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 $g = 9.8 \text{ m/s}^2$, 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.

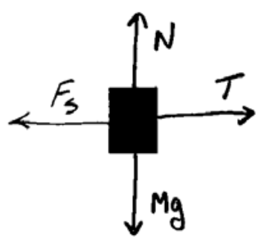
5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences 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

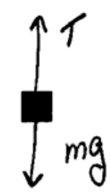
15 points total **Distribution of points**

(a) 3 points

$M = 8.0$ kg



$m = 4.0$ kg



For the 4 kg mass:
For two correctly labeled vertical vectors, one up and one down, and no horizontal vectors — 1 point
For the 8 kg mass:
For two correctly labeled vertical vectors, one up and one down — 1 point
For two correctly labeled horizontal vectors, one left and one right — 1 point
<u>Note</u>: *Labels could be in words, symbols, or correct numerical values. The two masses were considered independently. It was not necessary to indicate that the tension forces had the same magnitudes or that the weights were different.*

(b) 2 points

For a correct approach using Newton's 2nd law and the static equilibrium condition for the 4 kg mass that leads to a relationship between tension and weight — 1 point
$T = mg$
$T = (4.0\ \text{kg})\left(9.8\ \text{m/s}^2\right)$
For the correct answer — 1 point
$T = 39\ \text{N}$ (40 N using $g = 10\ \text{m/s}^2$)

(c) 3 points

For a correct application of Newton's 2nd law and the static equilibrium condition for the 8 kg mass leading to a relationship between tension from part (b) and spring force — 1 point
$T = F_S = k\,\Delta x$
$k = T/\Delta x$
For using the correct displacement of the spring from equilibrium — 1 point
$\Delta x = 0.25\ \text{m} - 0.20\ \text{m} = 0.05\ \text{m}$
For a correct calculation leading to a positive value of k using the tension from (b) — 1 point
$k = 39\ \text{N}/0.05\ \text{m}$
$k = 780\ \text{N/m}$ ($800\ \text{N/m}$ using 40 N from part (b))

Question 1 (continued)

Distribution of points

(d) 2 points

For a correct kinematic approach for an accelerating system applied to the 4 kg mass — 1 point

$$y = \frac{1}{2}gt^2$$

$$t = \sqrt{2y/g}$$

$$t = \sqrt{2(0.70\ \text{m})/(9.8\ \text{m/s}^2)}$$

For the correct answer — 1 point

$t = 0.38\ \text{s}$ (0.37 s using $g = 10\ \text{m/s}^2$)

<u>Note</u>: *An alternate approach using conservation of energy to determine the speed at the bottom and then use of a kinematic equation for time could also earn full credit.*

(e) 2 points

For a correct approach to calculating the frequency (*f* or ω) of a mass-spring system — 1 point

$$f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \quad \text{OR} \quad \omega = \sqrt{\frac{k}{m}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{780\ \text{N/m}}{8.0\ \text{kg}}} \quad \text{OR} \quad \omega = \sqrt{\frac{780\ \text{N/m}}{8.0\ \text{kg}}}$$

For a correct value of frequency (*f* or ω) consistent with the value of *k* from part (c) — 1 point

$f = 1.6\ \text{Hz}$ OR $\omega = 10\ \text{rad/s}$

(f) 2 points

For using conservation of energy, setting the spring potential energy equal to the kinetic energy of the block — 1 point

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

$$v = \sqrt{\frac{k}{m}}A$$

$$v = \sqrt{\frac{780\ \text{N/m}}{8.0\ \text{kg}}}(0.05\ \text{m})$$

For a correct calculation of speed consistent with the value of *k* from part (c) and the correct displacement from equilibrium — 1 point

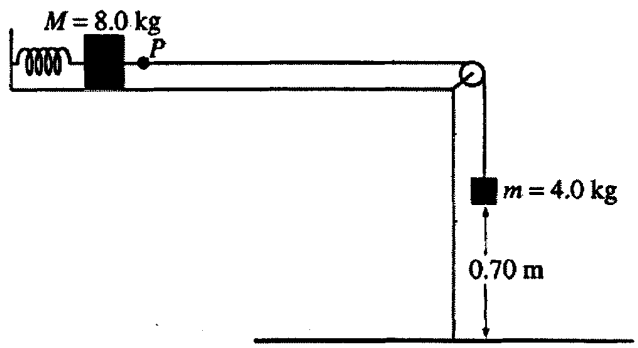
$v = 0.49\ \text{m/s}$ ($0.50\ \text{m/s}$ using $800\ \text{N/m}$ from part (c))

(Global) 1 point

For correct units and a reasonable number of digits in all numerical answers obtained (must have at least one final numerical answer to earn this point) — 1 point

PHYSICS B
SECTION II
Time—90 minutes
6 Questions

Directions: Answer all six questions, which are weighted according to the points indicated. The suggested times are about 17 minutes for answering each of Questions 1-4 and about 11 minutes for answering each of Questions 5-6. 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.

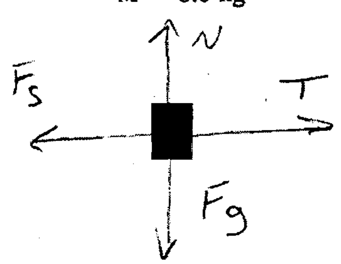


1. (15 points)

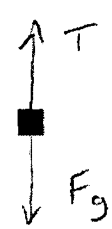
An ideal spring of unstretched length 0.20 m is placed horizontally on a frictionless table as shown above. One end of the spring is fixed and the other end is attached to a block of mass $M = 8.0$ kg. The 8.0 kg block is also attached to a massless string that passes over a small frictionless pulley. A block of mass $m = 4.0$ kg hangs from the other end of the string. When this spring-and-blocks system is in equilibrium, the length of the spring is 0.25 m and the 4.0 kg block is 0.70 m above the floor.

(a) On the figures below, draw free-body diagrams showing and labeling the forces on each block when the system is in equilibrium.

$M = 8.0$ kg



$m = 4.0$ kg



(b) Calculate the tension in the string.

$\Sigma F = 0 = T - F_g$

$T = F_g = mg = (4\ \text{kg})(9.81\ \text{m/s}^2) = 39.24\ \text{N}$

(c) Calculate the force constant of the spring.

$\Sigma F = 0 = F_s - T \quad F_s = T = 39.24\,N$

$F_s = kx$

$39.24\,N = k(.05\,m)$

$k = 784.8\,N/m$

The string is now cut at point *P*.

(d) Calculate the time taken by the 4.0 kg block to hit the floor.

$x = v_0 t + \frac{1}{2} a t^2$

$.7m = (0)t + \frac{1}{2}(9.81\,m/s^2)t^2$

$.7m = \frac{1}{2}(9.81\,m/s^2)t^2$

$t = .38\ s$

(e) Calculate the frequency of oscillation of the 8.0 kg block.

$T_s = 2\pi\sqrt{\frac{m}{k}}$

$T_s = 2\pi\sqrt{\frac{8\,kg}{784.8\,N/m}} = .63\ s$

$f = \frac{1}{T} = \frac{1}{.63\,s} = 1.59$ oscillations per second

(f) Calculate the maximum speed attained by the 8.0 kg block.

$E_{el} = E_k$

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

$(784.8\,N/m)(.05\,m)^2 = (8\,kg)v^2$

$v = .5\ m/s$

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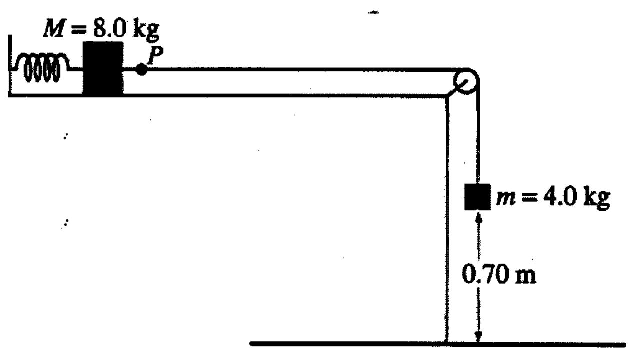

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(a) On the figures below, draw free-body diagrams showing and labeling the forces on each block when the system is in equilibrium.

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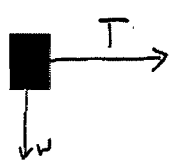

m = 4.0 kg

(b) Calculate the tension in the string.

$T = w$

$T = mg$

$T = (4\,kg)(9.8\,m/s^2)$

$\boxed{T = 39.2\,N}$

(c) Calculate the force constant of the spring.

$F = -kx$

$-\frac{F}{x} = k$

$-\frac{39.2N}{.5m} = k$

$k = 78.4\ N/m$

The string is now cut at point *P*.

(d) Calculate the time taken by the 4.0 kg block to hit the floor.

$d = .7m$ $t = ?$

$a = 9.8 m/s^2$

$V_i = 0 m/s$

$\Delta d = V_i t + \frac{1}{2}at^2$

$\Delta d = \frac{1}{2}at^2$

$\sqrt{\frac{\Delta d}{2a}} = t$

$t = \sqrt{\frac{.7m}{2(9.8m/s^2)}}$

$t = .19s$

(e) Calculate the frequency of oscillation of the 8.0 kg block.

$T_s = 2\pi\sqrt{\frac{m}{k}}$

$T_s = 2\pi\sqrt{\frac{8kg}{78.4N/m}}$

$T_s = 2$

$T_s = \frac{1}{f}$ $f = \frac{1}{T_s}$

$\boxed{f = \frac{1}{2}\ Hz}$

(f) Calculate the maximum speed attained by the 8.0 kg block.

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

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

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

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

$\sqrt{\frac{(78.4N/m)(.25m)^2}{8kg}} = v = \boxed{.78 m/s}$

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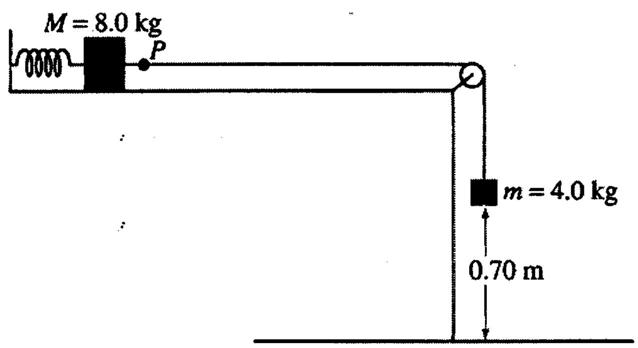

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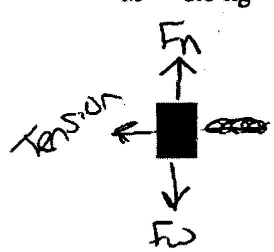

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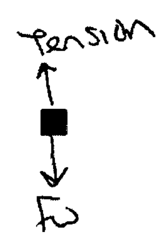

(b) Calculate the tension in the string.

$F_{net} = ma$

$F_{net} = 4(9.8)$

$F_{net} = 39.2 N$

(c) Calculate the force constant of the spring.

$F = -kx$

$39.2 = -k(.2)$

$-k = 196$

$k = -196$

The string is now cut at point *P*.

(d) Calculate the time taken by the 4.0 kg block to hit the floor.

$d = \frac{1}{2} a t^2$

$.7 = \frac{1}{2}(9.8) t^2$

$t = .378 s$

(e) Calculate the frequency of oscillation of the 8.0 kg block.

$T = 2\pi\sqrt{\frac{l}{g}}$

$T = 2\pi\sqrt{\frac{2}{9.8}}$ $T = \frac{1}{f}$

$T = 2.837$ $f = \frac{1}{2.837}$ hz

(f) Calculate the maximum speed attained by the 8.0 kg block.

If the distance from block M to block m was 2 meters, then...

$2m - .7m$

$v_f^2 = \cancel{v_i^2} + 2a(x_0 - x)$

$v_f^2 = 2(9.8)(1.3m)$

$v_f = 5.048 m/s$

AP® PHYSICS B
2006 SCORING COMMENTARY

Question 1

Overview

This was a 15-point question designed to test student understanding of several topics in mechanics: basic kinematics, Newton's second law and statics, the properties of springs, and simple harmonic motion. Part (a) asked students to draw the free-body diagram for two blocks at rest connected by a string running over a pulley. One block (of mass 8 kg) was on a frictionless table connected to a wall by a spring, and the other block (of mass 4 kg) was freely hanging. Part (b) asked students to calculate the tension in the string. In part (c) students were asked to find the force constant of the spring. In part (d) the string was cut and the hanging block fell freely. Students were asked to find how long it took the block to fall a given distance to the floor. At the same time that the 4 kg block was falling, the 8 kg block on the table was undergoing simple harmonic motion since the spring was initially in a stretched position. Students were asked in part (e) to find the frequency of oscillation and in part (f) to find the maximum speed attained by the 8 kg block.

Sample: B1A
Score: 15

This response shows excellent work for all parts and follows the scoring guidelines exactly.

Sample: B1B
Score: 9

Part (a) received 1 point for correct forces on the 4 kg mass. Part (b) received full credit. Part (c) earned 1 point for equating the tension from (b) to the spring force. Part (d) received only 1 point for correct kinematics since an error is made in solving for the time. Full credit was earned for part (e) since it correctly uses the value of the spring constant from part (c). The wrong value is used for the amplitude in part (f), so it only received the point for conservation of energy. The global units and reasonable digits point was also earned.

Sample: B1C
Score: 5

One horizontal vector is missing, so part (a) earned 2 points. Part (b) earned no credit since there is no expression of zero net force and no mention of the tension. Part (c) earned 1 point for equating the tension from (b) to the spring force. Part (d) is correct, but part (e) earned no credit since it uses the expression for the period of a pendulum. Part (f) earned nothing, and the global point was lost because there are no units on the spring constant.