2021

AP® CollegeBoard

AP® Physics 1: Algebra-Based

Scoring Guidelines

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

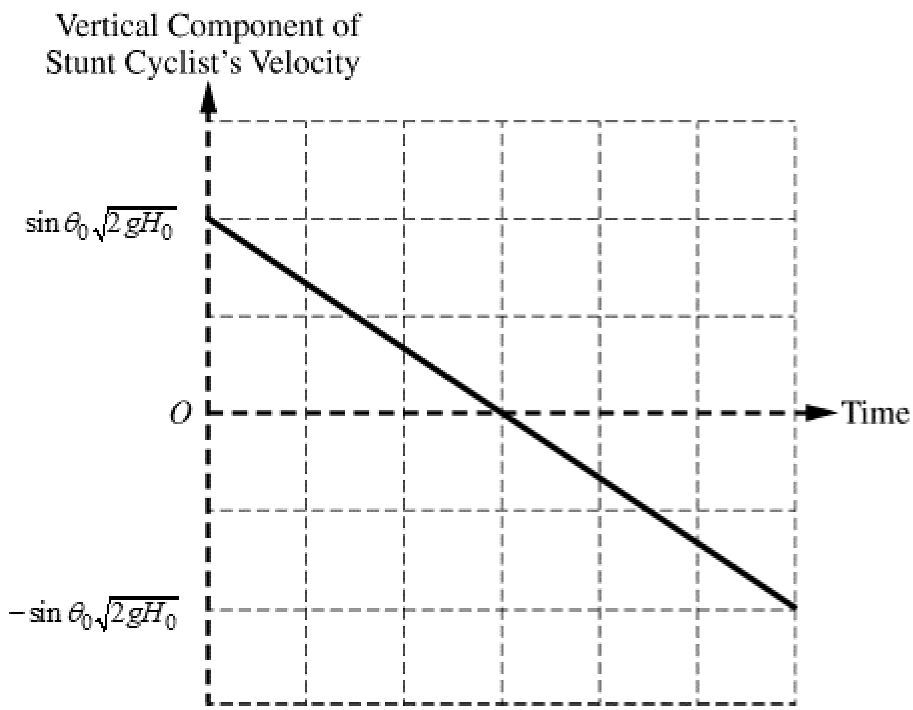
For an answer and justification that attempts to use the functional dependence of the horizontal distance on the initial height — **1 point**

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

Question 2: Experimental Design — 12 points

(a)	For measuring the radius or diameter of rods with different radii using an appropriate tool	**1 point**
	For measuring force using an appropriate tool	**1 point**
	For a plausible/practical way to directly or indirectly determine F_{max} for a given rod	**1 point**
	For attempting to reduce experimental uncertainty in an experiment that involves breaking the rods	**1 point**

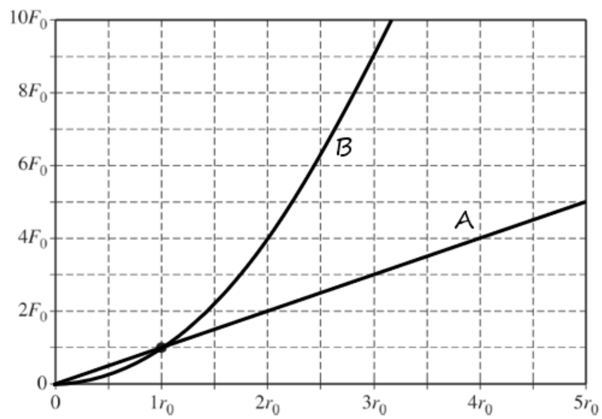
Example response for part (a)

Measure the diameter D of each rod with a ruler.
Students should pull on the rod with the force probe until the rod breaks.
Record the force F_{max} just before breaking.
Repeat each trial several times to reduce error.
Then trade for a new set of rods with different radii.
Repeat this experiment for several different radii rods.

Total for part (a) — 4 points

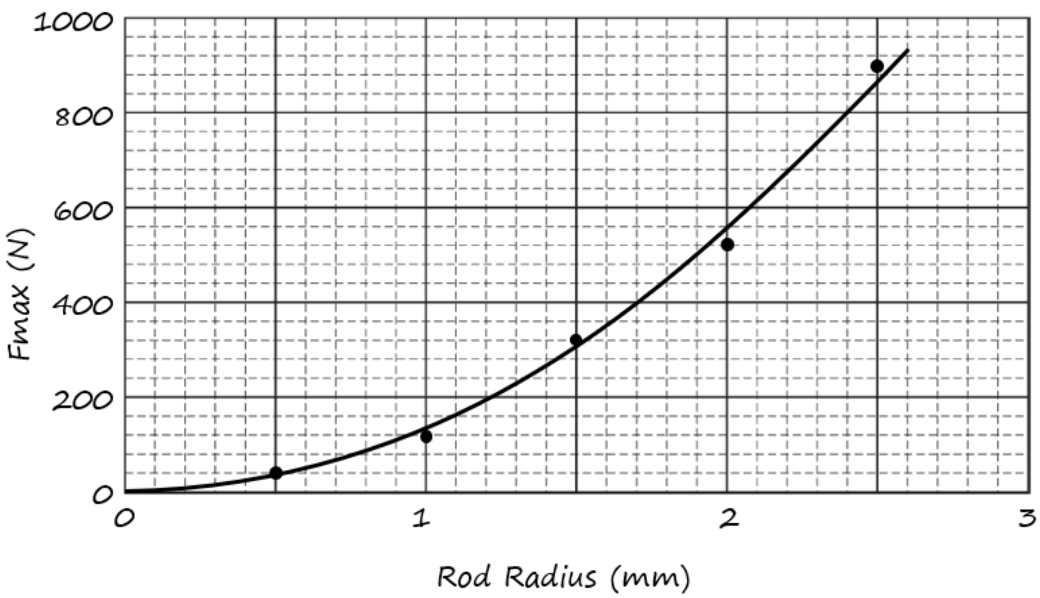
(b)	For a straight-line graph marked "A" with a slope of $\frac{F_0}{r_0}$	**1 point**
	For a graph marked "B" that is concave up	**1 point**
	For a graph marked "B" that shows a quadratic relationship at the correct points	**1 point**
	For two graphs that both contain the point (r_0, F_0)	**1 point**

Example response for part (b)



Total for part (b) — 4 points

(c)	For linear scales with appropriate labels and units **AND** for a graph where the plotted points cover at least half of the grid's width and height	**1 point**
	For plotting the points correctly	**1 point**
	For drawing a reasonable best-fit curve	**1 point**
	Example response for part (c)	

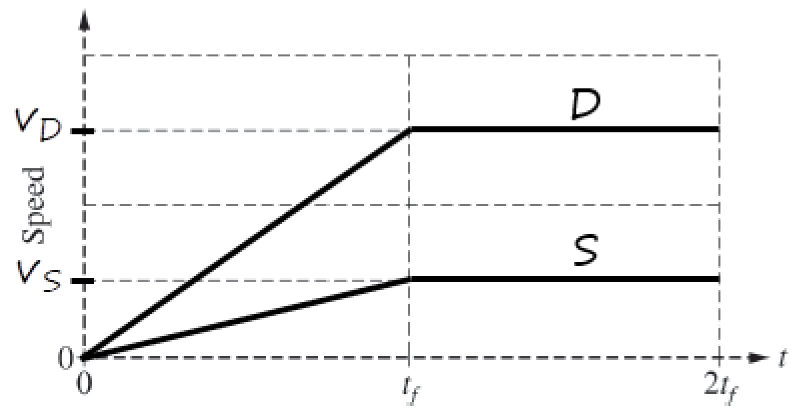


	Total for part (c)	**3 points**
(d)	For identifying Model B and for indicating that F_{max} increases as the square of the radius increases	**1 point**
	Example response for part (d) *In this graph,* F_{max} *seems to be proportional to* R^2 *, so that if we graph* F_{max} *on the vertical axis and* R^2 *on the horizontal axis, it should show a linear graph.*	
	Total for question 2	**12 points**

Question 3: Qualitative/Quantitative Translation — 12 points

(a)	**i.**	For a correct answer $v_D = \dfrac{F_H t_f}{M_D}$	**1 point**
	ii.	For indicating the total momentum of the system is the same before and after the collision **Scoring Note**: If the response only includes a correct final answer of $\dfrac{M_S}{M_D}$, the response earns this point but not the next point.	**1 point**
		For correctly substituting the appropriate variables into a conservation of momentum equation **AND** an answer in the form $\dfrac{v_D}{v_S} = \ ...$ **Scoring Notes:** This point can be earned only if the first point is earned. The answer need not be correct to earn this point.	**1 point**
		Example response for part (a)(ii) $p_i = p_f$ $0 = M_S v_S - M_D v_D$ $\dfrac{v_D}{v_S} = \dfrac{M_S}{M_D}$	
		Total for part (a)	**3 points**
(b)		For two functions that are straight segments for $t < t_f$, **AND** begin at the origin, **AND** have two different positive slopes	**1 point**
		For two functions that are horizontal functions for $t > t_f$ **AND** are continuous over the entire time range $0 < t < 2t_f$	**1 point**
		For labeling values on the vertical axis with $v_D > v_S$ **OR** The curve labeled D is greater than the curve labeled S for all t > 0 **Scoring note:** This point can still be earned if the labels are not on the vertical axis but clearly indicate that $v_D > v_S$.	**1 point**

Example response for part (b)

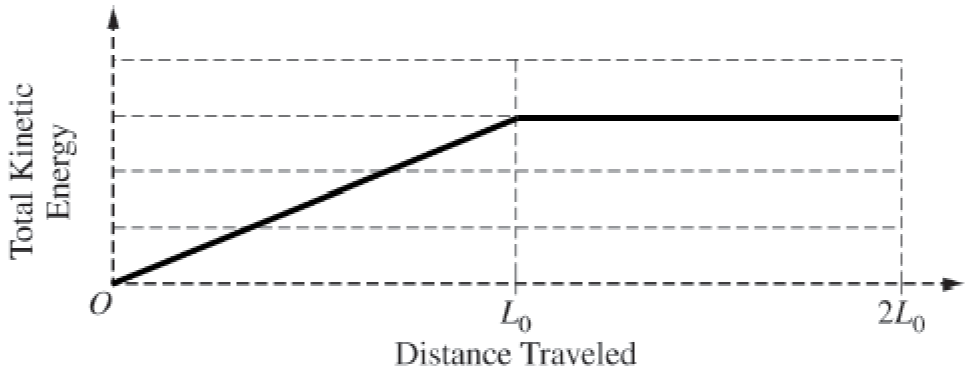


		Total for part (b)	**3 points**
(c)	**i.**	For stating or mathematically representing that if the disk is much more massive, then the block will have little effect on the motion of disk 1 **OR** For stating or mathematically representing that when $M_D >> M_B$, $v_{cm} = v_1$	**1 point**
	ii.	For correct reasoning. Correct answer: When $M_D << M_B$, $v_{cm} = 0$	**1 point**
		Example response for part (c) (ii) *If the block is much more massive, then it will barely move when the disk collides and sticks to it.*	
	iii.	For using conservation of momentum	**1 point**
		For a correct answer $v_{cm} = \dfrac{m_D v_1}{m_D + m_B}$	**1 point**
	iv.	For an attempt to use limiting-case reasoning or functional dependence with the equation in part (c)(iii)	**1 point**
		For recognizing the equation from (c)(iii) reduces to a simpler form and the simplified form is correctly compared to their answer in (c)(i)	**1 point**
		Example 1 response for part (c) (iv) *Yes. If M_B is very small, then the denominator of the equation simplifies to M_D, which then can cancel out of the equation leaving $v_{cm} = v_1$.*	
		Total for part (c)	**6 points**
		Total for question 3	**12 points**

Question 4: Paragraph-Length Response — 7 points

(a)	For a straight line with a positive slope beginning at the origin and reaching a maximum value when the distance traveled is L_0	**1 point**
	For a nonzero horizontal line between L_0 and $2L_0$	**1 point**

Example response for part (a)



	Total for part (a)	**2 points**
(b)	For indicating that both objects start with the same gravitational potential energy in the object-Earth system	**1 point**
	For a correct statement about the energy transformations that occur to the cylinder as it travels down the ramp	**1 point**
	For a correct statement about the energy transformations that occur to the block as it travels down the ramp	**1 point**
	For indicating that the cylinder's final rotational kinetic energy is equal to the amount of the block-Earth system's initial mechanical energy that is dissipated by friction	**1 point**
	For a logical, relevant, and internally consistent argument that addresses the required argument or question asked, and follows the guidelines described in the published requirements for the paragraph-length response	**1 point**

Example response for part (b)

Both objects start with the same gravitational potential energy in the object-Earth system. The block-Earth system's mechanical energy is converted into kinetic energy, and some of it is dissipated by friction as the block slides down the ramp. The cylinder-Earth system's mechanical energy is transformed into translational kinetic energy and some is transformed into rotational kinetic energy. The cylinder's final rotational kinetic energy is equal to the amount of the block-Earth system's initial mechanical energy that is dissipated by friction.

Total for part (b)	**5 points**
Total for question 4	**7 points**

Question 5: Short Answer — 7 points

(a) **i.** For correct expressions for the torques from the weight of each object — **1 point**

The torques are $m_0 g(2r_0)$ for object 1 and $(1.5m_0 g)r_0$ for object 2

For indicating that the two torques are exerted in opposite directions — **1 point**

$\tau_{net} = m_0 g(2r_0) - (1.5m_0 g)r_0$

For the derivation of a correct answer of $0.5m_0 g r_0$ — **1 point**

Example response for part (a)(i)

$$\tau_{net} = \tau_1 - \tau_2$$
$$\tau_{net} = m_0 g(2r_0) - (1.5m_0 g)r_0$$
$$\tau_{net} = 0.5m_0 g r_0$$

ii. For an explanation that object 1 exerts a larger torque than object 2 — **1 point**

Example response for part (a)(ii)

Object 1 is twice as far from the axle as object 2, while object 2 has only 1.5 times the weight of object 1. So, object 1 exerts a larger torque.

Total for part (a) — 4 points

(b) Correct answer: "Opposite directions"

Scoring note: If the wrong answer is selected, the response is not graded.

For a correct answer and a correct explanation — **1 point**

Example response for part (b)

The objects exerted torques in opposite directions, with object 1 exerting a larger torque, so object 1 determines the net torque direction. With the torque from object 1 removed, the net torque and angular acceleration switch direction (becoming clockwise) to the torque from object 2. The angular velocity does not change direction immediately and is still counterclockwise.

(c)	For a linear graph between 0 and t_C, with an initial angular velocity of zero and nonzero slope **Scoring note**: The slope can be positive or negative.	**1 point**
	For a change in the sign of the slope at $t = t_C$ **AND** no discontinuity.	**1 point**

Example response for part (c)

Total for part (c) **2 points**

Total for question 5 **7 points**