PART I: MULTIPLE CHOICE

Each multiple choice question has one best answer -- circle the letter of the best answer. Partial credit will be given on the multiple choice questions. If you circle two answers, one of which is correct, you will receive half credit for the question. No credit will be given for more than two answers, even if one of them is correct. (4 points each for full credit)

1. If a ball is thrown upwards, which of the choices below is true at the top of the ball’s flight?
   a) velocity = 0 and acceleration ≠ 0
   b) velocity = 0 and acceleration = 0
   c) velocity ≠ 0 and acceleration ≠ 0
   d) velocity ≠ 0 and acceleration = 0

2. A car is traveling on the Mass Pike. Suppose we choose the positive x direction to be east (driving toward Boston). In which of the following situations is the average acceleration of the car negative?
   a) The car is initially going 10 m/s east and then, at a later time, goes 30 m/s east.
   b) The car is initially going 10 m/s west and then, at a later time, goes 30 m/s west.
   c) The car is initially going 30 m/s east and then, at a later time, goes 10 m/s east.
   d) The car is initially going 30 m/s west and then, at a later time, goes 10 m/s west.
   e) The car is initially going 10 m/s east and then, at a later time, goes 30 m/s west.
   f) two of the above
   g) three of the above

3. A boy and a girl are standing on a bridge above a stream. The girl throws a rock horizontally at exactly the same time the boy drops a rock vertically.
   a) The girl’s rock strikes the water first because its speed is greater.
   b) The boy’s rock strikes the water first because it doesn’t travel as far.
   c) Both rocks strike the water at the same time.
   d) Which rock strikes first will depend on the initial horizontal velocity as well as the height of the bridge.

4. A pilot drops a supply package from a plane flying horizontally. When the package hits the ground, the horizontal location of the plane will
   a) be behind the package.
   b) be over the package.
   c) be in front of the package.
   d) depend on the speed of the plane when the package was released.
5. The number of forces acting on a car parked on a hill is
   a) one.
   b) two.
   c) three.
   d) four.

6. Two boxes of mass m and 2m are connected by a rope and sit on a frictionless surface. If they are accelerated by a force F, as shown, what is the tension in the connecting rope?
   a) 3F
   b) F
   c) F/2
   d) F/3

7. A car of mass m goes around a banked curve of radius r with speed v. If the road is frictionless due to ice, the car can still negotiate the curve if the horizontal component of the normal force on the car from the road is equal in magnitude to
   a) mg/2
   b) mg
   c) mv^2/r
   d) tan[v^2/(rg)]

8. The moon’s mass is approximately 1/80 of the earth’s. Dr. Evil lives on the moon and has a scheme to make the moon larger by transferring part of the earth to the moon. After this transfer, the gravitational force between the earth and moon would
   a) increase.
   b) decrease.
   c) remain the same.
   d) either increase or decrease, depending on the distance between the earth and moon.
PART II: FREE RESPONSE

9. Consider the situation represented in the figure — a ball rolls down a small incline and reaches a flat horizontal track at time \( t = t_0 \). At time \( t = t_1 \), it rolls down a straight inclined track and reaches another horizontal section at time \( t = t_2 \), and then reaches the end at time \( t = t_3 \). A coordinate system in which the x-axis is horizontal and the y-axis is vertical, with the lowest part of the track being at \( y = 0 \), is also shown. Complete the graphs below by qualitatively indicating the acceleration, velocity, and position of the ball as a function of time in both the x and y directions. Although qualitative, use some care in drawing to distinguish between what you mean to be straight and curved lines in your graphs. [3 pts each graph for a total of 18 pts]
10. At serve, a tennis player aims to hit the ball horizontally as shown in the diagram.

a) What minimum speed is required for the ball to clear the 0.90-m-high net located 15.0 m from
the server, if the ball is served from a height of 2.0 m? [6 pts]
b) Where will the ball land if it just clears the net (and will the serve be “good” in the sense that
it lands within 7.0 m of the net)? [6 pts]
c) What is the speed of the ball when it hits the ground? [3 pts]
d) At what angle (with respect to the horizontal) does it hit the ground? [3 pts]
11. Jean, who likes physics experiments, dangles her keys from a piece of string while the jetliner she is in takes off from Logan Airport. She notices that the string makes an angle of 25° with respect to the vertical while the aircraft accelerates down the runway for takeoff, which takes about 18 seconds. From this information she estimates the takeoff speed of the aircraft. What is it? [16 pts]
12. A child ties a toy at the end of a string and swings it around overhead in a small (horizontal) circle at a constant 60 revolutions per minute. The mass of the toy is 250 g and the tensile strength of the string is 8.5 N (it breaks under tensions greater than that). The child now starts letting out more string (to make a larger circle) while maintaining the 60 rpm.

(a) Calculate the length of the string when it breaks. [8 pts]
(b) If the child’s hand is 1.5 m above the ground, how far from the child does the weight hit the ground when the string breaks? [8 pts]