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 $10\ \text{m/s}^2$ 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.

AP® PHYSICS C: MECHANICS
2012 SCORING GUIDELINES

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

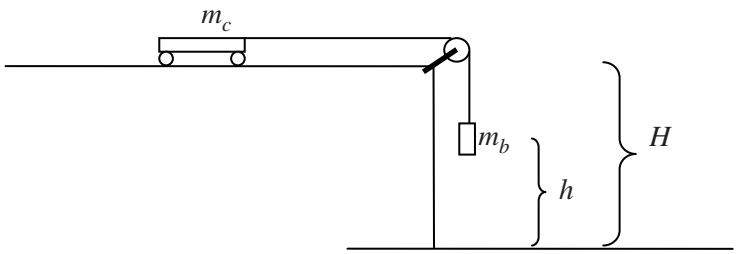
For a procedure that indicates the height needed to calculate gravitational potential energy — 1 point

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



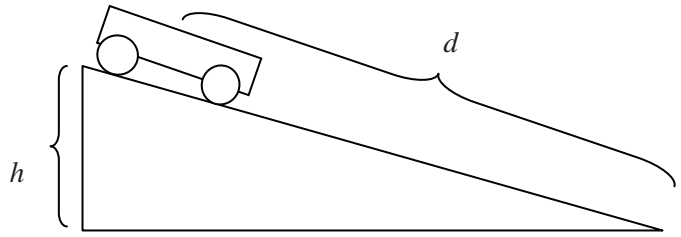
- Use the electronic balance to determine the mass m_c of the cart and the mass m_b of one object.
- Attach the object to the cart using the string.
- Place the cart on the track and hang the object so that the string passes through the pulley.
- Allow the object to fall a distance h from its initial 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 $d = \frac{1}{2}(v_0 + v_f)t$.

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

(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.

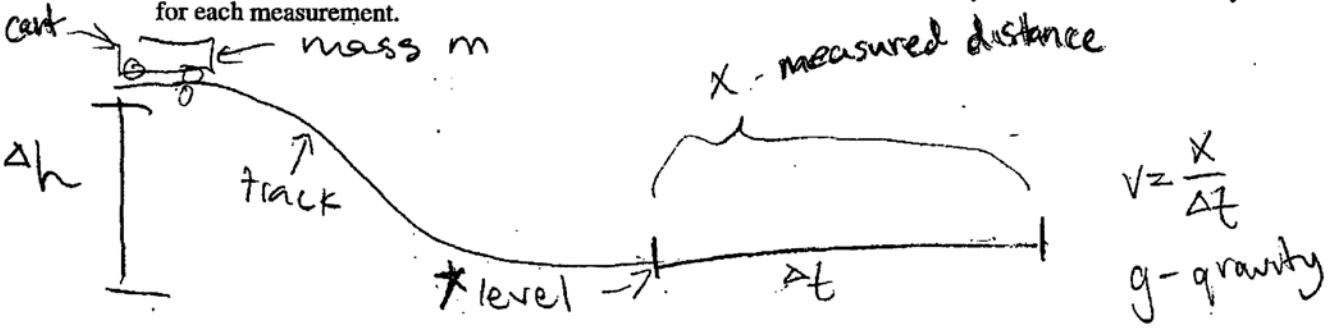
Mech. 2.

You are to perform an experiment investigating the conservation of mechanical energy involving a transformation from initial gravitational potential energy to translational kinetic energy.

(a) You are given the equipment listed below, all the supports required to hold the equipment, and a lab table. On the list below, indicate each piece of equipment you would use by checking the line next to each item.

✓ Track	✓ Meterstick	✓ Set of objects of different masses
✓ Cart	✓ Electronic balance	___ Lightweight low-friction pulley
___ String	✓ Stopwatch	

(b) Outline a procedure for performing the experiment. Include a diagram of your experimental setup. Label the equipment in your diagram. Also include a description of the measurements you would make and a symbol for each measurement.



- create an incline using the track
- measure the height that the cart starts at using the meterstick
- have a measured distance on the flat part of the track using the meterstick
- measure the time it takes using the stopwatch for the cart to travel the measured distance.
- use the electronic balance to determine the mass of the cart
- repeat trials using different masses

GO ON TO THE NEXT PAGE.

(c) Give a detailed account of the calculations of gravitational potential energy and translational kinetic energy both before and after the transformation, in terms of the quantities measured in part (b).

Before: $U_{grav} = mgh$

$KE_{trans} = 0$

After: $U_{grav} = 0$

$KE_{trans} = \frac{1}{2}mv^2$

(d) After your first trial, your calculations show that the energy increased during the experiment. Assuming you made no mathematical errors, give a reasonable explanation for this result.

There could have been additional work added to the system. For example, if the cart was pushed, it would have an initial KE_{trans} instead of being 0 so the calculation of energy would increase.

(e) On all other trials, your calculations show that the energy decreased during the experiment. Assuming you made no mathematical errors, give a reasonable physical explanation for the fact that the average energy you determined decreased. Include references to conservative and nonconservative forces, as appropriate.

In the experiment, friction is a nonconservative force that would account for the decrease in energy. The work done by this external force would decrease the total energy of the system.

Mech. 2.

1 of 2

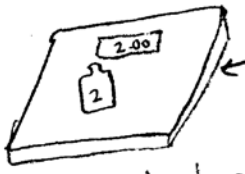
You are to perform an experiment investigating the conservation of mechanical ~~energy~~ involving a transformation from initial gravitational potential energy to translational kinetic energy.

(a) You are given the equipment listed below, all the supports required to hold the equipment, and a lab table. On the list below, indicate each piece of equipment you would use by checking the line next to each item.

____ Track	✓ Meterstick	✓ Set of objects of different masses
____ Cart	✓ Electronic balance	____ Lightweight low-friction pulley
____ String	✓ Stopwatch	

(b) Outline a procedure for performing the experiment. Include a diagram of your experimental setup. Label the equipment in your diagram. Also include a description of the measurements you would make and a symbol for each measurement.

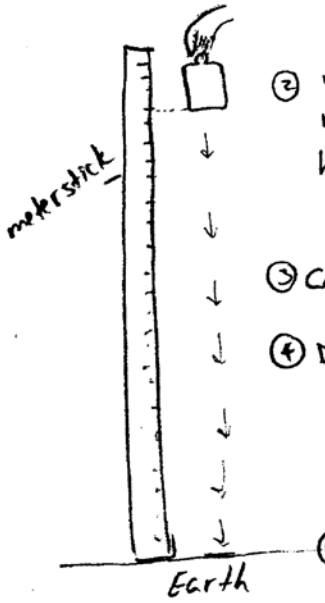
- set of objects of different masses



① ← electronic balance

Select an object and weigh it using the electronic balance

(mass = m)



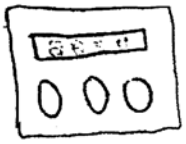
② use the meterstick to measure the initial height of object.

(height = h)

③ Calculate potential energy

$U = mgh$

④ Drop object



⑤ use the stopwatch to calculate the time it takes to reach the ground.

(time = seconds = s)

⑥ calculate velocity at instant before hitting earth

$V_f = V_o + at$

$V_f = 0 + (-9.8)$(calculated time)

$= gs$

GO ON TO THE NEXT PAGE.

(c) Give a detailed account of the calculations of gravitational potential energy and translational kinetic energy both before and after the transformation, in terms of the quantities measured in part (b).

Before: gravitational potential energy (U_g):

$U_g = mgh$ = (chosen mass)$(-9.8\ m/s^2)$(chosen height)

translational kinetic energy (K)

$K = \frac{mv^2}{2} = 0$ because velocity = 0

After: $U_g = mgh = 0$ because height = 0

$K = \frac{mv^2}{2}$ = (chosen mass)(velocity at instant before hitting earth [v_f])^2

(d) After your first trial, your calculations show that the energy <u>increased</u> during the experiment. Assuming you made no mathematical errors, give a reasonable explanation for this result.

(e) On all other trials, your calculations show that the energy <u>decreased</u> during the experiment. Assuming you made no mathematical errors, give a reasonable physical explanation for the fact that the average energy you determined decreased. Include references to conservative and nonconservative forces, as appropriate.

energy is lost as sound and heat when the object hits the ground.

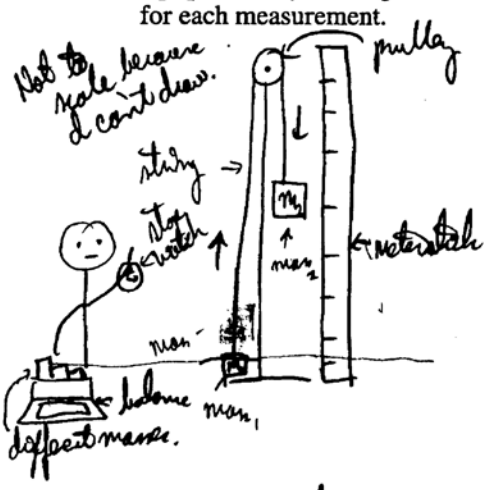
Mech. 2.

You are to perform an experiment investigating the conservation of mechanical energy involving a transformation from initial gravitational potential energy to translational kinetic energy.

(a) You are given the equipment listed below, all the supports required to hold the equipment, and a lab table. On the list below, indicate each piece of equipment you would use by checking the line next to each item.

____ Track	X Meterstick	X Set of objects of different masses
____ Cart	X Electronic balance	X Lightweight low-friction pulley
X String	X Stopwatch	

(b) Outline a procedure for performing the experiment. Include a diagram of your experimental setup. Label the equipment in your diagram. Also include a description of the measurements you would make and a symbol for each measurement.



1. So, need to set up the pulley system like in the diagram.
2. Find the mass of every object that will be attached to string. Record in data table.
3. Bring a mass one and attach and have it a 0m, as in against table, then attach m_2 of different mass onto other end.
4. Record the height m_2 is floating at.
5. Release mass while starting stop watch at same time. Stop the watch when m_2 hits the table, record time.
6. Repeat this process least 2 more times for a total of 3 trials before using a different m_2.

Trial	M_1	m_2	h	t
1				
2				
3				

m_1, m_2, height, time

* Description of what these measurements are plus their symbols.

GO ON TO THE NEXT PAGE.

(c) Give a detailed account of the calculations of gravitational potential energy and translational kinetic energy both before and after the transformation, in terms of the quantities measured in part (b).

Before

find potential energy

$U = m_2 g h$

$K = \frac{1}{2} m_1 v^2$ c find v $v = \frac{dx}{dt} = \frac{\Delta x}{\Delta t} = \frac{(h_f - h_0)}{(t_f - t_0)}$

After

find kinetic energy

$K = \frac{1}{2} m_2 v^2$

$U = m_1 g h$

find v

$v = \frac{dx}{dt} \rightarrow \frac{\Delta x}{\Delta t} = \frac{(h_f - h_0)}{t_f - t_0}$

$E_0 = E_f$

$\frac{1}{2} m_1 v^2 + m_2 g h = \frac{1}{2} m_2 v^2 + m_1 g h$

(d) After your first trial, your calculations show that the energy increased during the experiment. Assuming you made no mathematical errors, give a reasonable explanation for this result.

Ponible error include human reaction time for how one reats to start and stop a stop watch affects this.
May have recorded the wrong mass.

(e) On all other trials, your calculations show that the energy decreased during the experiment. Assuming you made no mathematical errors, give a reasonable physical explanation for the fact that the average energy you determined decreased. Include references to conservative and nonconservative forces, as appropriate.

Ponible error include human reaction time for how one reats to start a stop a stop watch affects this.
When m_2 hits the table, kinetic energy may have transfer into it.

AP® PHYSICS C: MECHANICS
2012 SCORING COMMENTARY

Question 2

Overview

This question assessed students' ability to outline a laboratory procedure to investigate energy transformation — specifically, the transformation of gravitational potential energy to translational kinetic energy.

Sample: M2-A
Score: 15

This is a good example of the strongest responses, and it received full credit. In part (a) the meterstick and the stopwatch are selected. The procedure and diagram clearly indicate measurements of height, distance, and time in part (b). All of the energies of the system are identified in part (c), and a correct calculation of the instantaneous velocity is shown as part of the procedure in part (b). Full credit was earned in parts (d) and (e) for clearly identifying and explaining the causes of the increase and decrease of energy, respectively.

Sample: M2-B
Score: 9

This response received full credit for parts (a) and (b). In part (a) the meterstick and the stopwatch are selected. In part (b) the procedure and diagram clearly indicate measurements of height, distance, and time. In part (c) 4 points were earned for a clear indication of all the energies of the system, but no calculation of the instantaneous velocity is shown. Part (d) is blank, so no credit was awarded. Part (e) earned no points because there is no clear indication of whether the energy loss resulted from the fall of the object or from the collision between the object and the floor.

Sample: M2-C
Score: 7

Full credit was earned in parts (a) and (b). In part (a) the meterstick and the stopwatch are selected. In part (b) the procedure and diagram clearly indicate measurements of height, distance, and time. Two points were earned in part (c) for the initial and final potential energies. The kinetic energies are incorrect, because both masses would be moving. The calculation of instantaneous velocity is also incorrect. No credit was earned in parts (d) and (e) for incorrect identifications of the causes of the increase and decrease in energy, respectively.