AP® Physics C: Mechanics
2012 Scoring Guidelines

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AP® PHYSICS
2012 SCORING GUIDELINES

General Notes About 2012 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 in part (b). One exception to this practice may occur in cases where the numerical answer to a later part should easily be recognized as wrong, for example, a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if the use of an 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 sheets. 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 owing 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 eliminate the level of accuracy required to determine the difference in the numbers, and some credit may be lost.

Question 1

15 points total **Distribution of points**

(a) 4 points

For writing a correct trigonometric equation for velocity as a function of time, including the negative sign — 1 point

$\upsilon(t) = -\upsilon_{max}\sin(\omega t) = -\upsilon_{max}\sin(2\pi t/T)$

For using $\omega = 2\pi f$ or $\omega = \dfrac{2\pi}{T}$ to solve for ω — 1 point

For using the correct period of 0.70 s from the graph — 1 point

$\omega = \dfrac{2\pi}{0.70\text{s}} = 9.0\ \text{rad/s}$

For using the correct value of the maximum speed from the graph (acceptable range of values for υ_{max}: $0.15\ \text{m/s}$ to $0.17\ \text{m/s}$) — 1 point

$\upsilon(t) = (-0.16)\sin(9.0t)$

Note: One point is deducted if incorrect phase shift ϕ is used. Full credit is awarded for a correct answer with no work shown. Students are also given credit if the value of k from part (c) is used to calculate ω using $\omega = \sqrt{k/m}$.

(b) 2 points

Take the integral of the velocity determined in part (a)

$x(t) = \int \upsilon(t)\,dt = \int (-0.16\ \text{m/s})\sin((9.0\ \text{rad/s})t)\,dt$

For a correct trigonometric expression consistent with integrating the answer from part (a) — 1 point

For a correct x_{max} consistent with the integrating the answer from part (a) — 1 point

$x_{max} = (0.16\ \text{m/s})/(9.0\ \text{rad/s}) = 0.018\ \text{m}$

$x(t) = (0.018)\cos(9.0t)$

Question 1 (continued)

Distribution of points

(b) continued

Alternate solution — *Alternate points*

For solving for a maximum displacement consistent with the answer from part (a) — *1 point*

$$v_{max} = x_{max}\omega$$

$$x_{max} = \frac{v_{max}}{\omega} = \frac{(0.16\ \text{m/s})}{(9.0\ \text{rad/s})}$$

$$x_{max} = 0.018\ \text{m}$$

For a correct trigonometric expression consistent with the answer from part (a) — *1 point*

$$x(t) = (0.018)\cos(9.0t)$$

Note: Full credit is awarded for a correct answer with no work shown. One earned point is deducted for incorrect initial conditions (e.g., subtracting a constant from the cosine function).

(c) 2 points

For a correct relationship between the period and the spring constant — 1 point

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

For substituting correct values from previous parts into a correct expression — 1 point

$$k = \frac{4\pi^2 m}{T^2} = \frac{(4\pi^2)(0.30\ \text{kg})}{(0.70\ \text{s})^2}$$

$$k = 24\ \text{N/m}$$

Alternate solution #1 — *Alternate points*

For a correct expression relating angular frequency and the spring constant — *1 point*

$$\omega = \sqrt{\frac{k}{m}}$$

For substituting correct values from previous parts into a correct expression — *1 point*

$$k = m\omega^2 = (0.30\ \text{kg})(9.0\ \text{rad/s})^2$$

$$k = 24\ \text{N/m}$$

Question 1 (continued)

Distribution of points

(c) continued

Alternate solution #2 — *Alternate points*

For a correct statement of the conservation of energy, applied to the position of maximum displacement and the equilibrium position — *1 point*

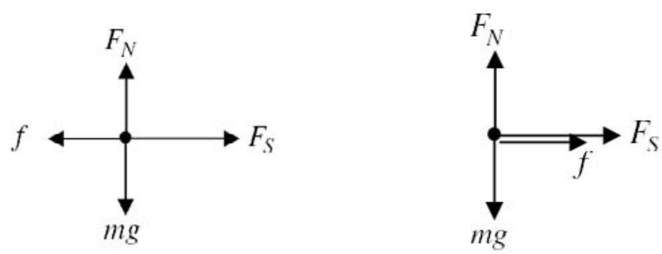
$\frac{1}{2}kx_{max}^2 = \frac{1}{2}mv_{max}^2$

For substituting correct values from previous parts into a correct expression — *1 point*

$k = \frac{mv_{max}^2}{x_{max}^2} = \frac{(0.30\ \text{kg})(0.16\ \text{m/s})^2}{(0.018\ \text{m})^2}$

$k = 24\ \text{N/m}$

(d) 4 points



Toward the equilibrium position — Away from the equilibrium position

For drawing and labeling F_N and mg correctly on both diagrams — 1 point

On diagram of the block moving toward the equilibrium position:

For a correctly drawn and labeled spring force to the right — 1 point

For a correctly drawn and labeled friction force to the left — 1 point

On diagram of the block moving away from the equilibrium position:

For a correctly drawn and labeled spring force and friction force to the right — 1 point

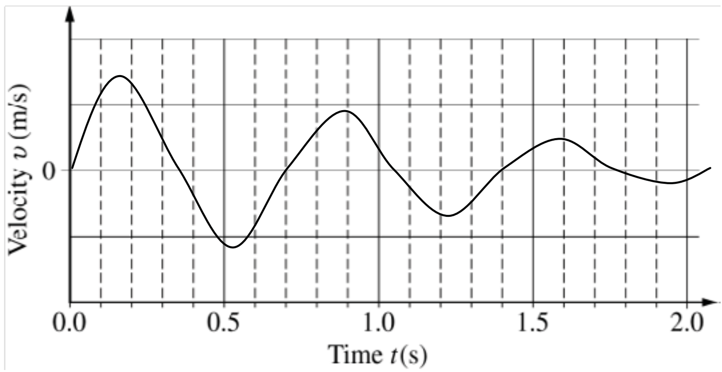
Notes

- Length of vectors is not considered, only direction.
- There is a 1-point maximum deduction for any vectors not touching (or at least almost touching) the dot or for any extraneous forces.Vectors can be drawn from the dot outward OR toward the dot, pointing inward and touching the dot.

Question 1 (continued)

Distribution of points

(e) 3 points



For a graph passing through equilibrium at 0.35 s intervals	1 point
For a graph displaying damped oscillations	1 point
For a graph that starts at zero with an increasing positive velocity	1 point

Question 2

15 points total — **Distribution of points**

(a) 1 point

For choosing the meterstick and stopwatch, regardless of what else is checked — 1 point

(b) 4 points

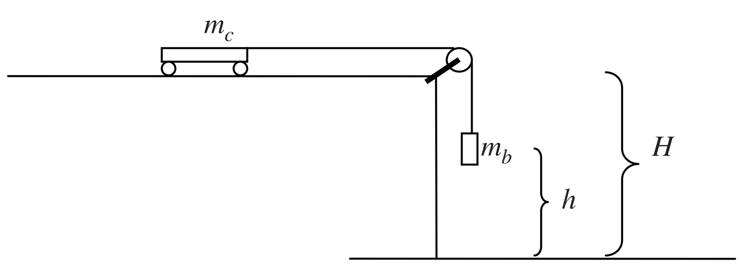
For a procedure that indicates the height needed to calculate gravitational potential energy — 1 point

For a procedure that indicates distance and time measurements to calculate velocity — 1 point

For a diagram and a clear indication of the height measurement — 1 point

For a diagram and a clear indication of the distance measurement — 1 point

Example #1



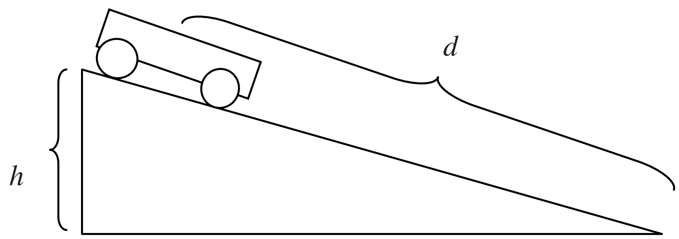
- Use the electronic balance to determine the mass m_c of the cart and the mass m_b of one object.
- Attach the object to the cart using the string.
- Place the cart on the track and hang the object so that the string passes through the pulley.
- Allow the object to fall a distance h from its initial position to the floor, using the meterstick to measure the distance fallen.
- Use the stopwatch to measure the time t it takes the object to fall the distance h.
- Measure the height H of the table.

Question 2 (continued)

Distribution of points

(b) continued

Example #2



- Use the electronic balance to determine the mass m of the cart.
- Set the track at an incline, and measure the height h of the incline.
- Place the cart at the top of the incline, and release from rest.
- Using the stopwatch, measure the time t it takes for the cart to move down the incline.
- Measure the distance d that the cart moves down the incline.

(c) 6 points

For a clear indication of the initial potential energy of the system	1 point
For a clear indication of the final potential energy of the system	1 point
For a clear indication of the initial kinetic energy of the system	1 point
For a clear indication of the final kinetic energy of the system	1 point
For a correct calculation of the instantaneous velocity of the system	2 points

Example #1

Initial gravitational potential energy: $U_{g0} = m_c gH + m_b gh$

Final gravitational potential energy: $U_{gf} = m_c gH$

Initial kinetic energy: $K_0 = 0$

Final kinetic energy: $K_f = \frac{1}{2}(m_c + m_b)v_f^2$

Acceleration is constant, so $d = \frac{1}{2}(v_0 + v_f)t$, where d is the distance along the track.

$$v_f = \frac{2h}{t}$$

Question 2 (continued)

Distribution of points

(c) continued

Example #2

Initial gravitational potential energy: $U_{g0} = mgh$

Final gravitational potential energy $U_{gf} = 0$

Initial kinetic energy $K_0 = 0$

Final kinetic energy $K_f = \frac{1}{2}mv_f^2$

Acceleration is constant, so $d = \frac{1}{2}\left(v_0 + v_f\right)t$.

$v_f = \frac{2d}{t}$

(d) 2 points

For identifying a reasonable cause for the increase in energy	1 point
For a reasonable explanation related to the cause identified	1 point

Example
An unintentional push was applied to the cart, thus increasing the initial energy.

(e) 2 points

For identifying a reasonable cause for the decrease in energy related to the nonconservative forces acting on the system	1 point
For a reasonable explanation related to the cause identified	1 point

Example
Friction acting on the object decreases the speed, thereby decreasing the energy.

Question 3

15 points total | **Distribution of points**

(a)

i. 3 points

For starting with Newton's second law for translation, with friction as the net force — 1 point

$\Sigma F = -f = Ma$

For a correct expression for the frictional force — 1 point

$f = \mu Mg$

For indicating that linear acceleration is the time derivative of velocity — 1 point

$a = \dfrac{d\upsilon}{dt}$

$\dfrac{d\upsilon}{dt} = -\mu g$

ii. 3 points

For starting with Newton's second law for rotation, with a correct substitution for the rotational inertia — 1 point

$\tau = MR^2\alpha$

For a correct expression for the torque, using the frictional force — 1 point

$\tau = \mu MgR$

For indicating that the angular acceleration is the time derivative of the angular velocity — 1 point

$\alpha = \dfrac{d\omega}{dt}$

$\dfrac{d\omega}{dt} = \dfrac{\mu g}{R}$

(b)

i. 2 points

For setting up the integral of the function determined in part (a)-i — 1 point

$\int_{\upsilon_0}^{\upsilon} d\upsilon = -\int_0^t \mu g dt$

For the correct answer — 1 point

$\upsilon = \upsilon_0 - \mu g t$

Alternate solution — *Alternate points*

For a clear substitution of the acceleration from part (a)-i into the kinematics equation — *1 point*

$a = -\mu g$

$\upsilon = \upsilon_0 + at$

For the correct answer — *1 point*

$\upsilon = \upsilon_0 - \mu g t$

Question 3 (continued)

	Distribution of points
(b) continued	
ii. 2 points	
For setting up the integral of the function determined in part (a)-ii	1 point
$\int_0^\omega d\omega = \int_0^t (\mu g/R)\,dt$	
For the correct answer	1 point
$\omega = \mu g t/R$	
Alternate solution	*Alternate points*
For a clear substitution of the angular acceleration from part (a)-ii into the correct rotational kinematics equation	*1 point*
$\alpha = \dfrac{\mu g}{R}$ $\omega = \omega_0 + \alpha t$	
For the correct answer	*1 point*
$\omega = \mu g t/R$	
(c) 2 points	
For indicating that the linear speed is equal to $R\omega$ when the slipping stops	1 point
$\upsilon = R\omega$ $\upsilon_0 - \mu g t = R\left(\dfrac{\mu g t}{R}\right)$	
For the correct answer	1 point
$t = \dfrac{\upsilon_0}{2\mu g}$	
(d) 1 point	
For substituting the time found in part (c) into a correct kinematics equation	1 point
$\upsilon = \upsilon_0 - \mu g\left(\dfrac{\upsilon_0}{2\mu g}\right)$ $\upsilon = \upsilon_0/2$	

Question 3 (continued)

Distribution of points

(e) 2 points

For setting up the integral of the velocity function determined in part (b)-i — 1 point

$$L = \int_0^t (\upsilon_0 - \upsilon g t)\,dt$$

For the correct answer, with correct supporting work — 1 point

$$L = \left[\upsilon_0 t - \frac{1}{2}\mu g t^2\right]_0^{\frac{\upsilon_0}{2\mu g}}$$

$$L = \frac{3\upsilon_0^2}{8\mu g}$$

Alternate solution #1 — *Alternate points*

For substituting the velocity from part (d) and the acceleration from part (a)-i into a correct equation that solves for L — *1 point*

$$\upsilon^2 = \upsilon_0^2 + 2a\Delta x$$

$$\left(\frac{\upsilon_0}{2}\right)^2 = \upsilon_0^2 + 2(-\mu g)L$$

For the correct answer, with correct supporting work — *1 point*

$$L = \frac{3\upsilon_0^2}{8\mu g}$$

Alternate solution #2 — *Alternate points*

For substituting the velocity from part (d) and the acceleration from part (a)-i into a correct equation that solves for L — *1 point*

Note: The time determined in part (c) must also be substituted.

$$\Delta x = \upsilon_0 t + \frac{1}{2}at^2$$

$$L = \upsilon_0\left(\frac{\upsilon_0}{2\mu g}\right) + \frac{1}{2}(-\mu g)\left(\frac{\upsilon_0}{2\mu g}\right)^2$$

For the correct answer, with correct supporting work — *1 point*

$$L = \frac{3\upsilon_0^2}{8\mu g}$$