



# AP<sup>®</sup> Physics 1

## 2016 Scoring Guidelines

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### AP<sup>®</sup> PHYSICS 1

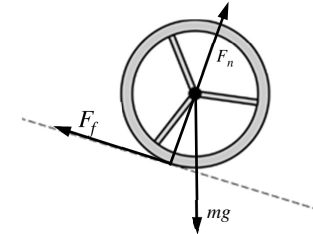
#### 2016 SCORING GUIDELINES

##### Question 1

7 points total

Distribution  
of points

- (a)  
i. 2 points



- For a labeled arrow representing the gravitational force, starting at the wheel's center and directed downward 1 point
- For labeled arrows representing the friction and normal forces or a single arrow representing the resultant of the friction and normal forces (i.e., the force exerted on the wheel by the surface), with no extraneous forces 1 point
- The friction force should start at the wheel-ramp contact and be directed up and left along the ramp.
- The normal force should start at the wheel-ramp contact and be perpendicular to the ramp and toward the wheel's center. It does not have to go exactly through the center but must come reasonably close.

- ii. 1 point

- Correct answer: The friction force
- No points are earned if the wrong force is given.
- For correctly explaining that friction is the only force that exerts a torque with respect to the wheel's center of mass 1 point
- This point is also earned for a causal chain of reasoning about forces: e.g., the gravitational force leads to a normal force (and acceleration down the ramp), which leads to a frictional force, which exerts a torque (or changes the angular velocity).

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**Question 1 (continued)**

**Distribution  
of points**

- (b) 2 points
- For an expression for the sum of the force components parallel to the ramp that recognizes that there are two forces with components parallel to the ramp  
The expression need not be correct or consistent with the force diagram in part (a).  
 $\sum F_{\parallel} = Mg \sin \theta - F_f$
- For indicating that the frictional force is  $(0.4)Mg \sin \theta$  (explicitly or implicitly) and correctly solving for the acceleration in terms of correct variables  
 $\sum F_{\parallel} = Mg \sin \theta - (0.4)Mg \sin \theta$   
 $a = \frac{\sum F_{\parallel}}{M} = \frac{Mg \sin \theta - 0.4Mg \sin \theta}{M} = \frac{0.6Mg \sin \theta}{M}$   
 $a = 0.6g \sin \theta$
- (c)
- i. 1 point
- Correct answer: Block  
No credit for answer without explanation.  
For a correct explanation in terms of forces  
Example: The wheel experiences a counteracting frictional force, so the block has a greater net force exerted upon it and therefore has greater acceleration.
- ii. 1 point
- For a correct explanation in terms of energy conservation  
Example: Both object-Earth systems lose the same amount of potential energy and therefore gain the same amount of kinetic energy. With the ice block — but not the wheel — all the kinetic energy is translational, and none is rotational, so the block is faster.

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**Question 2**

**Distribution  
of points**

**12 points total**

- Note: For parts (a) and (b), quantities that are proportional to mechanical energy, rather than energy itself, may be calculated, because terms like  $g$  or the ball's mass do not change during the experiment.
- (a) 4 points
- Parts i, ii, and iii are scored as a unit.
- For an overall plan in which quantities are measured that could be used to compare mechanical energy before and after a collision with a hard surface 1 point
- For a conceptually plausible plan to measure pre- and post-collision positions and/or speeds that could be used to compare pre- and post-collision mechanical energies, without extraneous equipment and/or measurements 1 point
- For having lab equipment and measurement procedures well specified 1 point
- For a procedure that includes trials of different pre-collision speeds, ranging from low speed to high speed (as is needed to test the student's hypothesis) 1 point
- Example 1:
- The drop height of the ball and the bounce height.
  - A meterstick to measure the heights and a video camera to record the ball's motion.
  - Place the meterstick upright against the wall.  
Drop the ball from 10 different drop heights, using the video camera to record the bounce heights.
- Example 2:
- The speed of the ball immediately before and immediately after it bounces.
  - A photogate near the floor, at a height just above the diameter of the ball, to measure the ball's speed.
  - Drop the ball through the photogate.  
Record the speeds measured by the photogate before and after the bounce.  
Change the drop height of the ball at least five times, covering a range of heights from "low" to "high."
- (b) 4 points
- For describing how to plot or otherwise represent the data in a way that could be used to test the hypothesis 1 point
- For describing how to compare the post-collision to pre-collision mechanical energy (or a plausible alternative) to quantify the elasticity of the collision 1 point
- For comparing the low-speed versus high-speed results 1 point
- For addressing the hypothesis with an analysis such as a slope, ratio, or difference 1 point

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**Question 2 (continued)**

**Distribution  
of points**

(b) (continued)

Example 1:

Make a graph of the bounce height  $h_f$  as a function of the drop height  $h_i$ . If the data are consistent with the hypothesis, then the data will (1) lie close to the line  $h_f = h_i$  for low drop heights, and (2) lie below this line for high drop heights.

Example 2:

Make a graph of  $v_f^2 - v_i^2$  as a function of  $v_i$ , where  $v_f$  and  $v_i$  are the ball's speed just after and just before the bounce, respectively. If the data are consistent with the hypothesis, then  $v_f^2 - v_i^2$  will (1) be close to zero for low speeds, and (2) be negative for high speeds.

(c)

i. 2 points

For drawing a graph or table that shows that the low-speed collisions are nearly perfectly elastic

1 point

For drawing a graph or table that shows a violation of a physics principle for higher-speed collisions

1 point

Example for energy conservation:

A graph of the ratio  $\frac{\text{Post-collision mechanical energy}}{\text{Pre-collision mechanical energy}}$  as a function of pre-collision speed, in which the graph stays near 1.0 for low initial speeds but becomes greater than 1.0 for high-speed collisions.

ii. 2 points

For a correct description of the aspect of the graph or table that shows a violation of the physical principle indicated

1 point

For a correct explanation of why the representation shows a violation of the physical principle indicated

1 point

Example for energy conservation using the graph described above: The value of the energy ratio shows a violation of conservation of energy when it becomes greater than 1.0 because the final energy cannot be greater than the initial energy.

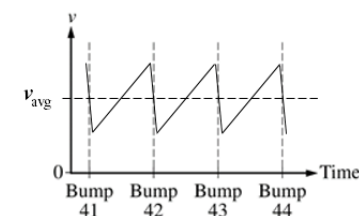
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**Question 3**

**12 points total**

**Distribution  
of points**

(a)



i. 3 points

For having a constant upward slope in each segment between bumps

1 point

For having the velocity “reset” abruptly at each bump (i.e., as a sawtooth function, not a sinusoidal curve) to a minimum positive value that is the same for each bump

1 point

For having the same maximum value in each cycle that occurs near the bump times. (This point can be earned for a sinusoidal curve with peaks at the bump times.)

1 point

ii. 1 point

For drawing a  $v_{avg}$  line that is horizontal and consistent with the graph drawn, even if that graph is wrong

1 point

(b) 2 points

Correct answer: Greater than

No points are earned if the correct answer is selected, but the explanation is completely incorrect or there is no explanation.

No points are earned if the wrong answer is selected.

For indicating that there is more time between bumps

1 point

For connecting that the cart has more time or more distance to accelerate between bumps

1 point

Example: The maximum speed is greater because the cart has more space (or time) to accelerate (build up speed) between bumps.

*Alternate solution in terms of energy*

*Alternate points*

*For indicating that the potential energy difference increases due to increased height between successive bumps*

*1 point*

*For relating the increase in potential energy to an increase in kinetic energy*

*1 point*

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**Question 3 (continued)**

**Distribution  
of points**

(c) 2 points

Correct answer: Greater than

No points are earned if the correct answer is selected, but the explanation is completely incorrect or there is no explanation.

No points are earned if the wrong answer is selected.

For indicating that the acceleration is greater

For indicating that the component of the gravitational force increases

1 point

1 point

*Alternate solution in terms of energy*

*Alternate points*

*For indicating that the potential energy difference increases due to increased height between successive bumps*

*1 point*

*For relating the increase in potential energy to an increase in kinetic energy*

*1 point*

(d)

i. 2 points

Correct answer: No

No points are earned if the correct answer is selected, but the explanation is completely incorrect or there is no explanation.

For indicating that  $v_{\text{avg}}$  is not proportional to  $M$

1 point

For connecting the equation to the data

1 point

Examples:

The y-intercept of the graph is not zero, but the equation indicates that it should be zero.

Doubling the mass from the graph does not double  $v_{\text{avg}}$ , but the equation indicates that it should double.

If “yes” is selected, one point may be earned for explaining that  $v_{\text{avg}}$  increases

with  $M$  or that  $v_{\text{avg}}$  looks (approximately) proportional to  $M$  for a limited portion of the data (e.g., the points at  $M = 1.0$  kg and  $M = 2.0$  kg).

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**Question 3 (continued)**

**Distribution  
of points**

(d)

ii. 2 points

Correct answer: No

For indicating that the distance dependency is incorrect

1 point

For indicating that, according to the equation, greater  $d$  leads to a smaller  $v_{\text{avg}}$ , OR for stating or implying the contradiction between this inverse relation and the reasoning of part (b)

1 point

Credit is earned for any answer that is consistent with reasoning in part (b).

Example: According to the equation, a larger  $d$  corresponds to a smaller  $v_{\text{avg}}$ ,

because they are inversely proportional. But according to the reasoning of part (b), a bigger distance  $d$  between the bumps leads to a larger maximum average speed, showing that the equation is implausible.

If “yes” is selected, one point can be earned for indicating that an increase in the angle increases  $v_{\text{avg}}$ .

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**Question 4**

**7 points total**

**Distribution  
of points**

(a) 3 points

Correct ranking is  $(A = D) > (B = C)$ .

For indicating that the potential difference is the same across  $A$  and  $D$  because the current is the same through each ( $A$  and  $D$  are in series.)

1 point

For indicating that the potential difference is the same across  $B$  and  $C$  because  $B$  and  $C$  are in parallel

1 point

For indicating that the potential difference is less across  $B$  (and/or  $C$ ) than across  $A$  (and/or  $D$ ) because the current splits or the current is less through  $B$  and  $C$

1 point

Example: The full battery current passes through both  $A$  and  $D$ , so they have the same current. Because they have the same resistance,  $\Delta V_A = \Delta V_D$ .  $B$  and  $C$  are in parallel, so  $\Delta V_B = \Delta V_C$ . Less than the full current passes through  $B$ , and  $A$  and  $B$  have the same resistance, so  $\Delta V_B$  is less than  $\Delta V_A$ .

(b) 2 points

Correct answer: Decrease

No points are earned if the correct answer is selected, but the explanation is completely incorrect, or there is no explanation.

If the wrong answer is selected, up to one point can still be earned.

For indicating that the effective resistance of the circuit increases

1 point

For a correct explanation of why the current through  $A$  decreases based on changes in current or potential difference throughout the circuit

1 point

Examples:

Because  $B$  is replaced with an infinite resistance, the effective resistance of the circuit increases and the battery current decreases. Because the battery current decreases and that current equals the current through  $A$ , the current through  $A$  decreases.

When  $B$  is removed, the effective resistance of that piece of the circuit increases because there is no longer a parallel combination there. Because the resistance is greater, the potential difference across that piece is a greater percent of the total. So the potential difference across  $A$  decreases and thus the current through it decreases.

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**Question 4 (continued)**

**Distribution  
of points**

(c) 2 points

Correct answer: Increase

No points are earned if the correct answer is selected, but the explanation is completely incorrect, or there is no explanation.

If the wrong answer is selected, up to one point can still be earned.

For indicating that all the current from the battery passes through  $C$ ; the current no longer splits

1 point

For making either a current argument or potential difference argument for the increase (i.e., an argument for why an increase in current through  $C$  more than compensates for the decrease in the full current or explaining that, by the loop rule, the potential difference across  $C$  must increase in order for the potential difference around the circuit loop to remain zero)

1 point

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**Question 5**

**7 points total**

**Distribution  
of points**

(a) 2 points

- |                                                                                                                             |         |
|-----------------------------------------------------------------------------------------------------------------------------|---------|
| For indicating that there is more rope or weight below one point than the other                                             | 1 point |
| For indicating (explicitly or implicitly) that the tension at any point counteracts or supports the weight below that point | 1 point |

Examples:

The rope at  $P$  supports more weight than the rope at  $Q$  so the tension must be higher at  $P$ .

The section of rope below  $P$  has an upward force from the rope above it and a downward gravitational force. The same goes for  $Q$ . Because the gravitational force is greater on the longer section (the section below  $P$ ), the upward force — the tension — must be greater at  $P$ .

(b) 5 points

- |                                                                                                                                                            |         |
|------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| For indicating that the wavelength is longer near the top of the rope (or shorter near the bottom)                                                         | 1 point |
| For indicating (explicitly or implicitly) that the frequency is the same throughout the rope                                                               | 1 point |
| For using $v = \lambda f$ to conclude that wave speed is greater near the top of the rope (or less near the bottom), based on the difference in wavelength | 1 point |
| For indicating (explicitly or implicitly) that, as stated in part (a), tension is greater near the top of the rope (or less near the bottom)               | 1 point |
| For a response that has sufficient paragraph structure, as described in the published requirements for the paragraph-length response                       | 1 point |