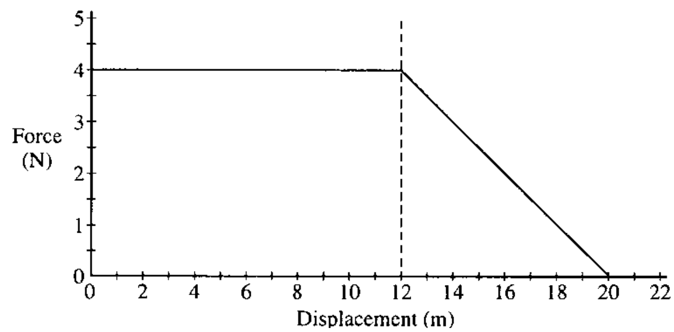
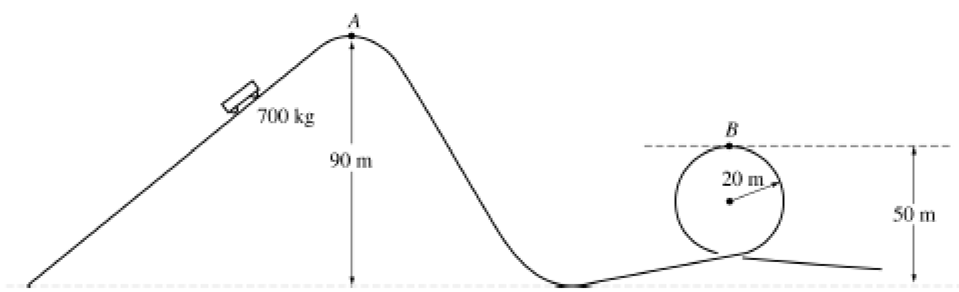


1. A 0.20 kg object moves along a straight line. The net force acting on the object varies with the object's displacement as shown in the graph above. The object starts from rest at displacement x = 0 and time t = 0 and is displaced a distance of 20 m. Determine each of the following.

a. The acceleration of the particle when its displacement x is 6 m.
b. The time taken for the object to be displaced the first 12 m.
c. The amount of work done by the net force in displacing the object the first 12 m.
d. The speed of the object at displacement x = 12 m.
e. The final speed of the object at displacement x = 20 m.



2. A roller coaster ride at an amusement park lifts a car of mass 700 kg to point *A* at a height of 90 m above the lowest point on the track, as shown above. The car starts from rest at point *A*, rolls with negligible friction down the incline and follows the track around a loop of radius 20 m. Point *B*, the highest point on the loop, is at a height of 50 m above the lowest point on the track.
(a)

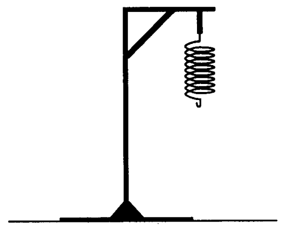
i. Indicate on the figure the point *P* at which the maximum speed of the car is attained.
ii. Calculate the value v_{max} of this maximum speed.

(b) Calculate the speed v_B of the car at point *B*.

(c) Draw and label a free-body diagram for the car when it is upside down at point *B*.

ii. Calculate the magnitude of all the forces identified in (c)

(d) Now suppose that friction is not negligible. How could the loop be modified to maintain the same speed at the top of the loop as found in (b)? Justify your answer.



3. A spring that can be assumed to be ideal hangs from a stand, as shown above.

a. You wish to determine experimentally the spring constant k of the spring.

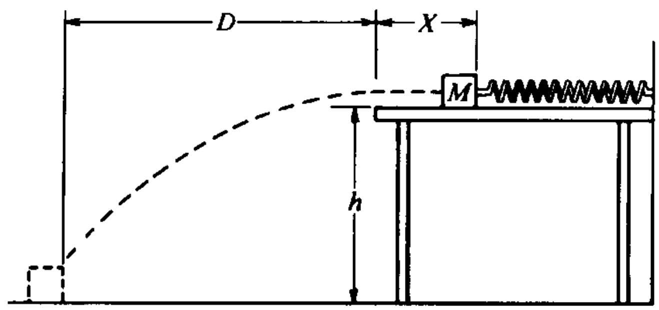
   i. What additional, commonly available equipment would you need?
   ii. What measurements would you make?
   iii. How would k be determined from these measurements?

b. Assume that the spring constant is determined to be 500 N/m. A 2.0-kg mass is attached to the lower end of the spring and released from a position where the spring is unstretched. How far will it fall before pausing?

c. Suppose that the spring is now used in a spring scale that is limited to a maximum value of 25 N, but you would like to weigh an object of mass M that weighs more than 25 N. You must use commonly available equipment and the spring scale to determine the weight of the object without breaking the scale.

   i. Draw a clear diagram that shows one way that the equipment you choose could be used with the spring scale to determine the weight of the object

   ii. Explain how you would make the determination.



4. One end of a spring is attached to a solid wall while the other end just reaches to the edge of a horizontal, frictionless tabletop, which is a distance *h* above the floor. A block of mass M is placed against the end of the spring and pushed toward the wall until the spring has been compressed a distance X, as shown above. The block is released, follows the trajectory shown, and strikes the floor a horizontal distance D from the edge of the table. Air resistance is negligible.

Determine expressions for the following quantities in terms of M, X, D, h, and g. Note that these symbols do not include the spring constant.

a. The time elapsed from the instant the block leaves the table to the instant it strikes the floor

b. The horizontal component of the velocity of the block just before it hits the floor

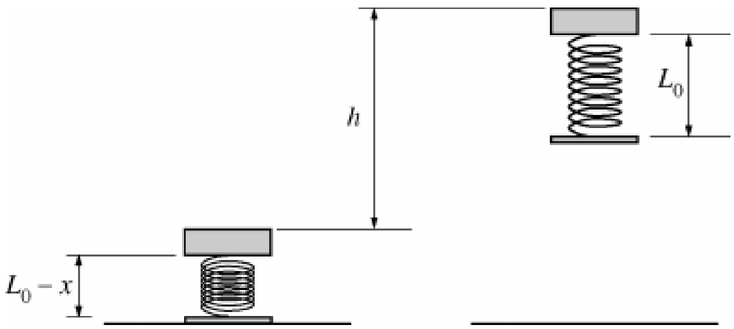
c. The work done on the block by the spring

d. The spring constant

e. Sketch graphs of kinetic, potential energy, and total energy versus height above the floor.

f. Sketch graphs of kinetic and potential energy versus time, taking t=0 when the block leaves the table.

g. What are three modifications that can be made to the system that would increase the value of *D*?



5. In an experiment, students are to calculate the spring constant *k* of a vertical spring in a small jumping toy that initially rests on a table. When the spring in the toy is compressed a distance *x* from its uncompressed length *L*0 and the toy is released, the top of the toy rises to a maximum height *h* above the point of maximum compression. The students repeat the experiment several times, measuring *h* with objects of various masses taped to the top of the toy so that the combined mass of the toy and added objects is *m*. The bottom of the toy and the spring each have negligible mass compared to the top of the toy and the objects taped to it.

(a) Derive an expression for the height *h* in terms of *m*, *x*, *k*, and fundamental constants.

With the spring compressed a distance $x = 0.020$ m in each trial, the students obtained the following data for different values of *m*.

	m (kg)	*h* (m)	
	0.020	0.49	
	0.030	0.34	
	0.040	0.28	
	0.050	0.19	
	0.060	0.18	

(b)

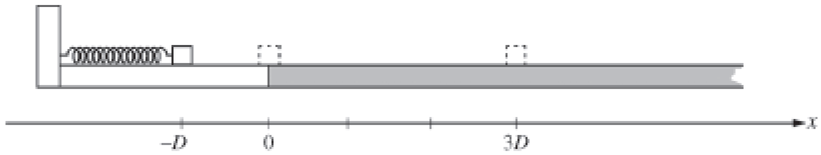
i. What quantities should be graphed so that the slope of a best-fit straight line through the data points can be used to calculate the spring constant *k* ?

ii. Fill in one or both of the blank columns in the table with calculated values of your quantities, including units.

(c) Plot your data and draw a best-fit straight line. Label the axes and indicate the scale.

(d) Using your best-fit line, calculate the numerical value of the spring constant.

(e) Describe a procedure for measuring the height *h* in the experiment, given that the toy is only momentarily at that maximum height.



6. A block is initially at position x = 0 and in contact with an uncompressed spring of negligible mass. The block is pushed back along a frictionless surface from position x = 0 to x = -D, as shown above, compressing the spring by an amount $\Delta x = D$. The block is then released. At x = 0 the block enters a rough part of the track and eventually comes to rest at position x = 3D. The coefficient of kinetic friction between the block and the rough track is μ.

a. Sketch and label graphs of the following two quantities as a function of the position of the block between x = -D and x = 3D. You do not need to calculate values for the vertical axis, but the same scale should be used for both quantities.

i. The kinetic energy K of the block.
ii. The potential energy U of the block-spring system.

The spring is now compressed twice as much, to $\Delta x = 2D$. A student is asked to predict whether the final position of the block will be twice as far at x = 6D. The student reasons that since the spring will be compressed twice as much as before, the block will have more energy when it leaves the spring, so it will slide farther along the track before stopping at position x = 6D.

(b)

i. Which aspects of the student's reasoning, if any, are correct? Explain.
ii. Which aspects of the student's reasoning, if any, are incorrect? Explain.

(c) Use quantitative reasoning, including equations as needed, to develop an expression for the new final position of the block. Express your answer in terms of D.

(d) Explain how any correct aspects of the student's reasoning identifies in part (b) are expressed by your mathematical relationships in part (c). Explain how your relationships in part (c) correct any incorrect aspects of the student's reasoning identified in part (b). Refer to the relationships you wrote in part (c), not just the final answer you obtained by manipulating those relationships.