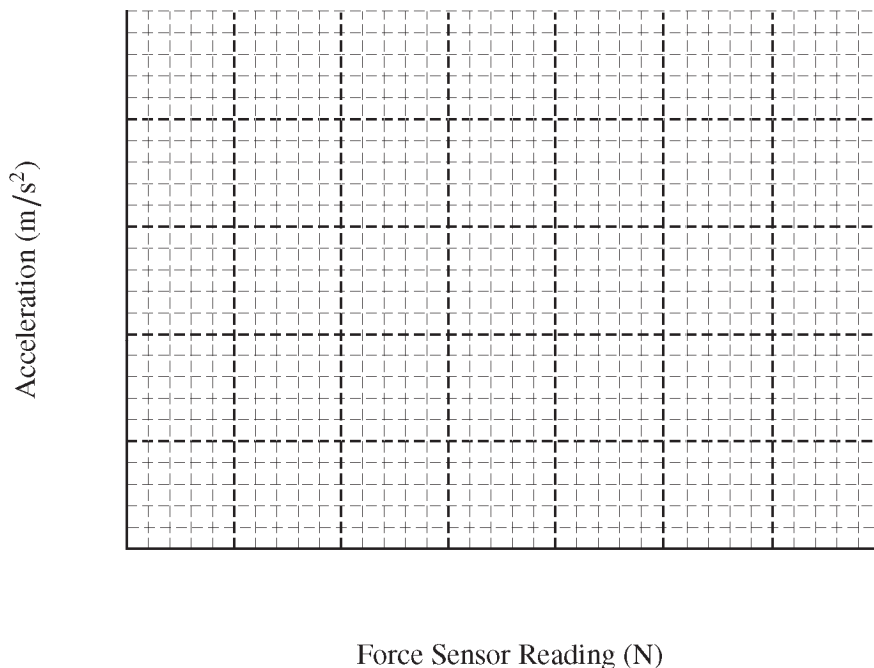


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(b)

- i. On the grid below, plot data points for the acceleration of the cart as a function of the force sensor reading. Clearly scale all axes. Draw a straight line that best represents the data.



- ii. Using the straight line from the graph, calculate the mass of the cart.
- iii. Using the straight line from the graph, determine the magnitude of the force of friction.

The above experiment is repeated by using a constant force sensor reading of 0.45 N. The cart starts from rest at time  $t = 0$  s and is pulled for a time of 2.0 s along the dynamics track.

(c)

- i. Determine the acceleration of the cart.
- ii. The string breaks at time  $t = 2.0$  s. Calculate the time it takes for the cart to stop after the string breaks.

The experiment and analysis in parts (a) and (b) are repeated with a cart that has the same mass but a greater force of friction.

(d)

- i. Will the slope of your new line be greater than, less than, or equal to the slope of your line in part (b)i?
- \_\_\_\_ Greater than      \_\_\_\_ Less than      \_\_\_\_ Equal to
- ii. Will the horizontal intercept of your new line be greater than, less than, or equal to the horizontal intercept of your line in part (b)i?
- \_\_\_\_ Greater than      \_\_\_\_ Less than      \_\_\_\_ Equal to

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Mech.2.

A block of mass  $2M$  rests on a horizontal, frictionless table and is attached to a relaxed spring, as shown in the figure above. The spring is nonlinear and exerts a force  $F(x) = -Bx^3$ , where  $B$  is a positive constant and  $x$  is the displacement from equilibrium for the spring. A block of mass  $3M$  and initial speed  $v_0$  is moving to the left as shown.

- (a) On the dots below, which represent the blocks of mass  $2M$  and  $3M$ , draw and label the forces (not components) that act on each block before they collide. Each force must be represented by a distinct arrow starting on, and pointing away from, the appropriate dot.

Block of Mass  $2M$

Block of Mass  $3M$



The two blocks collide and stick to each other. The two-block system then compresses the spring a maximum distance  $D$ , as shown above. Express your answers to parts (b), (c), and (d) in terms of  $M$ ,  $B$ ,  $v_0$ , and physical constants, as appropriate.

- (b) Derive an expression for the speed of the blocks immediately after the collision.  
 (c) Determine an expression for the kinetic energy of the two-block system immediately after the collision.  
 (d) Derive an expression for the maximum distance  $D$  that the spring is compressed.

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(e)

- i. In which direction is the net force, if any, on the block of mass  $2M$  when the spring is at maximum compression?

\_\_\_\_\_ Left      \_\_\_\_\_ Right      \_\_\_\_\_ The net force on the block of mass  $2M$  is zero.

Justify your answer.

- ii. Which of the following correctly describes the magnitude of the net force on each of the two blocks when the spring is at maximum compression?

\_\_\_\_\_ The magnitude of the net force is greater on the block of mass  $2M$ .  
\_\_\_\_\_ The magnitude of the net force is greater on the block of mass  $3M$ .  
\_\_\_\_\_ The magnitude of the net force on each block has the same nonzero value.  
\_\_\_\_\_ The magnitude of the net force on each block is zero.

Justify your answer.

- (f) Do the two blocks, which remain stuck together and attached to the spring, exhibit simple harmonic motion after the collision?

\_\_\_\_\_ Yes      \_\_\_\_\_ No

Justify your answer.

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**Question 2**

**15 points total**

**Distribution  
of points**

(a) 2 points



For correctly drawing and labeling vectors on the block of mass  $2M$

1 point

For correctly drawing and labeling vectors on the block of mass  $3M$  using symbols for the vectors that are physically correct and different from those on the block of mass  $2M$

1 point

Note: A maximum of one point can be earned if there are any extraneous vectors.

(b) 2 points

Using a proper expression for conservation of momentum

$$p_1 = p_2$$

For correctly substituting into the above equation

1 point

$$3Mv_0 = (3M + 2M)v_f$$

For a correct answer

1 point

$$v_f = \frac{3}{5}v_0$$

(c) 1 point

Using a proper expression for kinetic energy of the two-block system

$$K = \frac{1}{2}mv^2$$

$$K = \frac{1}{2}(5M)\left(\frac{3}{5}v_0\right)^2$$

For an answer consistent with part (b)

1 point

$$K = \frac{9}{10}Mv_0^2$$

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**Question 2 (continued)**

	<b>Distribution of points</b>
(d) 4 points	
For a correct expression of the conservation of energy $\Delta K_{\text{system}} + \Delta U_{\text{system}} = 0$	1 point
$K_0 = U_{\text{final}}$ For attempting to integrate the spring force equation	1 point
$\frac{9}{10} M v_0^2 = - \int_{x_1}^{x_2} -Bx^3 dx$	
$\frac{9}{10} M v_0^2 = \int_{x_1}^{x_2} Bx^3 dx$	
For using the correct limits of integration or an appropriate constant of integration	1 point
$\frac{9}{10} M v_0^2 = \int_0^D Bx^3 dx$	
$\frac{9}{10} M v_0^2 = \left[ \frac{Bx^4}{4} \right]_0^D$	
For an answer consistent with the speed from (b) or the kinetic energy from part (c)	1 point
$D = \sqrt[4]{\frac{18 M v_0^2}{5B}}$	
(e)	
i. 2 points	
For selecting the correct answer “Right” with a reasonable attempt at a justification	1 point
If the incorrect selection is made, no points are earned for the justification.	
For an indication that at maximum compression the block of mass $2M$ has an acceleration to the right due to the forces acting on the block of mass $2M$ or an acceleration to the right due to the external spring force acting on the system of blocks	1 point
Example: At maximum compression the two-block system is instantaneously at rest. The only horizontal external force acting on the system is due to the spring. This force is directed to the right. The system and therefore the block of mass $2M$ is accelerated to the right, which implies that the net force acting on the block of mass $2M$ is also to the right.	

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**Question 2 (continued)**

**Distribution  
of points**

- (e)  
 ii. 2 points

The magnitude of the net force is greater on the block of mass  $3M$ .

If the incorrect selection is made, no points are earned for the justification.

For an indication that both blocks will have the same acceleration

1 point

For a correct justification for why the net force is greater on the block of mass  $3M$

1 point

Example:

Because the blocks stick together, both blocks must have the same acceleration.

Because the block of mass  $3M$  has more mass, the net force on it must be greater than the net force on the block of mass  $2M$ .

- (f) 2 points

For selecting the correct answer “No,” with a reasonable attempt at a justification

1 point

If the incorrect selection is made, no points are earned for the justification.

If the correct answer is selected without any justification, the point is not earned for the selection.

For an indication that the spring does not apply a linear force and that simple harmonic motion is the resulting motion of a linear restoring force

1 point

$$\left( a = -\frac{k}{m} \Delta x \right)$$

Example:

Because the blocks are sticking together and are attached to the spring, the spring will apply a restoring force to the blocks. However, because the restoring force exerted by a nonlinear spring is not proportional to the blocks’ displacement from equilibrium, the blocks do not exhibit simple harmonic motion.