1) (10 pts) The $y$-component of an object’s position as a function of time $t$ is given by $y(t) = ct^2 - dt^3$ where $c$ and $d$ are positive constants. Which of the following statements about the object is true?
A) Its acceleration is constant.
B) At time $t=0$ it moves in the negative $y$-direction.
C) At time $t=0$ its acceleration is zero.
D) It stops momentarily at time $2c/3d$.

2) (10 pts) A cannonball is fired from a castle wall at some height above the ground, with an initial velocity directed at 30° above the horizontal. It hits the level ground some horizontal distance from the wall. Which of the following is true about the cannonball?
A) Its velocity is zero at the highest point of the trajectory.
B) Its acceleration decreases up to the highest point, and then increases during the downward motion.
C) It hits the ground with a speed that equals the initial speed.
D) The horizontal velocity component when it hits the ground equals the initial horizontal velocity component.

3) (10 pts) A crate is suspended from a vertical rope. The tension in the rope is smallest when the crate is
A) moving up with constant velocity
B) moving down with constant velocity
C) moving down and speeding up
D) moving down and slowing down

4) (10 pts) A block of weight $W$ is sliding down a rough inclined plane at constant speed. We know that the magnitude $f$ of the force of kinetic friction satisfies:
A) $f = 0$
B) $0 < f < W$
C) $f = W$
D) $f > W$

5) (10 pts) A small toy car is driving vertical circles inside a hollow cylinder at constant speed. At what position does the normal force acting on the car have the smallest magnitude?
A) at the top
B) at the bottom
C) when the car is exactly halfway to the top
D) the normal force is the same everywhere.
6. A secret agent uses a parachute to descend with a constant speed $V_A$. The agent is some horizontal distance away from a building. The building has height $H$, and just as the agent reaches the same height, a blow gun shoots a letter with a secret message from the top of the building. The letter leaves the gun with an unknown speed at an angle $\theta$ above horizontal, as shown in the figure.

a) (10) Complete the diagram on the right with all information necessary to solve parts b) and c) below. Qualitatively sketch the trajectory of the letter.

OSE b) (20) In terms of relevant system parameters, derive an expression for the initial speed $V_0$ that the letter should have in order to reach the agent at distance $h$ above the ground.

OSE c) (20) In terms of given system parameters, derive an expression for the speed of the letter just before the agent catches it. You may use the initial speed $V_0$ of the letter and, if necessary, the time $T$ the letter takes to reach the agent as system parameters.
7. A box of mass $M$ is being lowered from the top of a ramp to the floor. The inclined ramp makes an angle $\theta$ with respect to the vertical. A block of mass $m$ moves along the frictionless incline and is connected to the box by a massless rope and a massless, frictionless pulley. The vertical wall is rough with a coefficient of kinetic friction $\mu$ between the wall and the box. A student pushes the box against the wall with a horizontal force of magnitude $P$.

a) (10 points) In the figure, superimpose fully labeled free-body diagrams for the block and the box, containing all information necessary to solve part b) below.

(OSE) b) (40 points) Derive an expression for the acceleration of the box, in terms of system parameters.
8. Two identical balls are tied together, each of mass $M$, using a cord of length $L$. Another cord, also of length $L$, is tied to one of the balls and both balls are swung in a vertical circle. The figure shows the two balls at the instant when both are at their lowest points. At that instant, the speed of the upper ball is $V$, and the speed of the lower ball is $2V$.

a) (10 points) Using the points masses drawn below, draw two fully-labeled free body diagrams, one for each ball ("upper" and "lower") and any other information needed to solve part b).

b) (OSE) (40 points) Treating the balls as point masses, derive an expression for the tension in the upper cord, in terms of relevant system parameters.