 1A
Spring 2015

Challenge Problem 7

A painter of mass M stands on a platform of mass m and pulls himself up by two massless ropes which hang over pulleys as shown. He pulls each rope with force F and accelerates upward with uniform acceleration. Find his acceleration.



Solution. A free body diagram for the man reveals that the sum of the forces on the painter in the y-direction is

$$\sum F_y = 2T + N - Mg, \tag{1}$$

where T is the tension in each rope and N is the normal force of the platform on the painter. The sum of the forces in the y-direction on the platform is

$$\sum F_y = 2T - mg - N \tag{2}$$

where we have used the fact that the painter exerts a force N on the platform, equal in magnitude but in the opposite direction to the force exerted by the platform on the painter. Since the painter and the platform are in contact and stationary relative to one another, their accelerations in the y-direction are the same, call them a, so Newton's Second Law for each gives the following two equations:

$$2T + N - Mg = Ma, \qquad 2T - mg - N = ma. \tag{3}$$

This is two equations and three unknowns T, N, a, but recall that the painter exerts a force F on each rope, and by Newton's Third Law, the ropes exert a force F back on him, which is exactly the tension, so we have a third equation

$$T = F, \tag{4}$$

Now we simply solve these three equations and three unknowns for a. This is most easily done by adding the two equations first, which eliminates N and gives

$$4F - (M + m)g = (M + m)a. \tag{5}$$

Solving for a then gives

$$\boxed{a = \frac{4F}{M + m} - g}. \tag{6}$$