

Kinematics

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Topic tags have been given for each question to enable you to know if you can do the question or whether you need to wait to cover the additional topic(s).

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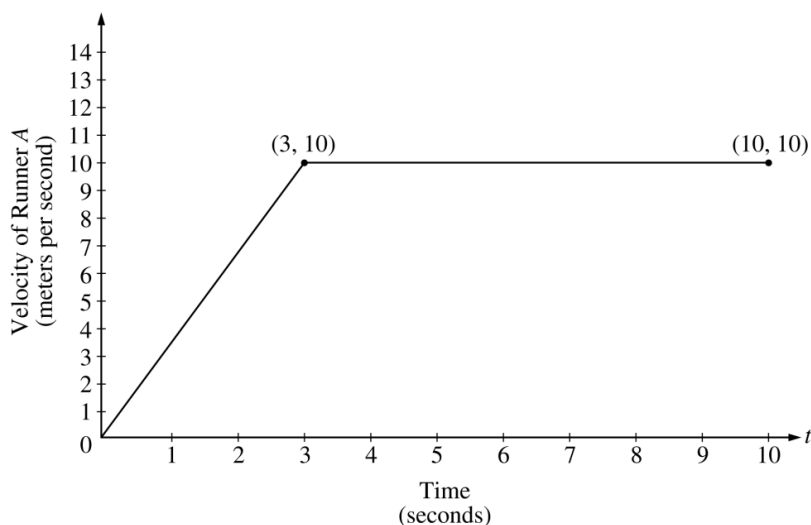
Question 1

Qualification: AP Calculus AB

Areas: Applications of Differentiation, Applications of Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Derivative Graphs, Integration Technique – Geometric Areas

Paper: Part A-Calc / Series: 2000 / Difficulty: Medium / Question Number: 2



2. Two runners, A and B , run on a straight racetrack for $0 \leq t \leq 10$ seconds. The graph above, which consists of two line segments, shows the velocity, in meters per second, of Runner A . The velocity, in meters per second, of Runner B is given by the function v defined by $v(t) = \frac{24t}{2t + 3}$.
- (a) Find the velocity of Runner A and the velocity of Runner B at time $t = 2$ seconds. Indicate units of measure.
 - (b) Find the acceleration of Runner A and the acceleration of Runner B at time $t = 2$ seconds. Indicate units of measure.
 - (c) Find the total distance run by Runner A and the total distance run by Runner B over the time interval $0 \leq t \leq 10$ seconds. Indicate units of measure.

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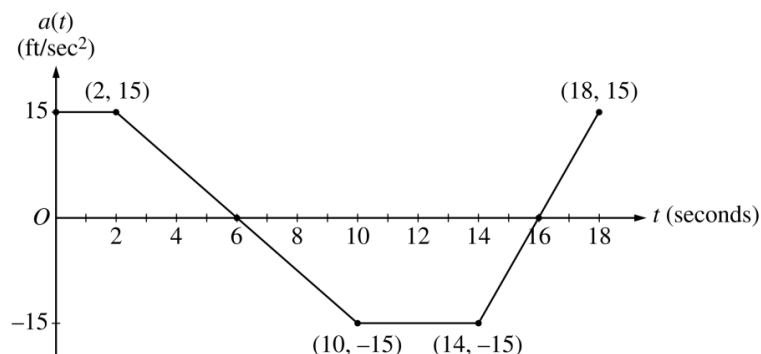
Question 2

Qualification: AP Calculus AB

Areas: Applications of Differentiation, Applications of Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Increasing/Decreasing, Integration - Area Under A Curve, Global or Absolute Minima and Maxima, Derivative Graphs

Paper: Part A-Calc / Series: 2001 / Difficulty: Very Hard / Question Number: 3



3. A car is traveling on a straight road with velocity 55 ft/sec at time $t = 0$. For $0 \leq t \leq 18$ seconds, the car's acceleration $a(t)$, in ft/sec^2 , is the piecewise linear function defined by the graph above.
- (a) Is the velocity of the car increasing at $t = 2$ seconds? Why or why not?
 - (b) At what time in the interval $0 \leq t \leq 18$, other than $t = 0$, is the velocity of the car 55 ft/sec? Why?
 - (c) On the time interval $0 \leq t \leq 18$, what is the car's absolute maximum velocity, in ft/sec, and at what time does it occur? Justify your answer.
 - (d) At what times in the interval $0 \leq t \leq 18$, if any, is the car's velocity equal to zero? Justify your answer.

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Question 3

Qualification: AP Calculus AB

Areas: Applications of Integration, Applications of Differentiation, Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Total Amount, Increasing/Decreasing, Integration of Absolute Value Functions, Integration Technique – Exponentials, Differentiation Technique – Exponentials

Paper: Part B-Non-Calc / Series: 2003-Form-B / Difficulty: Hard / Question Number: 4

4. A particle moves along the x -axis with velocity at time $t \geq 0$ given by $v(t) = -1 + e^{1-t}$.
- (a) Find the acceleration of the particle at time $t = 3$.
 - (b) Is the speed of the particle increasing at time $t = 3$? Give a reason for your answer.
 - (c) Find all values of t at which the particle changes direction. Justify your answer.
 - (d) Find the total distance traveled by the particle over the time interval $0 \leq t \leq 3$.

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Question 4

Qualification: AP Calculus AB

Areas: Applications of Integration, Applications of Differentiation

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Increasing/Decreasing , Global or Absolute Minima and Maxima

Paper: Part A-Calc / Series: 2004 / Difficulty: Hard / Question Number: 3

3. A particle moves along the y -axis so that its velocity v at time $t \geq 0$ is given by $v(t) = 1 - \tan^{-1}(e^t)$. At time $t = 0$, the particle is at $y = -1$. (Note: $\tan^{-1} x = \arctan x$)
- (a) Find the acceleration of the particle at time $t = 2$.
 - (b) Is the speed of the particle increasing or decreasing at time $t = 2$? Give a reason for your answer.
 - (c) Find the time $t \geq 0$ at which the particle reaches its highest point. Justify your answer.
 - (d) Find the position of the particle at time $t = 2$. Is the particle moving toward the origin or away from the origin at time $t = 2$? Justify your answer.

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Question 5

Qualification: AP Calculus AB

Areas: Integration, Applications of Differentiation, Applications of Integration

Subtopics: Riemann Sums – Midpoint, Interpreting Meaning in Applied Contexts, Mean Value Theorem, Kinematics (Displacement, Velocity, and Acceleration), Average Value of a Function

Paper: Part A-Calc / Series: 2004-Form-B / Difficulty: Medium / Question Number: 3

t (minutes)	0	5	10	15	20	25	30	35	40
$v(t)$ (miles per minute)	7.0	9.2	9.5	7.0	4.5	2.4	2.4	4.3	7.3

3. A test plane flies in a straight line with positive velocity $v(t)$, in miles per minute at time t minutes, where v is a differentiable function of t . Selected values of $v(t)$ for $0 \leq t \leq 40$ are shown in the table above.
- (a) Use a midpoint Riemann sum with four subintervals of equal length and values from the table to approximate $\int_0^{40} v(t) dt$. Show the computations that lead to your answer. Using correct units, explain the meaning of $\int_0^{40} v(t) dt$ in terms of the plane's flight.
- (b) Based on the values in the table, what is the smallest number of instances at which the acceleration of the plane could equal zero on the open interval $0 < t < 40$? Justify your answer.
- (c) The function f , defined by $f(t) = 6 + \cos\left(\frac{t}{10}\right) + 3 \sin\left(\frac{7t}{40}\right)$, is used to model the velocity of the plane, in miles per minute, for $0 \leq t \leq 40$. According to this model, what is the acceleration of the plane at $t = 23$? Indicate units of measure.
- (d) According to the model f , given in part (c), what is the average velocity of the plane, in miles per minute, over the time interval $0 \leq t \leq 40$?

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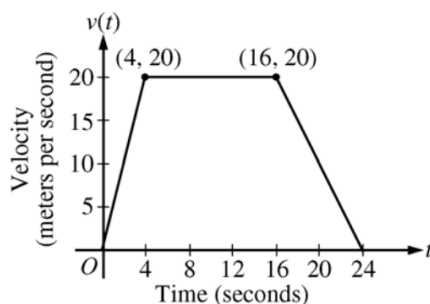
Question 6

Qualification: AP Calculus AB

Areas: Integration, Applications of Integration, Limits and Continuity, Applications of Differentiation

Subtopics: Interpreting Meaning in Applied Contexts, Kinematics (Displacement, Velocity, and Acceleration), Integration Technique – Geometric Areas, Differentiability, Derivative Graphs, Rates of Change (Average), Mean Value Theorem

Paper: Part B-Non-Calc / Series: 2005 / Difficulty: Hard / Question Number: 5



5. A car is traveling on a straight road. For $0 \leq t \leq 24$ seconds, the car's velocity $v(t)$, in meters per second, is modeled by the piecewise-linear function defined by the graph above.
- Find $\int_0^{24} v(t) dt$. Using correct units, explain the meaning of $\int_0^{24} v(t) dt$.
 - For each of $v'(4)$ and $v'(20)$, find the value or explain why it does not exist. Indicate units of measure.
 - Let $a(t)$ be the car's acceleration at time t , in meters per second per second. For $0 < t < 24$, write a piecewise-defined function for $a(t)$.
 - Find the average rate of change of v over the interval $8 \leq t \leq 20$. Does the Mean Value Theorem guarantee a value of c , for $8 < c < 20$, such that $v'(c)$ is equal to this average rate of change? Why or why not?

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Question 7

Qualification: AP Calculus AB

Areas: Applications of Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Average Value of a Function, Total Amount

Paper: Part A-Calc / Series: 2005-Form-B / Difficulty: Medium / Question Number: 3

3. A particle moves along the x -axis so that its velocity v at time t , for $0 \leq t \leq 5$, is given by $v(t) = \ln(t^2 - 3t + 3)$. The particle is at position $x = 8$ at time $t = 0$.
- (a) Find the acceleration of the particle at time $t = 4$.
 - (b) Find all times t in the open interval $0 < t < 5$ at which the particle changes direction. During which time intervals, for $0 \leq t \leq 5$, does the particle travel to the left?
 - (c) Find the position of the particle at time $t = 2$.
 - (d) Find the average speed of the particle over the interval $0 \leq t \leq 2$.

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Question 8

Qualification: AP Calculus AB

Areas: Applications of Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Rates of Change (Average), Interpreting Meaning in Applied Contexts, Riemann Sums – Midpoint

Paper: Part B-Non-Calc / Series: 2006 / Difficulty: Medium / Question Number: 4

t (seconds)	0	10	20	30	40	50	60	70	80
$v(t)$ (feet per second)	5	14	22	29	35	40	44	47	49

4. Rocket A has positive velocity $v(t)$ after being launched upward from an initial height of 0 feet at time $t = 0$ seconds. The velocity of the rocket is recorded for selected values of t over the interval $0 \leq t \leq 80$ seconds, as shown in the table above.
- (a) Find the average acceleration of rocket A over the time interval $0 \leq t \leq 80$ seconds. Indicate units of measure.
- (b) Using correct units, explain the meaning of $\int_{10}^{70} v(t) dt$ in terms of the rocket's flight. Use a midpoint Riemann sum with 3 subintervals of equal length to approximate $\int_{10}^{70} v(t) dt$.
- (c) Rocket B is launched upward with an acceleration of $a(t) = \frac{3}{\sqrt{t+1}}$ feet per second per second. At time $t = 0$ seconds, the initial height of the rocket is 0 feet, and the initial velocity is 2 feet per second. Which of the two rockets is traveling faster at time $t = 80$ seconds? Explain your answer.

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Question 9

Qualification: AP Calculus AB

Areas: Limits and Continuity, Applications of Integration

Subtopics: Interpreting Meaning in Applied Contexts, Derivative Tables, Kinematics (Displacement, Velocity, and Acceleration), Riemann Sums – Trapezoidal Rule, Intermediate Value Theorem, Mean Value Theorem

Paper: Part B-Non-Calc / Series: 2006-Form-B / Difficulty: Hard / Question Number: 6

t (sec)	0	15	25	30	35	50	60
$v(t)$ (ft/sec)	-20	-30	-20	-14	-10	0	10
$a(t)$ (ft/sec ²)	1	5	2	1	2	4	2

6. A car travels on a straight track. During the time interval $0 \leq t \leq 60$ seconds, the car's velocity v , measured in feet per second, and acceleration a , measured in feet per second per second, are continuous functions. The table above shows selected values of these functions.

- (a) Using appropriate units, explain the meaning of $\int_{30}^{60} |v(t)| dt$ in terms of the car's motion. Approximate

$\int_{30}^{60} |v(t)| dt$ using a trapezoidal approximation with the three subintervals determined by the table.

- (b) Using appropriate units, explain the meaning of $\int_0^{30} a(t) dt$ in terms of the car's motion. Find the exact value of $\int_0^{30} a(t) dt$.

- (c) For $0 < t < 60$, must there be a time t when $v(t) = -5$? Justify your answer.

- (d) For $0 < t < 60$, must there be a time t when $a(t) = 0$? Justify your answer.

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Question 10

Qualification: AP Calculus AB

Areas: Differential Equations, Applications of Differentiation, Differentiation

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Global or Absolute Minima and Maxima, Differentiation Technique – Chain Rule, Differentiation Technique – Trigonometry, Differentiation Technique – Exponentials, Verifying Solutions to Differential Equation

Paper: Part B-Non-Calc / Series: 2007 / Difficulty: Somewhat Challenging / Question Number: 4

4. A particle moves along the x -axis with position at time t given by $x(t) = e^{-t} \sin t$ for $0 \leq t \leq 2\pi$.

- (a) Find the time t at which the particle is farthest to the left. Justify your answer.
- (b) Find the value of the constant A for which $x(t)$ satisfies the equation $Ax''(t) + x'(t) + x(t) = 0$ for $0 < t < 2\pi$.

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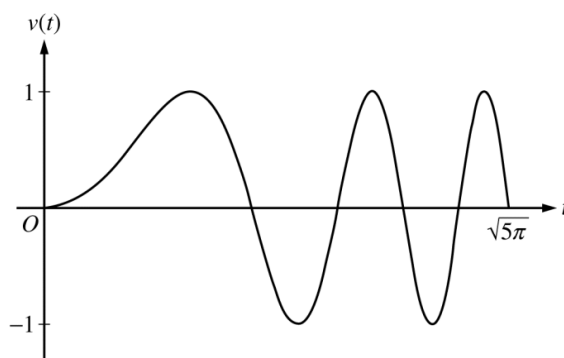
Question 11

Qualification: AP Calculus AB

Areas: Applications of Differentiation, Applications of Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Differentiation Technique – Trigonometry, Global or Absolute Minima and Maxima

Paper: Part A-Calc / Series: 2007-Form-B / Difficulty: Hard / Question Number: 2



2. A particle moves along the x -axis so that its velocity v at time $t \geq 0$ is given by $v(t) = \sin(t^2)$. The graph of v is shown above for $0 \leq t \leq \sqrt{5\pi}$. The position of the particle at time t is $x(t)$ and its position at time $t = 0$ is $x(0) = 5$.
- (a) Find the acceleration of the particle at time $t = 3$.
 - (b) Find the total distance traveled by the particle from time $t = 0$ to $t = 3$.
 - (c) Find the position of the particle at time $t = 3$.
 - (d) For $0 \leq t \leq \sqrt{5\pi}$, find the time t at which the particle is farthest to the right. Explain your answer.

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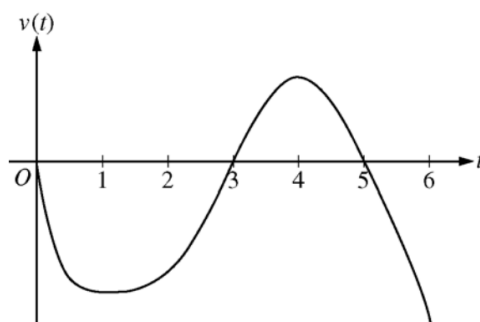
Question 12

Qualification: AP Calculus AB

Areas: Applications of Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Global or Absolute Minima and Maxima, Intermediate Value Theorem, Increasing/Decreasing

Paper: Part B-Non-Calc / Series: 2008 / Difficulty: Somewhat Challenging / Question Number: 4



Graph of v

4. A particle moves along the x -axis so that its velocity at time t , for $0 \leq t \leq 6$, is given by a differentiable function v whose graph is shown above. The velocity is 0 at $t = 0$, $t = 3$, and $t = 5$, and the graph has horizontal tangents at $t = 1$ and $t = 4$. The areas of the regions bounded by the t -axis and the graph of v on the intervals $[0, 3]$, $[3, 5]$, and $[5, 6]$ are 8, 3, and 2, respectively. At time $t = 0$, the particle is at $x = -2$.
- (a) For $0 \leq t \leq 6$, find both the time and the position of the particle when the particle is farthest to the left. Justify your answer.
- (b) For how many values of t , where $0 \leq t \leq 6$, is the particle at $x = -8$? Explain your reasoning.
- (c) On the interval $2 < t < 3$, is the speed of the particle increasing or decreasing? Give a reason for your answer.
- (d) During what time intervals, if any, is the acceleration of the particle negative? Justify your answer.
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Question 13

Qualification: AP Calculus AB

Areas: Applications of Integration, Differentiation

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Rates of Change (Instantaneous), Differentiation Technique – Chain Rule, Total Amount

Paper: Part A-Calc / Series: 2008-Form-B / Difficulty: Medium / Question Number: 2

2. For time $t \geq 0$ hours, let $r(t) = 120(1 - e^{-10t^2})$ represent the speed, in kilometers per hour, at which a car travels along a straight road. The number of liters of gasoline used by the car to travel x kilometers is modeled by $g(x) = 0.05x(1 - e^{-x/2})$.
- (a) How many kilometers does the car travel during the first 2 hours?
 - (b) Find the rate of change with respect to time of the number of liters of gasoline used by the car when $t = 2$ hours. Indicate units of measure.
 - (c) How many liters of gasoline have been used by the car when it reaches a speed of 80 kilometers per hour?

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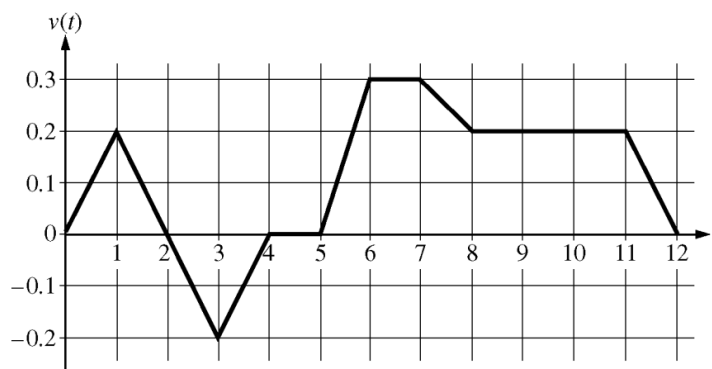
Question 14

Qualification: AP Calculus AB

Areas: Applications of Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Interpreting Meaning in Applied Contexts, Integration Technique – Geometric Areas, Accumulation of Change

Paper: Part A-Calc / Series: 2009 / Difficulty: Medium / Question Number: 1



1. Caren rides her bicycle along a straight road from home to school, starting at home at time $t = 0$ minutes and arriving at school at time $t = 12$ minutes. During the time interval $0 \leq t \leq 12$ minutes, her velocity $v(t)$, in miles per minute, is modeled by the piecewise-linear function whose graph is shown above.
- (a) Find the acceleration of Caren's bicycle at time $t = 7.5$ minutes. Indicate units of measure.
- (b) Using correct units, explain the meaning of $\int_0^{12} |v(t)| dt$ in terms of Caren's trip. Find the value of $\int_0^{12} |v(t)| dt$.
- (c) Shortly after leaving home, Caren realizes she left her calculus homework at home, and she returns to get it. At what time does she turn around to go back home? Give a reason for your answer.
- (d) Larry also rides his bicycle along a straight road from home to school in 12 minutes. His velocity is modeled by the function w given by $w(t) = \frac{\pi}{15} \sin\left(\frac{\pi}{12}t\right)$, where $w(t)$ is in miles per minute for $0 \leq t \leq 12$ minutes. Who lives closer to school: Caren or Larry? Show the work that leads to your answer.

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Question 15

Qualification: AP Calculus AB

Areas: Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Interpreting Meaning in Applied Contexts, Riemann Sums – Trapezoidal Rule, Derivative Tables, Rates of Change (Average)

Paper: Part B-Non-Calc / Series: 2009-Form-B / Difficulty: Somewhat Challenging / Question Number: 6

t (seconds)	0	8	20	25	32	40
$v(t)$ (meters per second)	3	5	-10	-8	-4	7

6. The velocity of a particle moving along the x -axis is modeled by a differentiable function v , where the position x is measured in meters, and time t is measured in seconds. Selected values of $v(t)$ are given in the table above. The particle is at position $x = 7$ meters when $t = 0$ seconds.
- (a) Estimate the acceleration of the particle at $t = 36$ seconds. Show the computations that lead to your answer. Indicate units of measure.
- (b) Using correct units, explain the meaning of $\int_{20}^{40} v(t) dt$ in the context of this problem. Use a trapezoidal sum with the three subintervals indicated by the data in the table to approximate $\int_{20}^{40} v(t) dt$.
- (c) For $0 \leq t \leq 40$, must the particle change direction in any of the subintervals indicated by the data in the table? If so, identify the subintervals and explain your reasoning. If not, explain why not.
- (d) Suppose that the acceleration of the particle is positive for $0 < t < 8$ seconds. Explain why the position of the particle at $t = 8$ seconds must be greater than $x = 30$ meters.

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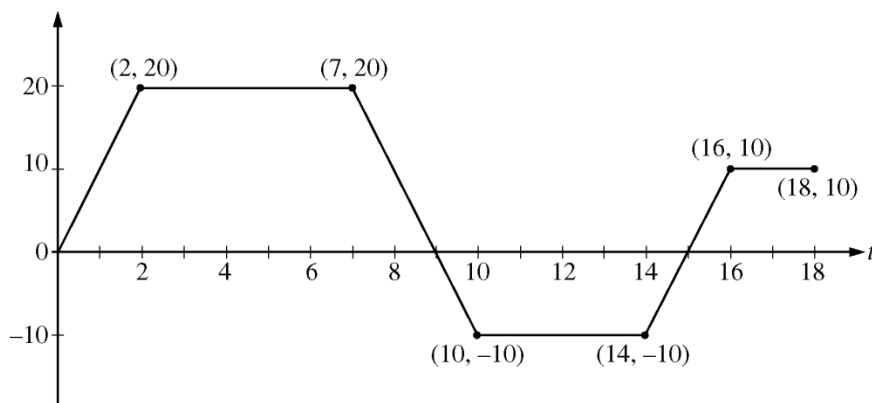
Question 16

Qualification: AP Calculus AB

Areas: Applications of Integration, Applications of Differentiation, Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Global or Absolute Minima and Maxima, Derivative Graphs, Integration Technique – Geometric Areas, Fundamental Theorem of Calculus (Second)

Paper: Part B-Non-Calc / Series: 2010-Form-B / Difficulty: Medium / Question Number: 4



4. A squirrel starts at building A at time $t = 0$ and travels along a straight, horizontal wire connected to building B . For $0 \leq t \leq 18$, the squirrel's velocity is modeled by the piecewise-linear function defined by the graph above.
- At what times in the interval $0 < t < 18$, if any, does the squirrel change direction? Give a reason for your answer.
 - At what time in the interval $0 \leq t \leq 18$ is the squirrel farthest from building A ? How far from building A is the squirrel at that time?
 - Find the total distance the squirrel travels during the time interval $0 \leq t \leq 18$.
 - Write expressions for the squirrel's acceleration $a(t)$, velocity $v(t)$, and distance $x(t)$ from building A that are valid for the time interval $7 < t < 10$.

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Question 17

Qualification: AP Calculus AB

Areas: Applications of Differentiation, Applications of Integration, Differentiation

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Increasing/Decreasing, Differentiation Technique – Trigonometry, Average Value of a Function

Paper: Part B-Non-Calc / Series: 2010-Form-B / Difficulty: Somewhat Challenging / Question Number: 6

6. Two particles move along the x -axis. For $0 \leq t \leq 6$, the position of particle P at time t is given by

$$p(t) = 2\cos\left(\frac{\pi}{4}t\right), \text{ while the position of particle } R \text{ at time } t \text{ is given by } r(t) = t^3 - 6t^2 + 9t + 3.$$

- (a) For $0 \leq t \leq 6$, find all times t during which particle R is moving to the right.
 - (b) For $0 \leq t \leq 6$, find all times t during which the two particles travel in opposite directions.
 - (c) Find the acceleration of particle P at time $t = 3$. Is particle P speeding up, slowing down, or doing neither at time $t = 3$? Explain your reasoning.
 - (d) Write, but do not evaluate, an expression for the average distance between the two particles on the interval $1 \leq t \leq 3$.
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Question 18

Qualification: AP Calculus AB

Areas: Applications of Integration

Subtopics: Increasing/Decreasing , Average Value of a Function, Kinematics (Displacement, Velocity, and Acceleration)

Paper: Part A-Calc / Series: 2011 / Difficulty: Easy / Question Number: 1

1. For $0 \leq t \leq 6$, a particle is moving along the x -axis. The particle's position, $x(t)$, is not explicitly given. The velocity of the particle is given by $v(t) = 2 \sin(e^{t/4}) + 1$. The acceleration of the particle is given by $a(t) = \frac{1}{2} e^{t/4} \cos(e^{t/4})$ and $x(0) = 2$.
- (a) Is the speed of the particle increasing or decreasing at time $t = 5.5$? Give a reason for your answer.
- (b) Find the average velocity of the particle for the time period $0 \leq t \leq 6$.
- (c) Find the total distance traveled by the particle from time $t = 0$ to $t = 6$.
- (d) For $0 \leq t \leq 6$, the particle changes direction exactly once. Find the position of the particle at that time.
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Question 19

Qualification: AP Calculus AB

Areas: Applications of Differentiation, Differentiation

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Rates of Change (Average), Riemann Sums – Left, Mean Value Theorem, Implicit Differentiation

Paper: Part B-Non-Calc / Series: 2011-Form-B / Difficulty: Medium / Question Number: 5

t (seconds)	0	10	40	60
$B(t)$ (meters)	100	136	9	49
$v(t)$ (meters per second)	2.0	2.3	2.5	4.6

5. Ben rides a unicycle back and forth along a straight east-west track. The twice-differentiable function B models Ben's position on the track, measured in meters from the western end of the track, at time t , measured in seconds from the start of the ride. The table above gives values for $B(t)$ and Ben's velocity, $v(t)$, measured in meters per second, at selected times t .
- (a) Use the data in the table to approximate Ben's acceleration at time $t = 5$ seconds. Indicate units of measure.
- (b) Using correct units, interpret the meaning of $\int_0^{60} |v(t)| dt$ in the context of this problem. Approximate $\int_0^{60} |v(t)| dt$ using a left Riemann sum with the subintervals indicated by the data in the table.
- (c) For $40 \leq t \leq 60$, must there be a time t when Ben's velocity is 2 meters per second? Justify your answer.
- (d) A light is directly above the western end of the track. Ben rides so that at time t , the distance $L(t)$ between Ben and the light satisfies $(L(t))^2 = 12^2 + (B(t))^2$. At what rate is the distance between Ben and the light changing at time $t = 40$?
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Question 20

Qualification: AP Calculus AB

Areas: Applications of Differentiation, Applications of Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Increasing/Decreasing

Paper: Part B-Non-Calc / Series: 2012 / Difficulty: Easy / Question Number: 6

6. For $0 \leq t \leq 12$, a particle moves along the x -axis. The velocity of the particle at time t is given by

$$v(t) = \cos\left(\frac{\pi}{6}t\right). \text{ The particle is at position } x = -2 \text{ at time } t = 0.$$

- (a) For $0 \leq t \leq 12$, when is the particle moving to the left?
 - (b) Write, but do not evaluate, an integral expression that gives the total distance traveled by the particle from time $t = 0$ to time $t = 6$.
 - (c) Find the acceleration of the particle at time t . Is the speed of the particle increasing, decreasing, or neither at time $t = 4$? Explain your reasoning.
 - (d) Find the position of the particle at time $t = 4$.
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Question 21

Qualification: AP Calculus AB

Areas: Applications of Differentiation, Applications of Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Increasing/Decreasing

Paper: Part A-Calc / Series: 2013 / Difficulty: Easy / Question Number: 2

2. A particle moves along a straight line. For $0 \leq t \leq 5$, the velocity of the particle is given by $v(t) = -2 + (t^2 + 3t)^{6/5} - t^3$, and the position of the particle is given by $s(t)$. It is known that $s(0) = 10$.
- (a) Find all values of t in the interval $2 \leq t \leq 4$ for which the speed of the particle is 2.
 - (b) Write an expression involving an integral that gives the position $s(t)$. Use this expression to find the position of the particle at time $t = 5$.
 - (c) Find all times t in the interval $0 \leq t \leq 5$ at which the particle changes direction. Justify your answer.
 - (d) Is the speed of the particle increasing or decreasing at time $t = 4$? Give a reason for your answer.
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Question 22

Qualification: AP Calculus AB

Areas: Applications of Differentiation, Applications of Integration

Subtopics: Rates of Change (Average), Interpreting Meaning in Applied Contexts, Riemann Sums – Right, Kinematics (Displacement, Velocity, and Acceleration), Average Value of a Function

Paper: Part B-Non-Calc / Series: 2015 / Difficulty: Medium / Question Number: 3

t (minutes)	0	12	20	24	40
$v(t)$ (meters per minute)	0	200	240	-220	150

3. Johanna jogs along a straight path. For $0 \leq t \leq 40$, Johanna's velocity is given by a differentiable function v . Selected values of $v(t)$, where t is measured in minutes and $v(t)$ is measured in meters per minute, are given in the table above.

(a) Use the data in the table to estimate the value of $v'(16)$.

(b) Using correct units, explain the meaning of the definite integral $\int_0^{40} |v(t)| dt$ in the context of the problem.

Approximate the value of $\int_0^{40} |v(t)| dt$ using a right Riemann sum with the four subintervals indicated in the table.

(c) Bob is riding his bicycle along the same path. For $0 \leq t \leq 10$, Bob's velocity is modeled by

$B(t) = t^3 - 6t^2 + 300$, where t is measured in minutes and $B(t)$ is measured in meters per minute.

Find Bob's acceleration at time $t = 5$.

(d) Based on the model B from part (c), find Bob's average velocity during the interval $0 \leq t \leq 10$.

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Question 23

Qualification: AP Calculus AB

Areas: Applications of Integration, Applications of Differentiation

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Increasing/Decreasing , Total Amount

Paper: Part A-Calc / Series: 2016 / Difficulty: Easy / Question Number: 2

2. For $t \geq 0$, a particle moves along the x -axis. The velocity of the particle at time t is given by

$$v(t) = 1 + 2\sin\left(\frac{t^2}{2}\right). \text{ The particle is at position } x = 2 \text{ at time } t = 4.$$

- (a) At time $t = 4$, is the particle speeding up or slowing down?
 - (b) Find all times t in the interval $0 < t < 3$ when the particle changes direction. Justify your answer.
 - (c) Find the position of the particle at time $t = 0$.
 - (d) Find the total distance the particle travels from time $t = 0$ to time $t = 3$.
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Question 24

Qualification: AP Calculus AB

Areas: Applications of Differentiation, Applications of Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Increasing/Decreasing

Paper: Part B-Non-Calc / Series: 2017 / Difficulty: Somewhat Challenging / Question Number: 5

5. Two particles move along the x -axis. For $0 \leq t \leq 8$, the position of particle P at time t is given by

$$x_P(t) = \ln(t^2 - 2t + 10), \text{ while the velocity of particle } Q \text{ at time } t \text{ is given by } v_Q(t) = t^2 - 8t + 15.$$

Particle Q is at position $x = 5$ at time $t = 0$.

- (a) For $0 \leq t \leq 8$, when is particle P moving to the left?
 - (b) For $0 \leq t \leq 8$, find all times t during which the two particles travel in the same direction.
 - (c) Find the acceleration of particle Q at time $t = 2$. Is the speed of particle Q increasing, decreasing, or neither at time $t = 2$? Explain your reasoning.
 - (d) Find the position of particle Q the first time it changes direction.
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Question 25

Qualification: AP Calculus AB

Areas: Applications of Differentiation, Applications of Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Interpreting Meaning in Applied Contexts

Paper: Part A-Calc / Series: 2018 / Difficulty: Easy / Question Number: 2

2. A particle moves along the x -axis with velocity given by $v(t) = \frac{10 \sin(0.4t^2)}{t^2 - t + 3}$ for time $0 \leq t \leq 3.5$.

The particle is at position $x = -5$ at time $t = 0$.

- (a) Find the acceleration of the particle at time $t = 3$.
- (b) Find the position of the particle at time $t = 3$.
- (c) Evaluate $\int_0^{3.5} v(t) \, dt$, and evaluate $\int_0^{3.5} |v(t)| \, dt$. Interpret the meaning of each integral in the context of the problem.
- (d) A second particle moves along the x -axis with position given by $x_2(t) = t^2 - t$ for $0 \leq t \leq 3.5$. At what time t are the two particles moving with the same velocity?

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Question 26

Qualification: AP Calculus AB

Areas: Applications of Integration, Applications of Differentiation

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Mean Value Theorem, Riemann Sums – Trapezoidal Rule, Modelling Situations

Paper: Part A-Calc / Series: 2019 / Difficulty: Somewhat Challenging / Question Number: 2

t (hours)	0	0.3	1.7	2.8	4
$v_P(t)$ (meters per hour)	0	55	-29	55	48

2. The velocity of a particle, P , moving along the x -axis is given by the differentiable function v_P , where $v_P(t)$ is measured in meters per hour and t is measured in hours. Selected values of $v_P(t)$ are shown in the table above. Particle P is at the origin at time $t = 0$.
- (a) Justify why there must be at least one time t , for $0.3 \leq t \leq 2.8$, at which $v_P'(t)$, the acceleration of particle P , equals 0 meters per hour per hour.
- (b) Use a trapezoidal sum with the three subintervals $[0, 0.3]$, $[0.3, 1.7]$, and $[1.7, 2.8]$ to approximate the value of $\int_0^{2.8} v_P(t) dt$.
- (c) A second particle, Q , also moves along the x -axis so that its velocity for $0 \leq t \leq 4$ is given by $v_Q(t) = 45\sqrt{t} \cos(0.063t^2)$ meters per hour. Find the time interval during which the velocity of particle Q is at least 60 meters per hour. Find the distance traveled by particle Q during the interval when the velocity of particle Q is at least 60 meters per hour.
- (d) At time $t = 0$, particle Q is at position $x = -90$. Using the result from part (b) and the function v_Q from part (c), approximate the distance between particles P and Q at time $t = 2.8$.

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Question 27

Qualification: AP Calculus AB

Areas: Applications of Differentiation, Applications of Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Increasing/Decreasing

Paper: Part A-Calc / Series: 2021 / Difficulty: Easy / Question Number: 2

2. A particle, P , is moving along the x -axis. The velocity of particle P at time t is given by $v_P(t) = \sin(t^{1.5})$

for $0 \leq t \leq \pi$. At time $t = 0$, particle P is at position $x = 5$.

A second particle, Q , also moves along the x -axis. The velocity of particle Q at time t is given by

$v_Q(t) = (t - 1.8) \cdot 1.25^t$ for $0 \leq t \leq \pi$. At time $t = 0$, particle Q is at position $x = 10$.

- (a) Find the positions of particles P and Q at time $t = 1$.
- (b) Are particles P and Q moving toward each other or away from each other at time $t = 1$? Explain your reasoning.
- (c) Find the acceleration of particle Q at time $t = 1$. Is the speed of particle Q increasing or decreasing at time $t = 1$? Explain your reasoning.
- (d) Find the total distance traveled by particle P over the time interval $0 \leq t \leq \pi$.

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Question 28

Qualification: AP Calculus AB

Areas: Applications of Differentiation

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Increasing/Decreasing, Calculating Limits Algebraically

Paper: Part B-Non-Calc / Series: 2022 / Difficulty: Medium / Question Number: 6

6. Particle P moves along the x -axis such that, for time $t > 0$, its position is given by $x_P(t) = 6 - 4e^{-t}$.

Particle Q moves along the y -axis such that, for time $t > 0$, its velocity is given by $v_Q(t) = \frac{1}{t^2}$. At time $t = 1$,

the position of particle Q is $y_Q(1) = 2$.

- (a) Find $v_P(t)$, the velocity of particle P at time t .
- (b) Find $a_Q(t)$, the acceleration of particle Q at time t . Find all times t , for $t > 0$, when the speed of particle Q is decreasing. Justify your answer.
- (c) Find $y_Q(t)$, the position of particle Q at time t .
- (d) As $t \rightarrow \infty$, which particle will eventually be farther from the origin? Give a reason for your answer.

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Question 29

Qualification: AP Calculus AB

Areas: Applications of Differentiation, Applications of Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Increasing/Decreasing, Total Amount

Paper: Part A-Calc / Series: 2023 / Difficulty: Medium / Question Number: 2

2. Stephen swims back and forth along a straight path in a 50-meter-long pool for 90 seconds. Stephen's velocity

is modeled by $v(t) = 2.38e^{-0.02t}\sin\left(\frac{\pi}{56}t\right)$, where t is measured in seconds and $v(t)$ is measured in meters per second.

- (a) Find all times t in the interval $0 < t < 90$ at which Stephen changes direction. Give a reason for your answer.
- (b) Find Stephen's acceleration at time $t = 60$ seconds. Show the setup for your calculations, and indicate units of measure. Is Stephen speeding up or slowing down at time $t = 60$ seconds? Give a reason for your answer.
- (c) Find the distance between Stephen's position at time $t = 20$ seconds and his position at time $t = 80$ seconds. Show the setup for your calculations.
- (d) Find the total distance Stephen swims over the time interval $0 \leq t \leq 90$ seconds. Show the setup for your calculations.

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Question 30

Qualification: AP Calculus AB

Areas: Applications of Differentiation, Applications of Integration

Subtopics: Kinematics (Displacement, Velocity, and Acceleration), Increasing/Decreasing , Total Amount

Paper: Part A-Calc / Series: 2024 / Difficulty: Easy / Question Number: 2

2. A particle moves along the x -axis so that its velocity at time $t \geq 0$ is given by $v(t) = \ln(t^2 - 4t + 5) - 0.2t$.
- (a) There is one time, $t = t_R$, in the interval $0 < t < 2$ when the particle is at rest (not moving). Find t_R . For $0 < t < t_R$, is the particle moving to the right or to the left? Give a reason for your answer.
 - (b) Find the acceleration of the particle at time $t = 1.5$. Show the setup for your calculations. Is the speed of the particle increasing or decreasing at time $t = 1.5$? Explain your reasoning.
 - (c) The position of the particle at time t is $x(t)$, and its position at time $t = 1$ is $x(1) = -3$. Find the position of the particle at time $t = 4$. Show the setup for your calculations.
 - (d) Find the total distance traveled by the particle over the interval $1 \leq t \leq 4$. Show the setup for your calculations.

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