2026

AP

AP® Physics 1: Algebra-Based

Free-Response Questions

PHYSICS 1

SECTION II

TIME – 1 HOUR AND 40 MINUTES

Directions:

Section II has 4 questions and lasts 1 hour and 40 minutes.

You may use the available paper for scratch work and planning, but only work written in the free-response booklet will be scored. Any work done on scratch paper will not be scored. Label parts (e.g., A, B, C) and sub-parts (e.g., i, ii, iii) as needed. Use a pencil or a pen with black or dark blue ink to write your responses.

A calculator is allowed in this section, as well as a ruler and straightedge. You may use a handheld four-function, scientific, or graphing calculator, or the calculator available in this application. Reference information, including lists of equations, can be used throughout the exam. A digital version is available in this application.

All final numerical answers should include appropriate units when applicable. Credit for your work depends on demonstrating that you know which physical principles to apply in a particular situation. Credit will be awarded only for work that is clearly designated as the solution to a specific part of a question. Credit also depends on the quality of your solutions and explanations. Therefore, you should show your work for each part in the space provided for that part. If you need more space, be sure to clearly indicate where you continue your work. When constructing a graph or diagram, use only one color of ink or pencil.

You may pace yourself as you answer the questions in this section, or you may use these optional timing recommendations:

It is suggested that you spend about 25 minutes each on Questions 1 and 3, about 30 minutes on Question 2, and about 20 minutes on Question 4.

You can go back and forth between questions in this section until time expires. The clock will turn red when 5 minutes remain—**the proctor will not give you any time updates or warnings.**

Note: This exam was originally administered digitally. It is presented here in a format optimized for teacher and student use in the classroom.

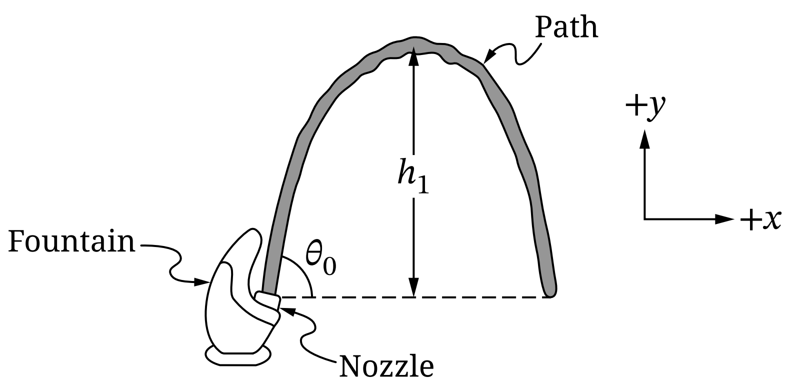
During the AP Exam administration, students have access to reference information. To see the reference information for this course, please visit AP Central: https://apcentral.collegeboard.org/exam-administration-ordering-scores/administering-exams/subject-specific/reference-information

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



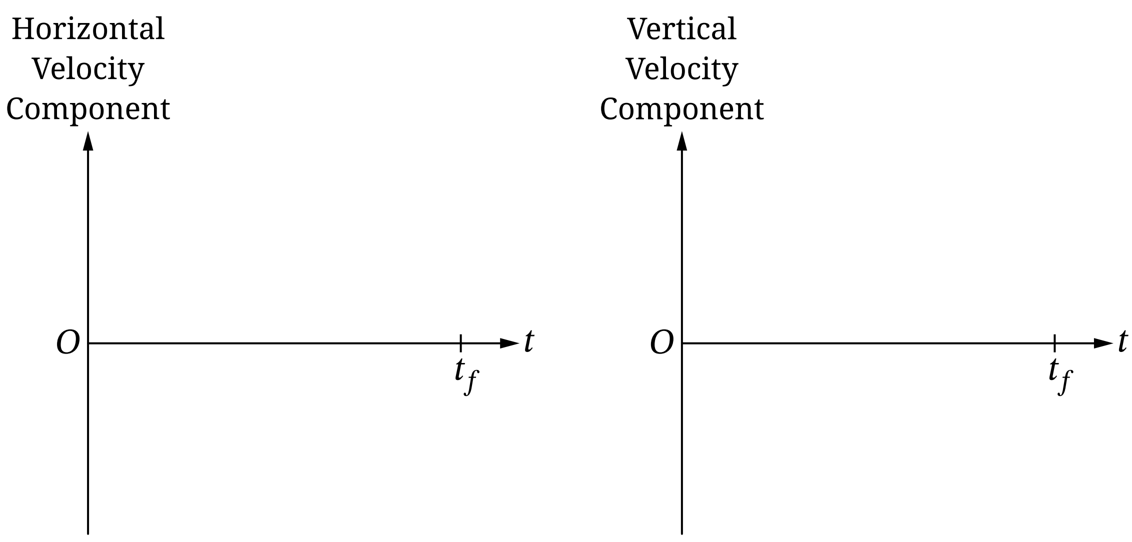
Note: Figure not drawn to scale.

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.

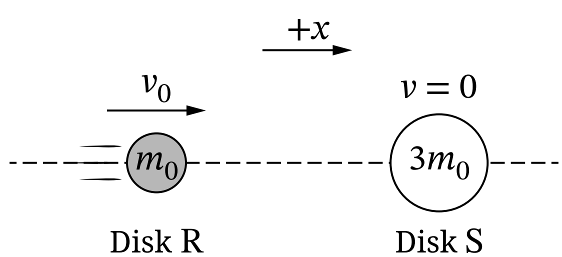
Question 2: Version J

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



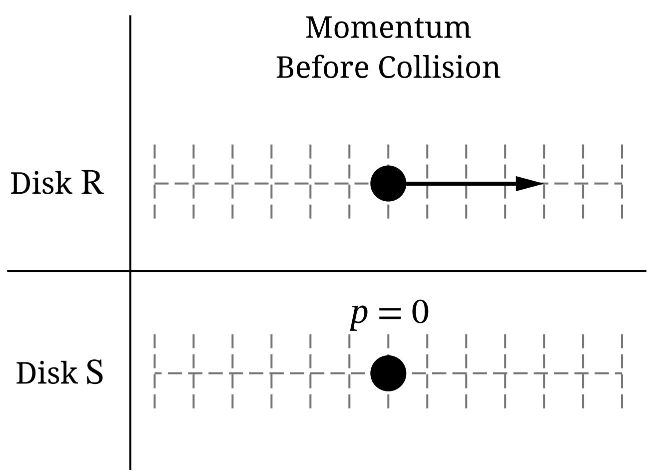
Top View

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.

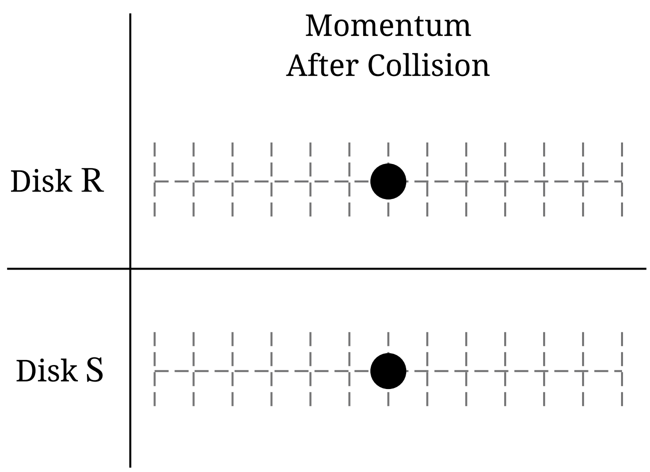
Figure 2



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.

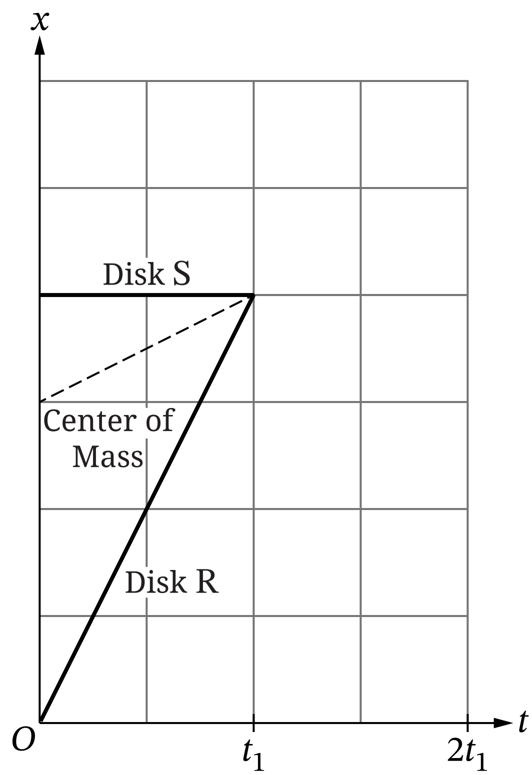
Part C

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.

Question 3: Version J

The following information applies to parts A and B.

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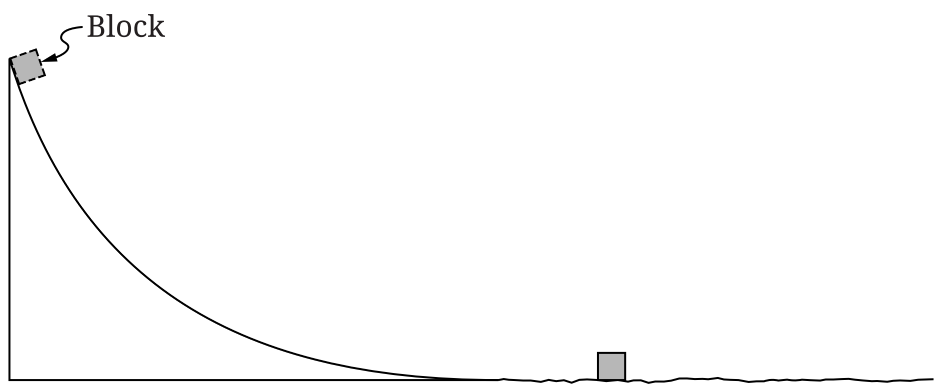
3. A group of students are investigating friction using the following procedure. The students release a block of unknown mass near the top of a curved ramp. The block slides down the ramp. The block then transitions to a horizontal surface, as shown in Figure 1. Frictional forces are negligible between the block and the curved ramp, but there is friction between the block and the horizontal surface.

Figure 1



The students are asked to perform an experiment in which a single quantity is varied in order to collect data that could be graphed to determine the value μ_k of the coefficient of kinetic friction between the block and the horizontal surface. The students have access to only a meterstick.

Part A

i. **Indicate** quantities that could be measured by the students that would allow them to determine μ_k using a linear graph.

ii. Briefly **describe** a method to reduce experimental uncertainty for the measured quantities.

Part B

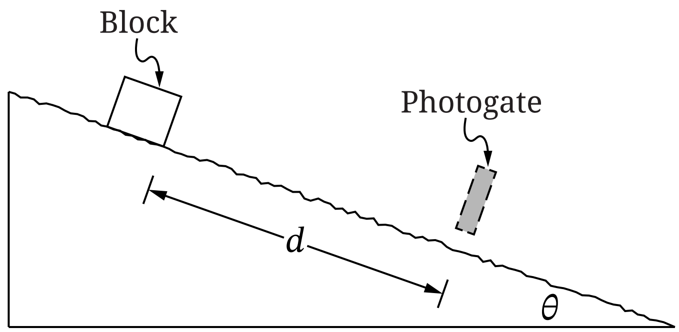
i. **Indicate** what quantities the students could graph on the horizontal and vertical axes to create a linear graph that can be used to determine μ_k. Clearly state which quantity will be graphed on each axis.

ii. Briefly **describe** the relationship between μ_k and a feature of the graph from part B (i). Your answer may include an equation that relates μ_k and the chosen feature of the graph.

The following information applies to parts C and D.

In a different experiment, the students release a block from rest on a rough ramp. The block is released a distance d from a photogate. The ramp is inclined at an angle θ above the horizontal, as shown in Figure 2. The block slides down the ramp and passes through the photogate, which is positioned near the bottom of the ramp. The photogate determines the speed v of the block as it passes through the photogate. The unknown coefficient of kinetic friction between the block and the ramp is μ_k.

Figure 2



The experiment is repeated several times with different release distances d for the same block. Table 1 shows the measured values of d and v.

Table 1

d (m)	v (m/s)
0.20	0.29
0.30	0.38
0.40	0.41
0.50	0.49
0.60	0.52

The students correctly determine that the relationship between d and v is given by

$$v^2 = [2g(\sin\theta - \mu_k \cos\theta)]d,$$

where $\theta = 30^\circ$. The students want to determine μ_k. The students create a graph with d plotted on the horizontal axis.

Part C

i. **Label** the vertical axis of Figure 3 with a measured or calculated quantity. Include units, as appropriate. The graphed quantities should yield a linear graph that can be used to determine μ_k.

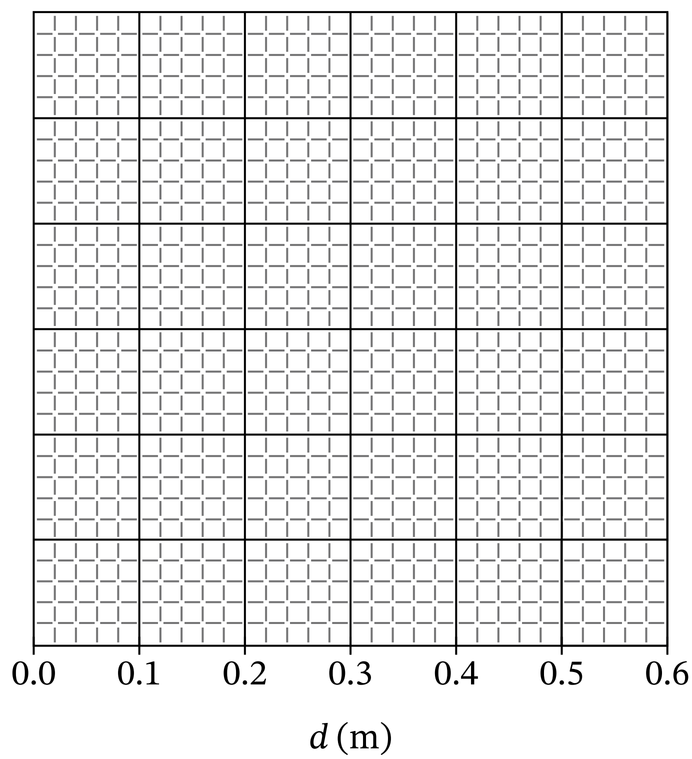
ii. On the grid provided in Figure 3, create a graph that can be used to determine μ_k.

- Clearly **label** the vertical axis with a numerical scale.
- **Plot** the corresponding data points on the grid.
- Table 2 is provided in your booklet for scratch work and will not be scored.

Figure 3

Quantity (units, if appropriate)

__________ __________



iii. **Draw** a best-fit line for the data plotted in part C (ii).

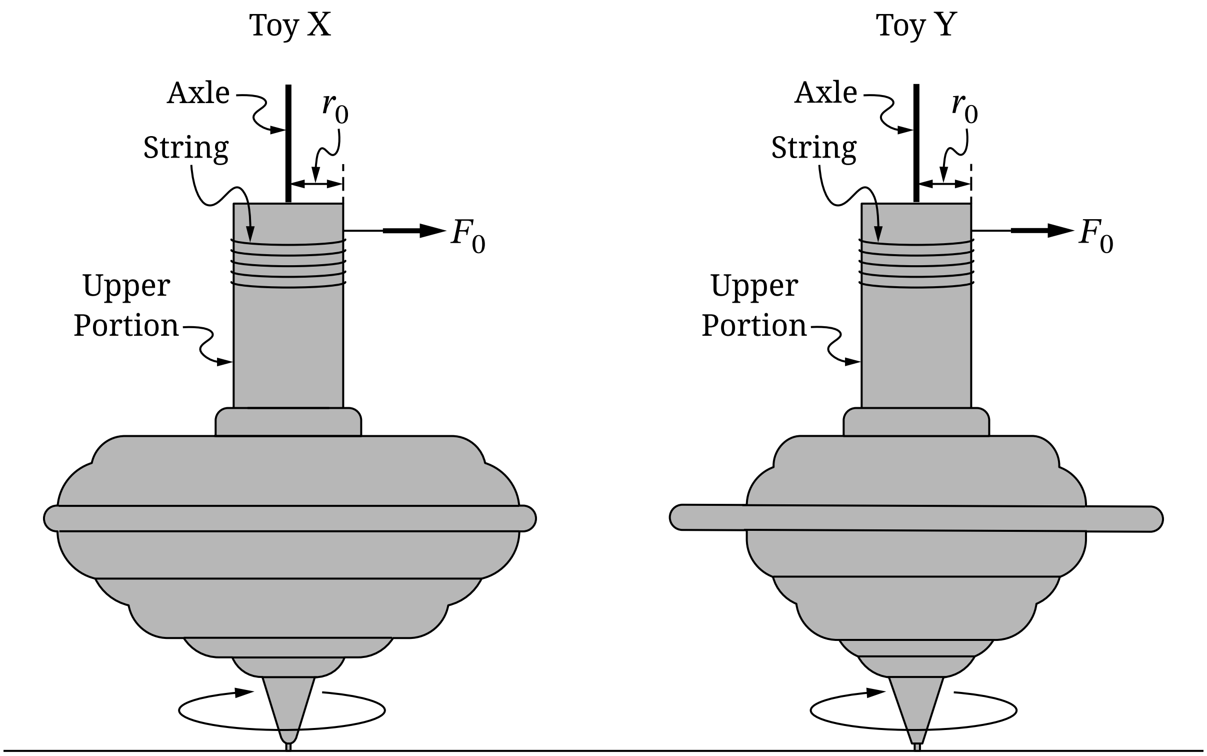
Part D

Using the best-fit line that you drew in part C (iii), **calculate** an experimental value for μ_k.

Question 4

4. Toys X and Y are free to rotate with negligible friction about a vertical axle through the center of each toy. The upper portion of each toy has a radius r_0, as shown in the side view in Figure 1. A string of length ℓ_0 is completely wrapped around the upper portion of each toy. The rotational inertia of Toy X is I_X, and the rotational inertia of Toy Y is $I_Y = \frac{1}{2} I_X$.

Figure 1



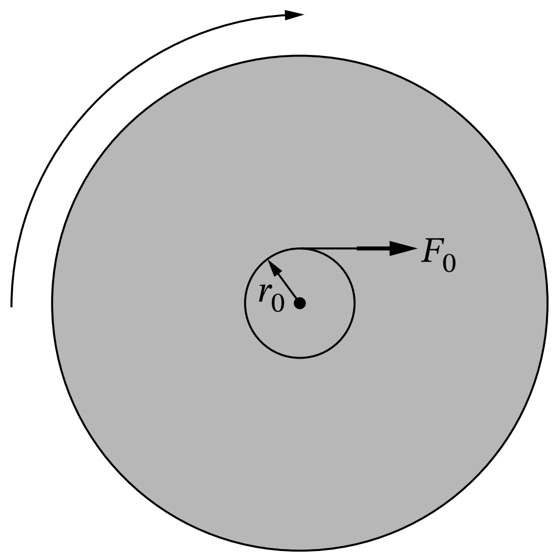
Side View

Toys X and Y are initially at rest. A constant horizontal force of magnitude F_0 is then exerted on the string of each toy, which causes the toys to rotate, as shown in the overhead view in Figure 2. The axles of the toys remain vertical as the force is exerted on the strings. The strings do not slip as the force is exerted on the strings.

When the string loses contact with the axle of Toy X, the angular speed of Toy X is ω_X.

When the string loses contact with the axle of Toy Y, the angular speed of Toy Y is ω_Y.

Figure 2



Overhead View

Part A

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

- $\omega_Y > \omega_X$
- $\omega_Y < \omega_X$
- $\omega_Y = \omega_X$

Justify your answer using qualitative reasoning beyond referencing equations.

Part B

Starting with the work-energy theorem or Newton's second law in rotational form, **derive** an expression for the angular speed ω_X of Toy X at the instant the string loses contact with the axle. Express your final answer in terms of ℓ_0, I_X, F_0, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

Part C

Justify how your derived equation in part B is or is not consistent with your reasoning in part A.

STOP

END OF EXAM