General Notes About 2006 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth 1 point, and a student's solution contains the application of that equation to the problem but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive an expression, it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics exam equation sheet. See pages 21–22 of the *AP Physics Course Description* for a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each.

4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m}/\text{s}^2$, but use of $10 \text{ m}/\text{s}^2$ is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

Question 2

15 points total | **Distribution of points**

(a) 1 point

For indicating that F vs. x^2 <u>or</u> $\sqrt{F}$ vs. x should be graphed, <u>or</u> 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
<u>Note</u>: If answer to (a) was incorrect or incomplete, (b) received no credit.

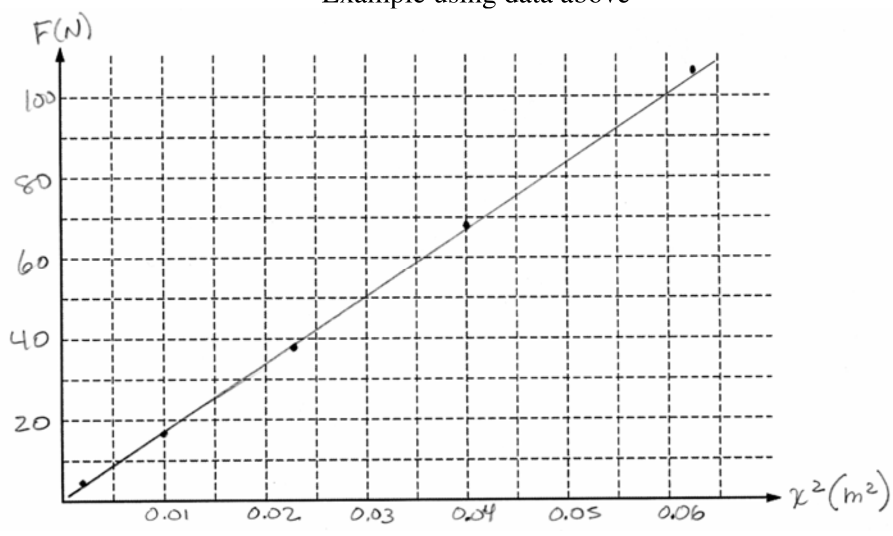
Example using F vs. x^2

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
<u>Note</u>: 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



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

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

For the correct answer with correct units	1 point

$W = 0.57$ 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

$v = 1.5$ 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.*

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)	x^2 (m^2)
0.05	4	.0025
0.10	17	.01
0.15	38	.0225
0.20	68	.04
0.25	106	.0625

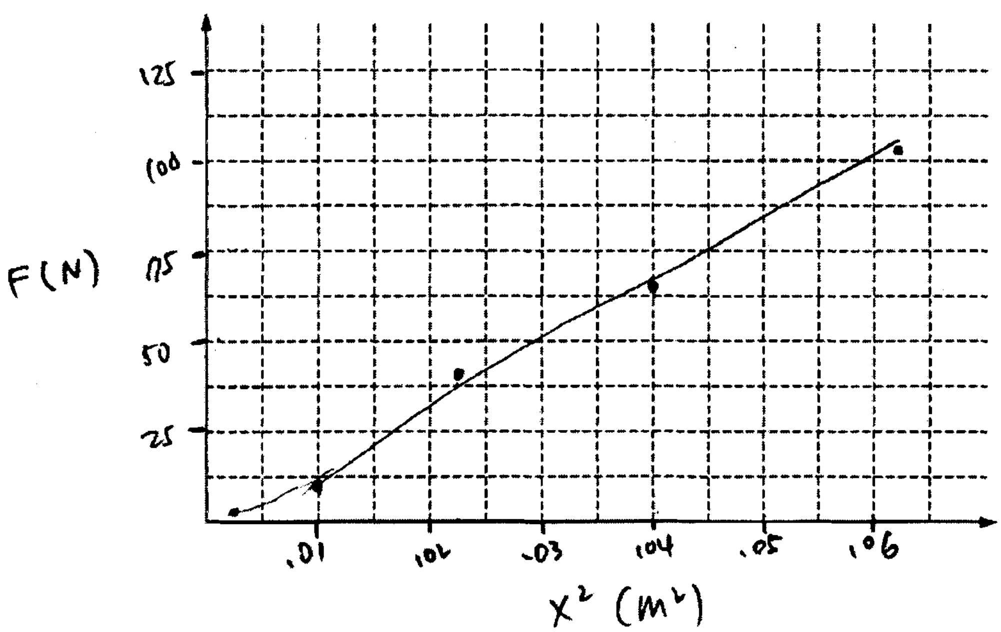
Assume that the magnitude of the force applied by the spring is of the form $F(x) = Ax^2$.

(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?

$F = Ax^2$, $A = \frac{F}{x^2}$ → a graph of x^2 vs. F

(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*.

$$A = \frac{\Delta F}{\Delta x^2} = \frac{106N - 4N}{.0625m^2 - .0025m^2} = \boxed{1700 \frac{N}{m^2}}$$

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.

$$W = E_{spring} = \int F(x)\,dx$$
$$= \int Ax^2\,dx = \frac{1}{3}Ax^3 = \frac{1}{3}(1700\frac{N}{m^2})(.1m)^3$$
$$= \boxed{.5666 J}$$

(f) Calculate the speed of the cart just before it strikes the spring.

$$KE = W$$
$$\frac{1}{2}mv^2 = W$$
$$v = \sqrt{\frac{2W}{m}} = \sqrt{\frac{2(.5666J)}{.5kg}}$$
$$= \boxed{1.5055 \frac{m}{s}}$$

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)	x^2 (m^2)
0.05	4	0.0025
0.10	17	0.010
0.15	38	0.0225
0.20	68	0.040
0.25	106	0.0625

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

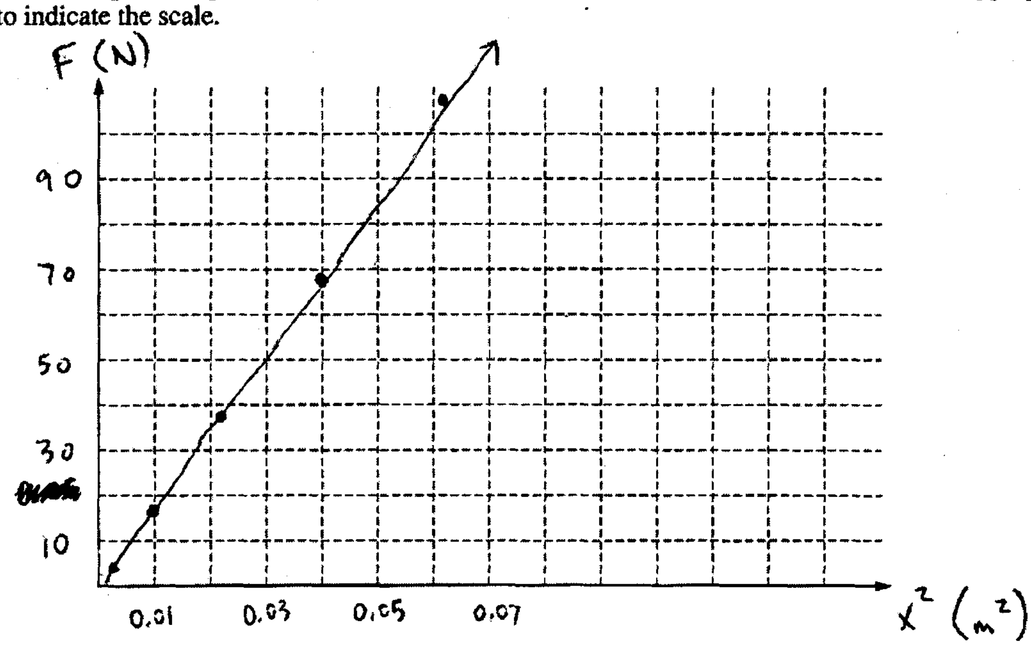
(a) Which quantities should be graphed in order to yield a straight line whose slope could be used to calculate a numerical value for A ?

F and X^2

$A = \frac{F}{x^2}$

(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.

A = slope of best fit line

$$\boxed{A \approx 1700 \ N/m^2}$$

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.

$F_s = -kx$

$F_s = -Ax$

$F_s = -1700(0.1)$

$F_s = -170 \ N$

$W = Fd$

$W = (-170)(0.10)$

$W = |-17| \ J$

$$\boxed{W = 17 \ J}$$

(f) Calculate the speed of the cart just before it strikes the spring.

$E_K = E_{el}$

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

$mv^2 = kx^2$

$v = \sqrt{\frac{kx^2}{m}}$

$v = \sqrt{\frac{(1700)(0.10)^2}{0.50}}$

$v = \sqrt{34}$

$$\boxed{v = 5.83 \ m/s}$$

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.

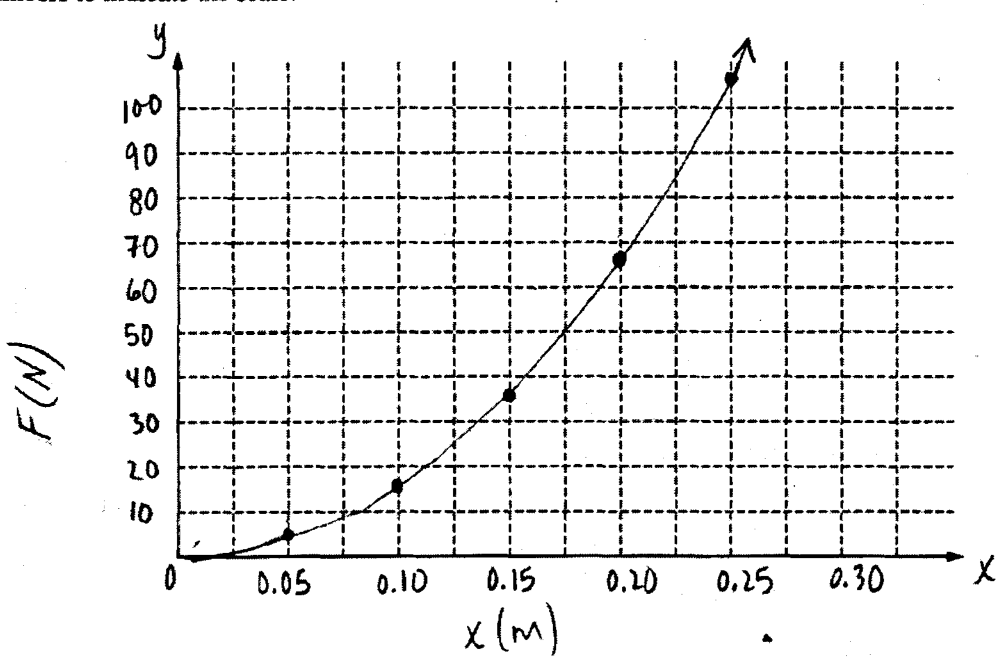
x (m)	F (N)	A (N/m²)
0.05	4	1600
0.10	17	1700
0.15	38	1689
0.20	68	1700
0.25	106	1696

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? The x-axis should contain the quantity "x" in meters (distance) and the y-axis should contain the quantity "F" in newtons (force).

(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.
(see chart above)

(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.

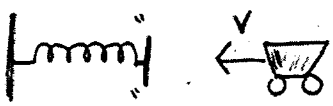
$A = \frac{F(x)}{x^2}$ so, $\boxed{A = \frac{F}{x^2}}$

2nd ORDER Direct function

(Graph needs to be modified by squaring the "x". Then, the graph will be linear, not parabolic.)

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.



$m = 0.50\ kg$
$d = 0.10\ m$

$W = F \cdot d$

$W = \left(\frac{4.9N}{(0.10m)^2}\right) \cdot (0.10m)$

$\boxed{W = 49J}$

(f) Calculate the speed of the cart just before it strikes the spring.

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

$(0.5)(0.50kg)(v^2) = (0.5)(49\ N/m)(0.10m)$

$\boxed{v = 3.13\ m/s}$

AP® PHYSICS C: MECHANICS
2006 SCORING COMMENTARY

Question 2

Overview

This question was intended to test two sets of skills. Parts (a) through (d) examined student graphing and graphical analysis skills: how to linearize data, and how to calculate values from a graph. Parts (e) and (f) examined student skills at applying physics and calculus to a nonlinear spring: how to calculate work done in compressing the spring, and how to apply the conservation of energy to a spring-cart system.

Sample: M2A
Score: 15

This response received full credit on all the parts. The solutions are succinct and easy to follow. A best-fit line was not required for the graph and since the all the data points were very close to being on a straight line, it was sufficient to use two data points to calculate the slope in part (d).

Sample: M2B
Score: 9

This response received the 8 points full credit for the first four parts. Part (e) received no credit for a calculation of work that is incorrect for this situation. Part (f) received 1 point for the recognition of the need to use conservation of energy, but neither a correct expression for the elastic potential energy nor a value of work consistent with the answer to part (e) is used, so no further credit was awarded.

Sample: M2C
Score: 4

Parts (a) and (b) received no credit since no pair of correct quantities is specified in (a). However, part (c) received 3 points full credit for correctly graphing the quantities that are mentioned in part (a). No credit was given for part (d) because the graph is not used to calculate *A*. The only additional point was given in part (f) for recognizing the need to conserve energy.