

4) (25 points) Pedagogical machine

A “pedagogical machine” consists of a large block of mass  $M_1$  that is resting on a horizontal frictionless surface with two other masses,  $M_2$  and  $M_3$ , connected to each other by an ideal rope that passes over an ideal pulley that is attached to the large block, as shown in the diagram.  $M_2$  can slide horizontally on the top of the large block, and  $M_3$  can slide vertically with respect to the large block. You may neglect friction on all surfaces in this entire problem.

a) If a constant external force  $F$  pointing to the right in the diagram is applied to the large block of mass  $M_1$  so that the hanging mass  $M_3$  does not accelerate upward or downward, then what is the tension in the rope? Express your answer in terms of any combination of  $M_1$ ,  $M_2$ ,  $M_3$ , and any relevant physical constants.

b) In that case, what is the magnitude of the acceleration of the block  $M_2$ ? Express your answer in terms of any combination of  $M_1$ ,  $M_2$ ,  $M_3$ , and any relevant physical constants.

c) In that case, what is the magnitude of the external horizontal force  $F$  being applied to the large block  $M_1$ ? Express your answer in terms of any combination of  $M_1$ ,  $M_2$ ,  $M_3$ , and any relevant physical constants. (hint: Note that the rope exerts forces on both the pulley and the two smaller blocks.)

d) For the rest of this problem, consider the case in which there is NO external horizontal force acting on the Pedagogical machine. What is the **direction** and **magnitude** of the acceleration of the large block  $M_1$ ?

e) In that case, what is the tension in the rope?

