CALCULUS BC

SECTION I, Part A

Time — 55 minutes

Number of questions — 28

A CALCULATOR MAY NOT BE USED ON THIS PART OF THE EXAMINATION.

Directions: Solve each of the following problems, using the available space for scratchwork. After examining the form of the choices, decide which is the best of the choices given and fill in the corresponding oval on the answer sheet. No credit will be given for anything written in the test book. Do not spend too much time on any one problem.

In this test: Unless otherwise specified, the domain of a function f is assumed to be the set of all real numbers x for which $f(x)$ is a real number.

1. What are all values of x for which the function f defined by $f(x) = x^3 + 3x^2 - 9x + 7$ is increasing?

   (A) $-3 < x < 1$
   (B) $-1 < x < 1$
   (C) $x < -3$ or $x > 1$
   (D) $x < -1$ or $x > 3$
   (E) All real numbers

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2. In the xy-plane, the graph of the parametric equations $x = 5t + 2$ and $y = 3t$, for $-3 \le t \le 3$, is a line segment with slope

(A) $\frac{3}{5}$ (B) $\frac{5}{3}$ (C) 3 (D) 5 (E) 13

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3. The slope of the line tangent to the curve $y^2 + (xy + 1)^3 = 0$ at $(2, -1)$ is

(A) $-\frac{3}{2}$ (B) $-\frac{3}{4}$ (C) 0 (D) $\frac{3}{4}$ (E) $\frac{3}{2}$

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4. $\displaystyle\int \frac{1}{x^2 - 6x + 8}\,dx =$

(A) $\frac{1}{2}\ln\left|\frac{x-4}{x-2}\right| + C$

(B) $\frac{1}{2}\ln\left|\frac{x-2}{x-4}\right| + C$

(C) $\frac{1}{2}\ln\left|(x-2)(x-4)\right| + C$

(D) $\frac{1}{2}\ln\left|(x-4)(x+2)\right| + C$

(E) $\ln\left|(x-2)(x-4)\right| + C$

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5. If f and g are twice differentiable and if $h(x) = f(g(x))$, then $h''(x) =$

(A) $f''(g(x))[g'(x)]^2 + f'(g(x))g''(x)$
(B) $f''(g(x))g'(x) + f'(g(x))g''(x)$
(C) $f''(g(x))[g'(x)]^2$
(D) $f''(g(x))g''(x)$
(E) $f''(g(x))$

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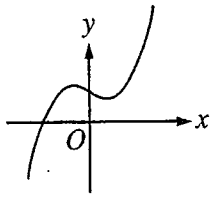

6. The graph of $y = h(x)$ is shown above. Which of the following could be the graph of $y = h'(x)$?

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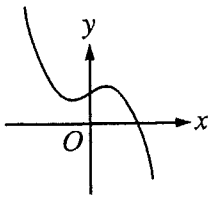

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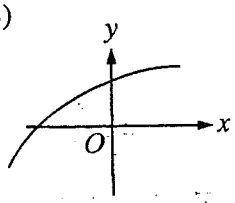

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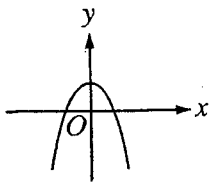

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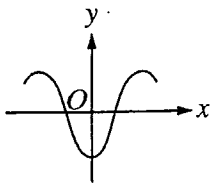

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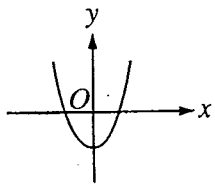

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7. $\int_1^e \left(\frac{x^2 - 1}{x}\right) dx =$

(A) $e - \frac{1}{e}$ (B) $e^2 - e$ (C) $\frac{e^2}{2} - e + \frac{1}{2}$ (D) $e^2 - 2$ (E) $\frac{e^2}{2} - \frac{3}{2}$

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8. If $\frac{dy}{dx} = \sin x \cos^2 x$ and if $y = 0$ when $x = \frac{\pi}{2}$, what is the value of y when $x = 0$?

(A) -1 (B) $-\frac{1}{3}$ (C) 0 (D) $\frac{1}{3}$ (E) 1

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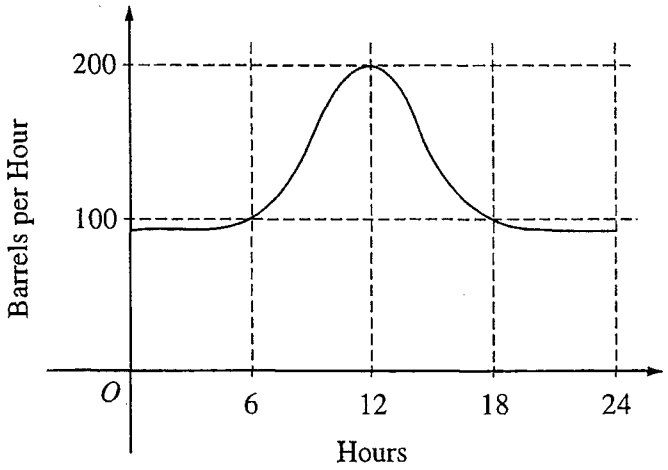

9. The flow of oil, in barrels per hour, through a pipeline on July 9 is given by the graph shown above. Of the following, which best approximates the total number of barrels of oil that passed through the pipeline that day?

(A) 500 (B) 600 (C) 2,400 (D) 3,000 (E) 4,800

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10. A particle moves on a plane curve so that at any time $t > 0$ its x-coordinate is $t^3 - t$ and its y-coordinate is $(2t - 1)^3$. The acceleration vector of the particle at $t = 1$ is

(A) (0, 1) (B) (2, 3) (C) (2, 6) (D) (6, 12) (E) (6, 24)

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11. If f is a linear function and $0 < a < b$, then $\int_a^b f''(x)\,dx =$

(A) 0 (B) 1 (C) $\frac{ab}{2}$ (D) $b - a$ (E) $\frac{b^2 - a^2}{2}$

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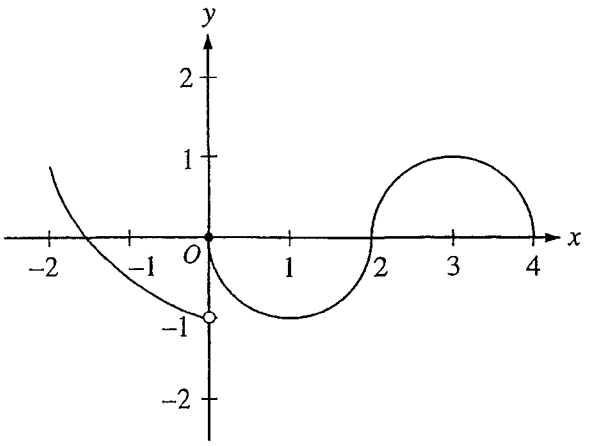
12. If $f(x) = \begin{cases} \ln x & \text{for } 0 < x \le 2 \\ x^2 \ln 2 & \text{for } 2 < x \le 4, \end{cases}$ then $\lim_{x \to 2} f(x)$ is

(A) $\ln 2$ (B) $\ln 8$ (C) $\ln 16$ (D) 4 (E) nonexistent



13. The graph of the function f shown in the figure above has a vertical tangent at the point (2, 0) and horizontal tangents at the points (1, −1) and (3, 1). For what values of x, $-2 < x < 4$, is f not differentiable?

(A) 0 only (B) 0 and 2 only (C) 1 and 3 only (D) 0, 1, and 3 only (E) 0, 1, 2, and 3

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14. What is the approximation of the value of sin 1 obtained by using the fifth-degree Taylor polynomial about $x = 0$ for $\sin x$?

(A) $1 - \frac{1}{2} + \frac{1}{24}$

(B) $1 - \frac{1}{2} + \frac{1}{4}$

(C) $1 - \frac{1}{3} + \frac{1}{5}$

(D) $1 - \frac{1}{4} + \frac{1}{8}$

(E) $1 - \frac{1}{6} + \frac{1}{120}$

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15. $\int x \cos x \, dx =$

(A) $x \sin x - \cos x + C$

(B) $x \sin x + \cos x + C$

(C) $-x \sin x + \cos x + C$

(D) $x \sin x + C$

(E) $\frac{1}{2}x^2 \sin x + C$

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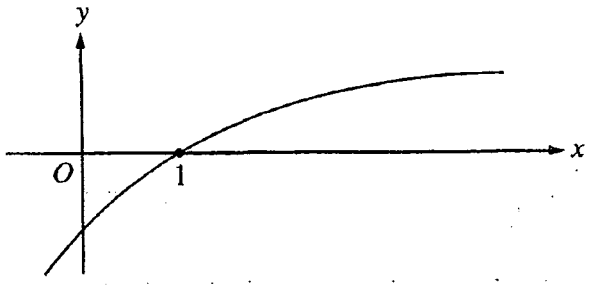
16. If f is the function defined by $f(x) = 3x^5 - 5x^4$, what are all the x-coordinates of points of inflection for the graph of f?

(A) -1 (B) 0 (C) 1 (D) 0 and 1 (E) -1, 0, and 1



17. The graph of a twice-differentiable function f is shown in the figure above. Which of the following is true?

(A) $f(1) < f'(1) < f''(1)$
(B) $f(1) < f''(1) < f'(1)$
(C) $f'(1) < f(1) < f''(1)$
(D) $f''(1) < f(1) < f'(1)$
(E) $f''(1) < f'(1) < f(1)$

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18. Which of the following series converge?

I. $\sum_{n=1}^{\infty} \frac{n}{n+2}$ II. $\sum_{n=1}^{\infty} \frac{\cos(n\pi)}{n}$ III. $\sum_{n=1}^{\infty} \frac{1}{n}$

(A) None
(B) II only
(C) III only
(D) I and II only
(E) I and III only

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19. The area of the region inside the polar curve $r = 4 \sin \theta$ and outside the polar curve $r = 2$ is given by

(A) $\frac{1}{2}\int_{0}^{\pi} (4 \sin \theta - 2)^2 \, d\theta$ (B) $\frac{1}{2}\int_{\frac{\pi}{4}}^{\frac{3\pi}{4}} (4 \sin \theta - 2)^2 \, d\theta$ (C) $\frac{1}{2}\int_{\frac{\pi}{6}}^{\frac{5\pi}{6}} (4 \sin \theta - 2)^2 \, d\theta$

(D) $\frac{1}{2}\int_{\frac{\pi}{6}}^{\frac{5\pi}{6}} (16 \sin^2\theta - 4) \, d\theta$ (E) $\frac{1}{2}\int_{0}^{\pi} (16 \sin^2\theta - 4) \, d\theta$

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20. When $x = 8$, the rate at which $\sqrt[3]{x}$ is increasing is $\frac{1}{k}$ times the rate at which x is increasing. What is the value of k ?

(A) 3 (B) 4 (C) 6 (D) 8 (E) 12

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21. The length of the path described by the parametric equations $x = \frac{1}{3}t^3$ and $y = \frac{1}{2}t^2$, where $0 \le t \le 1$, is given by

(A) $\int_0^1 \sqrt{t^2 + 1}\, dt$

(B) $\int_0^1 \sqrt{t^2 + t}\, dt$

(C) $\int_0^1 \sqrt{t^4 + t^2}\, dt$

(D) $\frac{1}{2}\int_0^1 \sqrt{4 + t^4}\, dt$

(E) $\frac{1}{6}\int_0^1 t^2\sqrt{4t^2 + 9}\, dt$

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22. If $\lim_{b\to\infty} \int_1^b \frac{dx}{x^p}$ is finite, then which of the following must be true?

(A) $\sum_{n=1}^{\infty} \frac{1}{n^p}$ converges

(B) $\sum_{n=1}^{\infty} \frac{1}{n^p}$ diverges

(C) $\sum_{n=1}^{\infty} \frac{1}{n^{p-2}}$ converges

(D) $\sum_{n=1}^{\infty} \frac{1}{n^{p-1}}$ converges

(E) $\sum_{n=1}^{\infty} \frac{1}{n^{p+1}}$ diverges

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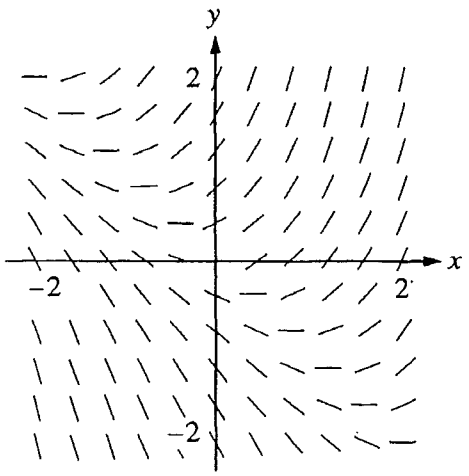
23. Let f be a function defined and continuous on the closed interval $[a, b]$. If f has a relative maximum at c and $a < c < b$, which of the following statements must be true?

I. $f'(c)$ exists.
II. If $f'(c)$ exists, then $f'(c) = 0$.
III. If $f''(c)$ exists, then $f''(c) \leq 0$.

(A) II only (B) III only (C) I and II only (D) I and III only (E) II and III only



24. Shown above is a slope field for which of the following differential equations?

(A) $\frac{dy}{dx} = 1 + x$ (B) $\frac{dy}{dx} = x^2$ (C) $\frac{dy}{dx} = x + y$ (D) $\frac{dy}{dx} = \frac{x}{y}$ (E) $\frac{dy}{dx} = \ln y$

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25. $\int_0^{\infty} x^2 e^{-x^3} dx$ is

(A) $-\frac{1}{3}$ (B) 0 (C) $\frac{1}{3}$ (D) 1 (E) divergent

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26. The population $P(t)$ of a species satisfies the logistic differential equation $\frac{dP}{dt} = P\left(2 - \frac{P}{5000}\right)$, where the initial population $P(0) = 3{,}000$ and t is the time in years. What is $\lim_{t \to \infty} P(t)$?

(A) 2,500 (B) 3,000 (C) 4,200 (D) 5,000 (E) 10,000

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27. If $\sum_{n=0}^{\infty} a_n x^n$ is a Taylor series that converges to $f(x)$ for all real x, then $f'(1) =$

(A) 0 (B) a_1 (C) $\sum_{n=0}^{\infty} a_n$ (D) $\sum_{n=1}^{\infty} na_n$ (E) $\sum_{n=1}^{\infty} na_n^{n-1}$

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28. $\lim_{x \to 1} \dfrac{\int_1^x e^{t^2} dt}{x^2 - 1}$ is

(A) 0 (B) 1 (C) $\frac{e}{2}$ (D) e (E) nonexistent

END OF PART A OF SECTION I

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON THIS PART ONLY.
DO NOT GO ON TO PART B UNTIL YOU ARE TOLD TO DO SO.

CALCULUS BC

SECTION I, Part B

Time — 50 minutes

Number of questions — 17

A GRAPHING CALCULATOR IS REQUIRED FOR SOME QUESTIONS ON THIS PART OF THE EXAMINATION.

Directions: Solve each of the following problems, using the available space for scratchwork. After examining the form of the choices, decide which is the best of the choices given and fill in the corresponding oval on the answer sheet. No credit will be given for anything written in the test book. Do not spend too much time on any one problem.

BE SURE YOU ARE USING PAGE 3 OF THE ANSWER SHEET TO RECORD YOUR ANSWERS TO QUESTIONS NUMBERED 76-92.

YOU MAY NOT RETURN TO PAGE 2 OF THE ANSWER SHEET.

In this test:

(1) The exact numerical value of the correct answer does not always appear among the choices given. When this happens, select from among the choices the number that best approximates the exact numerical value.

(2) Unless otherwise specified, the domain of a function f is assumed to be the set of all real numbers x for which $f(x)$ is a real number.

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76. For what integer k, $k > 1$, will both $\sum_{n=1}^{\infty} \frac{(-1)^{kn}}{n}$ and $\sum_{n=1}^{\infty} \left(\frac{k}{4}\right)^n$ converge?

(A) 6 (B) 5 (C) 4 (D) 3 (E) 2

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77. If f is a vector-valued function defined by $f(t) = (e^{-t}, \cos t)$, then $f''(t) =$

(A) $-e^{-t} + \sin t$ (B) $e^{-t} - \cos t$ (C) $(-e^{-t}, -\sin t)$

(D) $(e^{-t}, \cos t)$ (E) $(e^{-t}, -\cos t)$

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78. The radius of a circle is decreasing at a constant rate of 0.1 centimeter per second. In terms of the circumference C, what is the rate of change of the area of the circle, in square centimeters per second?

(A) $-(0.2)\pi C$

(B) $-(0.1)C$

(C) $-\frac{(0.1)C}{2\pi}$

(D) $(0.1)^2 C$

(E) $(0.1)^2 \pi C$

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79. Let f be the function given by $f(x) = \frac{(x-1)(x^2-4)}{x^2-a}$. For what positive values of a is f continuous for all real numbers x?

(A) None
(B) 1 only
(C) 2 only
(D) 4 only
(E) 1 and 4 only

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80. Let R be the region enclosed by the graph of $y = 1 + \ln(\cos^4 x)$, the x-axis, and the lines $x = -\frac{2}{3}$ and $x = \frac{2}{3}$. The closest integer approximation of the area of R is

(A) 0 (B) 1 (C) 2 (D) 3 (E) 4

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81. If $\frac{dy}{dx} = \sqrt{1 - y^2}$, then $\frac{d^2y}{dx^2} =$

(A) $-2y$ (B) $-y$ (C) $\frac{-y}{\sqrt{1 - y^2}}$ (D) y (E) $\frac{1}{2}$

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82. If $f(x) = g(x) + 7$ for $3 \le x \le 5$, then $\int_3^5 [f(x) + g(x)]\,dx =$

(A) $2\int_3^5 g(x)\,dx + 7$

(B) $2\int_3^5 g(x)\,dx + 14$

(C) $2\int_3^5 g(x)\,dx + 28$

(D) $\int_3^5 g(x)\,dx + 7$

(E) $\int_3^5 g(x)\,dx + 14$

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83. The Taylor series for $\ln x$, centered at $x = 1$, is $\sum_{n=1}^{\infty} (-1)^{n+1} \frac{(x-1)^n}{n}$. Let f be the function given by the sum of the first three nonzero terms of this series. The maximum value of $\left|\ln x - f(x)\right|$ for $0.3 \le x \le 1.7$ is

(A) 0.030 (B) 0.039 (C) 0.145 (D) 0.153 (E) 0.529

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84. What are all values of x for which the series $\sum_{n=1}^{\infty} \frac{(x+2)^n}{\sqrt{n}}$ converges?

(A) $-3 < x < -1$ (B) $-3 \leq x < -1$ (C) $-3 \leq x \leq -1$ (D) $-1 \leq x < 1$ (E) $-1 \leq x \leq 1$

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x	2	5	7	8
$f(x)$	10	30	40	20

85. The function f is continuous on the closed interval [2, 8] and has values that are given in the table above. Using the subintervals [2, 5], [5, 7], and [7, 8], what is the trapezoidal approximation of $\int_2^8 f(x)dx$?

(A) 110 (B) 130 (C) 160 (D) 190 (E) 210

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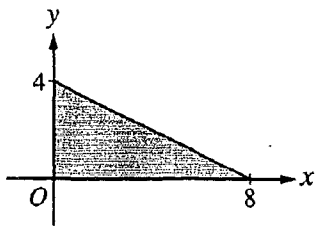

86. The base of a solid is a region in the first quadrant bounded by the x-axis, the y-axis, and the line $x + 2y = 8$, as shown in the figure above. If cross sections of the solid perpendicular to the x-axis are semicircles, what is the volume of the solid?

(A) 12.566 (B) 14.661 (C) 16.755 (D) 67.021 (E) 134.041

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87. Which of the following is an equation of the line tangent to the graph of $f(x) = x^4 + 2x^2$ at the point where $f'(x) = 1$?

(A) $y = 8x - 5$
(B) $y = x + 7$
(C) $y = x + 0.763$
(D) $y = x - 0.122$
(E) $y = x - 2.146$

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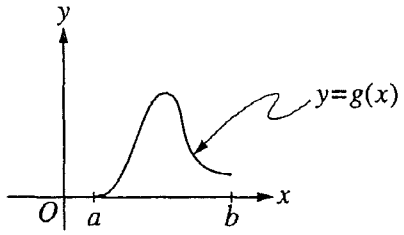
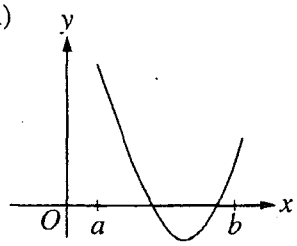


88. Let $g(x) = \int_a^x f(t)dt$, where $a \le x \le b$. The figure above shows the graph of g on $[a, b]$. Which of the following could be the graph of f on $[a, b]$?

(A)


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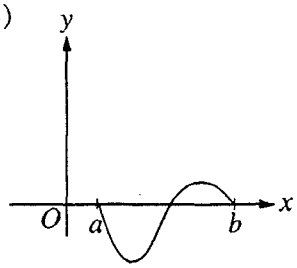

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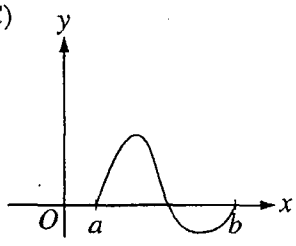

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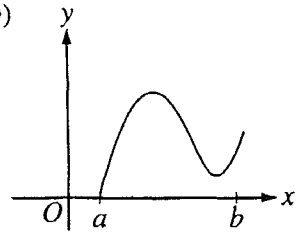

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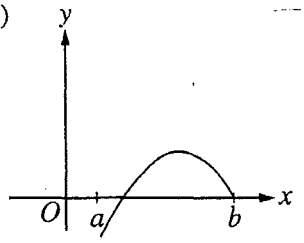

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89. The graph of the function represented by the Maclaurin series

$1 - x + \frac{x^2}{2!} - \frac{x^3}{3!} + \ldots + \frac{(-1)^n x^n}{n!} + \ldots$ intersects the graph of $y = x^3$ at $x =$

(A) 0.773 (B) 0.865 (C) 0.929 (D) 1.000 (E) 1.857

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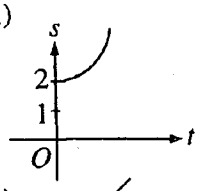
90. A particle starts from rest at the point (2, 0) and moves along the x-axis with a constant positive acceleration for time $t \geq 0$. Which of the following could be the graph of the distance $s(t)$ of the particle from the origin as a function of time t ?

(A)



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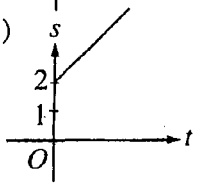

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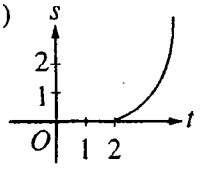

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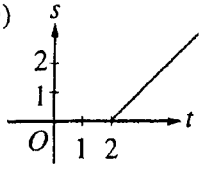
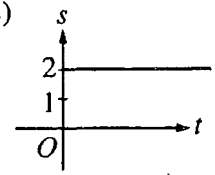


(E)



GO ON TO THE NEXT PAGE

t (sec)	0	2	4	6
$a(t)$ (ft/sec^2)	5	2	8	3

91. The data for the acceleration $a(t)$ of a car from 0 to 6 seconds are given in the table above. If the velocity at $t = 0$ is 11 feet per second, the approximate value of the velocity at $t = 6$, computed using a left-hand Riemann sum with three subintervals of equal length, is

(A) 26 ft/sec (B) 30 ft/sec (C) 37 ft/sec (D) 39 ft/sec (E) 41 ft/sec

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92. Let f be the function given by $f(x) = x^2 - 2x + 3$. The tangent line to the graph of f at $x = 2$ is used to approximate values of $f(x)$. Which of the following is the greatest value of x for which the error resulting from this tangent line approximation is less than 0.5 ?

(A) 2.4 (B) 2.5 (C) 2.6 (D) 2.7 (E) 2.8

END OF SECTION I

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY
CHECK YOUR WORK ON PART B ONLY.
DO NOT GO ON TO SECTION II UNTIL YOU ARE TOLD TO DO SO.

MAKE SURE YOU HAVE PLACED YOUR AP NUMBER LABEL ON YOUR ANSWER SHEET AND HAVE WRITTEN AND GRIDDED YOUR AP NUMBER IN THE APPROPRIATE SECTION OF YOUR ANSWER SHEET.

AFTER TIME HAS BEEN CALLED, ANSWER QUESTIONS 93-96.

Chapter III

Answers to the 1998 AP Calculus AB and Calculus BC Examinations

- Section I: Multiple Choice
  - Blank Answer Sheet
- Section II: Free Response
  - Student Preparation for the Exams
  - Free-Response Questions, Scoring Guidelines, and Sample Student Responses with Commentary
  - Section II, Calculus AB
  - Section II, Calculus BC

Section I: Multiple Choice

Listed below are the correct answers to the multiple-choice questions and the percentage of AP candidates who answered each question correctly. A copy of the blank answer sheet appears on the following pages for reference.

Section 1 Answer Key and Percent Answering Correctly
Calculus AB

Item No	Correct Answer	Percent Correct by Grade 5	4	3	2	1	Total Percent Correct
1	D	96%	92%	83%	70%	41%	78%
2	B	75%	55%	37%	24%	19%	43%
3	C	94%	85%	75%	60%	38%	71%
4	B	82%	62%	47%	36%	31%	52%
5	E	78%	64%	50%	39%	26%	52%
6	A	94%	86%	75%	53%	21%	68%
7	E	85%	59%	38%	22%	13%	43%
8	E	77%	53%	43%	37%	31%	48%
9	D	90%	77%	65%	55%	45%	67%
10	D	91%	83%	74%	62%	62%	74%
11	A	76%	50%	36%	27%	17%	42%
12	E	91%	71%	48%	29%	20%	52%
13	B	72%	55%	41%	31%	20%	46%
14	C	100%	99%	98%	94%	74%	94%
15	D	89%	83%	76%	59%	39%	71%
16	E	94%	87%	74%	54%	29%	69%
17	D	74%	44%	24%	12%	7%	33%
18	B	96%	86%	72%	54%	35%	71%
19	C	55%	36%	23%	17%	10%	28%
20	A	88%	83%	71%	62%	39%	69%
21	B	59%	34%	25%	20%	23%	31%
22	C	93%	84%	69%	57%	39%	69%
23	A	94%	85%	70%	51%	30%	68%
24	D	65%	54%	51%	51%	39%	52%
25	D	94%	83%	75%	62%	36%	71%
26	A	80%	51%	31%	21%	16%	41%
27	A	72%	50%	33%	21%	13%	40%
28	E	86%	71%	51%	32%	9%	56%
76	A	79%	65%	59%	56%	49%	61%
77	C	96%	82%	63%	41%	25%	63%
78	B	87%	66%	42%	22%	9%	46%
79	A	84%	66%	46%	27%	11%	47%
80	B	72%	57%	46%	34%	26%	48%
81	D	93%	82%	73%	66%	51%	74%
82	E	47%	28%	19%	15%	14%	24%
83	B	81%	60%	40%	28%	19%	45%
84	A	82%	57%	38%	21%	11%	42%
85	C	80%	56%	42%	29%	21%	46%
86	C	33%	15%	12%	17%	23%	19%
87	D	80%	50%	32%	20%	17%	40%
88	C	89%	71%	54%	38%	24%	55%
89	B	76%	48%	31%	19%	17%	38%
90	D	70%	45%	30%	20%	15%	36%
91	E	80%	64%	49%	34%	18%	51%
92	D	97%	91%	80%	62%	30%	76%

Section 1 Answer Key and Percent Answering Correctly
Calculus BC

Item No	Correct Answer	Percent Correct by Grade 5	4	3	2	1	Total Percent Correct
1	C	91%	81%	79%	67%	55%	80%
2	A	98%	96%	92%	85%	72%	92%
3	D	80%	63%	50%	30%	26%	58%
4	A	83%	65%	49%	32%	19%	61%
5	A	84%	64%	51%	35%	20%	60%
6	E	93%	89%	84%	69%	50%	83%
7	E	89%	74%	61%	41%	31%	68%
8	B	78%	60%	41%	28%	13%	55%
9	D	91%	83%	76%	67%	58%	80%
10	E	90%	78%	72%	64%	39%	75%
11	A	76%	57%	44%	34%	18%	55%
12	E	90%	77%	64%	49%	27%	72%
13	B	74%	66%	58%	45%	29%	62%
14	E	86%	73%	62%	43%	31%	68%
15	B	89%	80%	71%	63%	41%	76%
16	C	55%	40%	29%	25%	15%	37%
17	D	77%	59%	41%	24%	11%	54%
18	B	57%	36%	23%	21%	13%	35%
19	D	56%	34%	27%	17%	13%	37%
20	E	79%	56%	39%	32%	9%	53%
21	C	89%	78%	66%	46%	38%	73%
22	A	83%	69%	59%	56%	47%	68%
23	E	53%	28%	21%	14%	8%	31%
24	C	60%	38%	24%	17%	12%	38%
25	C	68%	44%	33%	16%	17%	45%
26	E	32%	16%	10%	12%	13%	20%
27	D	49%	29%	27%	16%	17%	35%
28	C	72%	47%	46%	33%	25%	56%
76	D	86%	64%	47%	34%	22%	60%
77	E	94%	90%	85%	83%	70%	87%
78	B	88%	76%	68%	41%	28%	69%
79	A	57%	47%	33%	33%	22%	45%
80	B	96%	92%	93%	86%	69%	91%
81	B	43%	21%	16%	10%	7%	25%
82	B	72%	44%	38%	28%	16%	48%
83	C	44%	24%	13%	12%	11%	27%
84	B	63%	38%	27%	20%	12%	40%
85	C	78%	58%	45%	38%	24%	58%
86	C	50%	26%	19%	11%	17%	32%
87	D	79%	56%	42%	35%	21%	57%
88	C	93%	83%	66%	48%	34%	75%
89	A	74%	55%	46%	37%	27%	56%
90	A	46%	31%	26%	20%	9%	32%
91	E	37%	25%	17%	17%	14%	26%
92	D	86%	66%	46%	31%	14%	65%