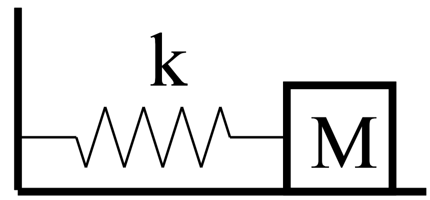
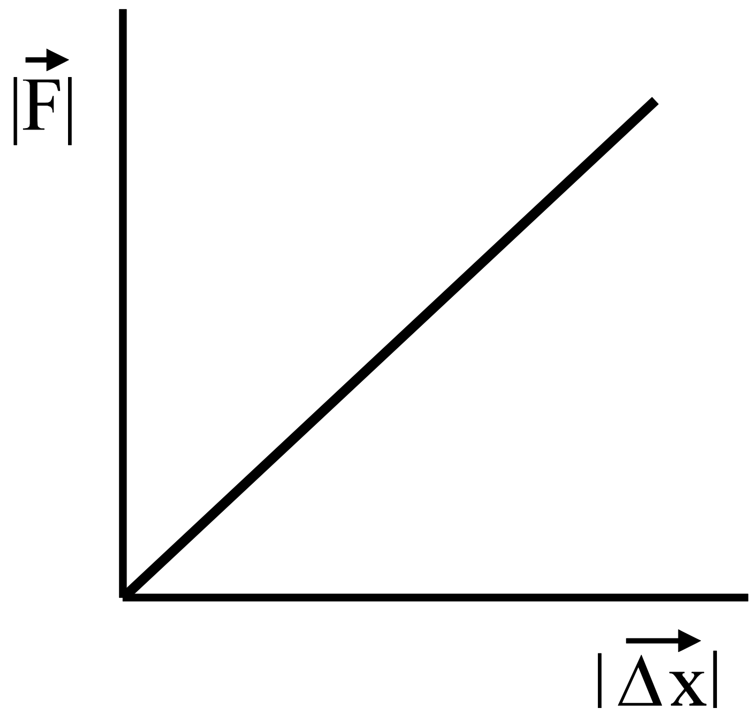
Springs and Spring Potential Energy

First Name:____________________ Last Name:________________________________

A mass M is connected to a spring as shown. The spring is accurately described by Hooke's Law with a force constant k. The surface is frictionless. The mass is pulled to the right and a force sensor measures the force exerted by the spring on the mass. The graph here plots the *magnitude* of the force exerted by the spring versus the *magnitude* of the displacement of the mass from its equilibrium position.



For each part below, a change is made in the system. On the graph that is already there, draw the new graph or explain why the graph is unchanged. After each change, the system reverts to its original state.

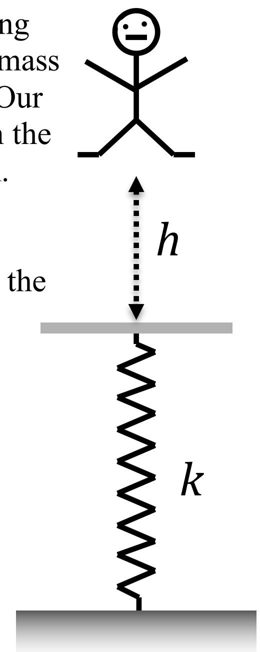


1. The mass connected to the spring is doubled.

2. The spring constant is doubled.

3. The spring constant is halved.

4. The spring is compressed instead of stretched.



A suspended platform of negligible mass is connected to the floor below by a long vertical massless spring of force constant $k = 1200$ N/m. A circus performer of mass $m = 70$ kg falls from rest onto the platform from a height of $h = 5.8$ m above it. Our ultimate objective is to determine the maximum compression of the spring when the performer lands on it. You will use this diagram for the remainder of the tutorial. Assume there is no air resistance.

5. Consider the system to consist of the performer, the platform, the spring and the Earth. Is the total mechanical energy of the system conserved in this situation? Explain your reasoning.

6. What is the initial kinetic energy of the system? Explain your answer.

7. What is the initial potential energy of the system? So that everyone is using the same coordinate system, define y=0 at the *initial* height of the platform. Don't forget that there are two types of potential energy in this problem.

8. What is the total mechanical energy of the system?

9. From the time the performer starts to fall until the instant when the spring reaches maximum compression describe what happens to the kinetic energy, the spring potential energy and the gravitational potential energy. You should describe whether they increase or decrease or whatever it is that happens to them and explain why.

Kinetic energy:

Spring potential energy:

Gravitational potential energy:

10. Two students are discussing their answers to Question #14.

Student 1: *I think that the kinetic energy is zero at the beginning and at the end since the performer has zero velocity at both times. Since I know the performer is moving in the intervening time, this means that the kinetic energy must increase and then decrease. The transition between these two must occur at the instant the performer hits the platform since the force exerted by the spring will start to slow the performer down.*

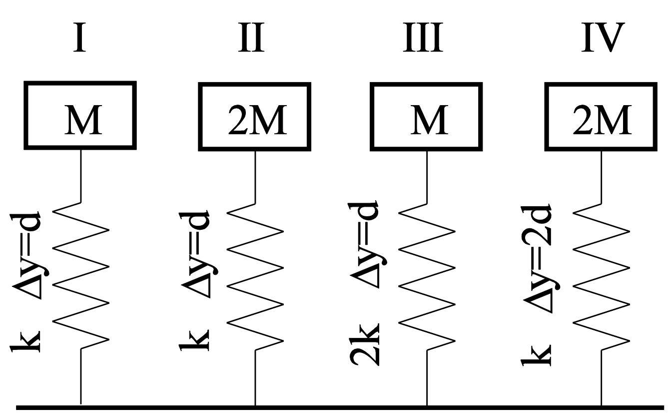
Student 2: *While I agree that the kinetic energy must increase and then decrease, I don't think the transition occurs when the performer hits the platform. Keep in mind that the force exerted by a spring is proportional to the compression of the spring. This means that the force exerted by the spring will initially be very small and it will increase as the spring gets more and more compressed. I think that the performer will continue to increase in velocity and kinetic energy even after hitting the platform. He will only start to slow down upwards force by the spring exceeds the downward force of gravity.*

Do you agree or disagree with either or both of the students? Explain your reasoning

11. Use the conservation of energy to determine the maximum compression of the spring.

12. Now that the performer has fully compressed the spring, explain what happens after that as accurately as possible.

Four different scenarios (I-IV) are shown here. In each scenario, a mass is held against a massless vertical spring. The masses are different, the spring constants are different and the compression of the springs is different in each scenario. When the force holding the masses down is removed, the masses fly up into the air and separate from the springs. You will use this diagram for the next five questions.



13. Rank the potential energy stored by the springs (before the masses are released) in the four scenarios from smallest to largest. Explain.

14. Rank the magnitude of the resulting acceleration of the mass from smallest to largest. Explain.

15. Rank the maximum height the mass reaches above its initial starting point from smallest to largest. Explain.

16. If you wanted to double the maximum height reached in scenario IV, by what factor would you need to change the compression of the spring (assuming that everything else is unchanged)? Explain. (Keep in mind that we are measuring the height from the initial position of the mass, so if the spring is compressed more or less that just changes the reference point.)