Week 1

AP Physics 1

Homework bundle for this week

本周作业合集

exercises.lol

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AP Physics 1 Name: ______________________ Score: ______

1. Which of these is a **vector** quantity?

   ☐ mass

   ☐ temperature

   ☐ velocity

   ☐ speed

2. A runner completes exactly one lap of a 400 m track. What is their **displacement**?

   ☐ 400 m

   ☐ 0 m

   ☐ 800 m

   ☐ 200 m

3. On a **position–time** graph, what does the slope of the line represent?

   ☐ acceleration

   ☐ velocity

   ☐ displacement

   ☐ distance

4. A passenger walks at $+2\ \frac{\mathrm{m}}{\mathrm{s}}$ toward the front of a train moving at $+30\ \frac{\mathrm{m}}{\mathrm{s}}$. What is the passenger's velocity relative to the ground, in $\frac{\mathrm{m}}{\mathrm{s}}$?

   ________________ m/s

5. A velocity of $10\ \frac{\mathrm{m}}{\mathrm{s}}$ points $37°$ above the horizontal. Its horizontal component is $10 \cos 37°$. With $\cos 37° = 0.8$, what is v_x in $\frac{\mathrm{m}}{\mathrm{s}}$?

   ________________ m/s

6. A velocity of $-8\ \frac{\mathrm{m}}{\mathrm{s}}$ is slower than a velocity of $+8\ \frac{\mathrm{m}}{\mathrm{s}}$.

   ☐ True ☐ False

7. A cyclist has a displacement of 240 m in 30 s. What is the average velocity, in $\frac{\mathrm{m}}{\mathrm{s}}$?

   ________________ m/s

8. On a **velocity–time** graph, what does the area between the line and the time axis represent?

   ☐ acceleration

   ☐ velocity

☐ displacement

☐ force

9. The same passenger now walks toward the **back** at 2 $\frac{\text{m}}{\text{s}}$. Velocity relative to the ground, in $\frac{\text{m}}{\text{s}}$?

_________________ m/s

10. For the same velocity, the vertical component is $10 \sin 37°$. With $\sin 37° = 0.6$, what is v_y in $\frac{\text{m}}{\text{s}}$?

_________________ m/s

AP Physics 1

1. **velocity**

   Velocity has a size **and** a direction, so it is a vector. Mass, temperature and speed are scalars (size only).

2. 0 **m**

   Displacement is the change in position. The runner ends where they started, so $\Delta x = 0$. The **distance** travelled is 400 m.

3. **velocity**

   Slope is rise over run $= \Delta x / \Delta t$, which is the **velocity**.

4. **32 m/s**

   Same line, same direction: $30 + 2 = 32\ \frac{\mathrm{m}}{\mathrm{s}}$.

5. **8 m/s**

   $v_x = A\cos\theta = 10 \times 0.8 = 8\ \frac{\mathrm{m}}{\mathrm{s}}$.

6. **False**

   Both have the same **speed** ($8\ \frac{\mathrm{m}}{\mathrm{s}}$). The minus sign is a direction, not a smaller size.

7. **8 m/s**

   $v_{\mathrm{avg}} = \dfrac{\Delta x}{\Delta t} = \dfrac{240}{30} = 8\ \frac{\mathrm{m}}{\mathrm{s}}$.

8. **displacement**

   Area $=$ velocity $\times$ time $= \Delta x$, the **displacement**.

9. **28 m/s**

   Now the walk is negative: $30 + (-2) = 28\ \frac{\mathrm{m}}{\mathrm{s}}$.

10. **6 m/s**

    $v_y = A\sin\theta = 10 \times 0.6 = 6\ \frac{\mathrm{m}}{\mathrm{s}}$.

1.1 Scalars and Vectors in One Dimension

Name: ______________ Class: __________ Date: ____________ **Total: 14 marks**

KEY WORDS vector 矢量 • direction 方向 • scalar 标量 • collinear 共线 • origin 原点

Objective

Build the skills to answer exam questions on **scalars and vectors in one dimension** — using signs for direction, choosing a coordinate system, and combining collinear vectors.

You must be able to:

- distinguish a **scalar** 标量 (magnitude only) from a **vector** 矢量 (magnitude **and** direction 方向)
- use a **positive or negative sign** to show a 1-D vector's direction along a chosen axis
- set up a **coordinate system** 坐标系 — an **origin** 原点 and a positive direction
- add and subtract **collinear** 共线 vectors to get a single **resultant** 合矢量

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Scalar or vector?

A **scalar** has size only; a **vector** has size **and** direction. Decide by asking: "does a direction belong to this quantity?"

scalar	vector
distance 距离, speed	displacement 位移, velocity
mass, time, energy	force, acceleration, momentum
temperature	any push or pull with a direction

■ Signs for direction in 1-D

Once you pick a positive direction, a vector along that line is just a **signed number**. Take **east as positive**:

- $+6\ \mathrm{m\ s^{-1}}$ means $6\ \mathrm{m\ s^{-1}}$ east
- $-6\ \mathrm{m\ s^{-1}}$ means $6\ \mathrm{m\ s^{-1}}$ **west** — same speed, opposite direction

The sign is the direction; the magnitude is the number without its sign, $|-6| =$

6 m s^{-1}.

■ **Choosing a coordinate system**

State the **origin** and the **positive direction** *before* putting numbers on anything. A ball starts at the origin, moves +3 m (right), then −8 m (left). Its position is

$$x = (+3) + (-8) = -5 \text{ m},$$

i.e. 5 m to the left of the start.

■ **Adding and subtracting collinear vectors**

Collinear vectors lie on one line, so **add the signed values**. Two forces on a box, right positive: $F_1 = +12$ N, $F_2 = -5$ N.

$$F_{\text{net}} = (+12) + (-5) = +7 \text{ N} \quad \text{(7 N to the right)}.$$

To **subtract** a vector, add its negative: $\vec{A} - \vec{B} = \vec{A} + (-\vec{B})$ — reverse $\vec{B}$, then add.

2 Practice

Now apply the methods above.

2.1 State whether each quantity is a scalar or a vector: (a) temperature, (b) velocity, (c) distance, (d) force. [2]

2.2 Taking **up as positive**, write the signed value of a displacement of 4 m **downward**. [1]

2.3 A drone flies +50 m then −30 m along an east-positive axis. Find its **resultant** displacement, with direction. [2]

2.4 Two collinear forces act on a trolley (right positive): +8 N and −15 N. Find the net force, with direction. [2]

3 Exam-style questions

3.1 Which quantity is a vector? [1]

- **A** distance
- **B** speed
- **C** acceleration
- **D** mass

3.2 A car moves along a straight road. Taking north as positive, its velocity is -25 m s^{-1}. This means the car moves [1]

- **A** at 25 m s^{-1} north
- **B** at 25 m s^{-1} south
- **C** at -25 m s^{-1} north
- **D** with a decreasing speed

3.3 An object on a number line starts at $x = +2$ m and undergoes a displacement of -9 m.

(a) Find its final position. [1]

(b) State how far it is from the origin, and on which side. [1]

3.4 Three collinear forces act at a point, with rightward positive: $+10$ N, -4 N and -2 N.

(a) Calculate the resultant force. [2]

(b) State whether the point is in equilibrium 平衡, and give a reason. [1]

Solutions

2.1 (a) scalar; (b) vector; (c) scalar; (d) vector.

2.2 -4 m.

2.3 $(+50) + (-30) = +20$ m; 20 m east.

2.4 $(+8) + (-15) = -7$ N; 7 N to the left.

3.1 C — acceleration is a vector; the others are scalars.

3.2 B — the sign gives the direction (south), and the speed is $|-25| = 25$ m s^{-1}.

3.3 (a) $x = (+2) + (-9) = -7$ m. (b) 7 m from the origin, on the negative side.

3.4 (a) $(+10) + (-4) + (-2) = +4$ N. (b) No — the resultant is not zero (+4 N), so the point is not in equilibrium.

1.2 Displacement, Velocity, and Acceleration

Name: ______ Class: ______ Date: ______ **Total: 14 marks**

KEY WORDS position 位置 • velocity 速度 • distance 距离 • speed 速率 • displacement 位移

Objective

Build the skills to answer exam questions on **displacement, velocity, and acceleration** — the language of motion along a line.

You must be able to:

- define **position** 位置 and **displacement** 位移 $\Delta x = x_f - x_i$ (a vector)
- find **average velocity** 平均速度 $v_{avg} = \dfrac{\Delta x}{\Delta t}$ and describe **instantaneous velocity** 瞬时速度
- tell **speed** 速率 (scalar) from **velocity** 速度 (vector), and see when their sizes differ
- find **average acceleration** 加速度 $a_{avg} = \dfrac{\Delta v}{\Delta t}$
- decide if an object is **speeding up** or **slowing down** from the signs of v and a

1 Worked examples

Study these first. Each one shows the method for a question type used later.

Displacement vs distance

Displacement is the change in position (a vector); **distance** 距离 is the path length (a scalar). A runner goes +100 m east then −40 m west:

- displacement $= (+100) + (-40) = +60$ m (60 m east)
- distance $= 100 + 40 = 140$ m

Average velocity and acceleration

Use the change over the interval:

$$v_{avg} = \frac{\Delta x}{\Delta t}, \qquad a_{avg} = \frac{\Delta v}{\Delta t}.$$

A car speeds from 8 m s^{-1} to 20 m s^{-1} in 4 s: $a = \dfrac{20-8}{4} = +3$ m s^{-2}.

■ **Speeding up or slowing down**

Compare the **signs** of v and a:

- same sign → speeding up
- opposite signs → slowing down

A ball moving in the + direction with $a = -2\ \mathrm{m\ s^{-2}}$ is slowing down.

2 Practice

2.1 A cyclist rides +300 m then returns −120 m. State (a) the displacement and (b) the distance travelled. [2]

2.2 A car's velocity changes from $+30\ \mathrm{m\ s^{-1}}$ to $+12\ \mathrm{m\ s^{-1}}$ in 6.0 s. Find its average acceleration. [2]

2.3 An object moves in the + direction while its acceleration is $-4\ \mathrm{m\ s^{-2}}$. State whether it is speeding up or slowing down, and why. [2]

2.4 In 5.0 s a train's displacement is +250 m. Find its average velocity. [1]

3 Exam-style questions

3.1 Which pair are **both** vectors? [1]

- **A** speed and distance
- **B** velocity and displacement
- **C** speed and velocity
- **D** distance and displacement

3.2 An object has velocity $-6\ \mathrm{m\ s^{-1}}$ and acceleration $-2\ \mathrm{m\ s^{-2}}$. The object is [1]

- **A** speeding up
- **B** slowing down
- **C** at rest
- **D** moving at constant velocity

3.3 A jogger runs one full lap of a 400 m track, returning to the start, in 100 s.

(a) State the total distance run. [1]

(b) State the magnitude of the displacement. [1]

(c) Hence find the average velocity for the lap. [1]

3.4 A stone's velocity changes from $+5\ \text{m s}^{-1}$ to $-5\ \text{m s}^{-1}$ in 2.0 s.

(a) Find the average acceleration. [1]

(b) Explain why the answer is negative even though the final speed equals the initial speed. [1]

Solutions

2.1 (a) $(+300) + (-120) = +180$ m. (b) $300 + 120 = 420$ m.

2.2 $a = \dfrac{12 - 30}{6.0} = -3.0 \text{ m s}^{-2}$.

2.3 Slowing down — v and a have opposite signs, so the acceleration opposes the motion.

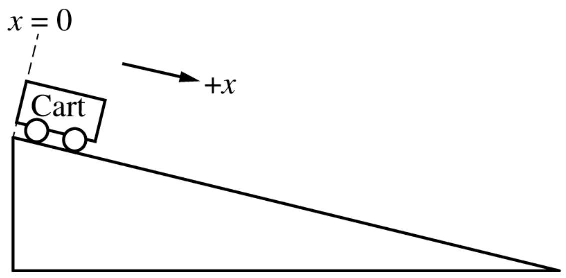
2.4 $v = \dfrac{250}{5.0} = +50 \text{ m s}^{-1}$.

3.1 **B**.

3.2 **A** — v and a have the same sign, so the object speeds up.

3.3 (a) 400 m. (b) 0 m — start and end are the same point. (c) $v_{avg} = 0/100 = 0 \text{ m s}^{-1}$.

3.4 (a) $a = \dfrac{-5 - (+5)}{2.0} = -5.0 \text{ m s}^{-2}$. (b) Velocity is a vector; its direction reversed, so $\Delta v \neq 0$ even though the speed is unchanged.



. (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: ________________

GO ON TO THE NEXT PAGE.

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.

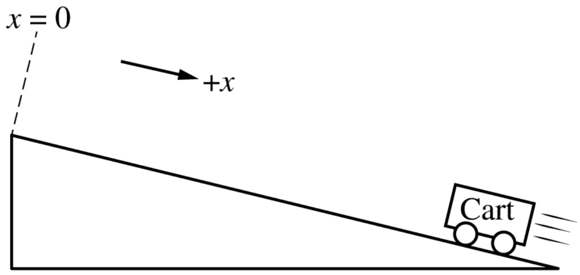
GO ON TO THE NEXT PAGE.

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

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

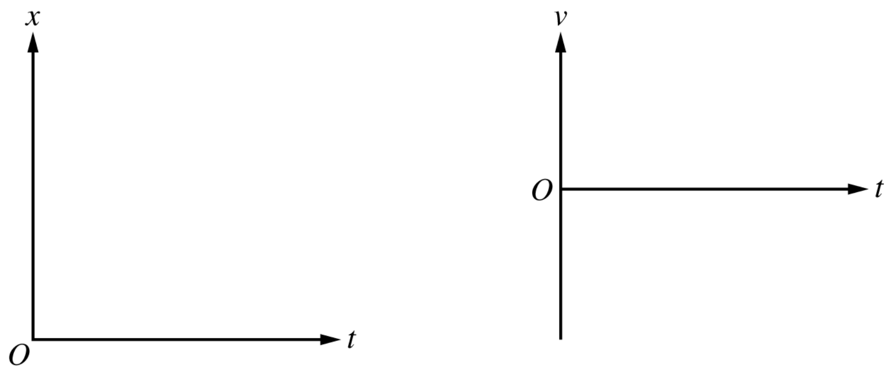
i. What is a physical reason, other than friction or air resistance, that could lead to a significant difference in the experimentally determined value of g_{exp} ?

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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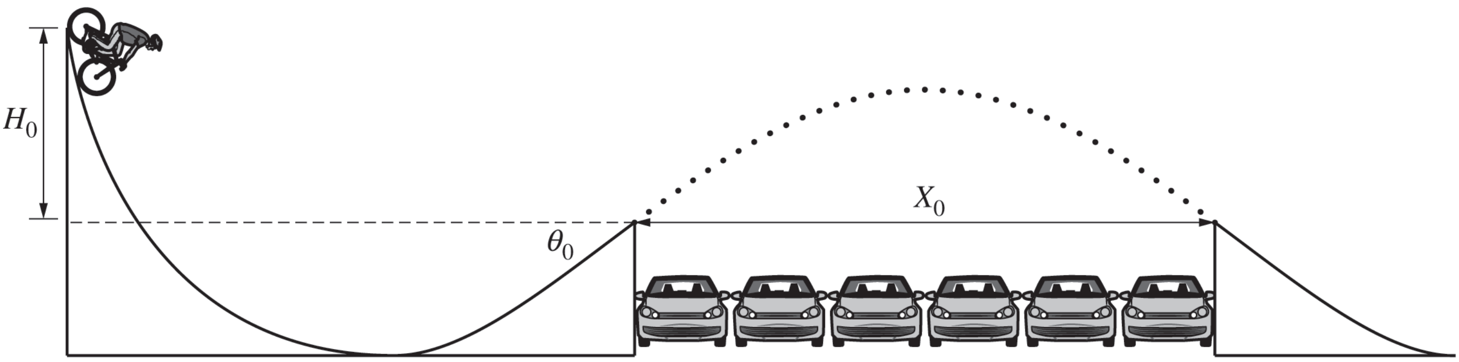
PHYSICS 1

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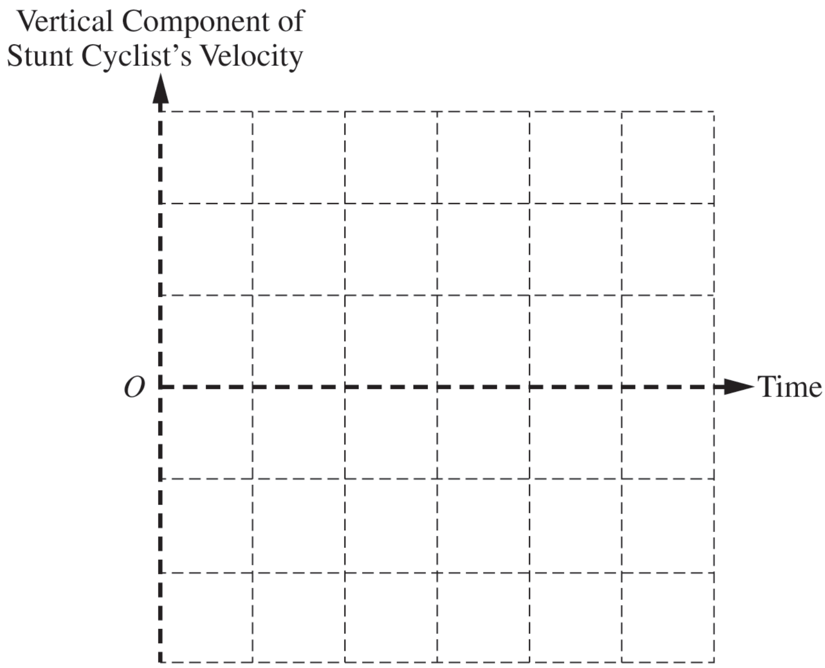
Continue your response to **QUESTION 1** on this page.

(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).

(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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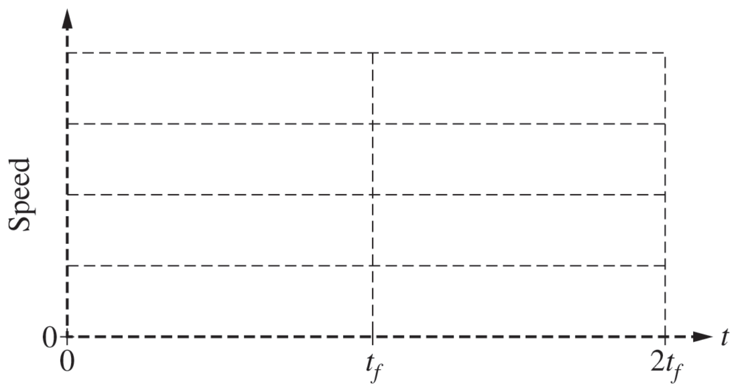
3. (12 points, suggested time 25 minutes)

(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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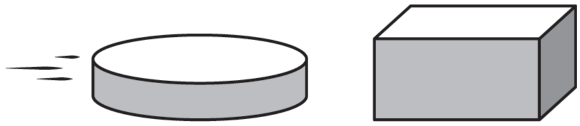

(c) The disk is now moving at a constant speed v_1 on the surface toward a block of mass M_B, which is at rest on the surface, as shown above. The disk and block collide head-on and stick together, and the center of mass of the disk-block system moves with speed v_{cm}.

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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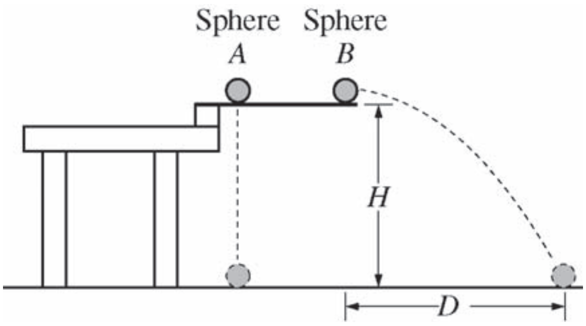
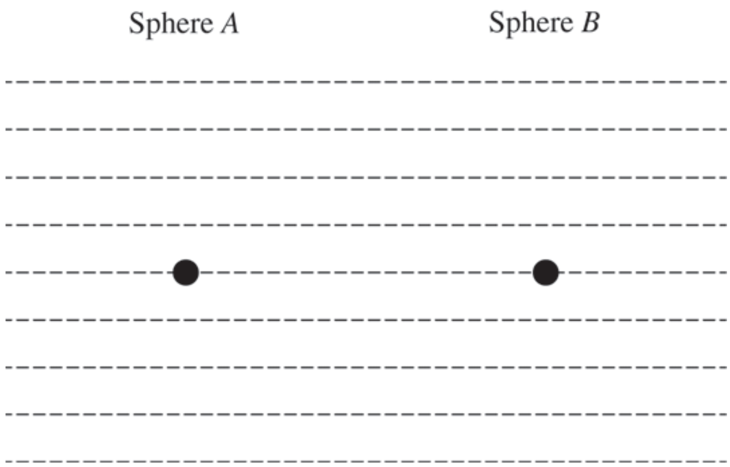


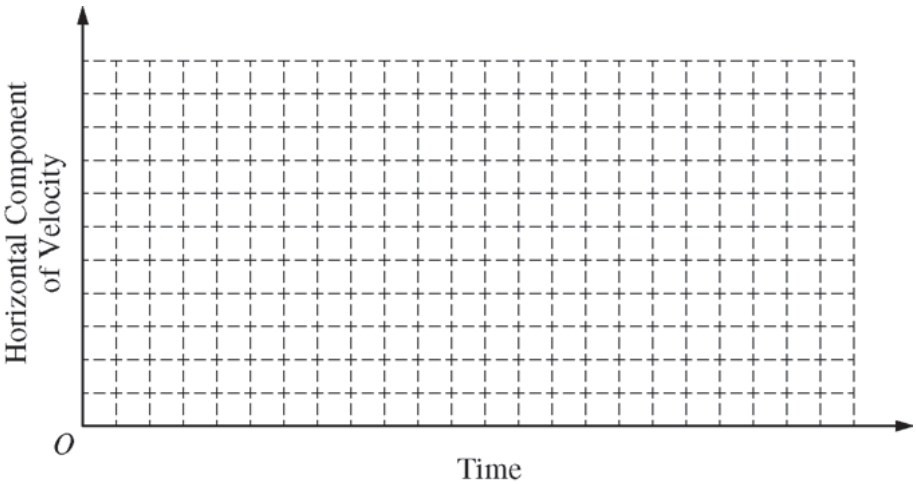
4. (7 points, suggested time 13 minutes)

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 $\frac{t_f}{2}$.



(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).

1.3 Representing Motion

Name: ______________ Class: __________ Date: ____________ **Total: 14 marks**

KEY WORDS slope 斜率 • area 面积 • free fall 自由落体 • kinematic equations 运动学方程 • velocity 速度

Objective

Build the skills to answer exam questions on **representing motion** — motion graphs and the equations for constant acceleration.

You must be able to:

- read **position-time**, **velocity-time**, and **acceleration-time** graphs
- use the **slope** 斜率: slope of an x-t graph = velocity; slope of a v-t graph = acceleration
- use the **area** 面积: area under a v-t graph = displacement; area under an a-t graph = change in velocity
- apply the **kinematic equations** 运动学方程 for constant acceleration
- analyse **free fall** 自由落体 with $g = 9.8$ m s^{-2}

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ The kinematic equations (constant a)

$$v = v_0 + at, \qquad \Delta x = v_0 t + \tfrac{1}{2}at^2,$$

$$v^2 = v_0^2 + 2a\,\Delta x, \qquad \Delta x = \tfrac{1}{2}(v_0 + v)\,t.$$

Choose the one that is **missing the quantity you don't know**.

■ Slopes and areas

On a v-t graph the **slope** is the acceleration and the **area** under the line is the displacement. A line rising from 0 to 12 m s^{-1} over 4.0 s: slope = 3.0 m s^{-2}; area = $\frac{1}{2}(4.0)(12) = 24$ m.

■ Free fall

Take down as positive, so $a = g = 9.8$ m s^{-2}. A ball dropped from rest for 2.0 s: $\Delta x = \frac{1}{2}(9.8)(2.0)^2 = 19.6$ m and $v = 9.8 \times 2.0 = 19.6$ m s^{-1}.

2 Practice

2.1 A car accelerates from rest at 2.0 m s^{-2} for 6.0 s. Find its final velocity. [1]

2.2 For the same car, find the distance it travels in that time. [2]

2.3 On a velocity-time graph, state what (a) the slope and (b) the area under the line represent. [2]

2.4 A stone is dropped from rest. Find its speed after 3.0 s (take $g = 9.8$ m s^{-2}). [1]

3 Exam-style questions

3.1 The area under a velocity-time graph gives the [1]

- **A** acceleration
- **B** displacement
- **C** speed
- **D** jerk

3.2 A ball is thrown straight up. At its highest point, its [1]

- **A** velocity and acceleration are both zero
- **B** velocity is zero and acceleration is 9.8 m s^{-2} downward
- **C** velocity is maximum and acceleration is zero
- **D** velocity and acceleration both point up

3.3 A car travelling at 25 m s^{-1} brakes to rest in a distance of 50 m.

(a) Find its acceleration. [2]

(b) Find the time it takes to stop. [1]

3.4 A ball is thrown vertically upward at 20 m s^{-1} (take $g = 10$ m s^{-2}).

(a) Find the time to reach the top. [1]

(b) Find the maximum height reached. [2]

Solutions

2.1 $v = 0 + 2.0(6.0) = 12 \text{ m s}^{-1}$.

2.2 $\Delta x = \frac{1}{2}(2.0)(6.0)^2 = 36$ m.

2.3 (a) acceleration; (b) displacement.

2.4 $v = 9.8(3.0) = 29.4 \text{ m s}^{-1}$.

3.1 **B**.

3.2 **B** — the speed is zero at the top but gravity still acts downward.

3.3 (a) $v^2 = v_0^2 + 2a\,\Delta x \Rightarrow 0 = 25^2 + 2a(50)$, so $a = -6.25 \text{ m s}^{-2}$. (b) $t = \dfrac{0 - 25}{-6.25} = 4.0$ s.

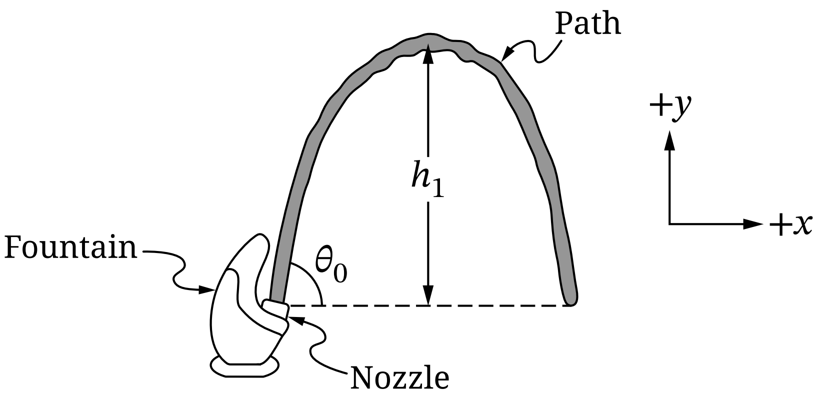
3.4 (a) $t = \dfrac{20}{10} = 2.0$ s. (b) $h = \dfrac{v_0^2}{2g} = \dfrac{20^2}{20} = 20$ m.

Question 1: Version J

1. Water exits the nozzle of a fountain at an angle θ_0 above the horizontal.

At time $t = 0$, a droplet of water exits the nozzle and follows the path shown in Figure 1. The droplet reaches a maximum height h_1 above the nozzle.

Figure 1



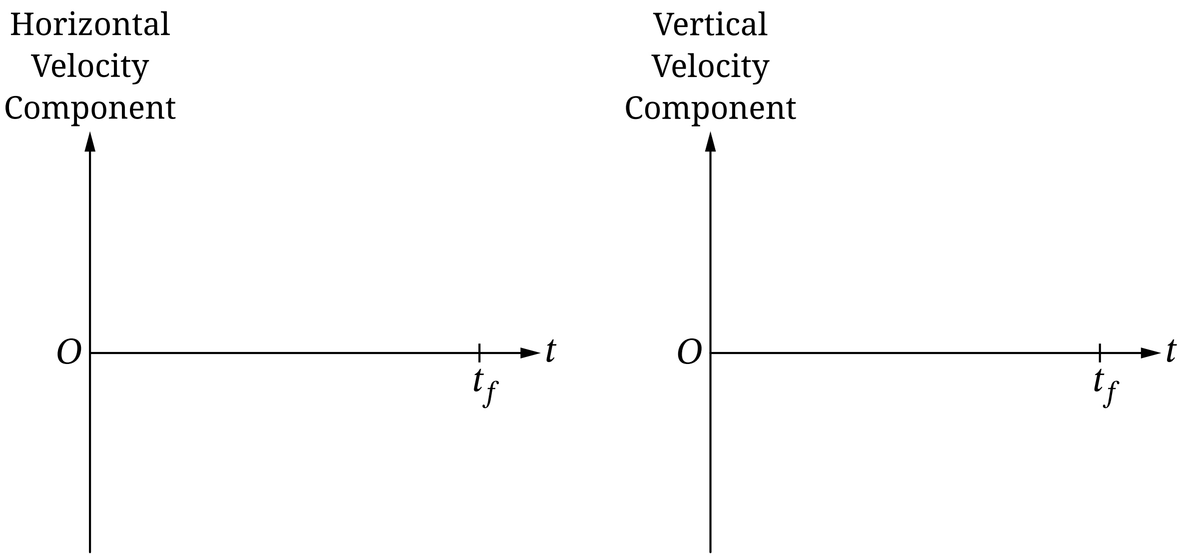
Note: Figure not drawn to scale.

At $t = t_f$, the droplet returns to the same height at which the droplet exited the nozzle.

Part A

i. On the axes shown in Figure 2, **sketch** graphs of the horizontal and vertical components of the velocity of the water droplet as functions of t from $t = 0$ to $t = t_f$.

Figure 2



ii. **Derive** an expression for the speed of the water exiting the nozzle. Express your final answer in terms of θ_0, h_1, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

iii. The nozzle has a circular cross-section with radius r_0. **Derive** an expression for the volume flow rate of the water exiting the nozzle. Express your final answer in terms of θ_0, h_1, r_0, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

Part B

The fountain nozzle is replaced with a new nozzle with a radius smaller than r_0. The water exits the new nozzle at the same angle θ_0 above the horizontal. The volume flow rate of the water exiting the new nozzle is equal to the volume flow rate of the water exiting the original nozzle. A water droplet exiting the new nozzle reaches a maximum height h_2 above the nozzle.

Indicate whether h_2 is greater than, less than, or equal to h_1 by writing one of the following.

- $h_2 > h_1$
- $h_2 < h_1$
- $h_2 = h_1$

Justify your answer. In your justification, include qualitative reasoning beyond mathematical derivations or expressions.

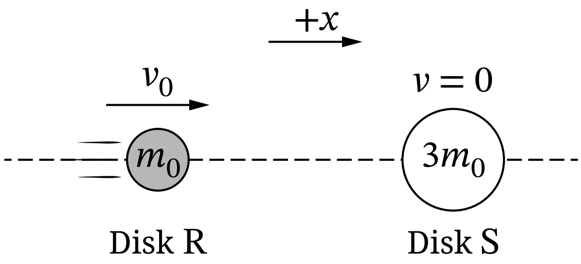
Question 2: Version J

2. Two small disks, R and S, are on a straight, horizontal track.

At time $t = 0$, Disk R of mass m_0 is located at position $x = 0$. Disk R is initially moving with speed v_0 in the $+x$-direction. Disk S of mass $3m_0$ is initially at rest, as shown in the top view in Figure 1. Frictional forces are negligible.

At $t = t_1$, the disks collide. Immediately after the collision, Disk R moves with speed $\frac{1}{2}v_0$ in the $-x$-direction.

Figure 1



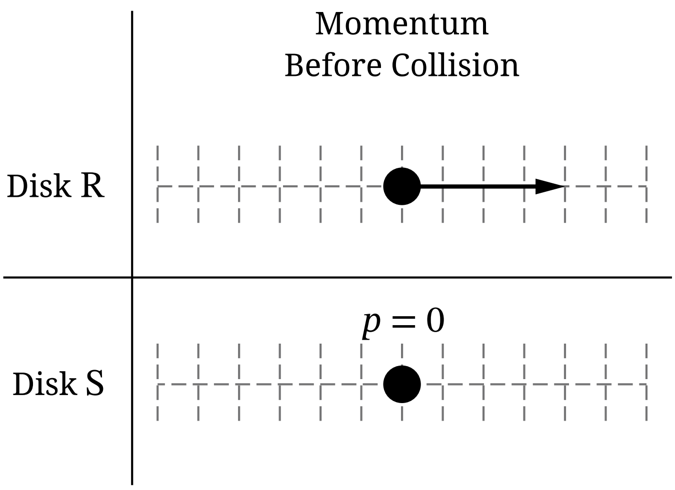
Top View

Note: Figure not drawn to scale.

Part A

The momentum-vector diagram in Figure 2 represents the momentums of Disk R and Disk S before the collision.

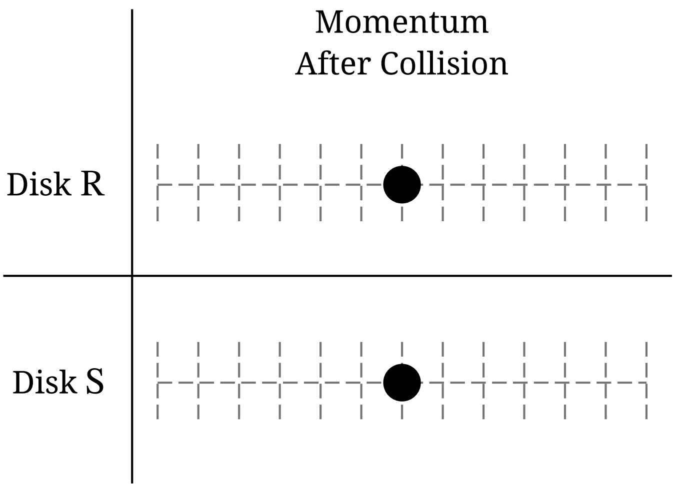
Figure 2



Draw arrows on Figure 3 to represent the momentum vectors of Disk R and Disk S after the collision.

- Each arrow must start on, and point away from, each dot.
- If the momentum of either disk is zero, write "$p = 0$" next to the dot.
- Draw the length of each arrow to represent the magnitude of each momentum, consistent with the scale used in Figure 2.

Figure 3



Part B

Starting with conservation of linear momentum, **derive** an expression for the kinetic energy of Disk S immediately after the collision. Express your final answer in terms of m_0, v_0, and physical constants, as appropriate. Begin your derivation by writing the fundamental physics principle or an equation from the reference information.

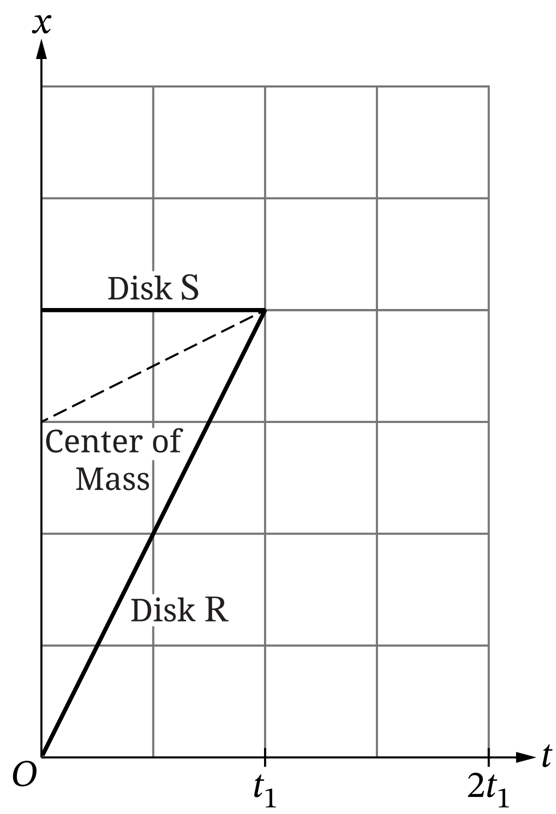
Part C

The graph shown in Figure 4 represents the positions x as functions of time t from $t = 0$ until $t = t_1$ for each of the following:

- Disk R
- Disk S
- The center of mass of the two-disk system

On the graph shown in Figure 4, **draw** three lines that represent the positions x of Disk R, Disk S, and the center of mass of the two-disk system as functions of t from $t = t_1$ to $t = 2t_1$. Distinctly **label** each line.

Figure 4



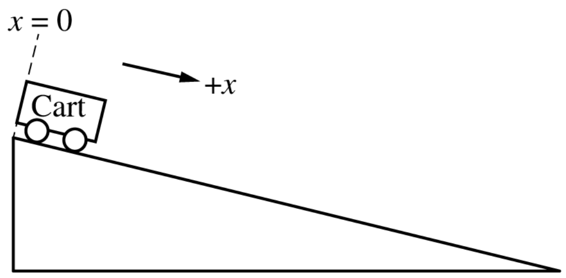
Part D

During the collision, the magnitudes of the changes in momentum of Disk R and Disk S are $|\Delta p_R|$ and $|\Delta p_S|$, respectively.

Indicate whether $|\Delta p_R|$ is greater than, less than, or equal to $|\Delta p_S|$ by writing one of the following.

- $|\Delta p_R| > |\Delta p_S|$
- $|\Delta p_R| < |\Delta p_S|$
- $|\Delta p_R| = |\Delta p_S|$

Briefly **justify** your response by referencing a fundamental physics principle.



. (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: ________________

GO ON TO THE NEXT PAGE.

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.

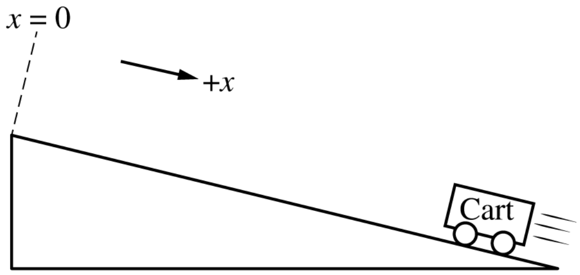
GO ON TO THE NEXT PAGE.

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

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

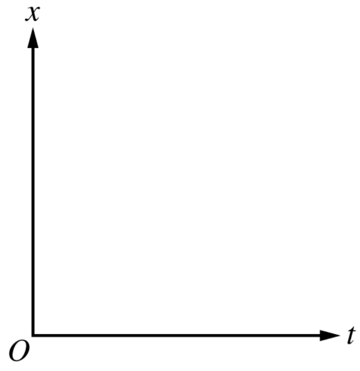
i. What is a physical reason, other than friction or air resistance, that could lead to a significant difference in the experimentally determined value of g_{exp} ?

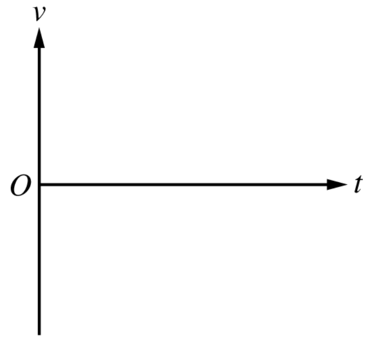
ii. Briefly explain how the physical reason you identified in part (c)(i) would lead to the decrease in the experimentally determined value of g_{exp} .



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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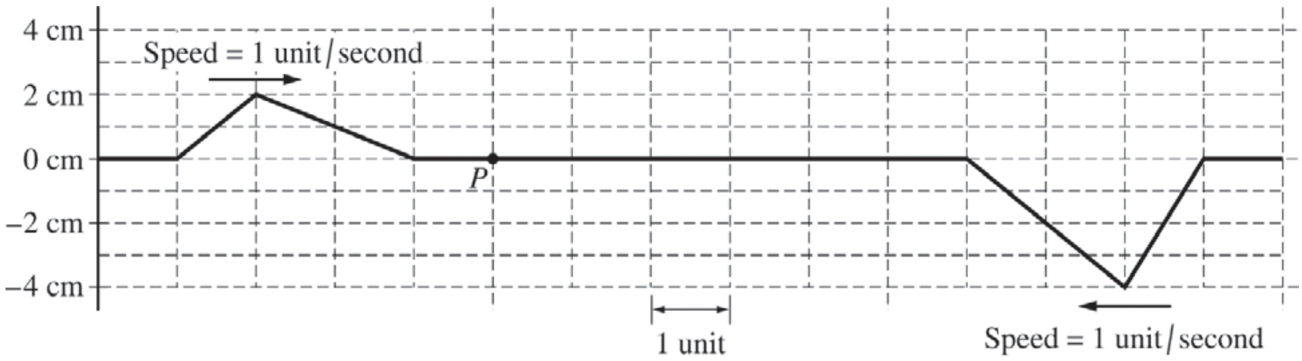
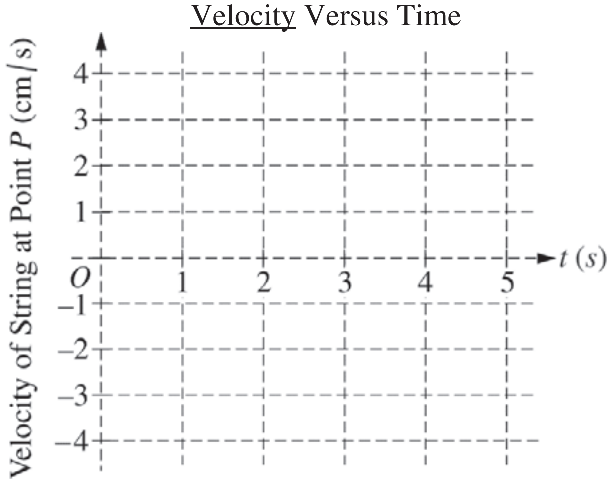


5. (7 points, suggested time 13 minutes)

Two wave pulses are traveling in opposite directions on a string. The shape of the string at $t = 0$ is shown above. Each pulse is moving with a speed of one unit per second in the direction indicated.

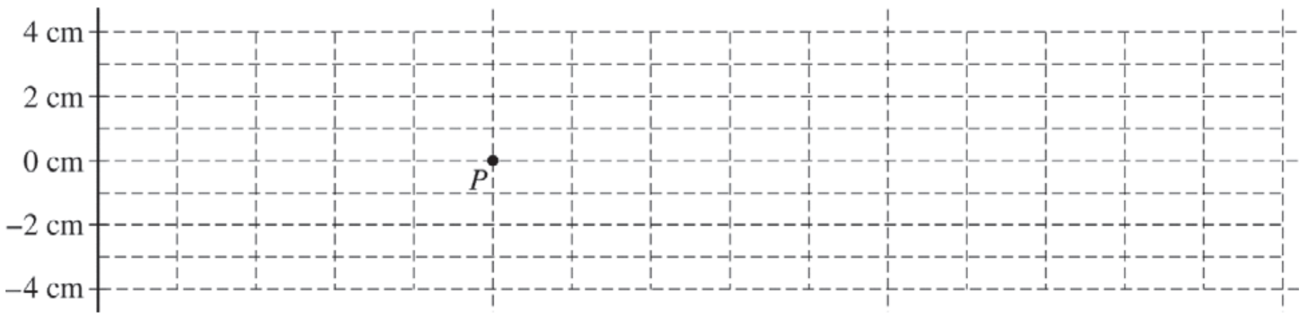
(a) Between time $t = 0$ and $t = 5$ seconds, the entire left-hand pulse approaches and moves beyond point P on the string. On the coordinate axes below, plot the velocity of the piece of string located at point P as a function of time between $t = 0$ and $t = 5$ seconds.

Velocity Versus Time

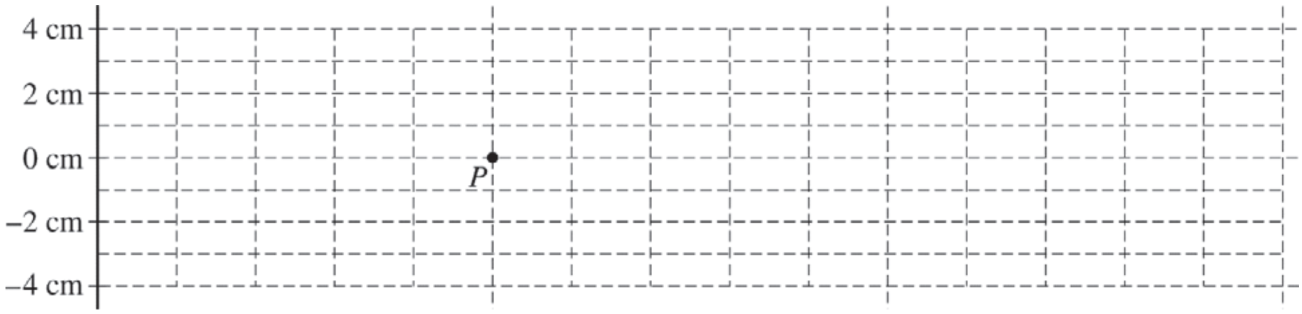


(b) At $t = 5$ s, the pulses completely overlap. On the grid provided below, sketch the shape of the entire string at $t = 5$ s.

Note: Do any scratch (practice) work on the grids on the following page. You will only be graded for the sketch made on the grid on this page.

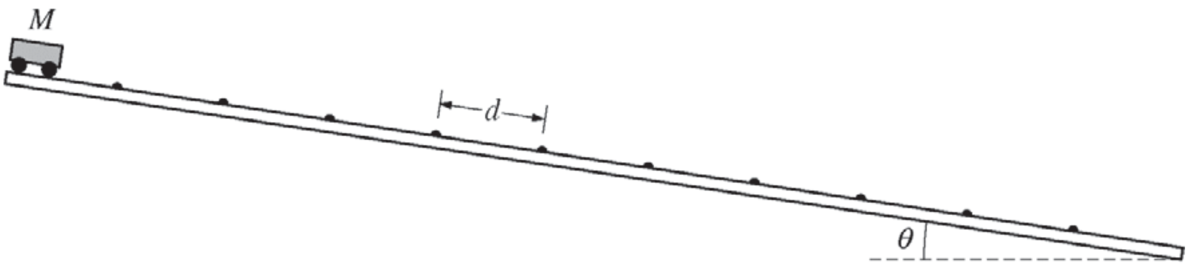


The grids below are provided for scratch work only. Sketches made below will NOT be graded.



STOP

END OF EXAM



Note: Figure not drawn to scale.

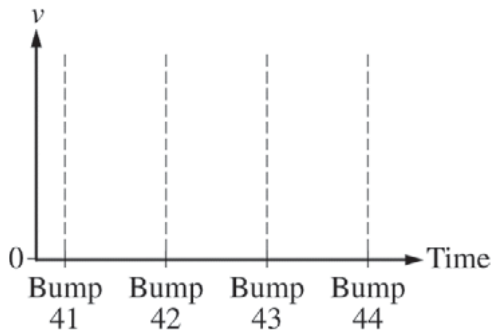
3. (12 points, suggested time 25 minutes)

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.

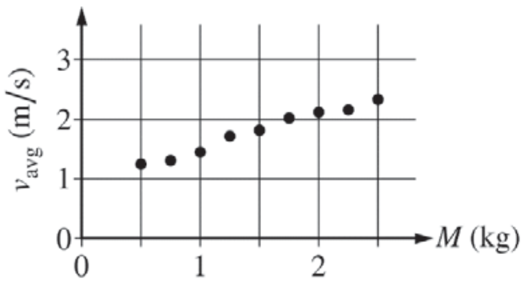
(c) With the bumps returned to the original spacing, the track is tilted to a greater ramp angle θ. Is the maximum speed of the cart greater than, less than, or the same as it was when the ramp angle was smaller?

____ Greater than ____ Less than ____ The same as

Briefly explain your reasoning.

(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: $v_{\text{avg}} = C\dfrac{Mg\sin\theta}{d}$, 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.

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.

1.4 Reference Frames and Relative Motion

Name: ____________ Class: ________ Date: __________ **Total: 10 marks**

KEY WORDS reference frame 参考系 • inertial reference frame 惯性参考系 • relative motion 相对运动 • velocity 速度 • acceleration 加速度

Objective

Build the skills to answer exam questions on **reference frames and relative motion**.

You must be able to:

- define a **reference frame 参考系** as the coordinate system an observer measures from
- explain that **displacement** and **velocity** depend on the observer's reference frame
- use **vector addition** to find a velocity relative to a different frame
- explain that **acceleration** is the same in all **inertial reference frames 惯性参考系**

1 Worked examples

Study these first. Each one shows the method for a question type used later.

Relative velocity in one dimension

The velocity of A relative to C is $v_{A/C} = v_{A/B} + v_{B/C}$. A passenger walks at $+2$ m s^{-1} on a train moving at $+30$ m s^{-1}: relative to the ground the passenger moves at $+32$ m s^{-1}.

Reversing a subscript

$v_{A/B} = -v_{B/A}$. If the train moves at $+30$ m s^{-1} relative to the ground, the ground moves at -30 m s^{-1} relative to the train.

The same acceleration in every inertial frame

Two observers moving at constant velocity relative to each other measure **different velocities** but the **same acceleration** — a constant relative velocity adds a constant, and the rate of change of a constant is zero.

2 Practice

2.1 A boat moves at $+4.0$ m s^{-1} relative to the water; the water flows at $+1.0$ m s^{-1} relative to the bank. Find the boat's velocity relative to the bank. [1]

2.2 A car moves at $+20$ m s^{-1} relative to the road. Find the road's velocity relative to the car. [1]

2.3 Two cars drive directly toward each other, each at 15 m s^{-1} relative to the road. Find the velocity of one car relative to the other. [2]

2.4 Explain why two observers in different inertial frames measure the same acceleration for one object. [2]

3 Exam-style questions

3.1 Quantities that depend on the reference frame include [1]

- **A** velocity but not acceleration
- **B** acceleration but not velocity
- **C** both velocity and acceleration
- **D** neither velocity nor acceleration

3.2 A person walks at 1.5 m s^{-1} toward the back of a bus moving forward at 12 m s^{-1}. The person's velocity relative to the ground is [1]

- **A** 13.5 m s^{-1} forward
- **B** 10.5 m s^{-1} forward
- **C** 1.5 m s^{-1} backward
- **D** 12 m s^{-1} forward

3.3 A plane flies at 200 m s^{-1} east relative to the air. A wind blows relative to the ground.

(a) Find the plane's ground velocity if the wind blows at 30 m s^{-1} east. [1]

(b) State its ground velocity if the wind instead blows 30 m s^{-1} west. [1]

Solutions

2.1 $+4.0 + 1.0 = +5.0$ m s^{-1}.

2.2 -20 m s^{-1}.

2.3 Take one car as $+15$ and the other as -15; relative velocity $= (+15) - (-15) = 30$ m s^{-1}, closing.

2.4 Their relative velocity is constant, so their measured velocities differ by a constant amount; the rate of change of velocity — the acceleration — is therefore the same.

3.1 **A**.

3.2 **B** — $12 + (-1.5) = 10.5$ m s^{-1} forward.

3.3 (a) $200 + 30 = 230$ m s^{-1} east. (b) $200 - 30 = 170$ m s^{-1} east.

AP PHYSICS 1 • EXERCISE SHEET

1.5 Vectors and Motion in Two Dimensions

Name: ______________ Class: __________ Date: ____________ **Total: 12 marks**

KEY WORDS components 分量 • projectile's 抛体 • range 射程 • independent 相互独立 • resultant 合矢量

Objective

Build the skills to answer exam questions on **vectors and motion in two dimensions** — components and projectile motion.

You must be able to:

- resolve a 2-D vector into perpendicular **components 分量** with $A_x = A\cos\theta$, $A_y = A\sin\theta$
- add vectors by combining components to find the **resultant 合矢量** (magnitude and direction)
- explain that a **projectile's 抛体** horizontal and vertical motions are **independent 相互独立**
- analyse projectile motion by applying the kinematic equations separately to x and y
- find the **range 射程**, maximum height, and time of flight

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ Resolving a vector

A force $A = 50$ N at 30° above the horizontal:

$$A_x = 50\cos 30° = 43 \text{ N}, \qquad A_y = 50\sin 30° = 25 \text{ N}.$$

■ Independence of projectile motion

Horizontal motion is constant velocity, $v_x = v_0\cos\theta$; vertical motion is free fall, $a_y = -g$. The two directions share only the **time**.

■ A projectile launched horizontally

A ball leaves a 20 m high table at 5.0 m s^{-1} (take $g = 10$ m s^{-2}). Time to fall: $20 = \frac{1}{2}(10)t^2 \Rightarrow t = 2.0$ s. Horizontal range $= 5.0 \times 2.0 = 10$ m.

2 Practice

2.1 A force of 80 N acts at 60° above the horizontal. Find its horizontal and vertical components. [2]

2.2 A ball rolls off a bench 1.25 m high at 3.0 m s^{-1} (take $g = 10$ m s^{-2}). Find the time to land. [2]

2.3 Hence find how far from the base of the bench the ball lands. [1]

2.4 State what the horizontal and vertical motions of a projectile have in common. [1]

3 Exam-style questions

3.1 For a projectile (ignore air resistance), the horizontal component of velocity [1]

- **A** increases
- **B** decreases
- **C** stays constant
- **D** is zero

3.2 At the top of its path, a projectile's vertical velocity is [1]

- **A** maximum
- **B** zero
- **C** equal to its horizontal velocity
- **D** equal to g

3.3 A stone is thrown at 20 m s^{-1} at 30° above the horizontal (take $g = 10$ m s^{-2}).

(a) Find the initial vertical velocity component. [1]

(b) Find the time to reach the top of the path. [1]

(c) Find the maximum height. [2]

Solutions

2.1 $A_x = 80\cos 60° = 40$ N; $A_y = 80\sin 60° = 69$ N.

2.2 $1.25 = \frac{1}{2}(10)t^2 \Rightarrow t^2 = 0.25$, $t = 0.50$ s.

2.3 $x = 3.0 \times 0.50 = 1.5$ m.

2.4 the time of flight (both motions last the same time).

3.1 **C**.

3.2 **B**.

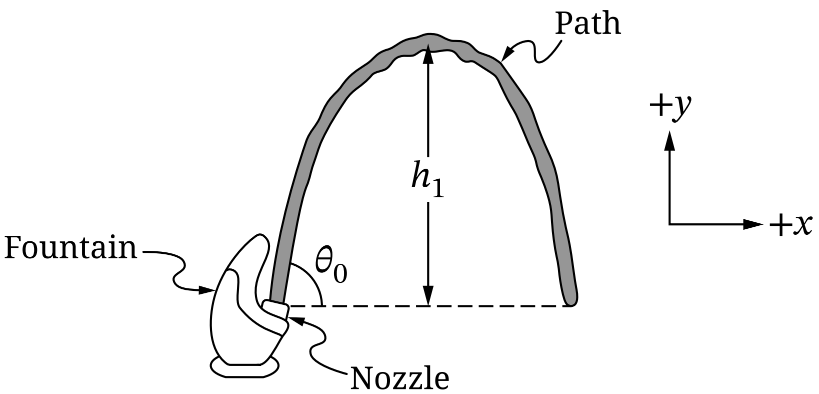
3.3 (a) $v_{0y} = 20\sin 30° = 10$ m s^{-1}. (b) $t = 10/10 = 1.0$ s. (c) $h = \dfrac{v_{0y}^2}{2g} = \dfrac{10^2}{20} = 5.0$ m.

Question 1: Version J

1. Water exits the nozzle of a fountain at an angle θ_0 above the horizontal.

At time $t = 0$, a droplet of water exits the nozzle and follows the path shown in Figure 1. The droplet reaches a maximum height h_1 above the nozzle.

Figure 1



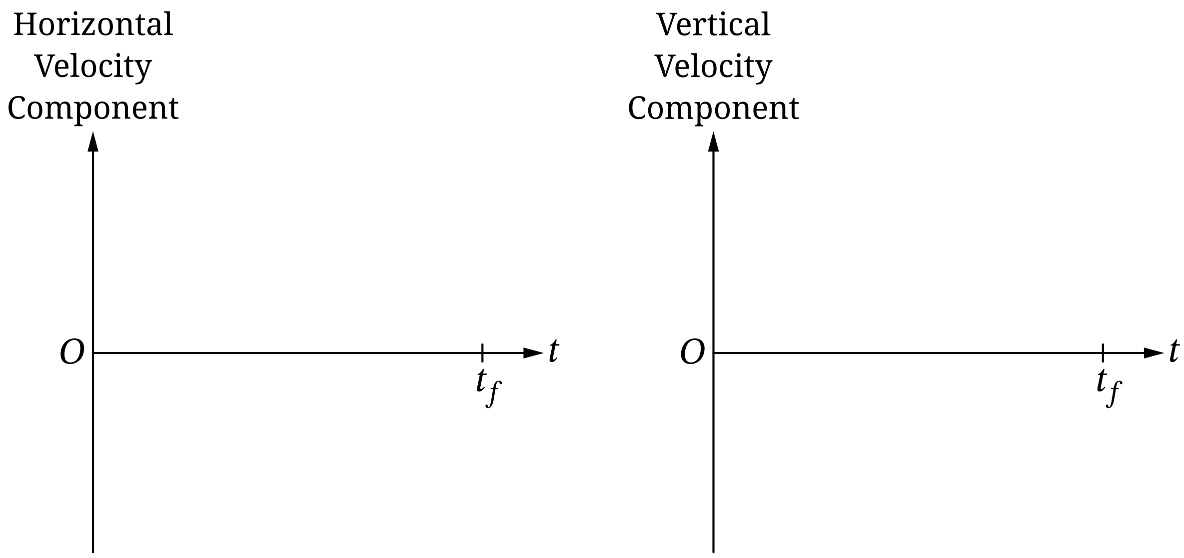
Note: Figure not drawn to scale.

At $t = t_f$, the droplet returns to the same height at which the droplet exited the nozzle.

Part A

i. On the axes shown in Figure 2, **sketch** graphs of the horizontal and vertical components of the velocity of the water droplet as functions of t from $t = 0$ to $t = t_f$.

Figure 2



ii. **Derive** an expression for the speed of the water exiting the nozzle. Express your final answer in terms of θ_0, h_1, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

iii. The nozzle has a circular cross-section with radius r_0. **Derive** an expression for the volume flow rate of the water exiting the nozzle. Express your final answer in terms of θ_0, h_1, r_0, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

Part B

The fountain nozzle is replaced with a new nozzle with a radius smaller than r_0. The water exits the new nozzle at the same angle θ_0 above the horizontal. The volume flow rate of the water exiting the new nozzle is equal to the volume flow rate of the water exiting the original nozzle. A water droplet exiting the new nozzle reaches a maximum height h_2 above the nozzle.

Indicate whether h_2 is greater than, less than, or equal to h_1 by writing one of the following.

- $h_2 > h_1$
- $h_2 < h_1$
- $h_2 = h_1$

Justify your answer. In your justification, include qualitative reasoning beyond mathematical derivations or expressions.

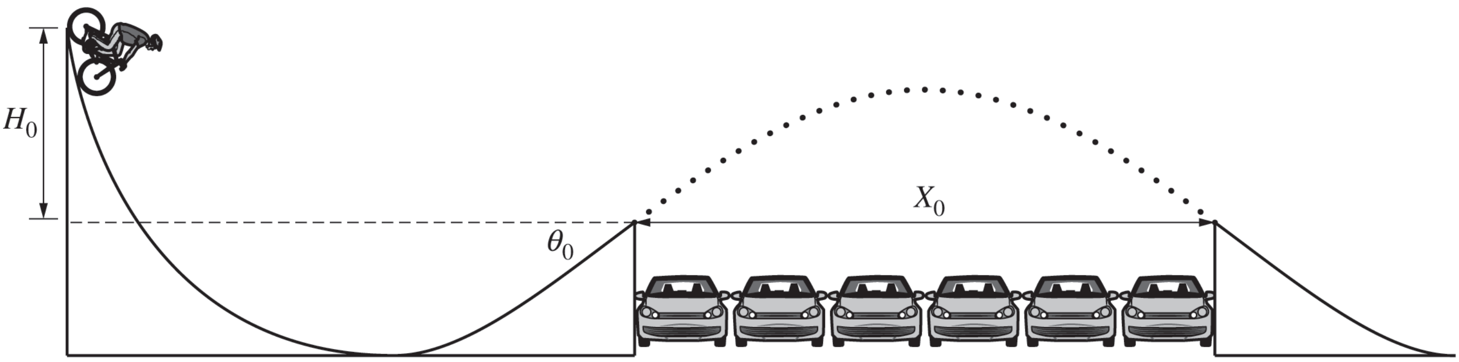
PHYSICS 1

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.

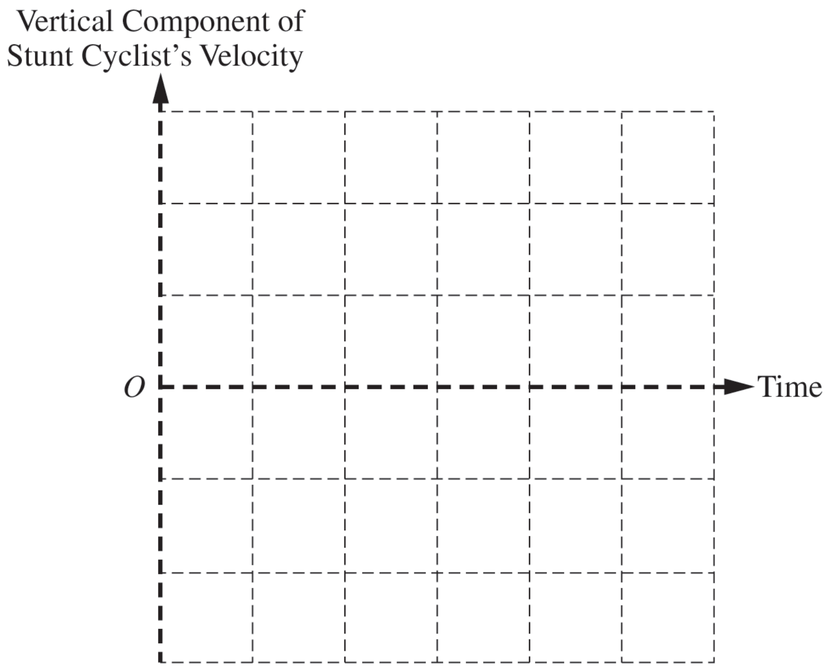
H_0 is the vertical distance between the top of the first ramp and the launch point.
θ_0 is the angle of the ramp at the launch point from the horizontal.
X_0 is the horizontal distance traveled while the cyclist and bicycle are in the air.
m_0 is the combined mass of the stunt cyclist and bicycle.

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

GO ON TO THE NEXT 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).

(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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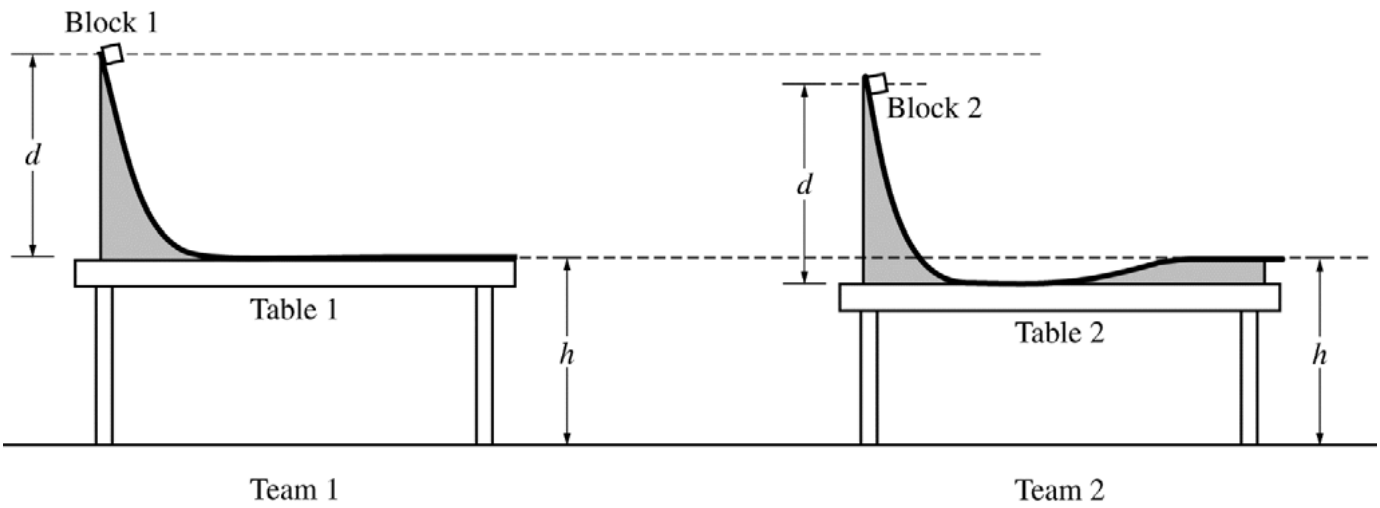


4. (7 points, suggested time 13 minutes)

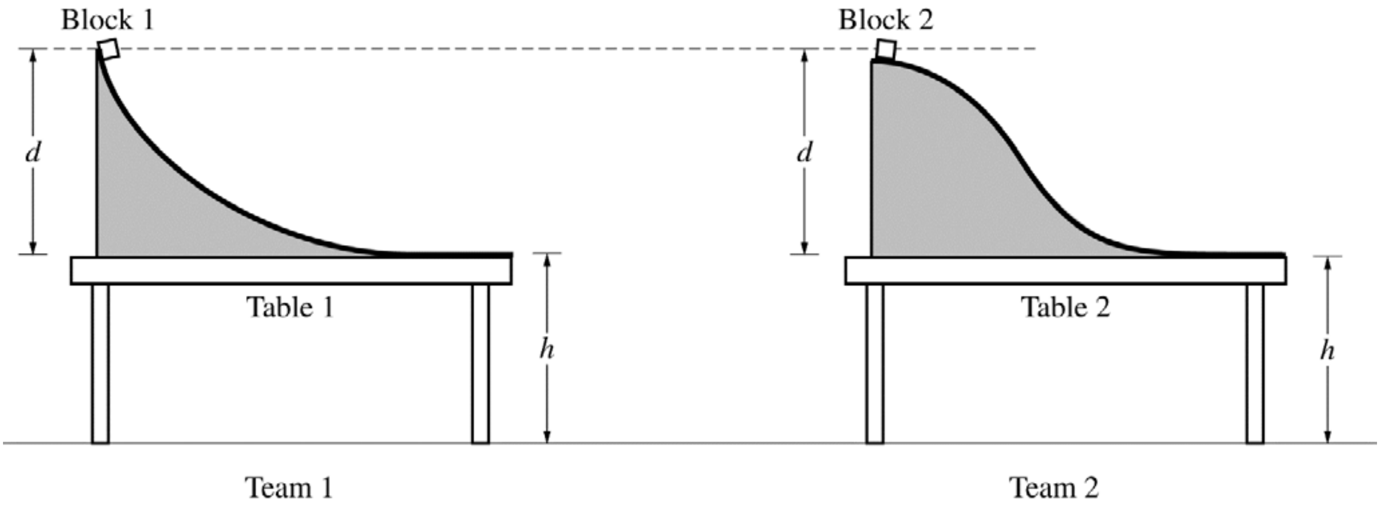
A physics class is asked to design a low-friction slide that will launch a block horizontally from the top of a lab table. Teams 1 and 2 assemble the slides shown above and use identical blocks 1 and 2, respectively. Both slides start at the same height d above the tabletop. However, team 2's table is lower than team 1's table. To compensate for the lower table, team 2 constructs the right end of the slide to rise above the tabletop so that the block leaves the slide horizontally at the same height h above the floor as does team 1's block (see figure above).

(a) Both blocks are released from rest at the top of their respective slides. Do block 1 and block 2 land the same distance from their respective tables?

____ Yes ____ No

Justify your answer.

In another experiment, teams 1 and 2 use tables and low-friction slides with the same height. However, the two slides have different shapes, as shown below.



(b) Both blocks are released from rest at the top of their respective slides at the same time.

i. Which block, if either, lands farther from its respective table?

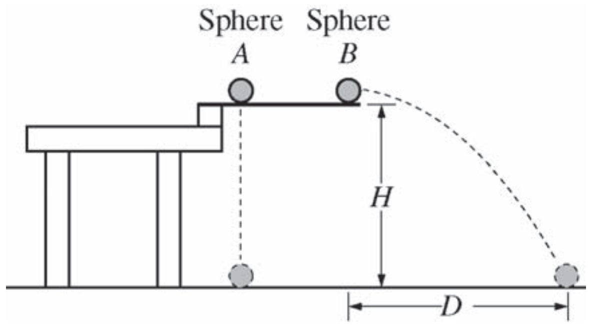
____ Block 1 ____ Block 2 ____ The two blocks land the same distance from their respective tables.

Briefly explain your reasoning without manipulating equations.

ii. Which block, if either, hits the floor first?

____ Block 1 ____ Block 2 ____ The two blocks hit the floor at the same time.

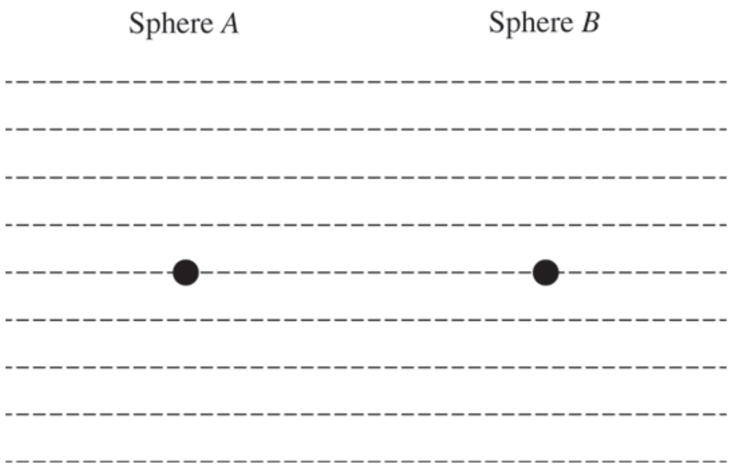
Briefly explain your reasoning without manipulating equations.



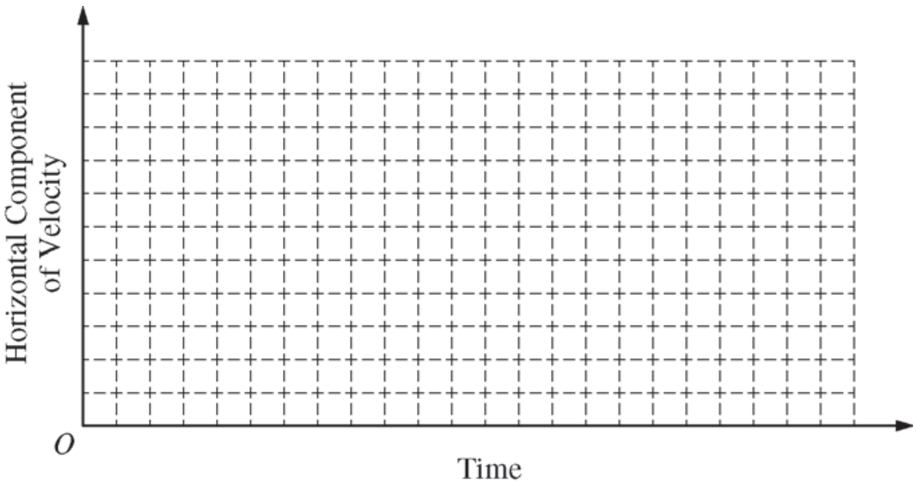
4. (7 points, suggested time 13 minutes)

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 $\frac{t_f}{2}$.



(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).