General Notes About 2008 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. 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*.

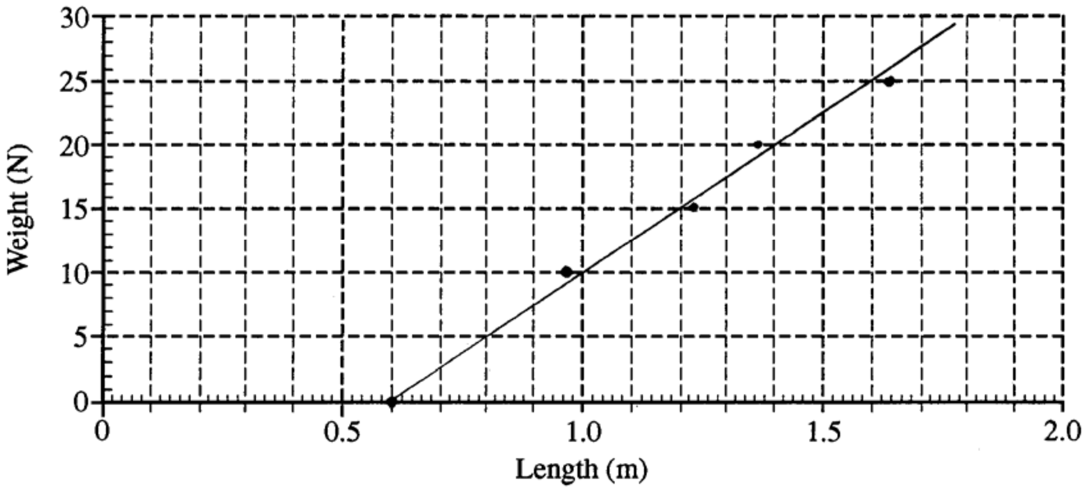
4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is, of course, also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

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 3

15 points total | **Distribution of points**

(a) 2 points



For four or more correctly plotted points with no extraneous points — 1 point
For a straight line drawn with at least one point above and one point below the line — 1 point

(b) 3 points

For any indication that the slope is used, or $W = k(L - L_0)$ — 1 point
For a calculation using two points from the straight line — 1 point
For example, using the example graph above

$$k = \text{slope} = \frac{20 - 0}{1.4 - 0.60}\ \frac{\text{N}}{\text{m}}$$

For a numeric answer between $23\ \text{N/m}$ and $27\ \text{N/m}$ — 1 point

$k = 25\ \text{N/m}$

Alternate solution
For an indication of a linear regression calculation using the student's calculator — *1 point*
For an indication that the slope is used to get k — *1 point*
For a numeric answer between $23\ \text{N/m}$ *and* $27\ \text{N/m}$ — *1 point*

Question 3 (continued)

	Distribution of points
(c) 3 points	
For an equation using the correct forms for gravitational and spring potential energies	1 point
$mgy_{max} = \frac{1}{2}kx^2$	
$m = kx^2 / 2gy_{max}$	
For a correct substitution of $y_{max} = 1.5$ m and k from part (a)	1 point
For a correct numeric substitution of $x = (1.5 \text{ m} - 0.60 \text{ m}) = 0.90 \text{ m}$	1 point
$m = \left(25 \text{ kg/s}^2\right)(0.90 \text{ m})^2 / 2\left(9.8 \text{ m/s}^2\right)(1.5 \text{ m})$	
$m = 0.69$ kg (or 0.68 kg using $g = 10 \text{ m/s}^2$)	
Note: The second and third points are awarded only if the first point is awarded.	

(d)

(i) 3 points

Maximum speed occurs when the net force is zero.	
$\Sigma F = 0$	
For a correct equation relating gravitational and spring forces	1 point
$mg = kx$	
$x = \frac{mg}{k}$	
For the correct numeric substitution of the mass obtained in part (c) and k obtained in part (a)	1 point
$x = \frac{(0.69 \text{ kg})(9.8 \text{ m/s}^2)}{25 \text{ kg/s}^2}$	
$x = 0.27$ m	
For adding the unstretched cord length to the value of x calculated above	1 point
$y_{\upsilon max} = 0.27 \text{ m} + 0.60 \text{ m}$	
$y_{\upsilon max} = 0.87 \text{ m}$	

Notes:

- The second and third points were awarded only if the first point was awarded.
- Full credit was awarded for a correct solution that takes the minimum of a potential function or the maximum of a kinetic energy function to determine $y_{\upsilon max}$.

Question 3 (continued)

Distribution of points

(d) (continued)

(ii) 2 points

Note: These points could be awarded only if the first point in (d)(i) was awarded.

For a correct statement that acceleration is zero or switches from downwards to upwards at that point — 1 point

Note: This point was also awarded for stating that the potential energy is a minimum at that point, which implies that the kinetic energy and speed are at their maximum values.

For an additional correct statement and no incorrect statements regarding the motion — 1 point

Example: The acceleration is zero when the two forces are equal in magnitude. Since the acceleration switches from downward to upward (aligned with the velocity to opposing the velocity), the velocity changes from increasing to decreasing.

(iii) 2 points

For a correct energy expression — 1 point

$$mgy_{\upsilon\max} = \frac{1}{2}kx^2 + \frac{1}{2}m\upsilon_{\max}{}^2$$

$$\frac{1}{2}m\upsilon_{\max}{}^2 = mgy_{\upsilon\max} - \frac{1}{2}kx^2$$

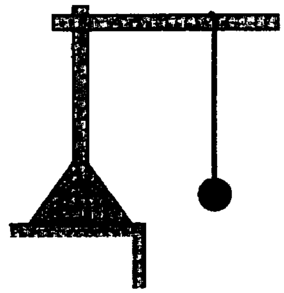
$$\upsilon_{\max}{}^2 = 2gy_{\upsilon\max} - \frac{k}{m}x^2$$

For correct substitution of values previously obtained (especially those from part (d)(i)) — 1 point

$$\upsilon_{\max}{}^2 = 2(9.8\ \text{m/s}^2)(0.87\ \text{m}) - \frac{(25\ \text{N/m})}{(0.69\ \text{kg})}(0.27\ \text{m})^2$$

$$\upsilon_{\max}{}^2 = 14.4(\text{m/s})^2$$

$$\upsilon_{\max} = 3.8\ \text{m/s}$$

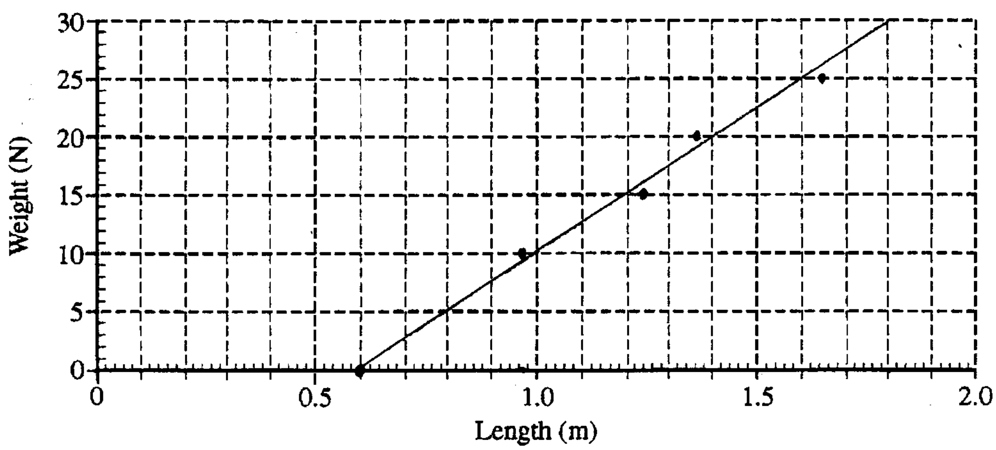


Mech. 3.

In an experiment to determine the spring constant of an elastic cord of length 0.60 m, a student hangs the cord from a rod as represented above and then attaches a variety of weights to the cord. For each weight, the student allows the weight to hang in equilibrium and then measures the entire length of the cord. The data are recorded in the table below:

Weight (N)	0	10	15	20	25
Length (m)	0.60	0.97	1.24	1.37	1.64

(a) Use the data to plot a graph of weight versus length on the axes below. Sketch a best-fit straight line through the data.



(b) Use the best-fit line you sketched in part (a) to determine an experimental value for the spring constant k of the cord.

$F = kx$

i.e. $k = \frac{F}{x} \doteq \frac{30}{1.2} \doteq 25 \text{ (N/m)}$

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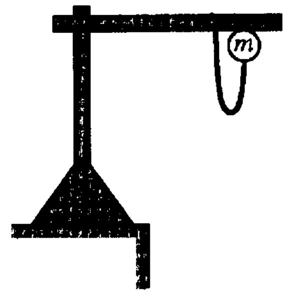

The student now attaches an object of unknown mass m to the cord and holds the object adjacent to the point at which the top of the cord is tied to the rod, as represented above. When the object is released from rest, it falls 1.5 m before stopping and turning around. Assume that air resistance is negligible.

(c) Calculate the value of the unknown mass m of the object.

$E_p = mgh = m \times 10 \times 1.5 = 15m$ (J) $\because$ energy conserved

$\therefore E_p = E_{P cord} = \frac{1}{2}k\Delta x^2 = \frac{1}{2} \times 25 \times (1.5 - 0.6)^2 = 10.125$ (J)

$\therefore 15m = 10.125$

$m = 0.675$ (kg)

(d) i. Calculate how far down the object has fallen at the moment it attains its maximum speed.

the maximum speed occurs when $F_{net} = 0$

i.e. $mg = k\Delta x$

$6.75 = 25\Delta x$

$\Delta x = 0.27$ (m)

total height $= 0.6 + \Delta x = 0.87$ (m)

ii. Explain why this is the point at which the object has its maximum speed.

at this point $F_{net} = 0$ thus $a = 0$ $\therefore$ the speed of the object neither increases nor decreases at this point

$\therefore$ at this point the object has its maximum speed.

iii. Calculate the maximum speed of the object.

energy conserved

$\therefore mgh_{total} = \frac{1}{2}mV_{max}^2 + \frac{1}{2}k(\Delta x)^2$

$0.675 \times 10 \times 0.87 = \frac{1}{2} \times 0.675 V_{max}^2 + \frac{1}{2} \times 25 \times 0.27^2$

$5.873 = 0.338 V_{max}^2 + 0.911$

$V_{max} = 3.832$ (m/s)

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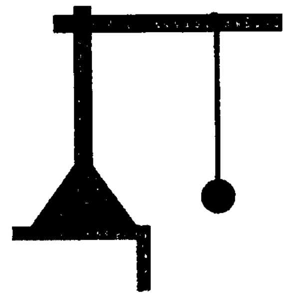

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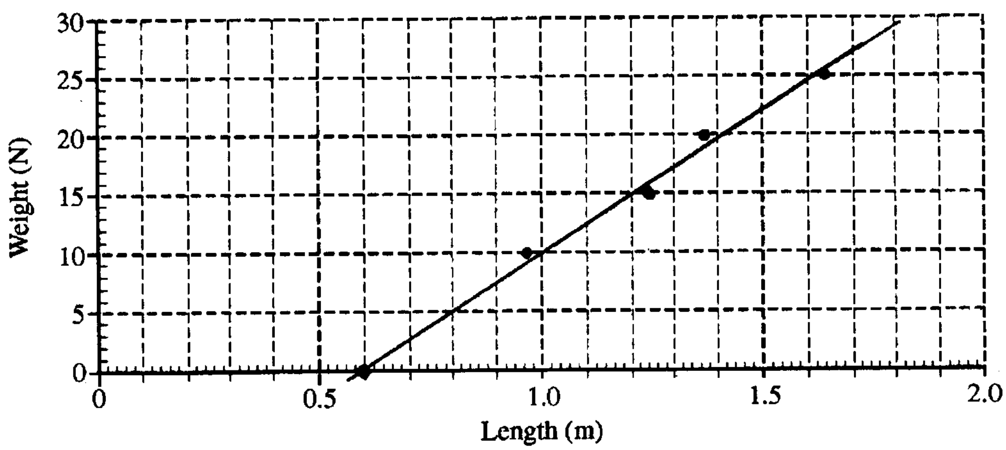

(b) Use the best-fit line you sketched in part (a) to determine an experimental value for the spring constant k of the cord.

K = Slope

$K \approx \boxed{25\ N/m}$

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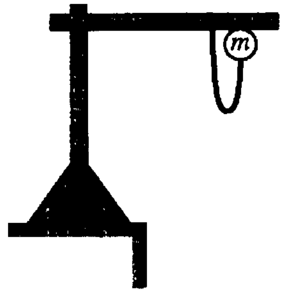

The student now attaches an object of unknown mass m to the cord and holds the object adjacent to the point at which the top of the cord is tied to the rod, as represented above. When the object is released from rest, it falls 1.5 m before stopping and turning around. Assume that air resistance is negligible.

(c) Calculate the value of the unknown mass m of the object.

$\Delta x = 1.5 - .60 = .9$

$mg(1.5m) = \frac{1}{2}k(.9m)^2$

$m = \frac{.81k(m^2)}{1.5(2)g} = \frac{.81(25)}{(3)(9.8)}\text{kg}^2 \approx \boxed{.69\text{ kg}}$

(d) i. Calculate how far down the object has fallen at the moment it attains its maximum speed.

$F = 0$ at that point

$mg = k\Delta x$

$\Delta x_s = \frac{mg}{k} = \frac{(.69)(9.8)}{25} \approx .27\text{ m}$

$\Delta x_f =$ Fallen: $.27 + .60 = \boxed{.87\text{ m}}$

ii. Explain why this is the point at which the object has its maximum speed.

The speed is a maximum b/c the net force acting upon it is in the ~~the~~ -y direction, until this point where the net force becomes zero

iii. Calculate the maximum speed of the object.

$E_1 = 0$ $\quad E_2 = \frac{1}{2}mv^2 - mg(\Delta x_f) + \frac{1}{2}k\Delta x_s^2$

$\frac{1}{2}mv^2 = 2mg(\Delta x_f) - \frac{\frac{1}{2}k\Delta x_s^2}{m}$

$v = \sqrt{2g\Delta x_f - \frac{k\Delta x_s^2}{m}} \approx \boxed{3.8\text{ m/s}}$

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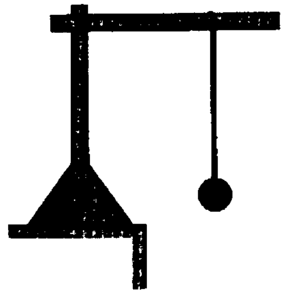

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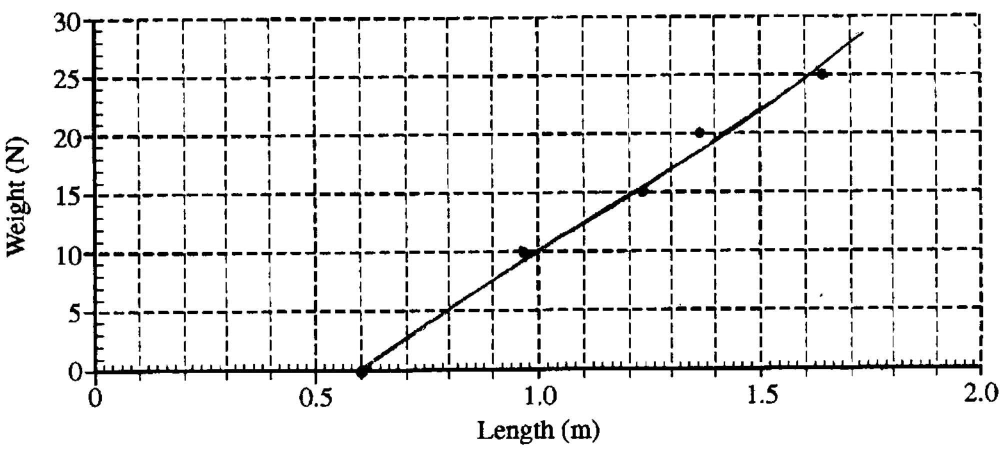

(b) Use the best-fit line you sketched in part (a) to determine an experimental value for the spring constant k of the cord.

$F = Kx$

$K = \frac{\Delta y}{\Delta x}$

$K = \frac{10-5}{1-.8}$

$K = 25 \frac{N}{m}$

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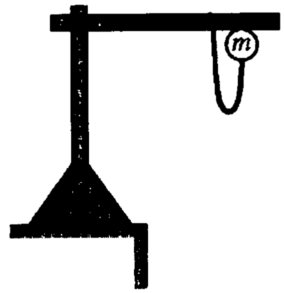

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(c) Calculate the value of the unknown mass m of the object.

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

$m(9.8)(.6) = \frac{1}{2}(25)(.9)^2$

$m = 1.7$ Kg

(d) i. Calculate how far down the object has fallen at the moment it attains its maximum speed.

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

$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2 + 0$

$h = \frac{v^2}{2g}$

$h = .6$ m

ii. Explain why this is the point at which the object has its maximum speed.

If it falls further the kenetic energy is transfered into elastic potential energy taking away velocity.

iii. Calculate the maximum speed of the object.

$gh = \frac{1}{2}v^2$

$9.8(.6) = \frac{1}{2}v^2$

$v = 3.43$ m/s

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Question 3

Overview

This question had three basic sections. The intent of the first section [parts (a) and (b)] was to assess whether students could use the experimental data provided to (1) create an appropriate graph of length versus applied force for a stretchable cord, and (2) obtain the force constant from the graph. Part (c) described the dropping of an object of unknown mass attached to the cord and asked students to determine the mass of the object based on a given maximum descent. The intent of this section was to assess their ability to utilize energy conservation. Finally, in part (d) students had to determine the position at which the object attached to the cord (after being dropped from rest) attained maximum speed and to calculate that maximum speed. Since the cord could be stretched but not compressed, this was not equivalent to the more usual mass-on-a-spring problem. Part (d) assessed the ability of students to do an analysis based on force (or energy) considerations when both gravitational and elastic forces are involved.

Sample: CM3A
Score: 15

While the student does not write the calculation in part (b) in terms of two specifically indicated points from the graph, the student is clearly reading the rise and run of the line drawn and thus associating k with the slope.

Sample: CM3B
Score: 12

Full credit was earned for the graph. Part (b) only earned 2 points, since nothing is written to indicate that points on the line were used to calculate the slope. Parts (c) and (d)(i) received full credit. Part (d)(ii) does not make a clear enough link to a correct argument to earn any points, but part (d)(iii) earned full credit.

Sample: CM3C
Score: 7

Parts (a) and (b) received full credit. In part (c) the value for y_{max} (labeled h in the solution) is incorrect, so only 2 of the points were earned. Part (d)(i) uses an incorrect approach, and part (d)(ii) is incorrect, so neither earned any credit. If the student had brought down the first equation from part (d)(i) to (d)(iii), 1 point would have been received since that equation is a correct general expression, but the specific equation is incorrect, so no credit was earned.