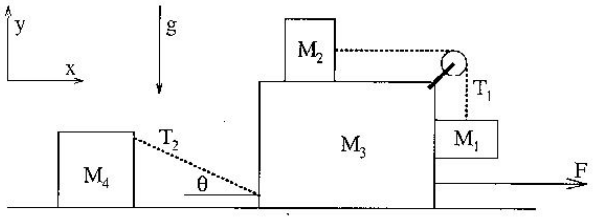
**QP4**




The system of blocks and pulleys shown above is being pulled to the right with a force $F$. This force is adjusted so that block $M_1$ neither falls nor rises, i.e. the y component of its acceleration vanishes. All surfaces are frictionless, the pulley is massless and frictionless, and the strings (dotted lines) are massless and inextensible. Strings are marked with their tensions and blocks with their masses. All surfaces shown to be in contact remain in contact at all times; in particular block $M_4$ does not "tip over". The string connecting blocks $M_3$ and $M_4$ makes an angle $\theta$ with the horizontal.

a) (3 points) Draw free body diagrams for all four masses, with all forces clearly shown and labeled.

b) (2 points) Write Newton's second law for blocks $M_1$ and $M_2$ in the $x$ and $y$ directions (i.e. 4 equations).

c) (2 points) What acceleration $a_3$ must block $M_3$ have? (Recall that block $M_1$ neither falls nor rises). Give your answer in terms of the masses $M_1$, $M_2$, $M_3$, $M_4$ and gravitational acceleration $g$.

d) (1 point) What is the magnitude of the force $F$?

e) (1 point) What is the normal force $N_4$ between the floor and block $M_4$? You may leave your answer in terms of the masses and $a_3$.

f) (1 point) What is the force $F_p$ (magnitude and direction) of the pulley on the string? You may leave your answer in terms of masses and $a_3$.