Past-paper walk-through

Representing Motion ▪ 1.3

eXercise

Questions in this set

- 2023 Set 2 Q1
- 2019 Set 1 Q1
- 2019 Set 2 Q2
- 2018 Q1
- 2015 Q1

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

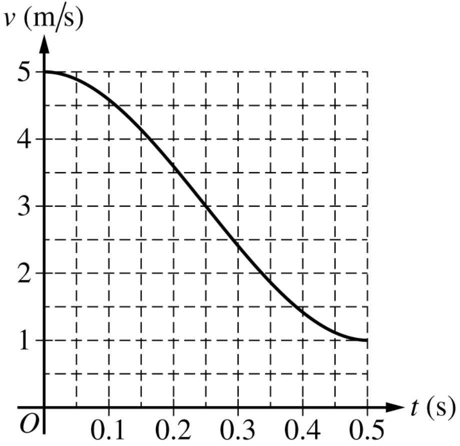
2023 Set 2 ▪ Q1

Scientists have created a new type of lightweight foam and are performing experiments to investigate the properties of the foam. The mass of Cart A is 1000 kg and the mass of Cart B is 2000 kg. A piece of foam with negligible mass is attached to the front of Cart A, as shown. Cart A moves with a constant speed toward Cart B, which is initially at rest. At time $t = 0$ s, the foam connected to Cart A makes contact with Cart B. The foam remains in contact with Cart B for 0.5 s, after which the carts separate and both carts move with constant velocities.
[Diagram: Cart A (with a block labeled “Foam” attached to its front) approaching Cart B along a horizontal track, both carts shown as boxes on wheels.]
(a)(i) The graph shows the velocity v of Cart A as a function of time t for the time interval when the foam and Cart B are in contact.

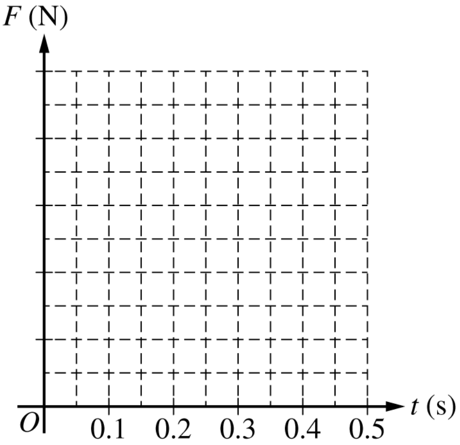
Question 1

[Graph: v (m/s) vs. t (s); y-axis from 0 to 5 m/s in increments of 1, x-axis from 0 to 0.5 s in increments of 0.1 s; curve starts at $(0, 5)$ and decreases smoothly, concave up, leveling off toward approximately $(0.5, 1)$.]
What feature(s) of the graph could be used to estimate the displacement of Cart A during the collision?
(a)(ii) Using the information shown in the graph, determine the speed of Cart B at $t = 0.5$ s.
(a)(iii) On the following grid, draw a smooth curve of the velocity of Cart B as a function of time.
[Grid: v (m/s) vs. t (s); y-axis from 0 to 5 m/s in increments of 1, x-axis from 0 to 0.5 s in increments of 0.1 s; the curve for Cart A is already plotted and labeled "Cart A," starting at $(0, 5)$ and decreasing to approximately $(0.5, 1)$.]

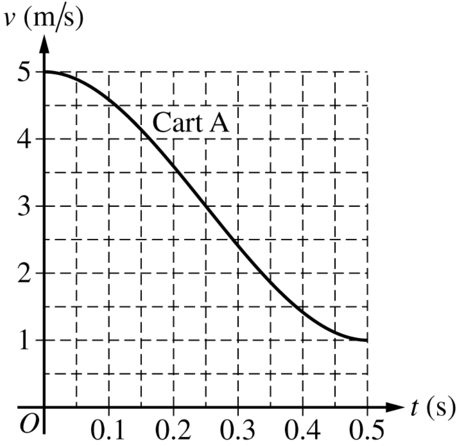
Question 1



Question 1



Question 1



Question 1

2023 Set 2 ▪ Q1

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[Diagram: Cart A (with a block labeled "Foam" attached to its front) approaching Cart B along a horizontal track, both carts shown as boxes on wheels.]

(b)(i) For $0 \leq t \leq 0.50$ s, the velocity v of Cart A can be described by the function $v(t) = 64t^3 - 48t^2 + 5$.

Calculate the magnitude of the maximum net force acting on Cart A during this interval.

Question 1

(b)(ii) On the following grid, draw a smooth curve of the magnitude of the force acting on Cart A as a function of time. Clearly indicate the value of the maximum force on the vertical axis.
[Grid: F (N) vs. t (s); x-axis from 0 to 0.5 s in increments of 0.1 s; y-axis unlabeled/blank for the student to fill in.]

Question 1

2023 Set 2 ▪ Q1

Scientists have created a new type of lightweight foam and are performing experiments to investigate the properties of the foam. The mass of Cart A is 1000 kg and the mass of Cart B is 2000 kg. A piece of foam with negligible mass is attached to the front of Cart A, as shown. Cart A moves with a constant speed toward Cart B, which is initially at rest. At time $t = 0$ s, the foam connected to Cart A makes contact with Cart B. The foam remains in contact with Cart B for 0.5 s, after which the carts separate and both carts move with constant velocities.

[Diagram: Cart A (with a block labeled “Foam” attached to its front) approaching Cart B along a horizontal track, both carts shown as boxes on wheels.]

(c) The foam is removed from the front of Cart A and the experiment is repeated. The carts collide, with both Cart A and Cart B having the same initial and final velocities as in the original collision. The time intervals during which the carts are in contact are different in the collision with the foam and the collision without the foam.

Question 1

In the collision without the foam, Cart A is in contact with Cart B for a shorter duration than in the original collision, when the foam was present.
For the original collision when the foam is present, the magnitude of the average net force exerted on Cart B is F_1. For the collision without the foam, the magnitude of the average net force exerted on Cart B is F_2.
What is the relationship between the magnitude of the average net force F_1 exerted on Cart B for the collision with the foam and the magnitude of the average net force F_2 exerted on Cart B for the collision without the foam?
_____ $F_1 > F_2$ _____ $F_1 < F_2$ _____ $F_1 = F_2$
Justify your answer.

Question 1

2019 Set 1 ▪ Q1

In an experiment, students used video analysis to track the motion of an object falling vertically through a fluid in a glass cylinder. The object of $m = 12$ g is released from rest at the top of the column of fluid, as shown above. The data for the speed v of the falling object as a function of time t are graphed on the grid below. The dashed curve represents the best fit chosen by the students for these data.
[Figure above the question: a cylinder of fluid on a table, with hands releasing an object labeled "Object, Mass = 12 g" at the top of the "Cylinder" containing "Fluid", resting on a "Table".]
[Graph: v (m/s) vs. t (s); y-axis from 0.0 to 1.0 in increments of 0.2, x-axis from 0.00 to 0.35 in increments of 0.05. Data points (dots) roughly follow a dashed best-fit curve that rises steeply from the origin, e.g. passing near (0.00, 0.0), (0.025, 0.17), (0.05, 0.25), (0.075, 0.42), (0.10, 0.47), (0.125, 0.58), (0.15, 0.66), (0.175, 0.65),

Question 1

(0.20, 0.76), (0.225, 0.78), (0.25, 0.80), (0.275, 0.90), (0.30, 0.93), (0.325, 0.92); the curve rises quickly at first then levels off, approaching an asymptote near $v \approx 1.0$ m/s.]

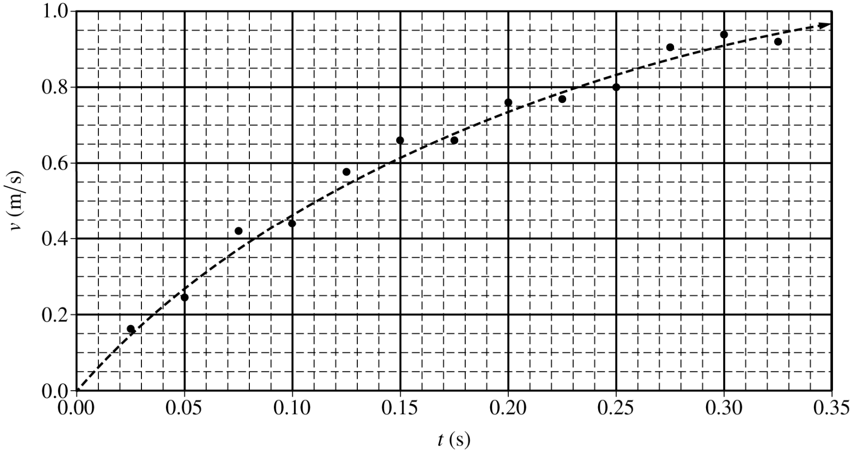
(a)(i) Does the speed of the object increase, decrease, or remain the same?

______ Increase   ______ Decrease   ______ Remain the same

(a)(ii) In a brief statement, describe the direction of the object's acceleration and how the magnitude of this acceleration changed as the object fell.

(a)(iii) Using the graph, calculate an approximate value for the magnitude of the acceleration of the object at $t = 0.20$ s.

Question 1



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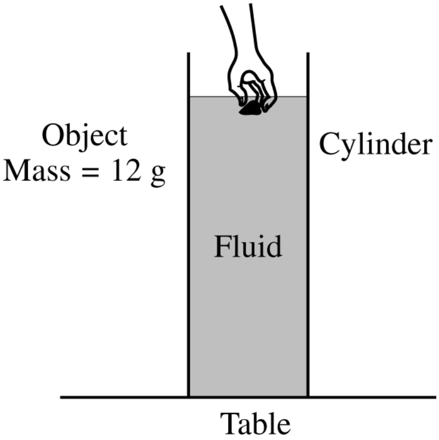

Question 1

2019 Set 1 ▪ Q1

In an experiment, students used video analysis to track the motion of an object falling vertically through a fluid in a glass cylinder. The object of $m = 12$ g is released from rest at the top of the column of fluid, as shown above. The data for the speed v of the falling object as a function of time t are graphed on the grid below. The dashed curve represents the best fit chosen by the students for these data.

[Figure above the question: a cylinder of fluid on a table, with hands releasing an object labeled "Object, Mass = 12 g" at the top of the "Cylinder" containing "Fluid", resting on a "Table".]

[Graph: v (m/s) vs. t (s); y-axis from 0.0 to 1.0 in increments of 0.2, x-axis from 0.00 to 0.35 in increments of 0.05. Data points (dots) roughly follow a dashed best-fit curve that rises steeply from the origin, e.g. passing near (0.00, 0.0), (0.025, 0.17), (0.05, 0.25), (0.075, 0.42), (0.10, 0.47), (0.125, 0.58), (0.15, 0.66), (0.175, 0.65), (0.20, 0.76), (0.225, 0.78), (0.25,

Question 1

0.80), (0.275, 0.90), (0.30, 0.93), (0.325, 0.92); the curve rises quickly at first then levels off, approaching an asymptote near $v \approx 1.0$ m/s.]

(b)(i) The students use the equation $v = A\left(1 - e^{-Bt}\right)$ to model the speed of the falling object and find the best fit coefficients to be $A = 1.18$ m/s and $B = 5$ s^{-1}. Use the above equation to derive an expression for the magnitude of the vertical displacement $y(t)$ of the falling object as a function of time t.

(b)(ii) Derive an expression for the magnitude of the net force $F(t)$ exerted on the object as it falls through the fluid as a function of time t.

Question 1

2019 Set 1 ▪ Q1

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Question 1

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(c)(i) The students repeat the experiment with a taller glass cylinder that is filled with the same fluid. The cylinder is tall enough so that the object reaches a constant speed. Determine the constant speed of the object.

Justify your answer.

(c)(ii) Determine the force exerted by the fluid on the object at this time.

Justify your answer.

Solution 1

(a)(i)

Mark scheme

- The speed **Increases** (full credit for selecting 'Increase'). The object is falling and speeding up as it accelerates through the fluid.

Solution 1

(a)(ii)

Mark scheme

- The acceleration points downward (1 pt), and its magnitude decreases as the object falls (1 pt). Example: Because the object is moving downward and speeding up, the acceleration must be downward. Because the slope of the graph of speed vs. time is decreasing, the magnitude of the acceleration must be decreasing.

Solution 1

(a)(iii)

Mark scheme

- Draw a tangent line to the curve at $t = 0.20$ s and compute its slope using two points on that tangent line (1 pt): $a = \dfrac{\Delta v}{\Delta t} = \dfrac{(0.8 - 0.6)\ \text{m/s}}{(0.226 - 0.136)\ \text{s}}$. Correct answer using points from the tangent line (1 pt): $a \approx 2.22\ \text{m/s}^2$ (accept values close to this from a reasonable tangent line).

Solution 1

(b)(i) Mark scheme

- Recognize that vertical displacement is the integral of velocity (1 pt): $\Delta y = \int v\,dt = \int A(1 - e^{-Bt})\,dt$. Evaluate with appropriate limits or constant of integration (1 pt): $\Delta y = \int_0^t A(1 - e^{-Bt'})\,dt' = A\left[\left(t + \frac{1}{B}e^{-Bt}\right) - \left(0 + \frac{1}{B}e^{0}\right)\right]$. Correct final answer (1 pt): $\Delta y = A\left(t + \frac{1}{B}\left(e^{-Bt} - 1\right)\right) = 1.18\left(t + \frac{1}{5}\left(e^{-5t} - 1\right)\right)$. Credit is given for leaving the answer in terms of A and B or for plugging in the given numeric values.

Solution 1

(b)(ii)

Mark scheme

- Attempt the derivative of the speed equation (1 pt): $a = \frac{dv}{dt} = \frac{d}{dt}\left[A(1 - e^{-Bt})\right]$. Correct expression for acceleration (1 pt): $a = ABe^{-Bt}$. Multiply by the mass to get net force (1 pt): $F = ma = m\left(ABe^{-Bt}\right) = mABe^{-Bt}$, i.e. $F = (0.012)(1.18)(5)e^{-5t} = 0.071\,e^{-5t}$ N. Credit is given for leaving the answer in terms of A, B, m or for plugging in the given numeric values.

Solution 1

(c)(i)

Mark scheme

- State that the constant (terminal) speed is $v = A$ (1 pt), found by letting $t \to \infty$ in the fit equation (1 pt). After a long time the falling object reaches a terminal constant speed in the fluid; setting $t \to \infty$ in $v = A(1 - e^{-Bt})$ gives the constant speed $v = A = 1.18$ m/s.

Solution 1

(c)(ii)

Mark scheme

- Indicate that the net force is zero at constant speed (1 pt), and that the resistive (fluid) force therefore equals the weight of the object (1 pt). Since the object moves at constant speed, the net force is zero; the only vertical forces are gravity and the fluid's resistive force, so the resistive force equals the weight: $F = mg = (0.012 \text{ kg})(9.8 \text{ m/s}^2) = 0.12 \text{ N}$.

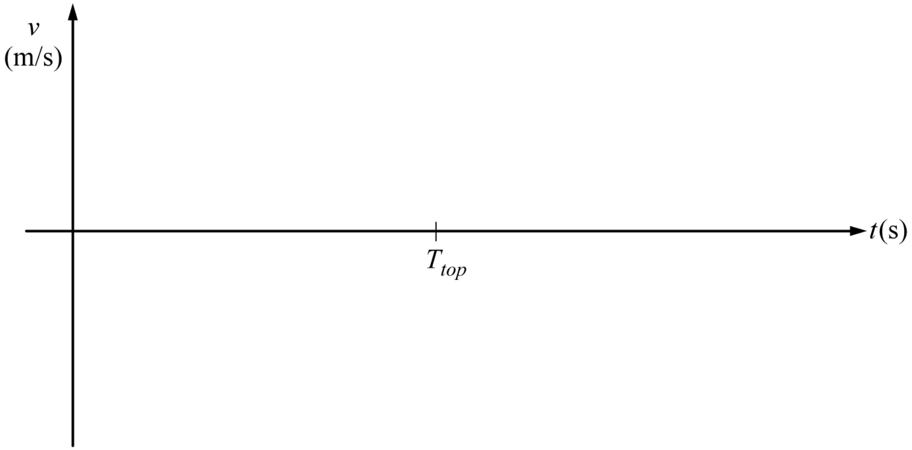
Question 2

2019 Set 2 ▪ Q2

A toy rocket of mass 0.50 kg starts from rest on the ground and is launched upward, experiencing a vertical net force. The rocket's upward acceleration a for the first 6 seconds is given by the equation $a = K - Lt^2$, where $K = 9.0$ m/s^2, $L = 0.25$ m/s^4, and t is the time in seconds. At $t = 6.0$ s, the fuel is exhausted and the rocket is under the influence of gravity alone. Assume air resistance and the rocket's change in mass are negligible.

(a) Calculate the magnitude of the net impulse exerted on the rocket from $t = 0$ to $t = 6.0$ s.

Question 2



Question 2

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(b) Calculate the speed of the rocket at $t = 6.0$ s.

Question 2

2019 Set 2 ▪ Q2

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(c)(i) Calculate the kinetic energy of the rocket at $t = 6.0$ s.

(c)(ii) Calculate the change in gravitational potential energy of the rocket-Earth system from $t = 0$ to $t = 6.0$ s.

Question 2

2019 Set 2 ▪ Q2

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(d) Calculate the maximum height reached by the rocket relative to its launching point.

Question 2

2019 Set 2 ▪ Q2

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(e) On the axes below, assuming the upward direction to be positive, sketch a graph of the velocity v of the rocket as a function of time t from the time the rocket is launched to the time it returns to the ground. T_{top} represents the time the rocket reaches its maximum height. Explicitly label the maxima with numerical values or algebraic expressions, as appropriate.

Question 2

[Graph axes: vertical axis labeled v (m/s), horizontal axis labeled t(s); the origin is at the intersection, with a tick mark labeled T_{top} on the horizontal axis to the right of the origin. The axes are otherwise unscaled and blank for the student to sketch on.]

Solution 2

(a)

Mark scheme

- $J = \int F(t)\,dt = \int ma(t)\,dt = (0.50)\int_0^6 (9.0 - 0.25t^2)\,dt$ (1 pt for the correct expression and substitution of $a(t)$ and m). Integrating with the correct limits: $J = (0.50)\left[9.0t - \frac{1}{12}t^3\right]_0^6 = (0.50)\left[(9.0)(6) - \frac{1}{12}(6)^3\right] = (0.50)(54 - 18)$ (1 pt for correct integration/limits). Final answer: $J = 18\ \mathrm{N}\cdot\mathrm{s}$.

Solution 2

(b)

Mark scheme

- Relate impulse to the change in momentum: $J = \Delta p = m(v_2 - v_1)$ (1 pt for correctly relating impulse to speed). Substitute $J = 18$ N $\cdot$ s from part (a): $(18 \text{ N} \cdot \text{s}) = (0.50 \text{ kg})(v_2 - 0)$ (1 pt for correct substitution), giving $v_2 = 36$ m/s.

Solution 2

(c)(i)

Mark scheme

- $K = \frac{1}{2}mv^2$. Substitute the mass of the rocket (1 pt) and the speed $v = 36$ m/s found in part (b) (1 pt): $K = \frac{1}{2}(0.50 \text{ kg})(36 \text{ m/s})^2 = 324$ J.

Solution 2

(c)(ii)

Mark scheme

- Integrate the acceleration twice to obtain position. First: $v(t) = \int a(t)\,dt = \int (9.0 - 0.25t^2)\,dt = 9.0t - \frac{1}{12}t^3 + v_0 = 9.0t - \frac{1}{12}t^3$ (1 pt for integrating with correct limits/constant of integration, since $v_0 = 0$). Then integrate again: $\Delta y = \int_0^6 v(t)\,dt = \left[\frac{9}{2}t^2 - \frac{1}{48}t^4\right]_0^6 = \frac{9}{2}(36) - \frac{1}{48}(1296) = 135$ m (1 pt for the second integration with correct limits). Substitute into $\Delta U_g = mg\Delta y = (0.50\text{ kg})(9.8\text{ m/s}^2)(135\text{ m}) \approx 660$ J (1 pt for substituting into the potential-energy equation).

Solution 2

(d) Mark scheme

- Use $v_2^2 = v_1^2 + 2a(y_2 - y_1)$ with $a = g = -9.8\ \mathrm{m/s^2}$ after burnout and $v_2 = 0$ at maximum height: $y_2 - y_1 = -\dfrac{v_1^2}{2a}$ (1 pt for using $a = g$ in a correct kinematics equation). Substitute the speed $v_1 = 36\ \mathrm{m/s}$ from part (b) (1 pt): $y_2 - y_1 = -\dfrac{(36\ \mathrm{m/s})^2}{2(-9.8\ \mathrm{m/s^2})} \approx 66\ \mathrm{m}$. Add the height already gained by $t = 6.0$ s, $\Delta y = 135\ \mathrm{m}$ from part (c)(ii) (1 pt for substituting the height from part (c)): $y_2 = 66\ \mathrm{m} + 135\ \mathrm{m} = 201\ \mathrm{m}$ (199.8 m if $g = 10\ \mathrm{m/s^2}$). [Equivalent alternate solutions using energy conservation, $mg\Delta y = \frac{1}{2}mv^2$, or $K_1 + U_1 = U_{top}$ with parts (c)(i)/(c)(ii): $324 + 660 = (0.5)(9.8)\Delta y$, also earn full credit.]

Solution 2

(e) Mark scheme

- Sketch: for $0 \leq t \leq 6.0$ s, an initial concave-down curve starting at the origin $(0, 0)$ that rises to a maximum of $v = 36$ m/s at $t = 6.0$ s (1 pt, for an initial concave-down curve starting at the origin, consistent with the decreasing-but-positive acceleration $a = 9.0 - 0.25t^2$). The curve then transitions, before T_{top}, into a straight line with constant negative slope $-g$ (1 pt, for a transition before T_{top} into a straight line of negative slope). Label the maximum value 36 m/s (consistent with part (b)) with the line crossing the time axis exactly at $t = T_{top}$, continuing to negative v as the rocket falls back to the ground (1 pt, for labeling the maximum consistent with part (b) and crossing the axis at T_{top}).

Question 1

2018 ▪ Q1

A student wants to determine the value of the acceleration due to gravity g for a specific location and sets up the following experiment. A solid sphere is held vertically a distance h above a pad by an electromagnet, as shown in the figure above. The experimental equipment is designed to release the sphere when the electromagnet is turned off. A timer also starts when the electromagnet is turned off, and the timer stops when the sphere lands on the pad.
[Diagram: A vertical stand on a table. An electromagnet is mounted at the top of the stand, holding a sphere directly beneath it. The distance from the sphere down to a pad on the table is labeled h. Labels: "Electromagnet", "Sphere", "h" (vertical arrow), "Pad", "Table".]
(a) While taking the first data point, the student notices that the electromagnet actually releases the sphere after the timer begins. Would the value of g calculated

Question 1

from this one measurement be greater than, less than, or equal to the actual value of g at the student's location?

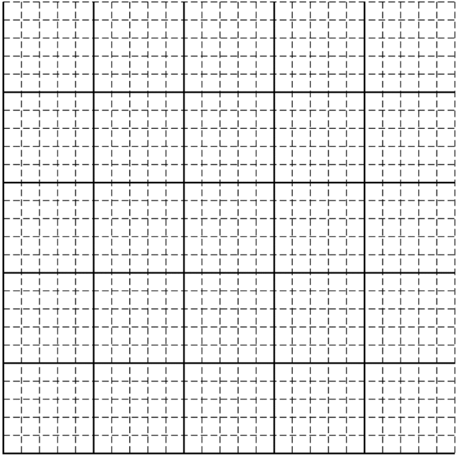
$G^{reaterthan}{}_{L^{essthan}}{}_{E^{qualto}}$

Justify your answer.

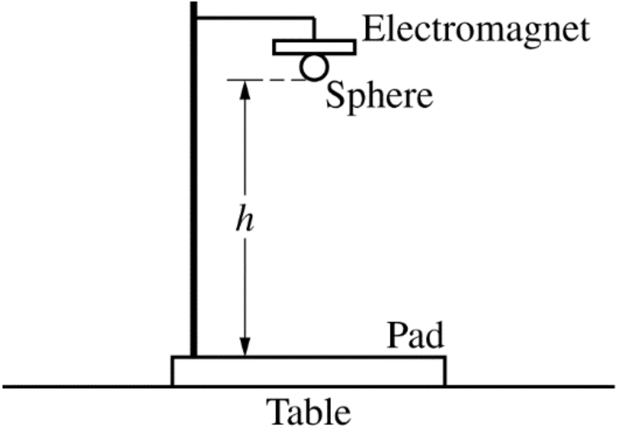
The electromagnet is replaced so that the timer begins when the sphere is released. The student varies the distance h. The student measures and records the time Δt of the fall for each particular height, resulting in the following data table.

h (m)	0.10	0.20	0.60	0.80	1.00
Δt (s)	0.105	0.213	0.342	0.401	0.451

Question 1



Question 1



Question 1

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Question 1

2018 ▪ Q1

A student wants to determine the value of the acceleration due to gravity g for a specific location and sets up the following experiment. A solid sphere is held vertically a distance h above a pad by an electromagnet, as shown in the figure above. The experimental equipment is designed to release the sphere when the electromagnet is turned off. A timer also starts when the electromagnet is turned off, and the timer stops when the sphere lands on the pad.

[Diagram: A vertical stand on a table. An electromagnet is mounted at the top of the stand, holding a sphere directly beneath it. The distance from the sphere down to a pad on the table is labeled h. Labels: "Electromagnet", "Sphere", "h" (vertical arrow), "Pad", "Table".]

(b) Indicate below which quantities should be graphed to yield a straight line whose slope could be used to calculate a numerical value for g.

Vertical axis: ________________

Horizontal axis: ________________

Question 1

Use the remaining rows in the table above, as needed, to record any quantities that you indicated that are not given in the table. Label each row you use and include units.

Question 1

2018 ▪ Q1

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(c) Plot the data points for the quantities indicated in part (b) on the graph below. Clearly scale and label all axes, including units if appropriate. Draw a straight line that best represents the data.

Question 1

[Graph: A blank grid (approximately 6 columns $\times$ 16 rows of small squares) provided for the student to plot data and draw a best-fit straight line. No axes, scale, or data are pre-printed.]

Question 1

2018 ▪ Q1

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(d) Using the straight line, calculate an experimental value for g.

Another student fits the data in the table to a quadratic equation. The student's equation for the distance fallen y as a function of time t is $y = At^2 + Bt + C$, where

Question 1

$A = 5.75$ m/s^2, $B = -0.524$ m/s, and $C = +0.080$ m. Vertically down is the positive direction.

Question 1

2018 ▪ Q1

A student wants to determine the value of the acceleration due to gravity g for a specific location and sets up the following experiment. A solid sphere is held vertically a distance h above a pad by an electromagnet, as shown in the figure above. The experimental equipment is designed to release the sphere when the electromagnet is turned off. A timer also starts when the electromagnet is turned off, and the timer stops when the sphere lands on the pad.

[Diagram: A vertical stand on a table. An electromagnet is mounted at the top of the stand, holding a sphere directly beneath it. The distance from the sphere down to a pad on the table is labeled h. Labels: "Electromagnet", "Sphere", "h" (vertical arrow), "Pad", "Table".]

(e)(i) Using the student's equation above, derive an expression for the velocity of the sphere as a function of time.

(e)(ii) Using the student's equation above, calculate the new experimental value for g.

Question 1

(e)(iii) Using 9.81 m/s^2 as the accepted value for g at this location, calculate the percent error for the value found in part (e)ii.
(e)(iv) Assuming the sphere is at a height of 1.40 m at $t = 0$, calculate the velocity of the sphere just before it strikes the pad.

Solution 1

(a) Mark scheme

- Less than. Justification: because the electromagnet actually released the sphere after the timer had already begun, the measured time is longer than the true fall time for that height. Since $g = 2h/\Delta t^2$ (i.e. $a \propto 1/t^2$), a longer measured Δt makes the calculated value of g smaller than the true value, so the computed g is LESS THAN the actual g. (1 point for selecting "Less than" with an attempt at a relevant justification; 1 point for a correct justification, e.g. "the measured time to fall the same distance is larger, so the acceleration must be less" or "the time is larger and $a \propto 1/t^2$, so g must decrease.")

Solution 1

(b)

Mark scheme

- Vertical axis: h. Horizontal axis: $(\Delta t)^2$. Since $h = \frac{1}{2}g(\Delta t)^2$, plotting h vs. $(\Delta t)^2$ gives a straight line through the origin with slope $g/2$. Full credit is also given if the axes are reversed (horizontal h, vertical $(\Delta t)^2$, slope $= 2/g$) or for any other combination of quantities that yields a straight line usable to find g.

Solution 1

(c) Mark scheme

- Using the part (b) quantities, compute $(\Delta t)^2$ for each row: $h = 0.10$ m $\to (\Delta t)^2 = 0.011$ s^2; $h = 0.20 \to 0.045$; $h = 0.60 \to 0.117$; $h = 0.80 \to 0.161$; $h = 1.00 \to 0.203$ s^2. Plot h (vertical) vs $(\Delta t)^2$ (horizontal) and draw a best-fit straight line through the points (the official answer graph is linear, passing near the origin, rising from about (0.01,0.10) to (0.20,1.00)). Scoring: 1 point for a scale that uses more than half the grid; 1 point for correctly labeling axes with the part-(b) variables and units; 1 point for correctly plotting the data consistent with part (b); 1 point for drawing a straight line consistent with the plotted data.

Solution 1

(d)

Mark scheme

- Using two points ON THE BEST-FIT LINE (not raw data points): slope $= \dfrac{\Delta h}{\Delta(\Delta t)^2} = \dfrac{(0.80 - 0.20)\ \text{m}}{(0.160 - 0.039)\ \text{s}^2} \approx 4.96\ \text{m/s}^2$ (linear regression on all data gives $4.83\ \text{m/s}^2$). Since slope $= \frac{1}{2}g$, $g = 2 \times$ slope. So $g = 2(4.96) = 9.92$ m/s^2 (linear regression: $9.66\ \text{m/s}^2$). 1 point for using points on the line (not the raw data) to compute the slope; 1 point for correctly relating the slope to g.

Solution 1

(e)(i)

Mark scheme

- Matching $y = At^2 + Bt + C$ to the kinematic form $y = y_0 + v_i t + \frac{1}{2}at^2$ and differentiating: $v(t) = \dfrac{dy}{dt} = 2At + B$. (Credit is also earned for substituting the given numbers: $v(t) = (11.5\ \mathrm{m/s^2})t - 0.524\ \mathrm{m/s}$.)

Solution 1

(e)(ii)

Mark scheme

- Comparing $y = y_0 + v_i t + \frac{1}{2}at^2$ to $y = At^2 + Bt + C$ gives $A = \frac{1}{2}a$, so $a = 2A$. Here the acceleration is g (free fall), so $g = 2A = 2(5.75\ \mathrm{m/s^2}) = 11.5\ \mathrm{m/s^2}$. 1 point for correctly relating the given equation to a correct kinematic equation; 1 point for correctly relating the equation to the value of g (i.e. $g = 2A$).

Solution 1

(e)(iii)

Mark scheme

- $\%\text{error} = \dfrac{|\text{acc} - \text{exp}|}{\text{acc}} \times 100\% = \dfrac{|11.5 - 9.81|\ \text{m/s}^2}{9.81\ \text{m/s}^2} \times 100\% = 17.2\%$. Credit is earned whether the percent error is expressed as positive or negative.

Solution 1

(e)(iv) Mark scheme

- From the fitted equation: $v_i = B = -0.524$ m/s, $a = 2A = 11.5$ m/s^2, $y_0 = C = 0.080$ m, so $\Delta y = 1.40 - 0.080 = 1.32$ m. Using $v^2 = v_i^2 + 2a\Delta y$: $v = \sqrt{(-0.524)^2 + 2(11.5)(1.32)} = 5.54$ m/s. 1 point for relating the equation's coefficients to the kinematic variables v_i, a, y_0; 1 point for correctly using an appropriate kinematics equation to find v. (Equivalent full-credit alternates: solve the quadratic $5.75t^2 - 0.524t - 1.32 = 0$ for $t = 0.53$ s and substitute into part (e)(i)'s $v(t)$; or use conservation of energy $mgh + \frac{1}{2}mv_i^2 = \frac{1}{2}mv^2$ — both give $v = 5.54$ m/s.)

Question 1

2015 ▪ Q1

A block of mass m is projected up from the bottom of an inclined ramp with an initial velocity of magnitude v_0.
The ramp has negligible friction and makes an angle θ with the horizontal. A motion sensor aimed down the ramp is mounted at the top of the incline so that the positive direction is down the ramp. The block starts a distance D from the motion sensor, as shown above. The block slides partway up the ramp, stops before reaching the sensor, and then slides back down.
[Diagram: An inclined ramp making angle θ with the horizontal. A Motion Sensor is mounted at the top of the incline, aimed down the ramp, with a y-axis pointing up-left from the sensor and an x-axis pointing along the ramp surface down and to the right. The point $x = 0$ is at the sensor (top of ramp); the point $x = D$ is at the bottom of the ramp where the block starts. A dashed line labeled D spans from the sensor down

Question 1

to a small dashed box partway down the ramp. A block near the bottom of the ramp (at $x = D$) has an arrow labeled $\vec{v}_0$ pointing up the ramp (toward the sensor).]

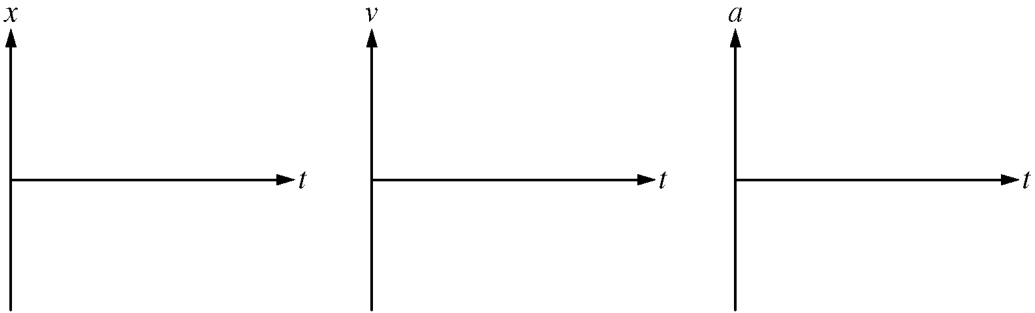
(a) Consider the motion of the block at some time t after it has been projected up the ramp. Express your answers in terms of m, D, v_0, t, θ and physical constants, as appropriate.

(a)(i) Determine the acceleration a of the block.

(a)(ii) Determine an expression for the velocity v of the block.

(a)(iii) Determine an expression for the position x of the block.

Question 1



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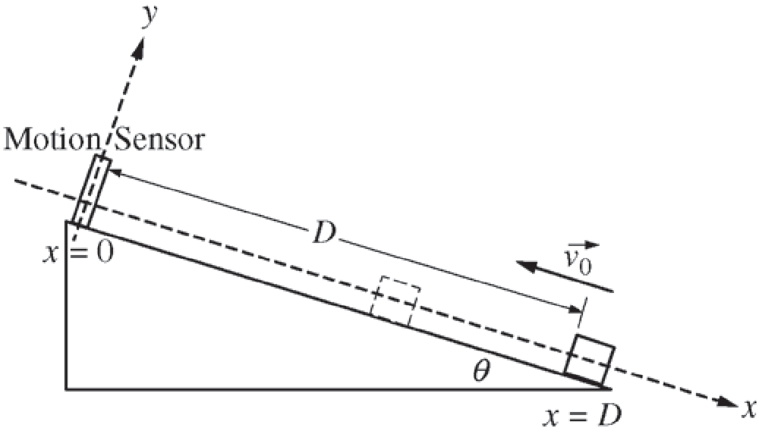

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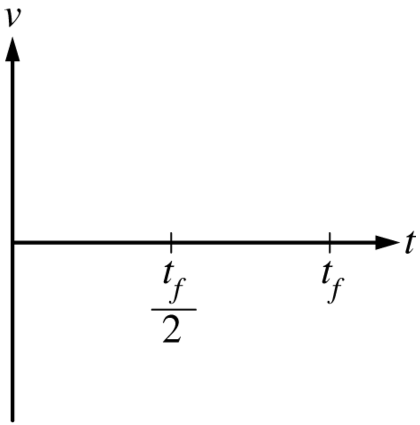

Question 1

2015 ▪ Q1

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Question 1

ramp. A block near the bottom of the ramp (at $x = D$) has an arrow labeled $\vec{v}_0$ pointing up the ramp (toward the sensor).]

(b) Derive an expression for the position x_{min} of the block when it is closest to the motion sensor. Express your answer in terms of m, D, v_0, θ, and physical constants, as appropriate.

Question 1

2015 ▪ Q1

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Question 1

ramp. A block near the bottom of the ramp (at $x = D$) has an arrow labeled $\vec{v}_0$ pointing up the ramp (toward the sensor).]

(c) On the axes provided below, sketch graphs of position x, velocity v, and acceleration a as functions of time t for the motion of the block while it goes up and back down the ramp. Explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.

[Three blank axes side by side, each with a horizontal t-axis and a vertical axis. The first is labeled x, the second labeled v, the third labeled a. All axes are unlabeled/blank grids for the student to sketch on — no data is plotted.]

Question 1

2015 ▪ Q1

A block of mass m is projected up from the bottom of an inclined ramp with an initial velocity of magnitude v_0.

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(d) After the block slides back down and leaves the bottom of the ramp, it slides on a horizontal surface with a coefficient of friction given by μ_k. Derive an expression for the distance the block slides before stopping. Express your answer in terms of m, D, v_0, θ, μ_k, and physical constants, as appropriate.

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2015 ▪ Q1

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Question 1

ramp. A block near the bottom of the ramp (at $x = D$) has an arrow labeled $\vec{v}_0$ pointing up the ramp (toward the sensor).]

(e) Suppose the ramp now has friction. The same block is projected up with the same initial speed v_0 and comes back down the ramp. On the axes provided below, sketch a graph of the velocity v as a function of time t for the motion of the block while it goes up and back down the ramp, arriving at the bottom of the ramp at time t_f. Explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.

[Blank axes with vertical axis v and horizontal axis t. Two tick marks are pre-labeled on the t-axis: $\frac{t_f}{2}$ and t_f. The graph itself is blank for the student to sketch.]