AP® PHYSICS C: MECHANICS
2007 SCORING GUIDELINES

General Notes About 2007 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 and 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.

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Question 3

15 points total **Distribution of points**

(a) 2 points

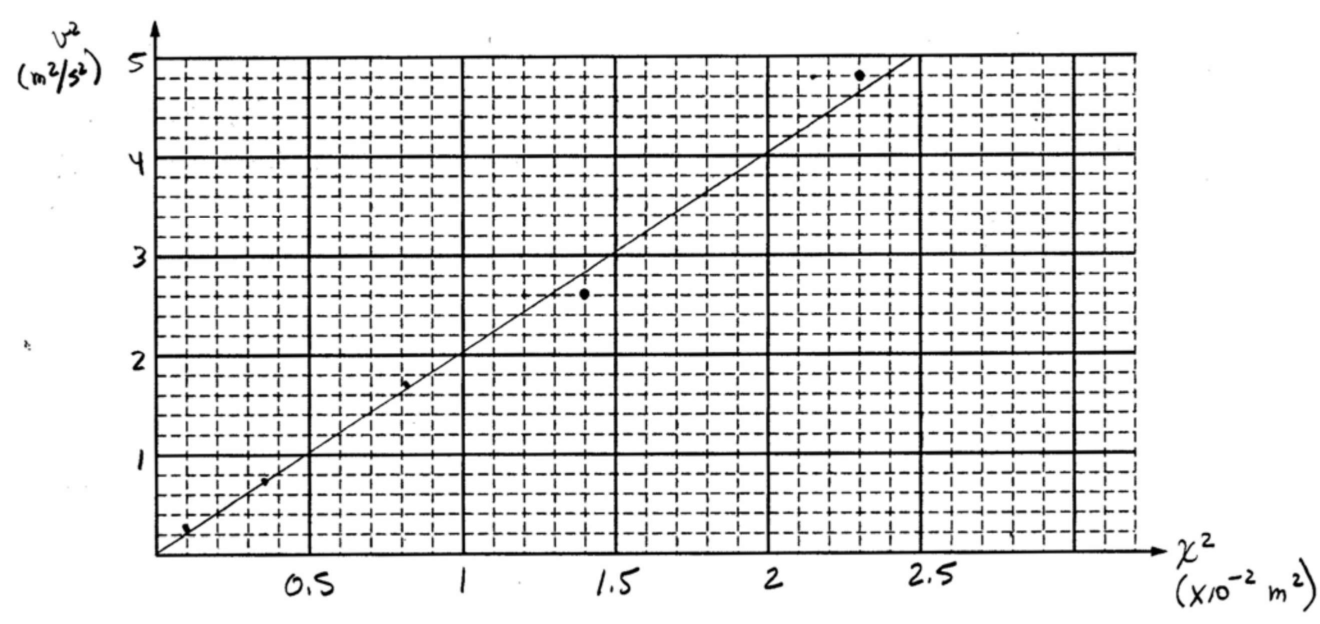
For a correct equation using conservation of energy — 1 point

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

For a correct substitution of the numerical value of k in part (a) <u>or</u> in a subsequent part of the problem — 1 point

$$\frac{1}{2}mv^2 = \frac{1}{2}(40)x^2$$

(b) and (c)



(b) 3 points

For correct axis labels and units on both axes — 1 point
For correct linear scales on both axes — 1 point
For plotting at least 4 of 5 points in the correct location — 1 point

<u>Note:</u> *Full credit was awarded if both axes were reversed from the graph shown above and everything else was correct.*

Question 3 (continued)

Distribution of points

(c)

(i) 1 point

For a reasonable best-fit straight line — 1 point

Note: This point was awarded only if the axes had linear scales.

(ii) 3 points

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

$v^2 = \frac{k}{m}x^2$, so k/m is the slope of the graph of v^2 versus x^2

For use of a slope derived from the data — 1 point

For using two points in the calculation of the slope that are clearly on the best-fit line — 1 point

(Students using data points not on the line could not receive this second point.)

Example: Selecting the points (2.4×10^{-2}, 4.8) and (0.5×10^{-2}, 1.0), which are on the line shown in the graph

$$\text{Slope} = \frac{(4.8 - 1.0)\ \text{m}^2/\text{s}^2}{(2.4 - 0.5) \times 10^{-2}\ \text{m}^2} = 2.0 \times 10^2\ \text{s}^{-2} = \frac{k}{m}$$

$$m = \frac{k}{\text{slope}} = \frac{40\ \text{N/m}}{2.0 \times 10^2\ \text{s}^{-2}}$$

For a numerical answer in the range 0.18 kg to 0.22 kg — 1 point

$m = 0.20$ kg

(d)

(i) 4 points

For use of the correct energy types (K, U_g, and U_s) in a single equation — 1 point

For recognition that the difference in height is greater than h in the figure — 1 point

For a correct expression for U_g — 1 point

For substitution of U_g into a correct equation — 1 point

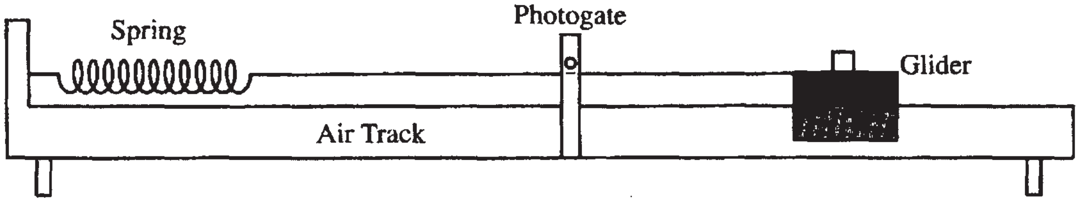
$$\frac{1}{2}mv^2 = \frac{1}{2}kx^2 + mg(h + x\sin\theta)$$

Note: Third and fourth points were awarded only if the first two points were awarded.

(ii) 2 points

For checking "No" — 1 point

For a clear justification explaining that v^2 varies with both x^2 and x. — 1 point



Mech. 3.

The apparatus above is used to study conservation of mechanical energy. A spring of force constant 40 N/m is held horizontal over a horizontal air track, with one end attached to the air track. A light string is attached to the other end of the spring and connects it to a glider of mass m. The glider is pulled to stretch the spring an amount x from equilibrium and then released. Before reaching the photogate, the glider attains its maximum speed and the string becomes slack. The photogate measures the time t that it takes the small block on top of the glider to pass through. Information about the distance x and the speed v of the glider as it passes through the photogate are given below.

Trial #	Extension of the Spring x (m)	Speed of Glider v (m/s)	Extension Squared x^2 (m^2)	Speed Squared v^2 (m^2/s^2)
1	0.30×10^{-1}	0.47	0.09×10^{-2}	0.22
2	0.60×10^{-1}	0.87	0.36×10^{-2}	0.76
3	0.90×10^{-1}	1.3	0.81×10^{-2}	1.7
4	1.2×10^{-1}	1.6	1.4×10^{-2}	2.6
5	1.5×10^{-1}	2.2	2.3×10^{-2}	4.8

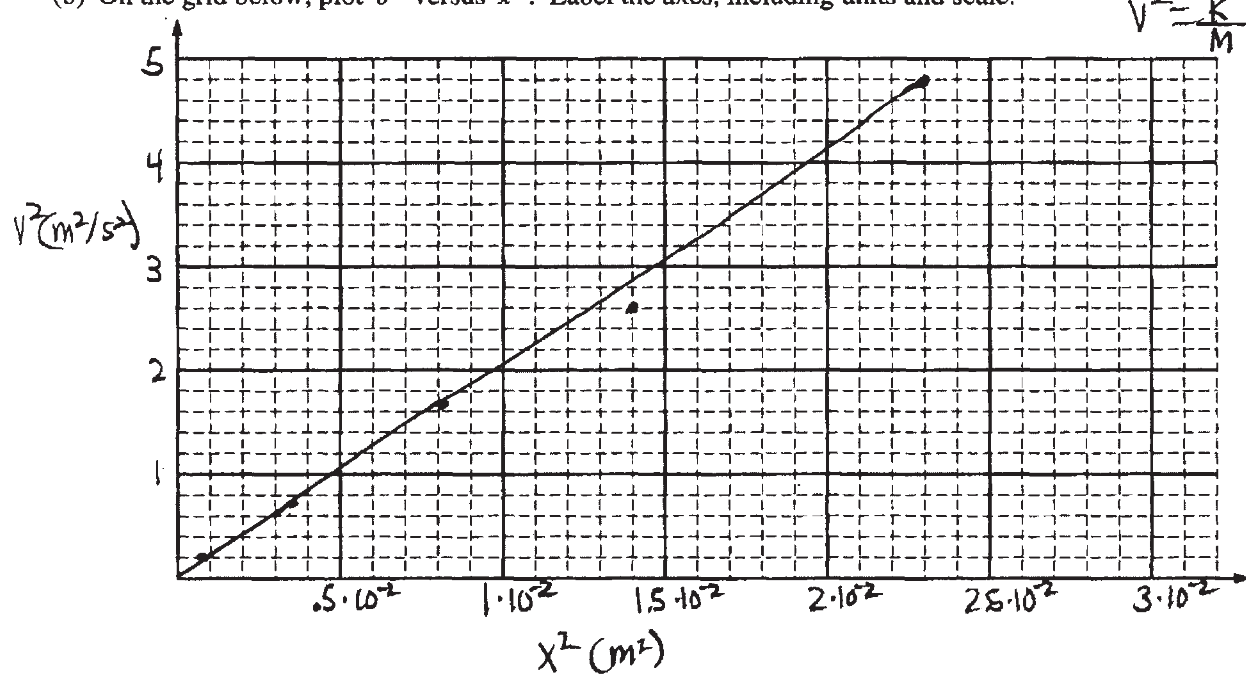
(a) Assuming no energy is lost, write the equation for conservation of mechanical energy that would apply to this situation.

$PE_S = KE_T$ $\quad \frac{1}{2}kx^2 = \frac{1}{2}mv_f^2$

$\boxed{kx^2 = mv^2}$

(b) On the grid below, plot v^2 versus x^2. Label the axes, including units and scale.

$v^2 = \frac{k}{m}x^2$



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(c)

i. Draw a best-fit straight line through the data.

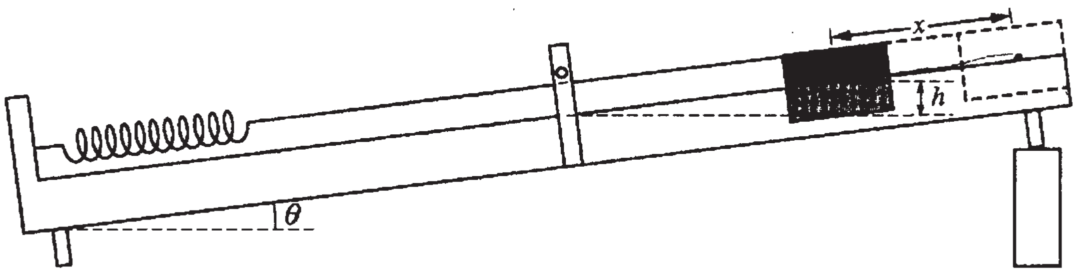
ii. Use the best-fit line to obtain the mass m of the glider.

ii. $\frac{K}{m} = \frac{4.8 - .22}{2.3e^{-2} - .09e^{-2}} = 207.240$

$207.240 = \frac{K}{m}$

$\boxed{m = .193\text{ Kg}}$

(d) The track is now tilted at an angle θ as shown below. When the spring is unstretched, the center of the glider is a height h above the photogate. The experiment is repeated with a variety of values of x.



i. Assuming no energy is lost, write the new equation for conservation of mechanical energy that would apply to this situation.

$PE_g + PE_s = KE_f$

$\boxed{mg(h + x\sin\theta) + \frac{1}{2}Kx^2 = \frac{1}{2}mv^2}$

ii. Will the graph of v^2 versus x^2 for this new experiment be a straight line?

_____ Yes __√__ No

Justify your answer.

$mgh + mgx\sin\theta + \frac{1}{2}Kx^2 = \frac{1}{2}mv^2$

$v^2 = \frac{2mgh + 2mgx\sin\theta + Kx^2}{m}$

$v^2 = 2gh + 2gx\sin\theta + \frac{K}{m}x^2$ because there is an x in the function, which $= \sqrt{x^2}$, there will be a square-root curve and not a line

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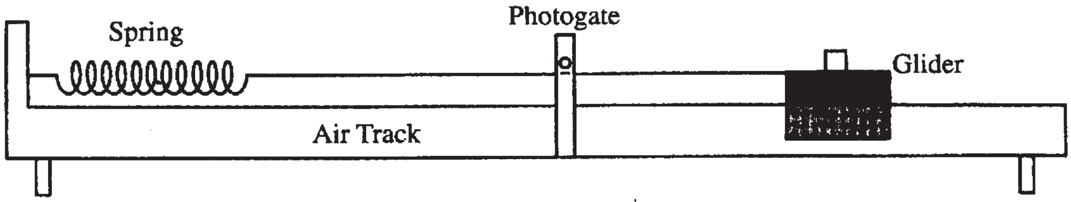

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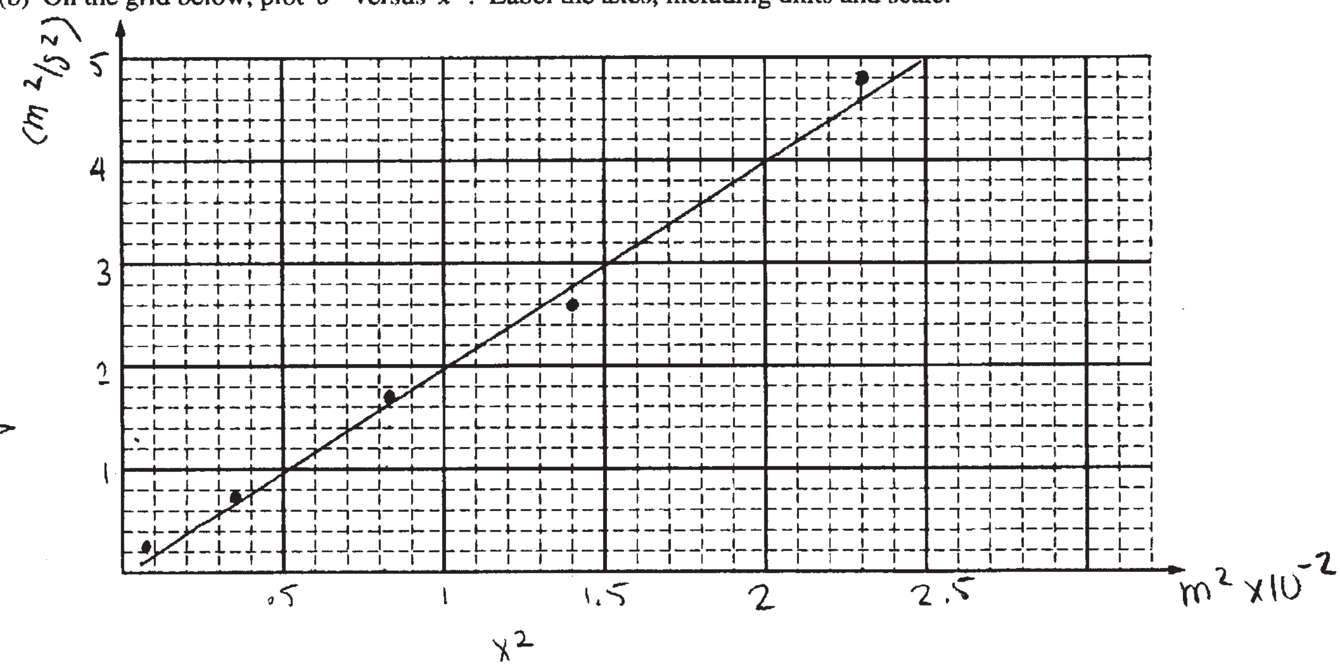
(a) Assuming no energy is lost, write the equation for conservation of mechanical energy that would apply to this situation.

$U_s = KE$

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

(b) On the grid below, plot v^2 versus x^2. Label the axes, including units and scale.



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(c)

i. Draw a best-fit straight line through the data.

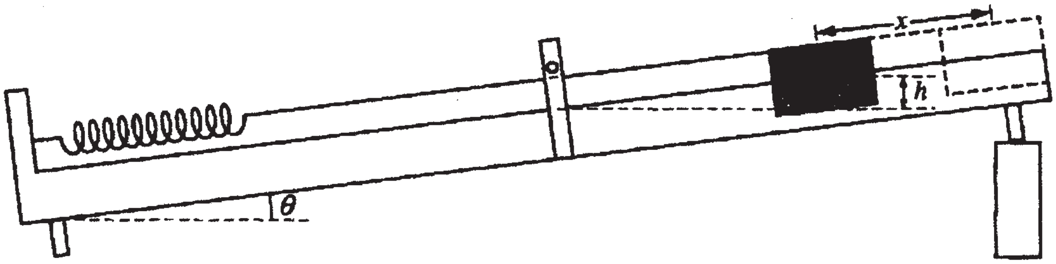
ii. Use the best-fit line to obtain the mass m of the glider.

$\cancel{\tfrac{1}{2}}kx^2 = \cancel{\tfrac{1}{2}}mv^2$

$k(1.5) = m(3)$ (using $x^2 = 1.5$, $v^2 = 3$

$\frac{40(1.5)}{3} = m = \boxed{20\text{ kg}}$

(d) The track is now tilted at an angle θ as shown below. When the spring is unstretched, the center of the glider is a height h above the photogate. The experiment is repeated with a variety of values of x.



i. Assuming no energy is lost, write the new equation for conservation of mechanical energy that would apply to this situation.

$KE = U_s + U_g$

$\frac{1}{2}mv^2 = -kx + mgh$

ii. Will the graph of v^2 versus x^2 for this new experiment be a straight line?

_____ Yes __✓__ No

Justify your answer. it will not be a straight line because now v^2 will be increasing at a greater rate than x^2 due to the addition of gravitational potential energy

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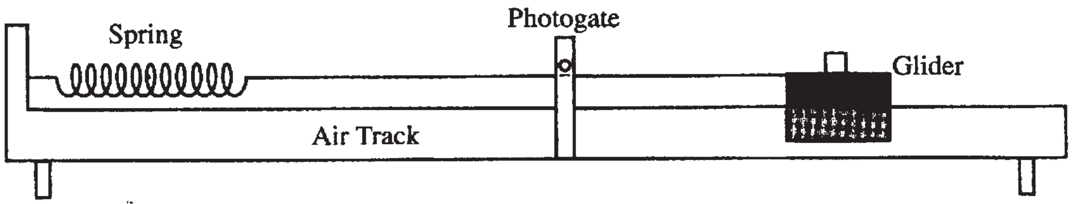

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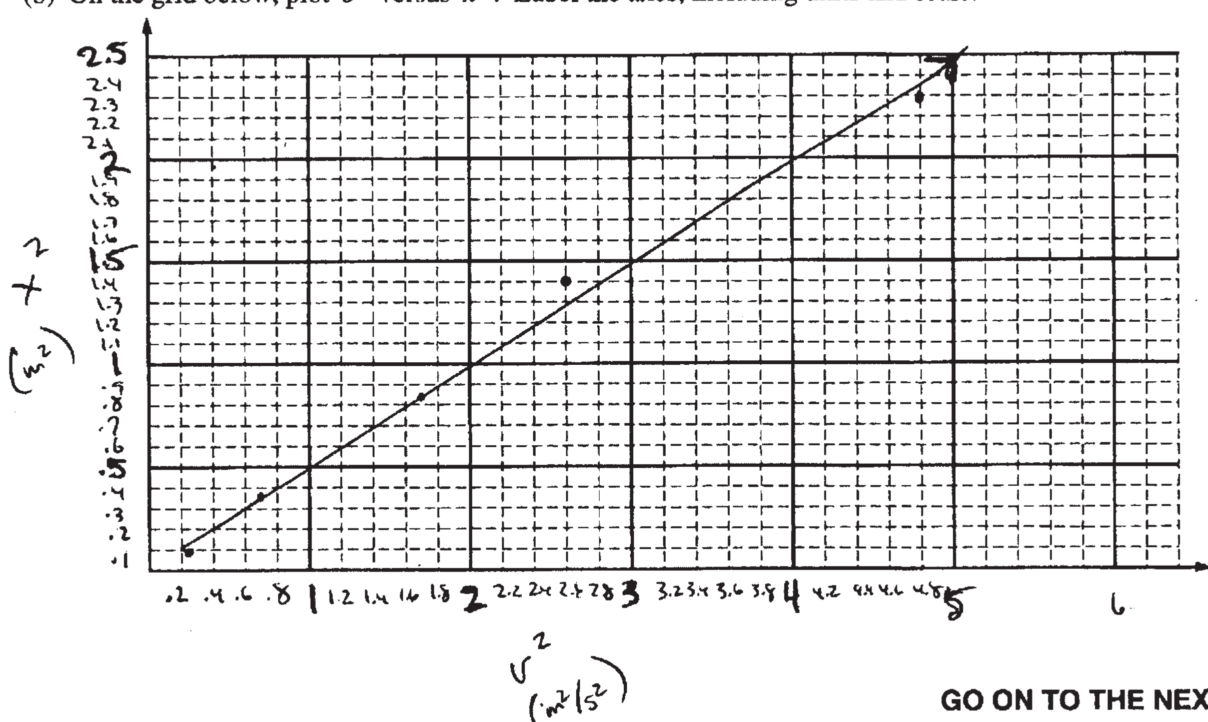
5	1.5×10^{-1}	2.2	2.3×10^{-2}	4.8

(a) Assuming no energy is lost, write the equation for conservation of mechanical energy that would apply to this situation.

$KE_i + PE_i = KE_f + PE_f$

(b) On the grid below, plot v^2 versus x^2. Label the axes, including units and scale.



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(c)

i. Draw a best-fit straight line through the data.

ii. Use the best-fit line to obtain the mass m of the glider.

$F = ma \quad d_x = v_0 t + \frac{1}{2}at^2$

$v = \frac{d}{t} \quad (2.3\times10^{-2}) = \frac{1}{2}a$

$\frac{4.8 - 2.3\times10^{-2}}{.22 - .09\times10^{-2}}$

Δ change $= 21.08$

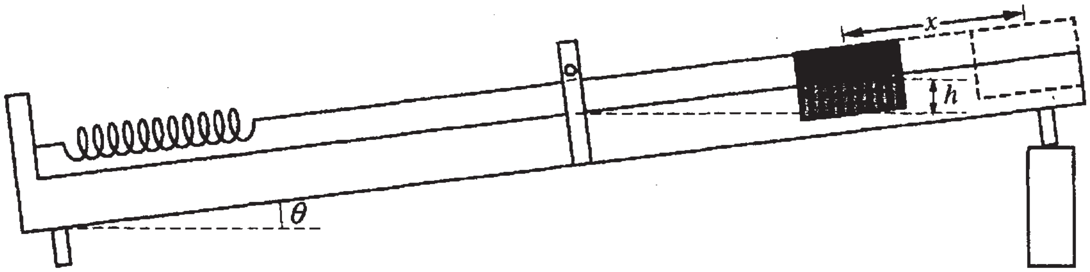
$\frac{1}{2}mv^2 = \frac{1}{2}kx^2$

$\frac{1}{2}m(4.8) = \frac{1}{2}(2.3\times10^{-2})(2.3\times10^{-2})$

$2.4\,m$

$m = 2.2\times10^{-3}$ kg

(d) The track is now tilted at an angle θ as shown below. When the spring is unstretched, the center of the glider is a height h above the photogate. The experiment is repeated with a variety of values of x.



i. Assuming no energy is lost, write the new equation for conservation of mechanical energy that would apply to this situation.

$KE_i + PE_i = (KE_f + PE_f)\cos\theta$

ii. Will the graph of v^2 versus x^2 for this new experiment be a straight line?

✓ Yes ____ No

Justify your answer.

~~The graph will be a decreasing line as the velocity with respect to~~

the graph will still be a straight line because the v^2 with respect to x^2 will still be equally proportional.

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AP® PHYSICS C: MECHANICS
2007 SCORING COMMENTARY

Question 3

Overview

This question was intended to measure students' knowledge about the conservation of mechanical energy; their ability to plot experimental data, draw a best-fit line, and utilize the fitted line to determine an unknown quantity (the mass of the glider); and their capacity to understand how and why the analysis would be affected if an initial assumption (that the track is level) was abandoned.

Sample: M2A
Score: 15

Full credit was awarded on all parts of this clear and well-organized response. The point in part (a) for substituting the numerical value for k was given in part (c).

Sample: M2B
Score: 9

Full credit was given for parts (a) and (b). The point in part (a) for substituting the numerical value for k was given in part (c). Part (c) received 3 of the 4 possible points, losing only the point for an answer in the correct range because the factor of 10^{-2} is missing. The calculation in part (c)(ii) uses a single point that is on the line, which is acceptable since the line also goes through (0,0). Part (d)(i) received no credit; although the answer seems to begin with an equation involving two potential energy terms, the student substitutes a force term for the potential energy of the spring and so failed to earn the first point. One point was given for the correct check mark in part (d)(ii), but no points were given for the incorrect justification.

Sample: M1C
Score: 3

No points were given for part (a) since the equation is not far enough along to evaluate. In part (b) 2 points were given for labels and units and for correct plotting of the points. Although the scales are linear, the factor $\times 10^{-2}$ is not included, so 1 point was lost. One point was given for part (c)(i). In part (c)(ii) the student uses a calculation reminiscent of a slope, but it appears to be $\frac{x_1 - y_1}{x_2 - y_2}$, which cannot be interpreted as the slope, so no points were awarded for this part. No points were given for part (d).