Points for a question are indicated in parentheses. Your solution to a question with OSE in front of it 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.

C 1)(5) You throw a baseball to a friend who is some distance away. When the ball is at its maximum height above the ground in its trajectory, the angle between its velocity and acceleration is:
   A) 0º
   B) less than 90º
   C) 90º
   D) greater than 90º

D 2)(5) Three forces: \( \vec{F}_1 \), \( \vec{F}_2 \) and \( \vec{F}_3 \) are acting on an object as shown in the diagram at the right. The \( x \)-component of the net force must necessarily be:
   A) \( F_3 - F_1 \)
   B) \( F_{3x} - F_{1x} \)
   C) \( F_1 + F_2 + F_3 \)
   D) \( F_{1x} + F_{2x} + F_{3x} \)

A 3)(5) A person stands on a scale while riding in an elevator that is speeding up. The reading on the scale:
   A) depends on the elevator’s direction of travel.
   B) will be smaller than his normal weight reading.
   C) will be the same as his normal weight reading.
   D) will be larger than his normal weight reading.

C 4)(5) A particle is moving counter clockwise in a circle as shown in the diagram at the right. When it is at point \( P \), it is speeding up. Which net force vector shown in the diagram could be the one acting on the particle at point \( P \)?
   A) A
   B) B
   C) C
   D) D

B 5)(5) A box of weight \( W \) is sitting on the floor. You pull straight up on the box with a force of magnitude \( P \) and the box does not move. The magnitude of the force that the floor exerts on the box is:
   A) \( W \)
   B) \( W - P \)
   C) \( W + P \)
   D) \( P - W \)

ABCD 6)(5) Prof. Bieniek made a mistake in one lecture, which forces him to insert an easy question on this exam. What do you believe? He made the mistake because he:
   A) secretly wants to be nice
   B) is really not careful
   C) does not know the physics
   D) is actually mean

Test Total = 180 / 180
7. A ball is thrown at some unknown angle from the edge of a cliff of height $H$. It hits the ground with speed $V_2$ at a horizontal distance $D$ from the base of the cliff.

a) (10) Complete the diagram at the right with the required information to do Part b). In working this problem, you MUST use a coordinate system with its ORIGIN at the point where the ball hits the ground, its x-axis pointing to the LEFT, and its y-axis pointing DOWN.

b) (40) OSE: Using concepts that have been presented in the course this semester, derive an expression for the speed $V_i$ at which the ball was thrown from the cliff.

Note: 
\[
V_1^2 = V_{1x}^2 + V_{1y}^2
\]
\[
V_2^2 = V_{2x}^2 + V_{2y}^2
\]
\[
V_{2x} = V_{1x} + 2a_x (x_2 - x_1) = V_{1x}
\]
\[
V_{2y} = V_{1y} + 2a_y (y_2 - y_1) = V_{1y} + 2\left(\frac{3}{2}\right)[0 - (-H)] = V_{1y} + 2gH
\]
\[
V_2^2 = V_{1x}^2 + V_{1y}^2 + 2gH
\]
\[
V_2 = V_1 + 2gH
\]
\[
V_1^2 = V_2^2 - 2gH
\]
\[
V_i = \sqrt{V_2^2 - 2gH}
\]
8. A block of mass $3M$ is moving to the right on a horizontal surface. It is connected by a massless rope that passes over a frictionless pulley to a block of mass $M$ that is on an inclined surface that makes an angle $\theta$ with the horizontal, as shown. Both blocks are on rough surfaces which have coefficients of kinetic friction between the blocks and the surfaces of $\mu$.

a)(10) On the diagram at the right, superimpose fully labeled free-body diagrams for each block. Remember that any algebraic quantity that you use in Part b) must appear in the diagram.

b)(40) OSE: Derive an expression for the acceleration of the block of mass $3M$ on the level surface, in terms of relevant system parameters.

\[
\sum F_x = M_1a_x \\
F_{1x} + N_1^y + T_x + F_{3x} = M_1a_x \\
(+f_1) + (-T) + (+F_{3y}\sin \theta) = M_1a_x \\
\mu N_1 - T + M_1g\sin \theta = M_1a_x
\]

\[
\sum F_y = M_1a_y \\
F_{1y} + N_1^y + F_{3y} + T_y = M_1a_y \\
(+N_1) + (-F_{3y}\cos \theta) = 0 \\
N_1 = F_{3y}\cos \theta = (M_1g)\cos \theta
\]

\[
\sum F_{3x} = M_3a_x \\
f_{3x} + T_x + N_3^y + F_{3y} = M_3a_x \\
(+f_3) + (+T) = (3M)a_x \\
\mu N_3 + T = 3M a_x
\]

\[
\sum F_{3y} = M_3a_y \\
f_{3y} + T_y + N_3^y + F_{3y} = M_3a_y \\
(+N_3) + (-F_{3y}) = 0 \\
N_3 = F_{3y} = M_3g = (3M)g
\]

\[
\text{Note: } +T-T=0 \\
dMg\cos \theta + M_3g\sin \theta + 3Mg = M_1a_x + 3M a_x = 4M a_x
\]

\[
a_x = \frac{g\sin \theta + M_3g\cos \theta + 3\mu g^2}{4} = \frac{g}{4} [\sin \theta + \mu (3\cos \theta)]
\]
9. A roller coaster car is moving to the right at the bottom of a circular portion of frictionless track of radius $R$. A wind is blowing on the car in a downward and rearward direction at angle $\theta$ from the vertical. The magnitude $B$ of the blowing force is one-half of the car's weight. At this moment, when the car is at the lowest point, the track exerts a force on the car that is equal in magnitude to three times the car's weight. Ignore friction in all that follows.

a)(10) On the diagram at the right, superimpose a fully labeled free-body diagram for the car. Remember that any algebraic quantity that you use in Part b) must appear in the diagram.

b)(30) OSE: Derive an expression in terms of relevant system parameters for the speed of the car when it is at the lowest point of the circular track.

\[ \Sigma F_y = M_y \]
\[ B_y + N_y + F_{y} = M_y \]
\[ (-B\cos\theta) + (M_b) + (-M_y) = M_x \]
\[ (-\frac{1}{2}M_y)\cos\theta + (3M_y) = M_y \frac{v^2}{R} \]
\[ v^2 = R \left[ 2g - \frac{1}{2}g\cos\theta \right] = R \left[ 2 - \frac{1}{2}\cos\theta \right] \]

c)(10) OSE: Derive an expression in terms of relevant system parameters for the rate of change of the car's speed when it is at the lowest point of the circular track.

\[ \frac{dv}{dt} = a_{x} \]
\[ \Sigma F_x = M_x \]
\[ B_x + N_x + F_{x} = M_x \]
\[ (-B\sin\theta) = M_x \]
\[ \frac{1}{2}M_x\sin\theta = M_x \]
\[ \frac{dv}{dt} = -\frac{1}{2}gsin\theta \]