Past-paper walk-through

Representing Motion ▪ 1.3

eXercise

Questions in this set

- 2026 Q1
- 2026 Q2
- 2023 Q2
- 2017 Q5
- 2016 Q3

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 1

2026 ▪ Q1

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: Side-view diagram of a fountain. A curved gray arc labeled "Path" rises from the nozzle to a peak and comes back down. A vertical double-headed arrow labeled h_1 marks the height from the dashed horizontal line at the nozzle up to the peak of the path. At the base, "Fountain" labels the fountain body, "Nozzle" labels the opening, and the angle θ_0 is marked between the nozzle direction and the dashed horizontal line. A small coordinate axis to the right shows $+y$ (up) and $+x$ (right). Note: Figure not drawn to scale.]
At $t = t_f$, the droplet returns to the same height at which the droplet exited the nozzle.

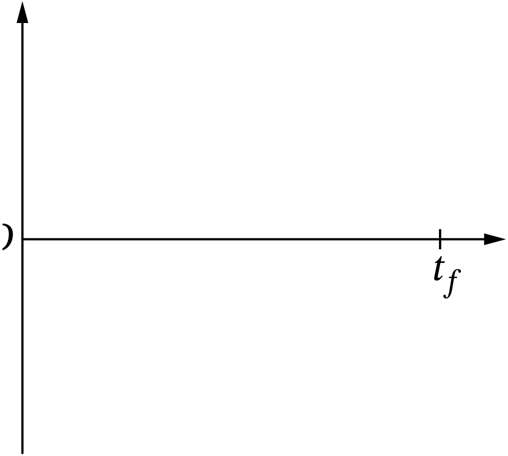
Question 1

(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: Two blank coordinate-axis grids side by side for sketching. Left graph: y-axis labeled "Horizontal Velocity Component", x-axis labeled t with origin O and a tick mark at t_f. Right graph: y-axis labeled "Vertical Velocity Component", x-axis labeled t with origin O and a tick mark at t_f. Both axes have arrows indicating positive directions upward and to the right, and each also extends slightly below the horizontal axis.]
(a)(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.
(a)(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

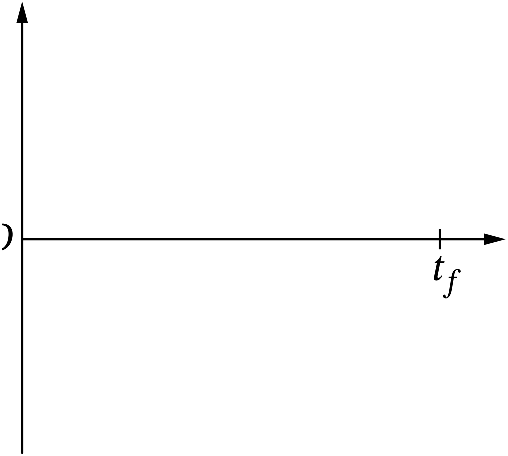
Question 1

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.

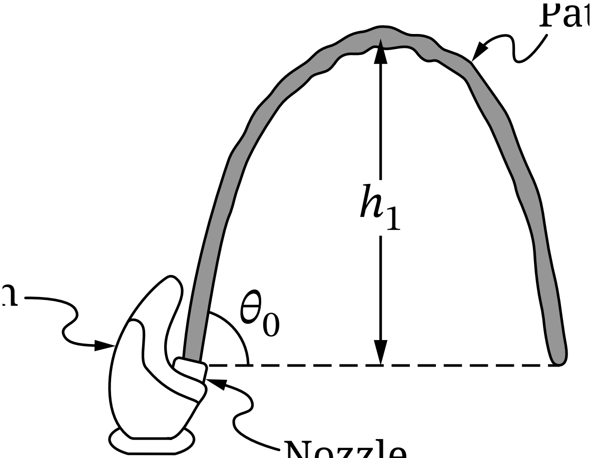
Question 1



Question 1



Question 1



Question 1

2026 ▪ Q1

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

(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

Question 1

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

2026 ▪ Q2

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): A horizontal dashed track with two disks. On the left, a smaller shaded disk labeled m_0 ("Disk R") has an arrow above it labeled v_0 pointing right (in the $+x$-direction, with a $+x$ axis arrow shown above). On the right, a larger open disk labeled $3m_0$ ("Disk S") is labeled $v = 0$ above it. Note: Figure not drawn to scale.]

Question 2

(a) The momentum-vector diagram in Figure 2 represents the momentums of Disk R and Disk S before the collision.
[Figure 2: Two rows, each with a horizontal dashed number-line-style axis (light vertical tick marks along it) crossing a vertical axis at a central dot. Top row labeled "Disk R": a solid arrow starts at the central dot and points right, labeled with the heading "Momentum Before Collision" above both rows. Bottom row labeled "Disk S": just a dot with no arrow, labeled "$p = 0$" above it.]
Draw arrows on Figure 3 to represent the momentum vectors of Disk R and Disk S after the collision.

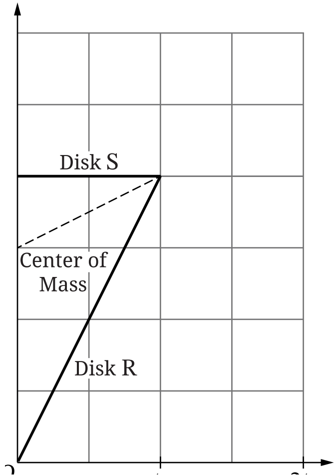
- Each arrow must start on, and point away from, each dot.
- If the momentum of either disk is zero, write "$p = 0$" next to the dot.

Question 2

- Draw the length of each arrow to represent the magnitude of each momentum, consistent with the scale used in Figure 2.

[Figure 3: Same style as Figure 2 but blank — two rows each with a horizontal dashed axis and a central dot, headed "Momentum After Collision", one row labeled "Disk R" and one row labeled "Disk S", for the student to draw arrows on.]

Question 2



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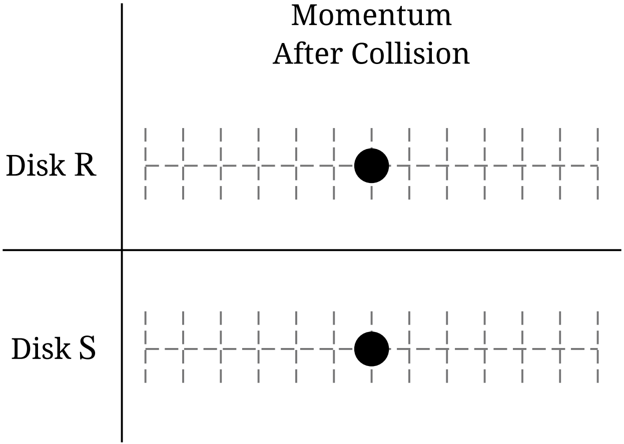

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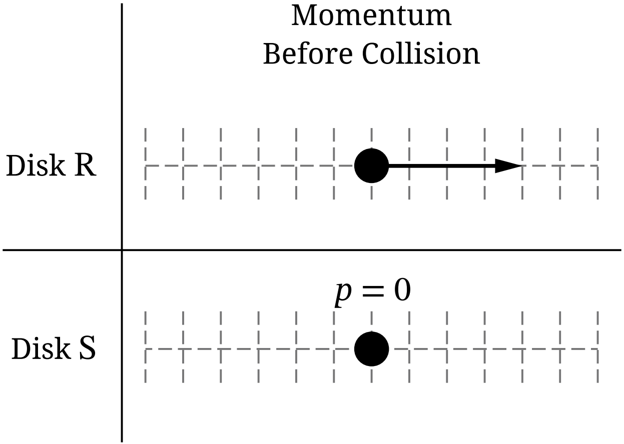

Question 2

2026 ▪ Q2

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(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

Question 2

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.

Question 2

2026 ▪ Q2

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(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:

Question 2

- 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: A position (x, vertical axis) vs. time (t, horizontal axis) grid. From $t = 0$ to $t = t_1$, three straight lines rise from the origin O: the steepest line (largest slope) is labeled "Disk S", a shallower line is labeled "Center of Mass" (shown as a dashed line), and the shallowest line is labeled "Disk R". The horizontal axis is marked with tick values t_1 and $2t_1$ (blank beyond t_1 for the student to continue the lines).]

Question 2

2026 ▪ Q2

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(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.

Question 2

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 2

2023 ▪ Q2

[Figure: A cart on an inclined ramp. The ramp rises from lower right to upper left. At the top of the ramp, the origin $x = 0$ is marked with a small cart icon, and an arrow labeled $+x$ points down the incline (down and to the right) indicating the positive x-direction along the ramp's surface.]

Students conduct an experiment to determine the acceleration a of a cart. The cart is released from rest 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

Question 2

(a)(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: ____________________

(a)(ii) [Continuation of Question 2.] 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.

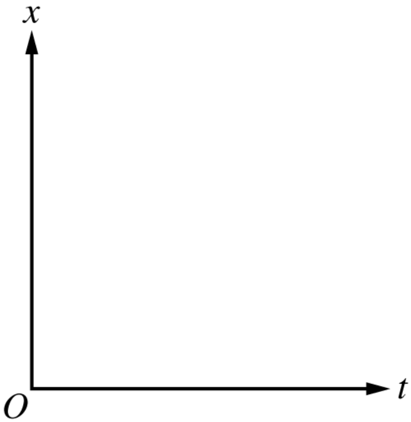
[Blank labeled grid for plotting, approximately 20 columns by 15 rows of light gridlines, no axes pre-drawn or pre-labeled.]

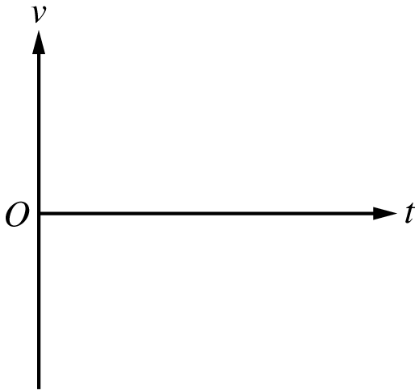
Question 2

(a)(iii) 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.

Question 2

Question 2





Question 2