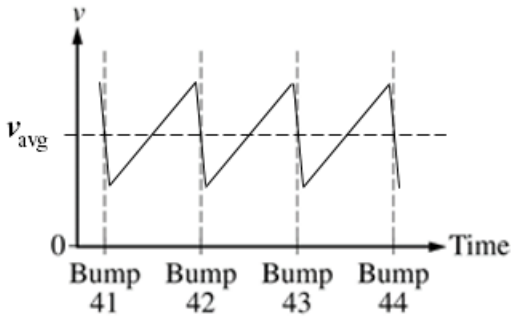
AP® PHYSICS 1
2016 SCORING GUIDELINES

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*

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 — 1 point
For indicating that the component of the gravitational force increases — 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_{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_{avg}, but the equation indicates that it should double.

If "yes" is selected, one point may be earned for explaining that v_{avg} increases with M or that v_{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).

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_{avg}, OR — 1 point

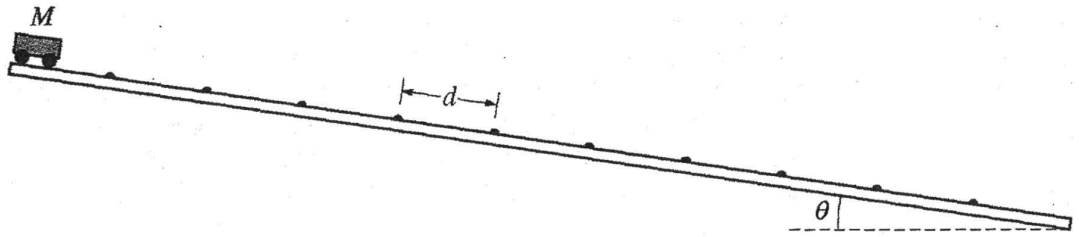
for stating or implying the contradiction between this inverse relation and the reasoning of part (b)

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_{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_{avg}.

P1 Q3 A1



Note: Figure not drawn to scale.

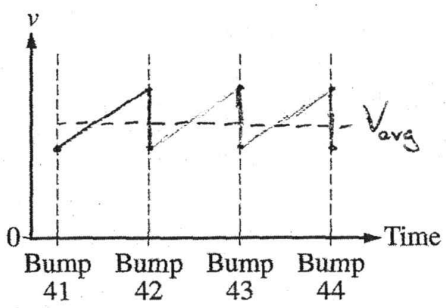
3. (12 points, suggested time 25 minutes)

A long track, inclined at an angle θ to the horizontal, has small speed bumps on it. The bumps are evenly spaced a distance d apart, as shown in the figure above. The track is actually much longer than shown, with over 100 bumps. A cart of mass M is released from rest at the top of the track. A student notices that after reaching the 40th bump the cart's average speed between successive bumps no longer increases, reaching a maximum value v_{avg}. This means the time interval taken to move from one bump to the next bump becomes constant.

(a) Consider the cart's motion between bump 41 and bump 44.

i. In the figure below, sketch a graph of the cart's velocity v as a function of time from the moment it reaches bump 41 until the moment it reaches bump 44.

ii. Over the same time interval, draw a dashed horizontal line at $v = v_{avg}$. Label this line "v_{avg}".



(b) Suppose the distance between the bumps is increased but everything else stays the same.

Is the maximum speed of the cart now greater than, less than, or the same as it was with the bumps closer together?

√ Greater than ___ Less than ___ The same as

Briefly explain your reasoning. Since cart will travel a greater distance there will be more time for the cart to accelerat, ergo it will be able to attain a higher speed.

(c) With the bumps returned to the original spacing, the track is tilted to a greater ramp angle θ. Is the maximum speed of the cart greater than, less than, or the same as it was when the ramp angle was smaller?

√ Greater than ___ Less than ___ The same as

Briefly explain your reasoning. With a greater angle more of the gravitational force will be directed in the same direction as the motion of the cart ergo increasing the carts acceleration along the ramp allowing the cart to reach a higher speed.

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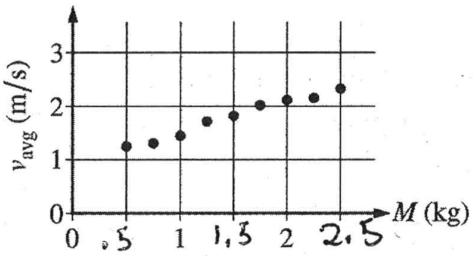
(d) Before deriving an equation for a quantity such as v_{avg}, it can be useful to come up with an equation that is intuitively expected to be true. That way, the derivation can be checked later to see if it makes sense physically. A student comes up with the following equation for the cart's maximum average speed: $v_{avg} = C\frac{Mg\sin\theta}{d}$, where C is a positive constant.

i. To test the equation, the student rolls a cart down the long track with speed bumps many times in front of a motion detector. The student varies the mass M of the cart with each trial but keeps everything else the same. The graph shown below is the student's plot of the data for v_{avg} as a function of M.



Are these data consistent with the student's equation?

____ Yes ✓ No

Briefly explain your reasoning. with the given equation one would expect that when the mass is doubled the V_{avg} would double bu that isn't the case with the graph. From .5 kg to 1 kg mass is doubled but not V_{avg}.

ii. Another student suggests that whether or not the data above are consistent with the equation, the equation could be incorrect for other reasons. Does the equation make physical sense?

____ Yes ✓ No

Briefly explain your reasoning.

One would expect that by increasing d, the distance between bumps, V_{avg} would also increase however the given equation suggests the opposite. It (equation) suggests that to increase V_{avg} one could shorten d (distance between bumps) but that makes no physical sense because the bumps slow down the cart so one would want to increase the distance between bumps to increase V_{avg} not decrease the distance.

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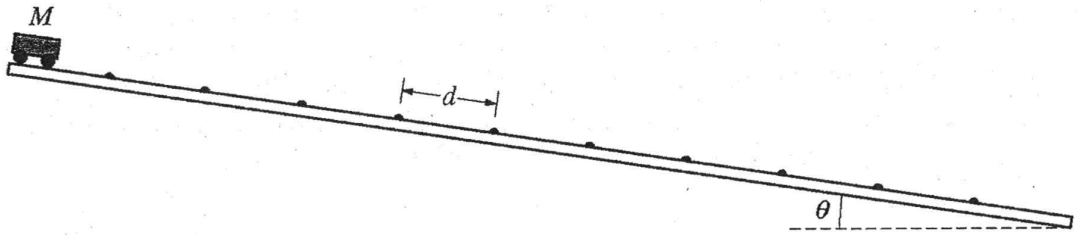

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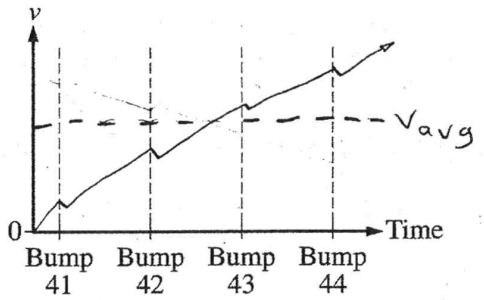


(b) Suppose the distance between the bumps is increased but everything else stays the same.

Is the maximum speed of the cart now greater than, less than, or the same as it was with the bumps closer together?

✓ Greater than ____ Less than ____ The same as

Briefly explain your reasoning.

The cart has more time to gain speed and when it hits a bump it doesn't lose as much speed as before.

(c) With the bumps returned to the original spacing, the track is tilted to a greater ramp angle θ. Is the maximum speed of the cart greater than, less than, or the same as it was when the ramp angle was smaller?

✓ Greater than ____ Less than ____ The same as

Briefly explain your reasoning.

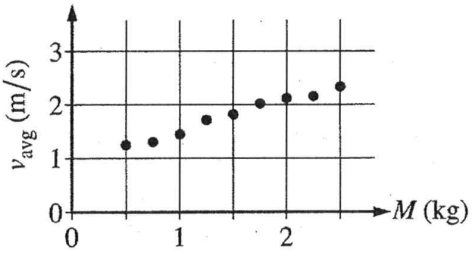
The cart has more force applied to it so it gains speed faster

GO ON TO THE NEXT PAGE.

(d) Before deriving an equation for a quantity such as v_{avg}, it can be useful to come up with an equation that is intuitively expected to be true. That way, the derivation can be checked later to see if it makes sense physically. A student comes up with the following equation for the cart's maximum average speed:

$v_{avg} = C\frac{Mg\sin\theta}{d}$, where C is a positive constant.

i. To test the equation, the student rolls a cart down the long track with speed bumps many times in front of a motion detector. The student varies the mass M of the cart with each trial but keeps everything else the same. The graph shown below is the student's plot of the data for v_{avg} as a function of M.



Are these data consistent with the student's equation?

✓ Yes ____ No

Briefly explain your reasoning.

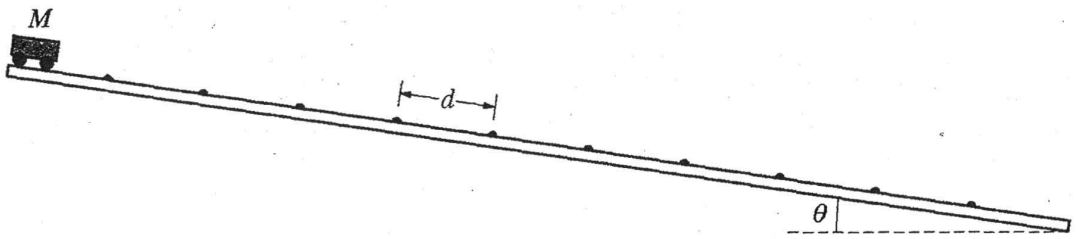
As the mass increases, the v_{avg} increases because the acceleration due to gravity is a lot more which shows the v_{avg} should be more.

ii. Another student suggests that whether or not the data above are consistent with the equation, the equation could be incorrect for other reasons. Does the equation make physical sense?

____ Yes ✓ No

Briefly explain your reasoning.

The less the distance, the less time the cart has to reach its max velocity. If the distance is less according to the equation, the velocity would be greater.



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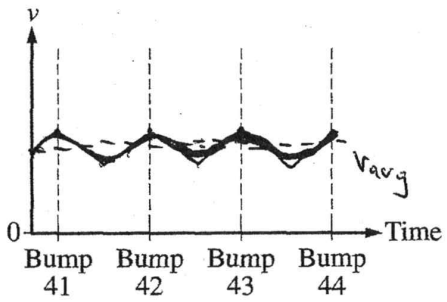

(b) Suppose the distance between the bumps is increased but everything else stays the same.

Is the maximum speed of the cart now greater than, less than, or the same as it was with the bumps closer together?

___ Greater than ___ Less than ✓ The same as

Briefly explain your reasoning.

The maximum speed is greater because there is more time for the carts v to reach its maximum before hitting a bump constantly
It would be the same because the force of gravity is constant so it doesn't increase the velocity

(c) With the bumps returned to the original spacing, the track is tilted to a greater ramp angle θ. Is the maximum speed of the cart greater than, less than, or the same as it was when the ramp angle was smaller?

✓ Greater than ___ Less than ___ The same as

Briefly explain your reasoning.

It would be greater because

(d) Before deriving an equation for a quantity such as v_{avg}, it can be useful to come up with an equation that is intuitively expected to be true. That way, the derivation can be checked later to see if it makes sense physically. A student comes up with the following equation for the cart's maximum average speed: $v_{avg} = C\frac{Mg\sin\theta}{d}$, where C is a positive constant.

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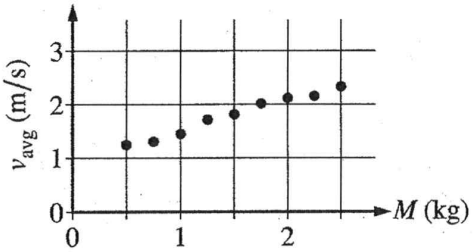

Are these data consistent with the student's equation?

____ Yes ___✓___ No

Briefly explain your reasoning.

ii. Another student suggests that whether or not the data above are consistent with the equation, the equation could be incorrect for other reasons. Does the equation make physical sense?

___✓___ Yes ____ No

Briefly explain your reasoning.

AP® PHYSICS 1
2016 SCORING COMMENTARY

Question 3

Overview

This question assessed learning objectives 2.B.1.1, 3.A.1.1, 3.A.3.1, 3.B.1.1, and 3.B.1.3. It probed students' conceptual and graphical understanding of kinematics, particularly how speed and average velocity are impacted by changing conditions of the motion of a cart rolling down a bumpy hill. The question focused on scientific thinking and the testing of a hypothesis with data and scientific reasoning.

Sample: P1 Q3 A
Score: 12

In part (a) all 4 points were earned for a correct graph and average velocity. Both points were earned in part (b) for indicating that there is more time between bumps and connecting the increased time of acceleration to a higher speed. Both points were earned in part (c) for indicating that the gravitational force has a greater component along the direction of motion; therefore, the acceleration is greater. Full credit was earned in part (d). In (d)(i) 2 points were earned for indicating that the proportional relation in the equation (doubling the mass results in doubling the average speed) is not indicated by the graph. In (d)(ii) 2 points were earned for explaining why the distance dependency in the equation does not make physical sense.

Sample: P1 Q3 B
Score: 7

In part (a)(i) 1 point was earned for a constant upward slope between bumps. The graph does not have the same maximum or minimum values. In (a)(ii) the horizontal line for the average velocity is consistent with the incorrect graph, and the point was earned. In part (b) both points were earned because the response indicated there is more time to gain speed, implying there is more time to accelerate. In part (c) one point was earned for indicating the cart gains speed faster, implying a greater acceleration. However, there was no indication that the component of the gravitational force along the ramp or direction of motion increased as a result of the increased angle. In part (d)(i) no points were earned. Though one point may be earned for selecting "yes," this point was not earned because the explanation incorrectly states that the acceleration due to gravity increases with mass. In (d)(ii) both points were earned for indicating that the distance dependency is incorrect and explaining the correct relationship.

Sample: P1 Q3 C
Score: 2

In part (a)(i) 1 point was earned for having the same maximum value in each cycle at the bump. The graph does not have a constant slope between bumps or abrupt transitions at the bumps. In part (a)(ii) the point was earned because the average velocity indicated is consistent with the incorrect graph. No points were earned in parts (b), (c), and (d) because the explanations are either incorrect, incomplete, or not present.