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.

A) 1)(5) The graph at the right shows the position of a particle moving along the x-axis as a function of time. Which of the following is true?
   A) Its speed at times t₁ and t₂ are equal
   B) Its speed is increasing between the time zero and time t₁
   C) Its speed is largest at time t₁
   D) Its maximum acceleration is at t = 0

C) 2)(5) You throw a rock straight up inside an airless room. In a coordinate system with the y-axis aimed upward, what is the y-component of the rock’s acceleration when it reaches its maximum height?
   A) 0
   B) g
   C) −g
   D) minus gravity

C) 3)(5) An object moves along the x-axis with position given by \( x(t) = Ae^{-t^2} \) [that is, \( x(t) = A \exp(-t^2) \)] in SI units. What is the x-component of its acceleration at \( t = 1 \) second in SI units?
   A) 6A/e
   B) 0
   C) 2A/e
   D) A/e

B) 4)(5) A block having weight magnitude \( F_g \) is accelerating down an inclined plane. The magnitude of the normal force acting on the block is
   A) equal to \( F_g \)
   B) less than \( F_g \)
   C) greater than \( F_g \)
   D) dependent on direction of motion

B) 5)(5) A block is sliding to the right on a flat rough surface but is changing its speed. The direction of the force of friction exerted on the block by the surface is:
   A) to the right
   B) to the left
   C) in the same direction as the normal force
   D) opposite the direction of the sum of other applied forces

ABCD) 6)(5) When Prof. Bieniek made a mistake in one lecture, he said he would give one simple multiple choice question. Did you think he:
   A) was telling the truth?
   B) does not know right from wrong?
   C) was playing with your mind?
   D) is a sweet, caring guy?
7. A ball is thrown upward from the edge of a vertical cliff of unknown height. As shown, it is thrown with speed \( V \) at an angle \( \theta \) down from the vertical. The ball follows the path shown by the dashed line. At the instant the ball is thrown, a dog waiting at the base of the cliff starts running in a straight line with a constant acceleration magnitude of \( g/2 \), eventually catching the ball.

a) (10) Complete the diagram with all information required to solve part b).

b) (40) OSE: Using the coordinate system supplied (whose origin is where the dog catches the ball), derive an expression for the height of the cliff in terms of relevant system parameters.

\[
\begin{align*}
H &= -V \cos \theta \left( \frac{4V \sin \theta}{g} \right) \\
&\quad + \frac{1}{2} \left( \frac{4V \sin \theta}{g} \right)^2
\end{align*}
\]

\[
\begin{align*}
H &= \frac{8V^2 \sin^2 \theta}{g} - \frac{4V^2 \sin \theta \cos \theta}{g} \\
&= \frac{4V^2}{g} \left[ 2 \sin^2 \theta - \sin \theta \cos \theta \right] \\
&= \frac{4V^2}{g} \sin \theta \left[ 2 \sin \theta - \cos \theta \right]
\end{align*}
\]

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8. A box of mass $M$ is attached to a heavier block of mass $2M$ via a taut perfect string that passes over a massless, frictionless pulley. The lighter box is moving to the right on a frictionless horizontal surface. A blowing wind pushes the hanging block (mass $2M$) against the rough side wall, but does not affect the lighter box (mass $M$). The blowing force has magnitude $B = Mg$ and is directed at angle $\theta$ from vertical. The coefficient of kinetic friction between the vertical wall and the heavier block is $\mu$.

a)(10) Draw in free-body diagrams for each box and any algebraic other quantities that you need to use to accomplish the task of part b).

b)(40) OSE: In terms of relevant system parameters, derive an expression for the coefficient of friction $\mu$ such that the block on the horizontal surface has an acceleration magnitude of $g/3$. 

Note: For the string to remain taut, the hanging block's acceleration must be directed downward.

\[ \sum F_{2x} = M_2 a_x \]
\[ P_{x} + f_{x} + T_{x} + N_{2x} + F_{2g} = (2m)(+a) \]
\[ (-B\cos\theta) + (-f) + (-T) + F_{2g} = (2m)(+\frac{g}{3}) \]
\[ -(Mg)\cos\theta - \mu N_{2} - T + (2m)g = \frac{2}{3}Mg \]
\[ -(Mg)\cos\theta - \mu N_{2} = \frac{1}{3}Mg + 2Mg = \frac{2}{3}Mg \]

For $N_{2}$:
\[ \sum F_{2y} = M_{2} a_{y} \]
\[ B_{y} + P_{y} + T_{y} + N_{2y} + F_{2g} = 0 \]
\[ (-B\sin\theta) + (+N_{2}) = 0 \]
\[ N_{2} = B\sin\theta = Mg\sin\theta \]

\[ \mu N_{2} = 2Mg - \frac{2}{3}Mg - \frac{1}{3}Mg - Mg\cos\theta \]
\[ \mu (Mg\sin\theta) = Mg - Mg\cos\theta = Mg (1 - \cos\theta) \]
\[ \mu \sin\theta = 1 - \cos\theta \]

\[ \mu = \frac{1 - \cos\theta}{\sin\theta} \]
\[ = \frac{1}{\sin\theta} - \cot\theta \]
\[ = \csc\theta - \cot\theta \]
9. A ball attached to a massless string of unknown length, revolves along a horizontal circle with a constant speed \( V \), making angle \( \theta \) with the vertical as shown on the diagram.

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

b) (40) OSE: In terms of relevant system parameters, derive an expression for the length of the string.

\[
\sum F_x = M a_x \\
T_x + F_{g_x} = M (\frac{a}{\theta}) \\
+T \sin \theta = M \left( \frac{V^2}{R} \right) = M \frac{V^2}{L \sin \theta} \\
T L \sin^2 \theta = M V^2
\]

To find \( T \):
\[
\sum F_y = M a_y \\
T_y + F_{g_y} = 0 \\
(F + T \cos \theta) + (-F_\theta) = 0 \\
T \cos \theta = F_\theta = Mg \\
T = \frac{Mg}{\cos \theta} \\
\left( \frac{Mg}{\cos \theta} \right) L \sin^2 \theta = M V^2
\]

\[
L = \frac{V^2 \cos \theta}{g \sin^2 \theta}
\]