Points for a question are indicated in parentheses. Solutions to questions marked with OSE must begin with an Official Starting Equation, with the math subsequently flowing from it for full credit. If you need more space to finish a question, write and circle “BPP” at the end of the space provided and complete your work on the Back of Previous Page. For Questions on this page, write the letter which you believe to be the best answer in the underlined space provided to the left of the question number. On subsequent pages, draw a box around your answer to each question. The expression for the final result must be in system parameters and simplified as far as possible. All information and algebraic quantities that you use to solve the problem must appear in the figure. Neglect air resistance. Calculators and notes cannot be used during the test. If you have any questions, ask the proctor.

1)(5) A ball of mass $2M$ falls from a height $h$ and a cube of mass $M$ slides from the same height down a curved frictionless track shown at right. Both start from rest. When they reach the ground, their speeds are $V_B$ for the ball and $V_C$ for the cube. Which is true?
   A) $V_B = V_C$  
   B) $V_B < V_C$  
   C) $V_B > V_C$  
   D) $V_B = 2V_C$

2)(5) A student is riding in an elevator moving vertically down at a constant speed $V$. If the mass of the student is $M$, the power delivered to the student by the normal force of the elevator floor is:
   A) $+MgV$  
   B) zero  
   C) $-MgV$  
   D) $2MgV$

3)(5) A particle experiences the one-dimensional potential energy $U(x)$ shown at right. At which of the following points is the force due to this potential directed in the positive $x$-direction?
   A) 1 & 2  
   B) 1 & 3  
   C) 3 & 4  
   D) 2 only

4)(5) An object is launched from a planet at escape speed. The total mechanical energy of the object at any time after launch is
   A) positive  
   B) gradually decreasing to zero  
   C) gradually increasing to zero  
   D) zero

5)(5) A ball bounces elastically off a wall shown at the right. The angle of incidence $\theta$ equals the angle of reflection. The impulse delivered to the ball by the wall is:
   A) in the positive $x$-direction.  
   B) in the negative $x$-direction.  
   C) zero.  
   D) in the $y$-direction.

6)(5) Prof. Bieniek should continue the tradition of asking a simple multiple-choice question on a test if he makes a single mistake because it:
   A) makes me feel good to see him in error.  
   B) allows him to ease his deserved guilt.  
   C) compensates for a too-comfortable lecture hall  
   D) – wait, does he ask an easy question somewhere?
7. A block of mass $M$ is on rough horizontal surface with coefficient of kinetic friction $\mu$. It is attached to a spring with force constant $k$. This block is also attached to another block of mass $3M$ by a massless rope that passes over a frictionless pulley. This second block is on a frictionless incline that makes angle $\theta$ with the horizontal. A constant downward blowing force of magnitude $2Mg$ acts on each block. The blocks are initially held in a position such that the spring is at its unstretched/uncompressed natural length.

a)(10) Complete the diagram with all information that you need to solve part b) below. Remember, you can add elements as you go along.

b)(40) OSE: The blocks are released from rest from their initial positions. Use energy methods to derive an expression, in terms of relevant system parameters, for the speed of the blocks when the spring has stretched a distance $D$. [You may assume, without proof, that the magnitude of the normal force that acts on the block of mass $M$ on the horizontal surface is equal to $3Mg$.]
8. A moon of mass $M$ and radius $R$ is in a circular orbit around a planet of mass $12M$ and radius $6R$. The moon is orbiting a distance $2R$ above the surface of the planet, as shown. A cannonball is shot from the surface of the planet at point A on the diagram when the moon is directly above and follows the dashed line path shown.

a) (30) OSE: Assuming that the moon and the planet do not move, derive an expression in terms of relevant system parameters for the speed with which the cannonball must leave point A if it is to hit the surface of the planet at point B with half that speed. [Note: Points A and B are 90° apart when viewed from the planet’s center.]

b) (20) OSE: Derive an expression in terms of relevant system parameters for the magnitude of the cannonball’s acceleration just after it was shot from the cannon at point A.
9. A block of mass $4M$ is moving to the right with speed $V$ on a rough level surface. A putty ball with mass $M$ is moving to the left with speed $2V$, as shown. They collide and the putty ball sticks to the block. After the collision, they slide a distance $D$ on the rough surface before coming to rest.

a) (5) Draw in any elements necessary to complete part b) below.

b) (45) **OSE:** Derive an expression for the coefficient of kinetic friction $\mu$ between the block and the surface, in terms of relevant system parameters.