CollegeBoard
Advanced Placement Program

AP® Physics C: Mechanics
2008 Scoring Guidelines

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AP® PHYSICS
2008 SCORING GUIDELINES

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 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*.

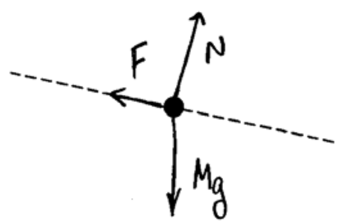
4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

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 correctly drawn and labeled weight vector, originating on the dot and with an arrowhead (Alternatively, correctly drawn and labeled components instead of the total weight vector was acceptable.) — 1 point

For a correctly drawn and labeled normal force vector, originating on the dot and with an arrowhead — 1 point

For a correctly drawn and labeled drag-force vector, originating on the dot and with an arrowhead — 1 point

One point was deducted if there were any extra vectors on the point, including components drawn with arrowheads.

(b) 4 points

For any expression of $F = Ma$ or any dimensionally correct application of $F = Ma$ — 1 point

For correctly expressing the component of the weight parallel to the plane as $Mg\sin\theta$ — 1 point

For correctly expressing the drag force as $-kx$ — 1 point

$Ma = Mg\sin\theta - bv$

For a dimensionally correct differential equation, including dv/dt and expressions for the drag force and the component of the weight parallel to the plane — 1 point

$$M\frac{dv}{dt} = Mg\sin\theta - bv$$

One point was deducted if the algebraic signs of the weight component and the drag force were not opposite somewhere in the solution, OR if only one of these two terms was included.

(c) 2 points

For an indication that $F_{net} = 0$, $a = 0$, or the parallel component of the weight $= bv_T$ — 1 point

$0 = Mg\sin\theta - bv_T$

$bv_T = Mg\sin\theta$

For the correct expression for the terminal velocity (or one consistent with part (b)) — 1 point

$v_T = Mg\sin\theta/b$

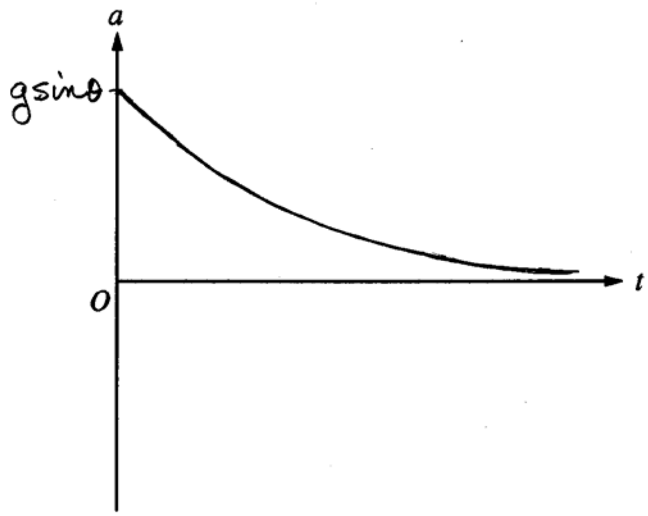
Question 1 (continued)

	Distribution of points
(d) 3 points	
For taking the differential equation from part (b) and correctly separating the variables in preparation for integration (definite or indefinite integral)	1 point
$M\dfrac{dv}{dt} = Mg\sin\theta - bv$	
$\dfrac{dv}{Mg\sin\theta - bv} = \dfrac{dt}{M}$	
For correct integration of both sides of equation	1 point
For example, using a method involving an indefinite integral	
Letting $u = Mg\sin\theta - bv$, so $du = -b\,dv$	
$-\dfrac{1}{b}\dfrac{du}{u} = \dfrac{dt}{M}$	
$\int \dfrac{du}{u} = -\dfrac{b}{M}\int dt$	
$\ln u = -\dfrac{b}{M}t + \ln C$	
$u = Ce^{-bt/M}$	
$Mg\sin\theta - bv = Ce^{-bt/M}$	
Using $v = 0$ at $t = 0$	
$Mg\sin\theta = C$	
$Mg\sin\theta - bv = Mg\sin\theta\, e^{-bt/M}$	
$-bv = Mg\sin\theta\, e^{-bt/M} - Mg\sin\theta$	
For a correct final expression for $v(t)$	1 point
$v = (Mg\sin\theta/b)\left(1 - e^{-bt/M}\right)$	

Question 1 (continued)

Distribution of points

(e) 3 points



For the correct initial value of *a* (or a value consistent with part (b)) 1 point

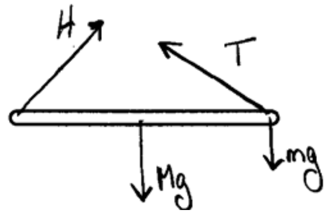
For a negatively sloped curve, concave up 1 point

For a curve asymptotic to the *t* axis 1 point
(This point was awarded even if the curve was not otherwise correct.)

Question 2

15 points total | **Distribution of points**

(a) 4 points



For correctly drawing and labeling T, the tension in the cord, or its components — 1 point

For correctly drawing and labeling Mg, the weight of the rod — 1 point

For correctly drawing and labeling mg, the weight of the block — 1 point

For correctly drawing or labeling H, the force exerted on the rod by the hinge, or its components — 1 point

One earned point was deducted if one or more of the following were present: a correct vector not starting on the body, a component if the total force was also shown, or any extraneous vectors.

(b) 4 points

The reading on the scale is equal to the tension in the cord.

For an indication that the sum of the torques is equal to zero — 1 point

$\sum \tau = 0$

For a correct expression for the torque exerted by the cord — 1 point

For a correct expression for both the torque due to the weight of the rod and the torque due to the weight of the hanging block — 1 point

The simplest method is to take the torque about the hinge, directly yielding an equation that can be solved for T. This is illustrated below. If the torque is taken about some other point, it must be combined with an equilibrium condition for the forces to eliminate the unknown H.

$TL\sin 30° - mgL - MgL/2 = 0$

Solving for T

$TL\sin 30° = mgL + MgL/2$

$$T = \frac{g}{\sin 30°}\left(m + \frac{M}{2}\right)$$

$$T = \frac{9.8\ \text{m/s}^2}{\sin 30°}\left(0.50\ \text{kg} + \frac{2.0\ \text{kg}}{2}\right)$$

For the correct answer (if previous 3 points were awarded) — 1 point

$T = 29\ \text{N}$ (or 30 N using $g = 10\ \text{m/s}^2$)

Question 2 (continued)

Distribution of points

(c) 3 points

For indicating that the rotational inertia of the system is the sum of the rotational inertia of both the rod and the hanging block — 1 point

$I_s = I_r + I_b$

For using the correct rotational inertia of the rod about its end (either determining it using the parallel axis theorem or simply stating it) — 1 point

$$I_r = I_{r,cm} + m\ell^2 = \frac{1}{12}ML^2 + M\left(\frac{L}{2}\right)^2 = \frac{4}{12}ML^2 = \frac{1}{3}ML^2$$

For a correct expression of the rotational inertia of the hanging block — 1 point

$I_b = mL^2$

$$I_s = \frac{1}{3}ML^2 + mL^2$$

$$I_s = \frac{1}{3}(2.0\text{ kg})(0.60\text{ m})^2 + (0.50\text{ kg})(0.60\text{ m})^2 = (0.24 + 0.18)\text{ kg}{\bullet}\text{m}^2$$

$$I_s = 0.42\text{ kg}{\bullet}\text{m}^2$$

(d) 3 points

For indicating that the sum of the torques is equal to $I\alpha$ — 1 point

$\sum \tau = I\alpha$

For a correct summation of the torques about the hinge due to the block and rod — 1 point

$$mgL + Mg\frac{L}{2} = I\alpha$$

$$\alpha = \frac{gL}{I}\left(m + \frac{M}{2}\right)$$

For substituting the rotational inertia calculated in part (c) — 1 point

$$\alpha = \frac{\left(9.8\text{ m/s}^2\right)(0.60\text{ m})}{0.42\text{ kg}\bullet\text{m}^2}\left(0.50\text{ kg} + \frac{2.0\text{ kg}}{2}\right)$$

$$\alpha = 21\text{ radians/s}^2$$

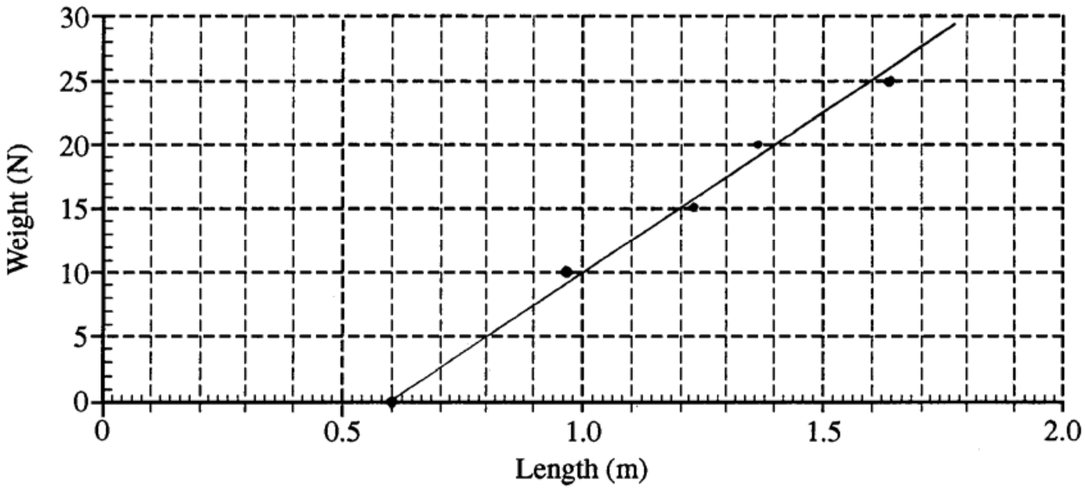
Unit point

For correct units on all student answers — 1 point

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 $y_{max} = 1.5\text{ m}$ 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

$m = \left(25\ \text{kg/s}^2\right)(0.90\text{ m})^2 / 2\left(9.8\ \text{m/s}^2\right)(1.5\text{ m})$

$m = 0.69\text{ kg}$ (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

$x = \frac{(0.69\text{ kg})(9.8\ \text{m/s}^2)}{25\ \text{kg/s}^2}$

$x = 0.27\text{ m}$

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
$\upsilon_{\max}{}^2 = 2(9.8\ \text{m/s}^2)(0.87\ \text{m}) - \frac{(25\ \text{N/m})}{(0.69\ \text{kg})}(0.27\ \text{m})^2$	
$\upsilon_{\max}{}^2 = 14.4(\text{m/s})^2$	
$\upsilon_{\max} = 3.8\ \text{m/s}$	