2021

AP® CollegeBoard

AP® Physics 1: Algebra-Based

Sample Student Responses and Scoring Commentary

Inside:

Free Response Question 1

- ☑ Scoring Guideline
- ☑ Student Samples
- ☑ Scoring Commentary

Question 1: Short Answer — 7 points

(a)	For using conservation of energy to find the speed v of the bicycle as it leaves the ramp	**1 point**
	For using kinematics, vertical components, attempting to find the time the bicycle is in the air	**1 point**
	For a correct expression for X_0 in terms of given quantities	**1 point**

Example response for part (a)

$$E_{top} = E_{bottom}$$
$$m_0 g H_0 = \tfrac{1}{2} m_0 v^2$$
$$v = \sqrt{2gH_0}$$
$$v_{fy} = v_{iy} + at$$
$$-v\sin\theta = v\sin\theta - gt$$
$$-2v\sin\theta = -gt$$

$$2\sin\theta_0\sqrt{2gH_0} = gt$$
$$t = \frac{2\sin\theta_0\sqrt{2gH_0}}{g}$$
$$X_0 = v_x t$$
$$X_0 = \cos\theta_0\sqrt{2gH_0}\,\frac{2\sin\theta_0\sqrt{2gH_0}}{g}$$
$$X_0 = 4H_0\cos\theta_0\sin\theta_0$$

Scoring Note:

Using the range equation to get $X_0 = 2H_0\sin 2\theta_0$ is sufficient to earn the second and third points.

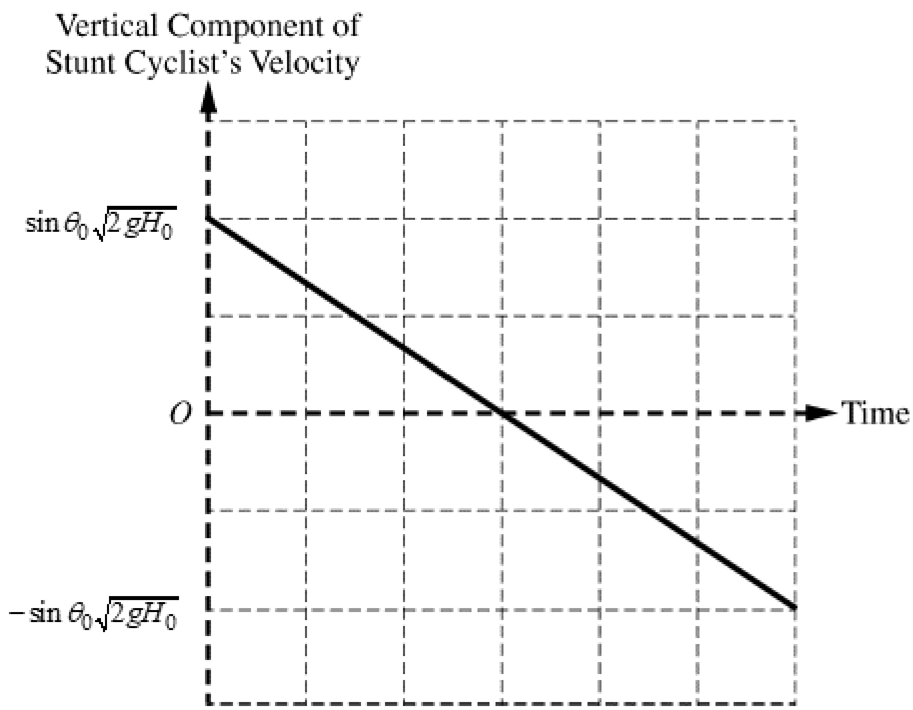
Total for part (a) — 3 points

(b)	Correct answer: 12 cars	
	For an answer and justification that attempts to use the functional dependence of the horizontal distance on the initial height	**1 point**
	For an answer consistent with the expression derived in part (a)	**1 point**

Total for part (b) — 2 points

(c)	For a linear graph with a constant negative slope	**1 point**
	For a graph that starts at v_y and ends at $-v_y$, using only allowed variables	**1 point**

Example response for part (c)



Total for part (c)	**2 points**
Total for Question 1	**7 points**

Begin your response to **QUESTION 1** on this page.

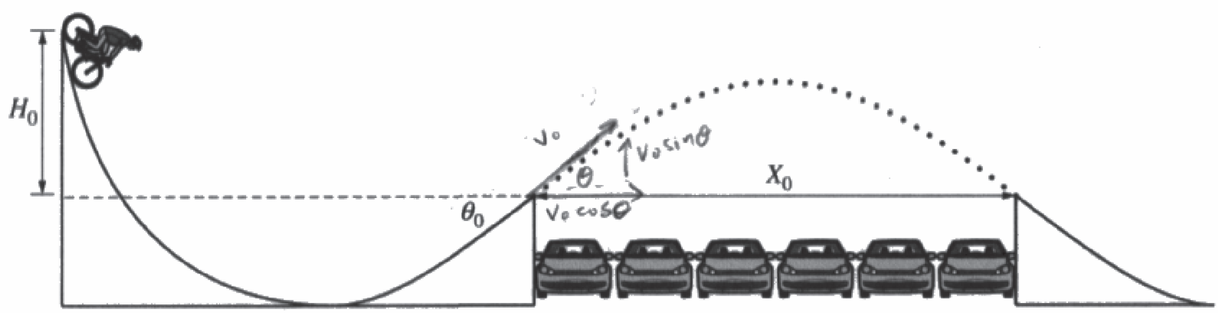
PHYSICS 1

SECTION II

Time—1 hour and 30 minutes

5 Questions

Directions: Questions 1, 4, and 5 are short free-response questions that require about 13 minutes each to answer and are worth 7 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



<u>Note:</u> Figure not drawn to scale.

1. (7 points, suggested time 13 minutes)

A stunt cyclist builds a ramp that will allow the cyclist to coast down the ramp and jump over several parked cars, as shown above. To test the ramp, the cyclist starts from rest at the top of the ramp, then leaves the ramp, jumps over six cars, and lands on a second ramp.

H_0 is the vertical distance between the top of the first ramp and the launch point.
θ_0 is the angle of the ramp at the launch point from the horizontal.
X_0 is the horizontal distance traveled while the cyclist and bicycle are in the air.
m_0 is the combined mass of the stunt cyclist and bicycle.

(a) Derive an expression for the distance X_0 in terms of H_0, θ_0, m_0, and physical constants, as appropriate.

$\Sigma E_i = \Sigma E_f$

$\cancel{m_0} g H_0 = \frac{1}{2} \cancel{m_0} v_0^2$

$v_0^2 = 2gH_0$

$v_0 = \sqrt{2gH_0}$

vertical: $\overset{0}{\cancel{x}} = \frac{1}{2}at^2 + v_0 \sin\theta_0 t$

$0 = \frac{1}{2}at + v_0 \sin\theta$

$0 = \frac{1}{2}(-9.8)t + v_0 \sin\theta$

$t = \frac{v_0 \sin\theta}{4.9} = \frac{\sqrt{2gH_0}\sin\theta}{4.9}$

horizontal: $x = vt$

$X_0 = \sqrt{2gH_0} \cdot \frac{\sqrt{2gH_0}\sin\theta}{4.9}$

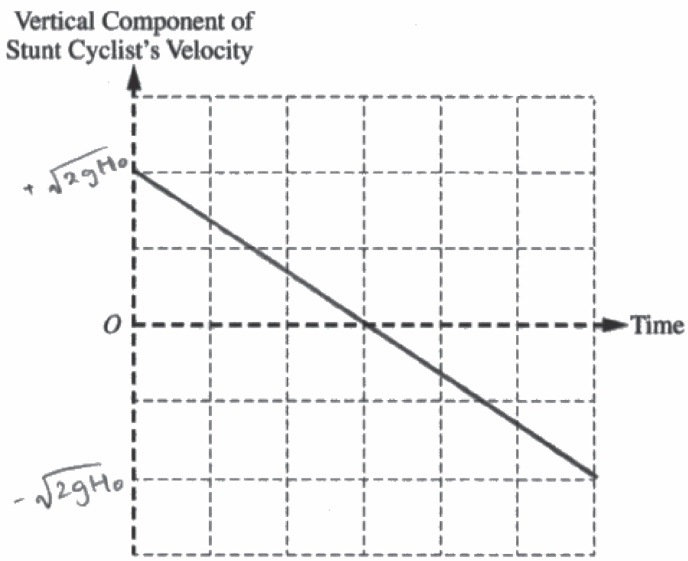
$X_0 = \frac{2gH_0 \sin\theta_0}{4.9}$

Continue your response to **QUESTION 1** on this page.

(b) If the vertical distance between the top of the first ramp and the launch point were $2H_0$ instead of H_0, with no other changes to the first ramp, what is the maximum number of cars that the stunt cyclist could jump over? Justify your answer, using the expression you derived in part (a).

The cyclist would be able to jump over 12 cars. In the expression in part (a), $X_0 \propto H_0$, so if H_0 doubles, then X_0 doubles as well. Double the amount of 6 cars (X_0) is 12 cars

(c) On the axes below, sketch a graph of the vertical component of the stunt cyclist's velocity as a function of time from immediately after the cyclist leaves the ramp to immediately before the cyclist lands on the second ramp. On the vertical axis, clearly indicate the initial and final vertical velocity components in terms of H_0, θ_0, m_0, and physical constants, as appropriate. Take the positive direction to be upward.



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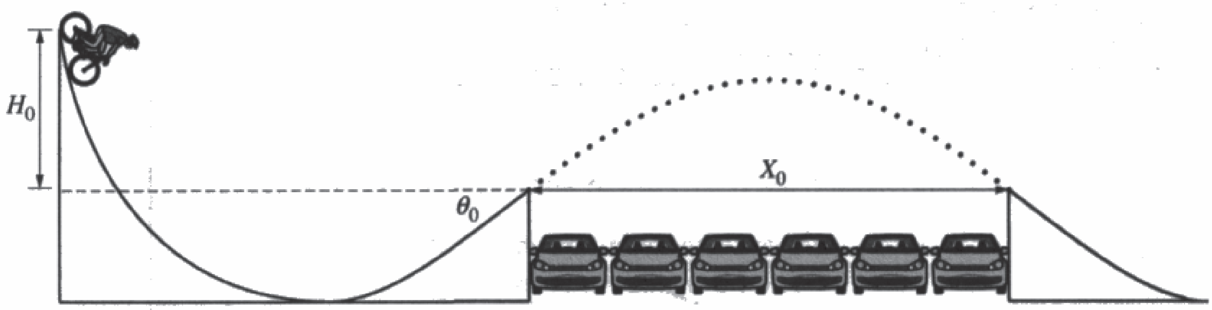

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1. (7 points, suggested time 13 minutes)

A stunt cyclist builds a ramp that will allow the cyclist to coast down the ramp and jump over several parked cars, as shown above. To test the ramp, the cyclist starts from rest at the top of the ramp, then leaves the ramp, jumps over six cars, and lands on a second ramp.

H_0 is the vertical distance between the top of the first ramp and the launch point.
θ_0 is the angle of the ramp at the launch point from the horizontal.
X_0 is the horizontal distance traveled while the cyclist and bicycle are in the air.
m_0 is the combined mass of the stunt cyclist and bicycle.

(a) Derive an expression for the distance X_0 in terms of H_0, θ_0, m_0, and physical constants, as appropriate.

$H_0 m_0 g = \frac{1}{2} m v^2$

$\sqrt{\frac{2(H_0 m_0 g)}{m}} = \sqrt{v^2}$ $m_0 g H$

$v = \sqrt{\frac{2 H_0 M_0 g}{m}}$

$x = \cancel{x_0} + v_{x0} t + \frac{1}{2} a_x t^2$

$X_0 = v_0 t + \frac{1}{2}(10) t$

$\boxed{X_0 = \sqrt{\frac{2(H_0 m_0 g)}{m}} + \frac{1}{2}(g) t}$

Continue your response to **QUESTION 1** on this page.

(b) If the vertical distance between the top of the first ramp and the launch point were $2H_0$ instead of H_0, with no other changes to the first ramp, what is the maximum number of cars that the stunt cyclist could jump over? Justify your answer, using the expression you derived in part (a).

$x_0 = \sqrt{\frac{2(2H_0 m_0 g)}{m}}$ $\quad x_2 = \sqrt{4H_0 g} + \frac{1}{2}gt$ $\quad \boxed{72 \text{ cars}}$

$x_0 = 6 \text{ cars}$ $\quad x_2 = \sqrt{4(1.8)(10)} + \frac{1}{2}gt$

$x_2 = \sqrt{72}$

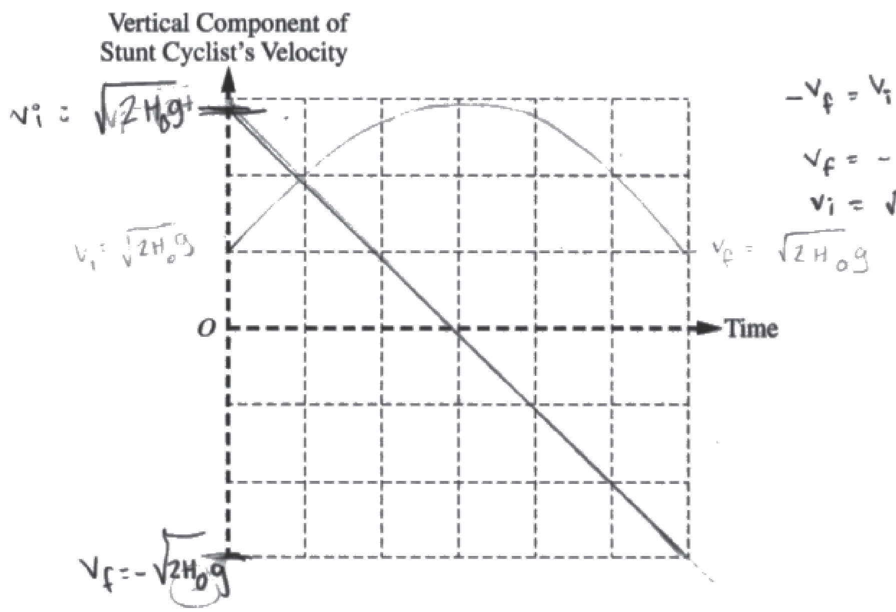
$\frac{2H_0 g}{36} \quad \frac{4H_0 g}{x}$

$6 = \sqrt{2H_0 g}$

$36 = 2H_0 g$ $\quad \frac{18}{10} = H_0 g$ $\quad H_0 = 1.8 \text{ cars.}$ $\quad \cancel{2H = 3.6 \text{ cars}}$ $\quad 72H_0 g = \cancel{H_0 g x}$

(c) On the axes below, sketch a graph of the vertical component of the stunt cyclist's velocity as a function of time from immediately after the cyclist leaves the ramp to immediately before the cyclist lands on the second ramp. On the vertical axis, clearly indicate the initial and final vertical velocity components in terms of H_0, θ_0, m_0, and physical constants, as appropriate. Take the positive direction to be upward.

(+)



$-v_f = v_i$

$v_f = -\sqrt{2H_0 g}$

$v_i = \sqrt{2H_0 g}$

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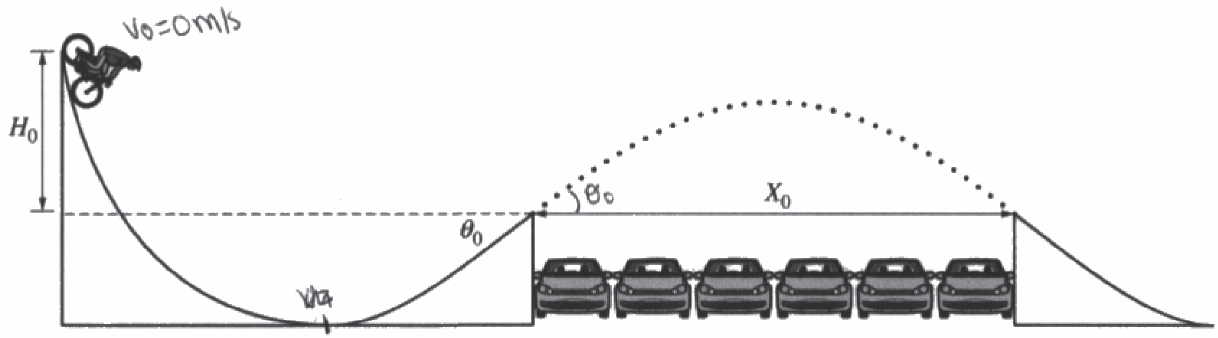

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m_0 is the combined mass of the stunt cyclist and bicycle.

(a) Derive an expression for the distance X_0 in terms of H_0, θ_0, m_0, and physical constants, as appropriate.

$dh_{max} = \frac{V^2 \sin 2\theta}{g}$

$V^2 = V_0^2 + 2gH_0$

$\boxed{X_0 = \frac{2gH_0 \sin 2\theta}{g}}$

Continue your response to **QUESTION 1** on this page.

(b) If the vertical distance between the top of the first ramp and the launch point were $2H_0$ instead of H_0, with no other changes to the first ramp, what is the maximum number of cars that the stunt cyclist could jump over? Justify your answer, using the expression you derived in part (a).

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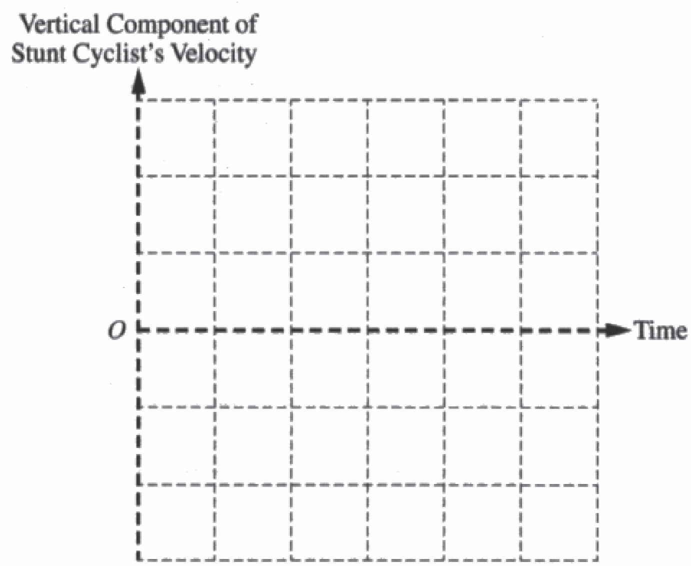

Question 1

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

This question was designed to assess the understanding of the following concepts:

Part (a)—Does the response demonstrate an understanding of derivations by demonstrating:
- a conservation of energy-based derivation,
- a kinematics-based derivation, and
- the use of mathematical synthesis to achieve a conclusion?

Part (b)—Does the response demonstrate an understanding of application by demonstrating:
- an understanding of physical relationships expressed mathematically, and
- the application of mathematically expressed changes to the physical problem?

Part (c)—Does the response demonstrate an understanding of analysis by demonstrating:
- the application of graphical analysis, and
- the use of dimensional analysis?

Sample: P1 Q1 A
Score: 6

Part (a) earned 2 points. The first point was earned for the work on the left-hand side of the derivation. The second point was earned for the work in the middle of the derivation due to substitution of vertical components into the horizontal distance equation. The third point was not earned because the final expression for X_0 is incorrect for missing a factor of $\cos\theta$. Note that $2g/4.9$ is the correct ratio. Parts (b) and (c) earned the full amount of points.

Sample: P1 Q1 B
Score: 3

Part (a) earned 1 point. The first point was earned for an attempt to isolate v from the simple energy equation. (The correct solution for v is not necessary to earn the first point.) The second point was not earned because the response mixes horizontal and vertical kinematics. The third point was not earned because the final expression for X_0 is incorrect. Part (b) earned 1 point. The first point was earned for substitution of the new height $2H_0$. The derivation in part (a) contains an additive term making the second point unattainable. Part (c) earned 1 point for a linear graph with a negative slope, but the vertical axis indicates incorrect vertical velocity expressions by omitting a factor of $\sin\theta$.

Sample: P1 Q1C
Score: 2

Part (a) earned 2 points. The first point was not earned because energy conservation is not used to isolate for the expression for launch speed. The second point was earned for kinematics by use of the range equation. The third point was earned for a final correct answer. Parts (b) and (c) earned no points.