

2006 AP[®] PHYSICS C: MECHANICS FREE-RESPONSE QUESTIONS

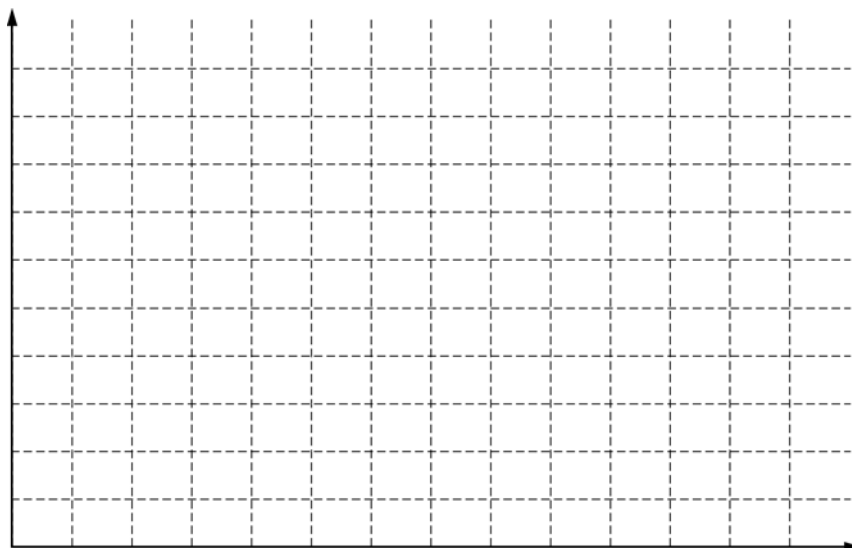
Mech 2.

A nonlinear spring is compressed various distances x , and the force F required to compress it is measured for each distance. The data are shown in the table below.

x (m)	F (N)	
0.05	4	
0.10	17	
0.15	38	
0.20	68	
0.25	106	

Assume that the magnitude of the force applied by the spring is of the form $F(x) = Ax^2$.

- (a) Which quantities should be graphed in order to yield a straight line whose slope could be used to calculate a numerical value for A ?
- (b) Calculate values for any of the quantities identified in (a) that are not given in the data, and record these values in the table above. Label the top of the column, including units.
- (c) On the axes below, plot the quantities you indicated in (a) . Label the axes with the variables and appropriate numbers to indicate the scale.



- (d) Using your graph, calculate A .

The spring is then placed horizontally on the floor. One end of the spring is fixed to a wall. A cart of mass 0.50 kg moves on the floor with negligible friction and collides head-on with the free end of the spring, compressing it a maximum distance of 0.10 m.

- (e) Calculate the work done by the cart in compressing the spring 0.10 m from its equilibrium length.
- (f) Calculate the speed of the cart just before it strikes the spring.

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Question 2

15 points total

**Distribution
of points**

(a) 1 point

For indicating that F vs. x^2 or \sqrt{F} vs. x should be graphed, or other equivalent correct response (Must clearly specify two variables in order to earn this point.)

1 point

(b) 2 points

For a correct column label, including units

1 point

For calculated values that match what is indicated in (a)

1 point

Note: If answer to (a) was incorrect or incomplete, (b) received no credit.

Example using F vs. x^2

x (m)	F (N)	x^2 (m ²)
0.05	4	0.0025
0.10	17	0.010
0.15	38	0.023
0.20	68	0.040
0.25	106	0.063

(c) 3 points

For appropriate linear axes scales

1 point

For correct axes labels

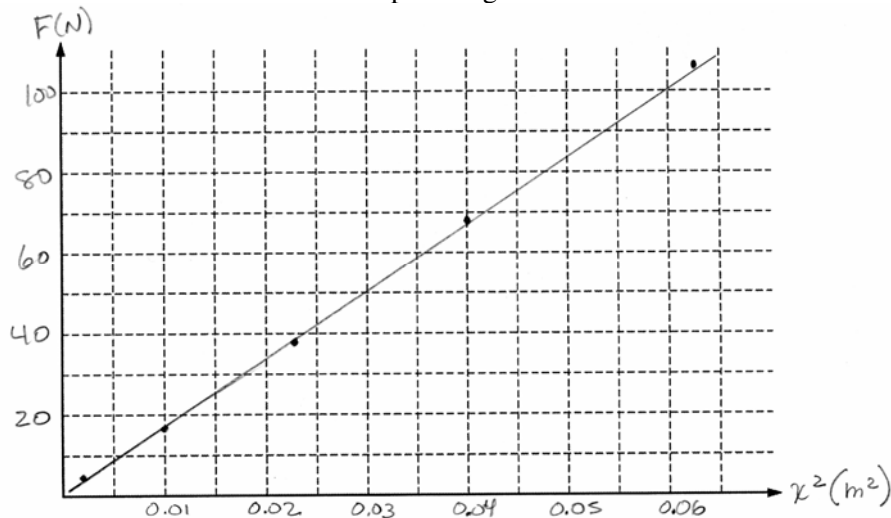
1 point

For plotting the points

1 point

Note: Axes and scales must match answer in (a). However, if (a) was incorrect or incomplete, points were awarded in (c) if graph was executed correctly. If (a) was blank or didn't include any variables, no credit was awarded for (b) or (c).

Example using data above



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Question 2 (continued)

**Distribution
of points**

(d) 2 points

For indication of a correct relationship between the coefficient A and the slope for the values graphed in (c) 1 point

For correct units and no more than four significant figures on value of A 1 point
Example using data in the table and two points on the line in the graph

$F = Ax^2$, so A is equal to the slope of the F vs. x^2 line.

$$A = \text{slope} = \frac{\Delta F}{\Delta x^2} = \frac{100 \text{ N} - 50 \text{ N}}{0.060 \text{ m}^2 - 0.030 \text{ m}^2} = 1.7 \times 10^3 \text{ N/m}^2$$

Notes:

This part stated to “calculate,” so an answer with correct units and significant figures but with no work shown earned 1 point.

Since all the data points are on the best-fine line, additional credit was not awarded for a correctly drawn best-fine line or for use of points on the line instead of data points.

(e) 4 points

Using the definition of work

$$W = \int F dx$$

For correct substitution of $F(x)$ into the integral for work 1 point

For correct limits on the integral 1 point

For correct evaluation of the integral 1 point

$$W = \int_0^{0.10 \text{ m}} Ax^2 dx = \frac{1}{3} A (0.10 \text{ m})^3 = \frac{1}{3} (1.7 \times 10^3 \text{ N/m}^2) (1.0 \times 10^{-3} \text{ m}^3)$$

For the correct answer with correct units 1 point

$$W = 0.57 \text{ J}$$

Note: *This part stated to “calculate,” so a correct answer with correct units, but with no work shown, earned 1 point.*

(f) 3 points

For an appropriate expression of conservation of energy or the work-energy theorem 1 point

For a correct expression for K and substitution of W from part (e), expressed algebraically or numerically 1 point

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

$$v = \sqrt{\frac{2W}{m}} = \sqrt{\frac{2(0.57 \text{ J})}{0.5 \text{ kg}}}$$

For a value of v consistent with the value of W in (e), with correct units 1 point

$$v = 1.5 \text{ m/s}$$

Note: *This part stated to “calculate,” so an answer consistent with (e) and with correct units, but with no work shown, earned 1 point.*