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.**

1) (5) You push against a spring and compress it. The work that the spring does on you is:
   A) in the direction you compress it
   B) positive
   C) in the direction opposite the compression
   D) negative

2) (5) An object is moving to the right while a conservative force acts on it to the left. The potential energy due to the conservative force is:
   A) to the right
   B) increasing
   C) to the left
   D) decreasing

3) (5) A rollercoaster car goes through a complete vertical loop. The work that the track does on the car in one complete loop is zero because
   A) the normal force on the car is zero
   B) the car starts and ends at the same point
   C) it is opposite gravity
   D) the track’s force is perpendicular to car’s velocity

4) (5) Two identical cars are moving directly at each other along the x-axis. Car 1 is travelling in the positive x-direction while Car 2 is travelling in the negative x-direction. Just before they collide, the cars are moving at the same speeds. The wreckage sticks together. The speed of wreckage is zero because the
   A) total linear momentum of the two-car system before the collision is zero
   B) total kinetic energy of the two-car system before the collision is zero
   C) net work done by forces other than frictional, gravitational, and normal forces is zero
   D) total mechanical energy of the two-car system remains zero

5) (5) A bomb is at rest in deep space. It explodes into many fragments. The total linear momentum of all the fragments is:
   A) positive because they were accelerated
   B) zero because $W_{\text{other}} = 0$.
   C) zero because there are no external forces
   D) positive because $W_{\text{other}} \neq 0$

A 6) (5) The videos that Dr. Bieniek shows before lectures are
   A) entertaining
   B) bad
   C) useless
   D) boring

Test Total = _____ / 180

_____ / 30 for this page
7. A battery-powered fan of mass $M$ is placed on its side and held at the top of a rough incline. The incline has length $L$, coefficient of sliding friction $\mu$, and makes an angle $\theta$ with the horizontal. The fan is turned on, and is released from rest. When the fan reaches the bottom of the incline, it travels along a horizontal frictionless surface, eventually running into a spring of force constant $k$. The fan’s rotating blades exert a continuous force on the surrounding air that has magnitude equal to one-fourth the fan’s weight and is always directed away from the surface on which the fan moves, as shown in the diagram.

(a)(10) Complete the diagram with all information needed to answer part (b).

(b)(40) **OSE:** Derive an expression in terms of relevant system parameters for the maximum distance that the spring is compressed.
8. An astronaut is held at rest at point $Q$ on a line connecting the centers of Planet A of mass $3M$ and radius $r$ and Planet B of mass $9M$ and radius $2r$. The point $Q$ is a distance $2L$ to the right of the center of Planet A and $3L$ to the left of the center of Planet B, with $r < L$, as shown in the diagram. Assume only gravitational forces act on the astronaut and that the planets remain stationary.

(a)(5) Complete the diagram with all information needed to answer parts (b) and (c).

(b)(20) OSE: The astronaut is released from rest at point $Q$. Derive an expression, in terms of system parameters, for the magnitude and direction of the astronaut’s acceleration at the moment of release.

(c)(25) OSE: Derive an expression, in terms of system parameters, for the astronaut’s speed after she has moved a distance $L$ from her initial position $Q$. 
9. Two putty balls, one of mass $M$ and the other of mass $2M$, collide and stick together. Just before the collision, the ball with mass $2M$ is moving at an angle $\theta$ with respect to the +y direction with speed $V$ and the ball with mass $M$ is moving in the +x direction with speed $2V$, as shown.

(a)(5) Complete the diagram (including “after collision”) with all information needed to answer part (b).

(b)(45) OSE: Using the coordinate system provided, derive an expression, in terms of system parameters, for the kinetic energy of the combined object right after the collision.