General Notes About 2009 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 one 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. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics Course Description*.

4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/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 1

15 points total **Distribution of points**

(a) 3 points

For a correct statement of conservation of mechanical energy (which might be implied in the next statement) — 1 point

For correct energy expressions set equal — 1 point

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

For solving for h, consistent with the energy equation — 1 point

$$h = \frac{kx^2}{2mg}$$

(b)

(i) 2 points

For a correct combination of ($1/m$ and h) or ($1/h$ and m), with or without constants — 2 points

Notes:

- If both $1/m$ and $1/h$ were chosen, only 1 point was earned.
- If part (b)(i) contained quantities that would not yield a correct graph for part (c), no credit was given for parts (b)(ii) through (d). But if part (b)(i) was left blank, parts (b)(ii) through (d) were examined for correct results.

The example of h versus $1/m$ is used in the remainder of the scoring guideline.

(ii) 2 points

$1/m$ (kg^{-1})	m (kg)	h (m)	
50	0.020	0.49	
33	0.030	0.34	
25	0.040	0.28	
20	0.050	0.19	
17	0.060	0.18	

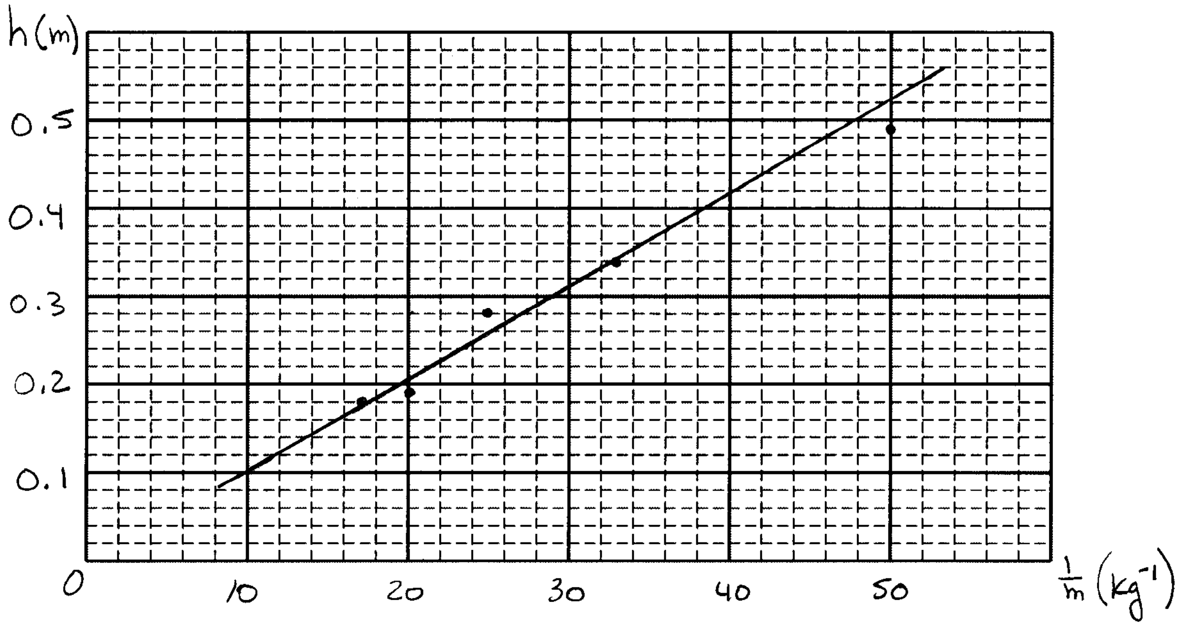
For correctly filling in the table with the appropriate data — 1 point

For including the correct units in the table — 1 point

Question 1 (continued)

Distribution of points

(c) 4 points



For correctly plotting appropriate data (all five data points plotted correctly, assuming the data represented an inverse relationship between m and h) — 1 point

For correctly drawing a best-fit straight line (a single straight line with data points reasonably scattered above and below the line) — 1 point

For correctly labeling both axes — 1 point

For correctly indicating the scale on both axes — 1 point

(d) 2 points

For correctly calculating the slope from points on the line — 1 point

For example: $\text{slope} = \dfrac{(0.42 - 0.10)\ \text{m}}{(40 - 10)\ \text{kg}^{-1}} = \dfrac{0.32\ \text{m}}{30\ \text{kg}^{-1}} = 1.07 \times 10^{-2}\ \text{m}{\bullet}\text{kg}$

For a correct numerical value of the spring constant — 1 point

From (a), $h = \dfrac{kx^2}{2mg}$, so the slope of the line $= \dfrac{kx^2}{2g}$

$$k = \frac{2g(\text{slope})}{x^2}$$

$$k = \frac{2\left(9.8\ \text{m/s}^2\right)\left(1.07 \times 10^{-2}\ \text{m}{\bullet}\text{kg}\right)}{(0.02\ \text{m})^2}$$

$k = 524\ \text{N/m}$ ($535\ \text{N/m}$ using $g = 10\ \text{m/s}^2$)

Note: Values between $450\ \text{N/m}$ and $550\ \text{N/m}$ were accepted.

Question 1 (continued)

Distribution of points

(e) 2 points

For a correct, complete procedure — 2 points

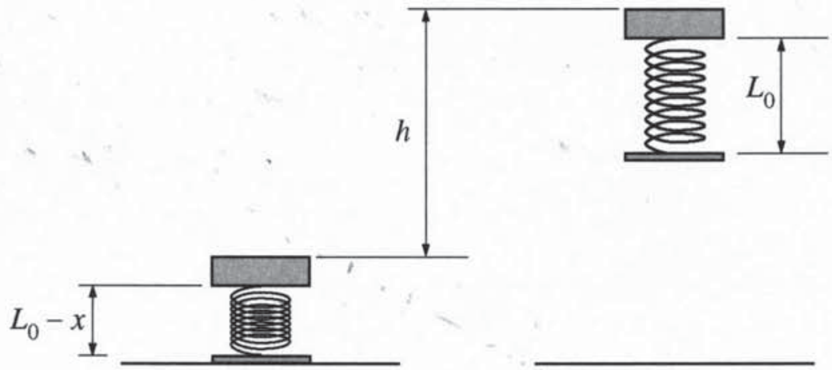
Examples: Use a meter stick and a visual recorder, such as the eye, a video camera, or a camera.
Use a sonic range finder and appropriate computer software.
Measure the time (either to rise or for a round trip) and give the correct appropriate kinematics equations (the equations must be included in the answer).

One point was awarded for a partially correct or incomplete procedure.

Examples: Use a meter stick.
Use a photogate.

PHYSICS B
SECTION II
Time—90 minutes
7 Questions

Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested times are about 17 minutes for answering each of Questions 1 and 3 and about 11 minutes for answering each of Questions 2 and 4-7. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the green insert.



Compressed Spring on Table Released Spring at Maximum Height

1. (15 points)

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.

$K_1 + U_{G1} + U_{E1} + W_0 = K_2 + U_{g2} + U_{E2}$

$\frac{1}{2}Kx^2 = mgh$

$h = \frac{Kx^2}{2mg}$

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

x (m)	m (kg)	h (m)	g (m/s²)
.02	0.020	0.49	9.8
.02	0.030	0.34	9.8
.02	0.040	0.28	9.8
.02	0.050	0.19	9.8
.02	0.060	0.18	9.8

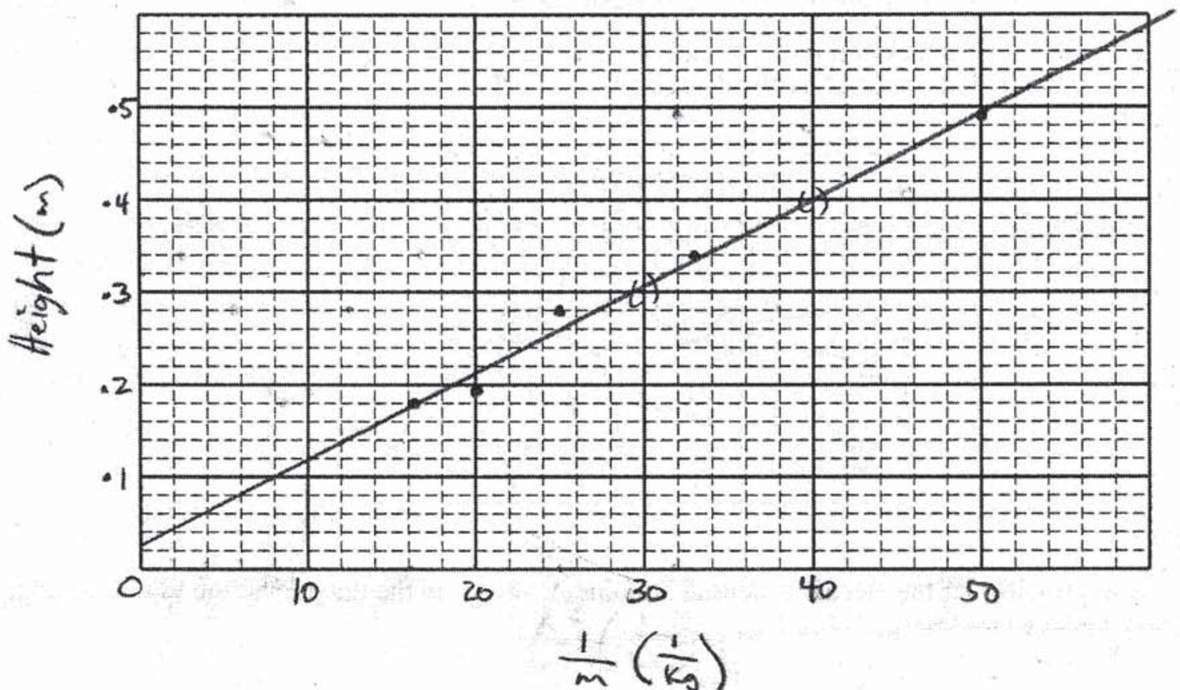
(b)

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 ?

h vs. $\frac{1}{m}$

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

(c) On the axes below, 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.

(40, .4)
(30, .3)

$$\text{Slope} = \frac{kx^2}{2g} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{.4 - .3}{40 - 30} = \frac{.1}{10} = .01$$

$$\frac{kx^2}{2g} = .01$$

$$kx^2 = (.01)(2g)$$

$$k = \frac{(.01)(2g)}{x^2} = \frac{(.01)(2)(9.8)}{(.02)^2} = \boxed{490}$$

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

Measure the time it takes for the toy to fall back down after being released. Divide time by 2 and plug into equation:

$$y = V_0 \sin\theta t - \frac{1}{2} g t^2$$

where $V_0 = 0\ m/s$

$$\left[y = -\frac{1}{2} g t^2 \right]$$

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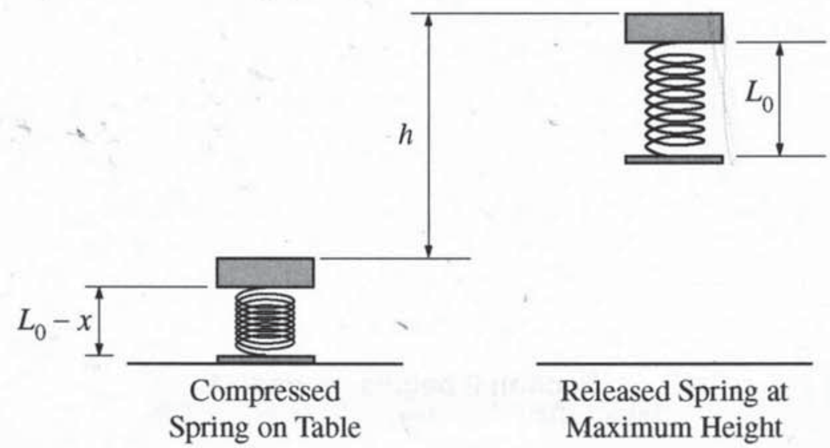


1. (15 points)

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.

$E_i = E_f$

$\frac{1}{2}kx_i^2 + mgh_0 = \frac{1}{2}kx_f^2 + mgh_f$

$\frac{1}{2}kx_i^2 = \frac{1}{2}kL_0^2 + mgh$

$$\frac{\frac{1}{2}k(x^2 - L_0^2)}{mg} = h$$

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	

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

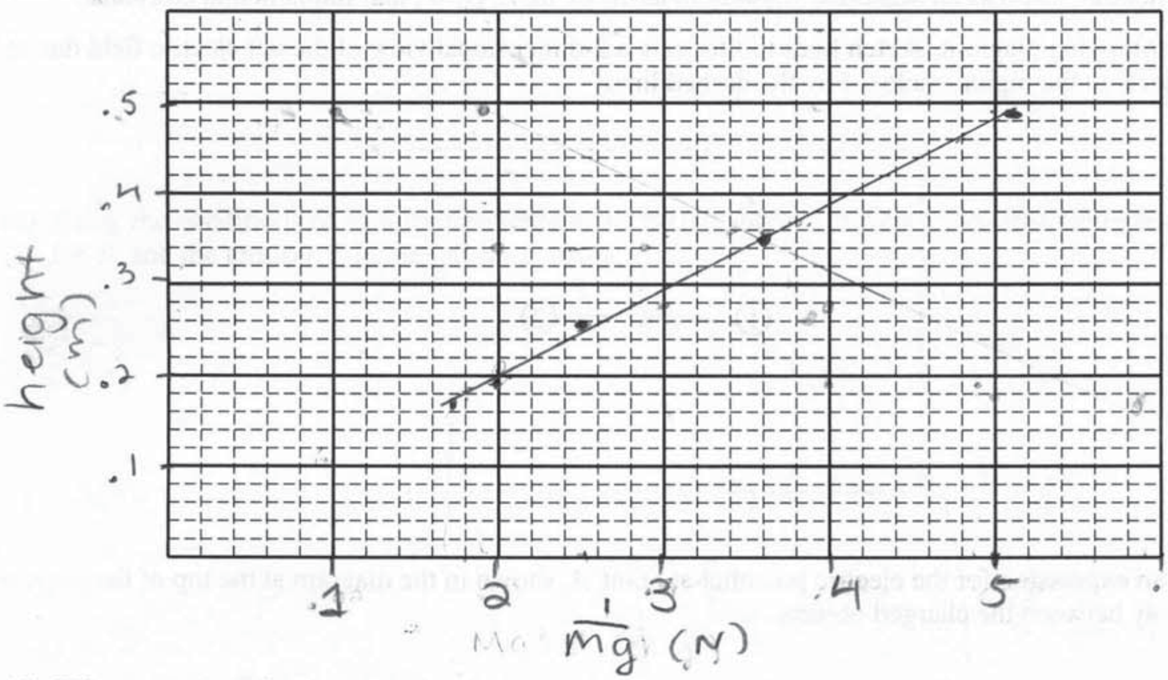
(b)

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 ?

the height and the inverse of the force of gravity

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

(c) On the axes below, 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.

$hmg = \frac{1}{2}kx^2$ slope of line is $\frac{1}{2}kx^2$

$\frac{.49 - .18}{(5.10 - 1.70)} = .09 = \frac{1}{2}k(.02)^2$ $k = 45$

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

One could measure the height by timing how long it takes for the spring to fall, which will allow you to find the velocity and then equivocate Ugrav with kinetic energy of the spring system.

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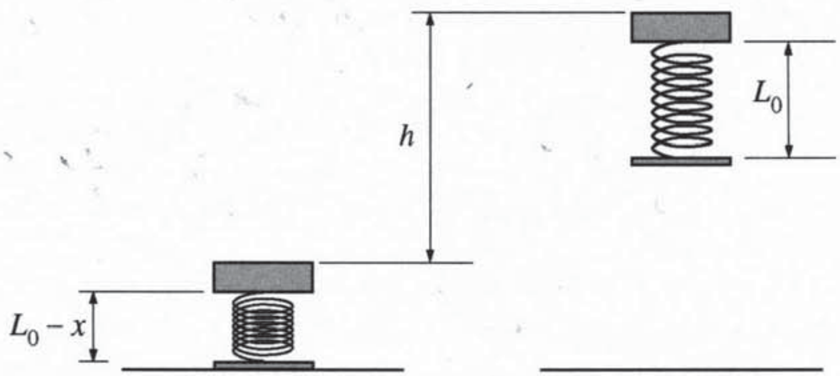


Compressed Spring on Table | Released Spring at Maximum Height

1. (15 points)

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.

$mgh = \frac{kx^2}{2}$ gravitational potential energy = spring potential energy

~~$h = \frac{mgkx^2}{2}$~~

$$h = \frac{kx^2}{2mg}$$

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	24.5 m/kg
	0.030	0.34	11.3 m/kg
	0.040	0.28	7.00 m/kg
	0.050	0.19	3.80 m/kg
	0.060	0.18	3.00 m/kg

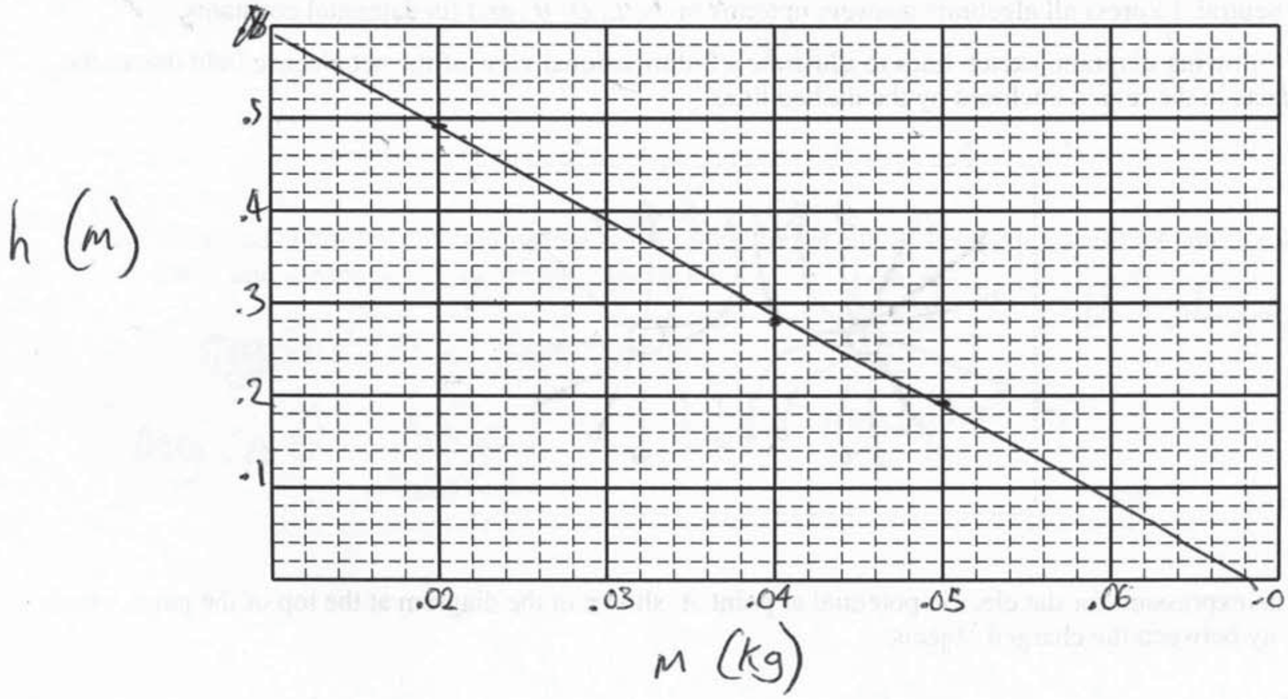
(b)

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 ?

m = 0.020, 0.040, 0.050

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

(c) On the axes below, 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.

15 N/m

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

Using a motion capture device and a camera, photograph the toy next to a meter stick for the instant it stops moving. V=0 when the object is at maximum height

Question 1

Overview

This was a lab question that tested students' ability to utilize conservation of energy and graphical analysis with a given set of data. The question also asked students to describe a suitable measurement procedure.

Sample: B-1A
Score: 13

This solution received full credit except for part (b)(ii), where the student lost both points for failing to tabulate $1/m$. In part (c) the student clearly identifies two points on the best-fit line, distinct from the actual data points, and uses them to determine the slope. The response for part (e) is a reasonable description of using a time measurement and kinematics to determine the height h.

Sample: B-1B
Score: 8

One point was lost in part (a) for an incorrect expression for the energy when the toy is at its peak height; the student effectively assumes the spring is compressed a distance L_0 rather than zero. Part (b)(i) has correct quantities to plot and earned 2 points. No data or units are given for part (b)(ii), so no points were earned. One point was deducted in part (c) for incorrectly labeling the units for the horizontal axis. In part (d) data points rather than points on the graph are used to calculate the slope, and a math error leads to an incorrect numerical result, so no points were earned. Finally, in part (e) a kinematical method is presented, but no equations are included to indicate how the data collected could be used to find the height. Thus only 1 point was earned.

Sample: B-1C
Score: 5

Part (a) is correct, earning all 3 points. For part (b)(i) no correct quantities are shown, and so parts (b)(ii) through (d) earned no points. Note that the student calculates h/m and enters the results in the data table for part (b)(ii) and plots h versus m in part (c). Finally, part (e) is reasonable and earned 2 points.