

(12 points, suggested time 25 minutes)

- (a) Students conduct an experiment to determine the acceleration a of a cart. The cart is released from rest at the top of the ramp at time $t = 0$ and moves down the ramp. The x -axis is defined to be parallel to the ramp with its origin at the top, as shown in the figure. The students collect the data shown in the following table.

	Position x (m)	Time t (s)	
	0.06	0.39	
	0.14	0.59	
	0.24	0.77	
	0.37	0.96	
	0.55	1.20	

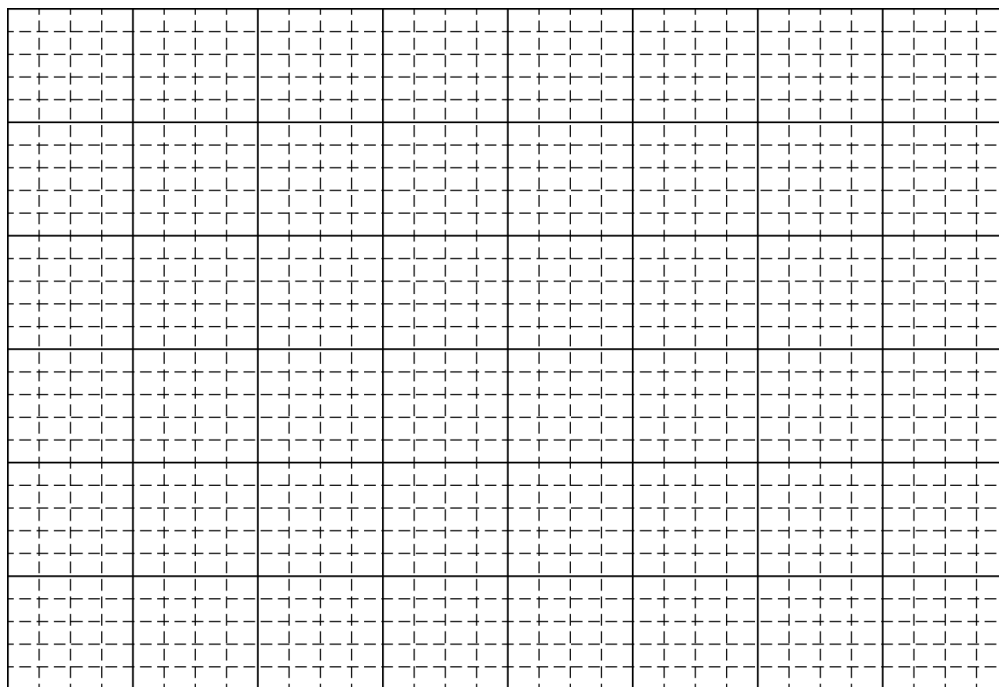
- i. Indicate which quantities could be graphed to yield a straight line whose slope could be used to determine the acceleration a of the cart. You may use the remaining columns in the table, as needed, to record any quantities (including units) that are not already in the table.

Vertical axis: _____ Horizontal axis: _____

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Continue your response to **QUESTION 2** on this page.

- ii. On the following grid, plot the appropriate quantities to create a graph that can be used to determine the acceleration a of the cart as it rolls down the ramp. Clearly scale and label all axes (including units), as appropriate. Draw a straight line that best represents the data.



- iii. Using the line you drew in part (a)(ii), calculate an experimental value for the acceleration a of the cart as it rolls down the ramp.

- (b) The students are asked to determine an experimental value for the acceleration due to gravity g_{exp} using their data.

i. What additional quantities do the students need to measure in order to calculate g_{exp} from a ?

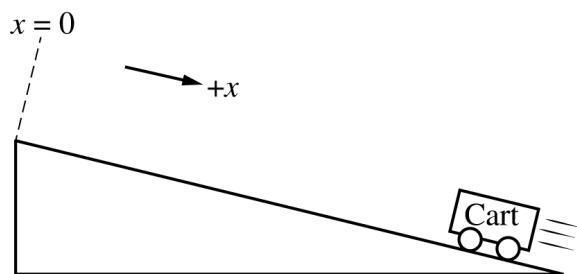
ii. Write an expression for the value of g_{exp} in terms of a .

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(c) The students calculate the value of g_{exp} to be significantly lower than the accepted value of 9.8 m/s^2 .

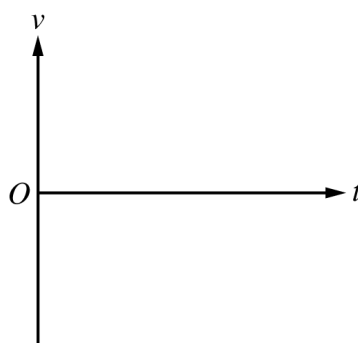
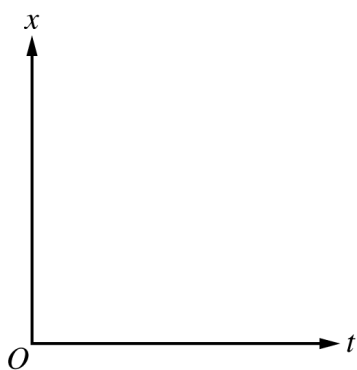
i. What is a physical reason, other than friction or air resistance, that could lead to a significant difference in the experimentally determined value of g_{exp} ?

ii. Briefly explain how the physical reason you identified in part (c)(i) would lead to the decrease in the experimentally determined value of g_{exp} .



The students want to confirm that the acceleration is the same whether the cart rolls up or down the ramp. The students start the cart at the bottom and give the cart a quick push so that it rolls up the ramp and momentarily comes to rest. The x -axis is still defined to be parallel to the ramp with the origin at the top.

(d) On the following graphs, sketch the position x and velocity v as functions of time t that correspond to the scenario shown while the cart moves up the ramp.



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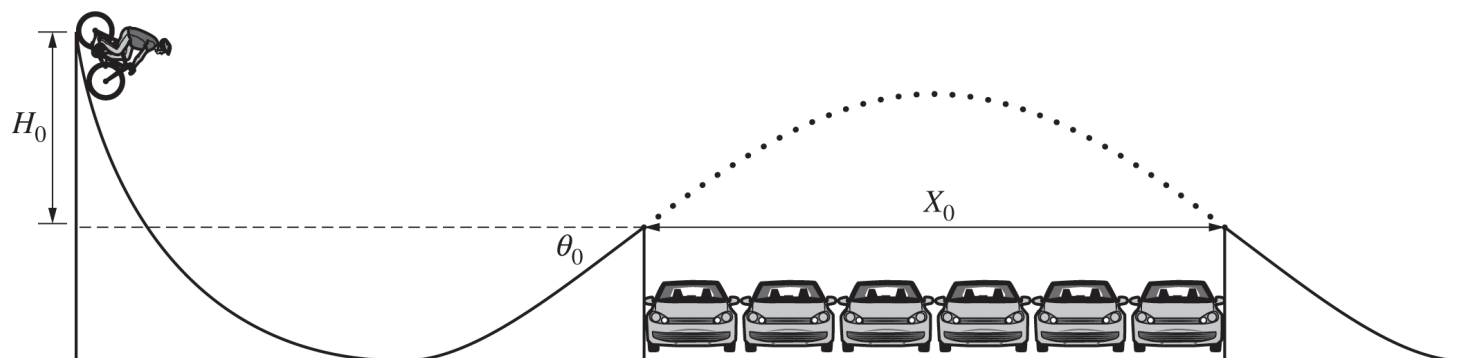
PHYSICS 1

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.



Note: 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.

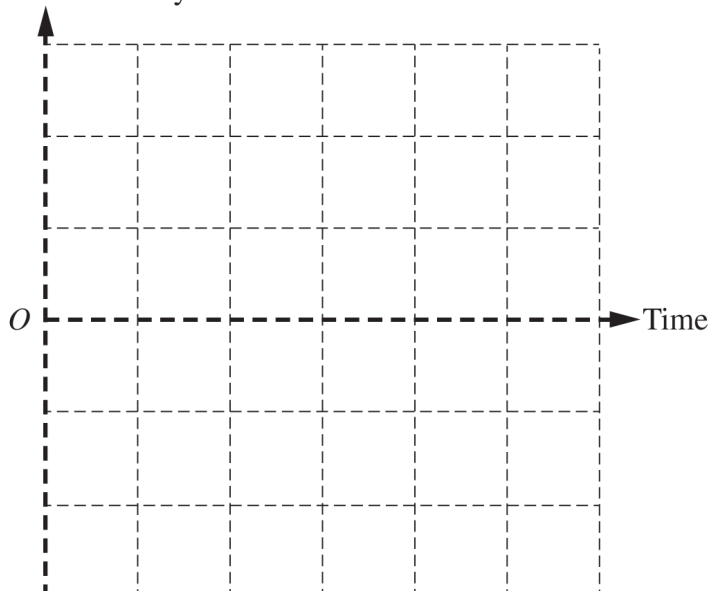
(a) Derive an expression for the distance X_0 in terms of H_0 , θ_0 , m_0 , and physical constants, as appropriate.

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- (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).
- (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.

Vertical Component of
Stunt Cyclist's Velocity



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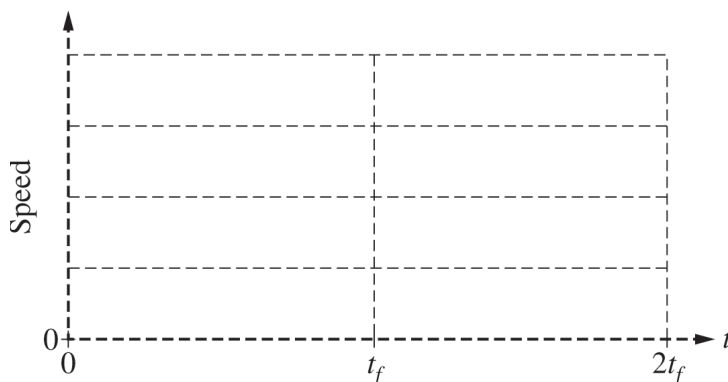
3. (12 points, suggested time 25 minutes)

(a) A student of mass M_S , standing on a smooth surface, uses a stick to push a disk of mass M_D . The student exerts a constant horizontal force of magnitude F_H over the time interval from time $t = 0$ to $t = t_f$ while pushing the disk. Assume there is negligible friction between the disk and the surface.

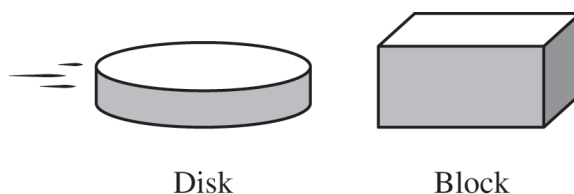
i. Assuming the disk begins at rest, determine an expression for the final speed v_D of the disk relative to the surface. Express your answer in terms of F_H , t_f , M_S , M_D , and physical constants, as appropriate.

ii. Assume there is negligible friction between the student's shoes and the surface. After time t_f , the student slides with speed v_S . Derive an equation for the ratio v_D / v_S . Express your answer in terms of M_S , M_D , and physical constants, as appropriate.

(b) Assume that the student's mass is greater than that of the disk ($M_S > M_D$). On the grid below, sketch graphs of the speeds of both the student and the disk as functions of time t between $t = 0$ and $t = 2t_f$. Assume that neither the disk nor the student collides with anything after $t = t_f$. On the vertical axis, label v_D and v_S . Label the graphs "S" and "D" for the student and the disk, respectively.

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Disk

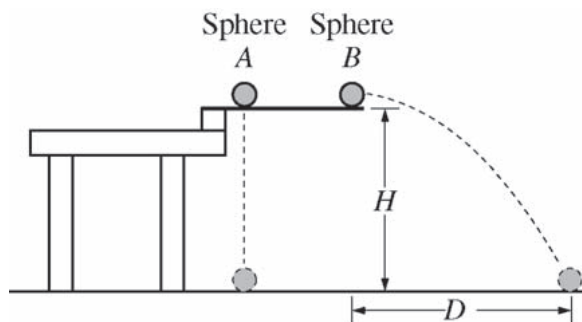
Block

(c) The disk is now moving at a constant speed v_1 on the surface toward a block of mass M_B , which is at rest on the surface, as shown above. The disk and block collide head-on and stick together, and the center of mass of the disk-block system moves with speed v_{cm} .

- i. Suppose the mass of the disk is much greater than the mass of the block. Estimate the velocity of the center of mass of the disk-block system. Explain how you arrived at your prediction without deriving it mathematically.
- ii. Suppose the mass of the disk is much less than the mass of the block. Estimate the velocity of the center of mass of the disk-block system. Explain how you arrived at your prediction without deriving it mathematically.
- iii. Now suppose that neither object's mass is much greater than the other but that they are not necessarily equal. Derive an equation for v_{cm} . Express your answer in terms of v_1 , M_D , M_B , and physical constants, as appropriate.
- iv. Consider the scenario from part (c)(i), where the mass of the disk was much greater than the mass of the block. Does your equation for v_{cm} from part (c)(iii) agree with your reasoning from part (c)(i) ?
____ Yes ____ No
Explain your reasoning by addressing why, according to your equation, v_{cm} becomes (or approaches) a certain value when M_D is much greater than M_B .

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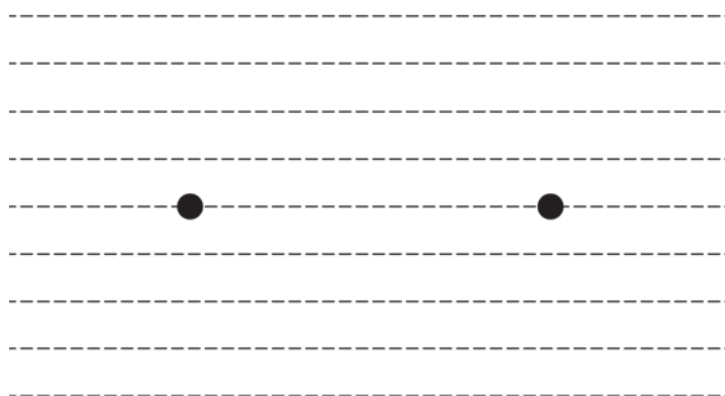
4. (7 points, suggested time 13 minutes)

Two identical spheres are released from a device at time $t = 0$ from the same height H , as shown above. Sphere A has no initial velocity and falls straight down. Sphere B is given an initial horizontal velocity of magnitude v_0 and travels a horizontal distance D before it reaches the ground. The spheres reach the ground at the same time t_f , even though sphere B has more distance to cover before landing. Air resistance is negligible.

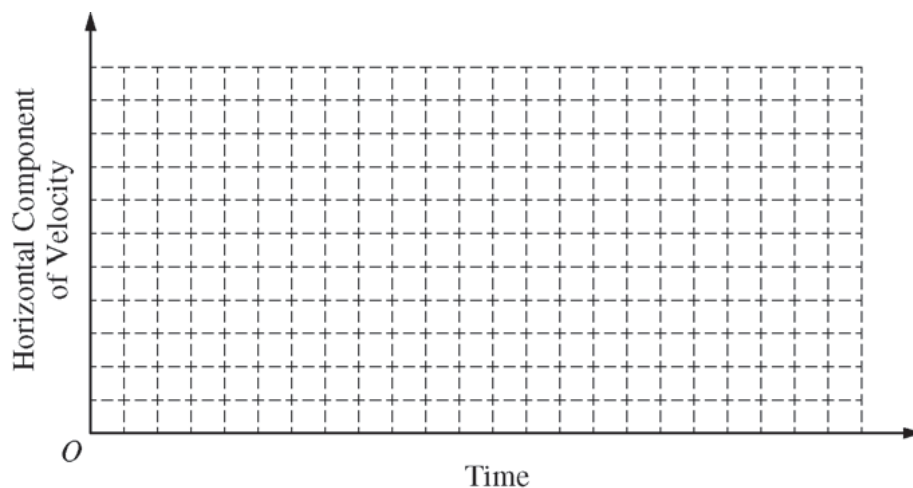
- (a) The dots below represent spheres A and B . Draw a free-body diagram showing and labeling the forces (not components) exerted on each sphere at time $\frac{t_f}{2}$.

Sphere A

Sphere B



- (b) On the axes below, sketch and label a graph of the horizontal component of the velocity of sphere *A* and of sphere *B* as a function of time.



- (c) In a clear, coherent, paragraph-length response, explain why the spheres reach the ground at the same time even though they travel different distances. Include references to your answers to parts (a) and (b).