



**CollegeBoard**

Advanced Placement  
Program

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**2008**  
**AP<sup>®</sup> Calculus AB**  
**Exam**

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## **The College Board**

The College Board is a not-for-profit membership association whose mission is to connect students to college success and opportunity. Founded in 1900, the association is composed of more than 5,600 schools, colleges, universities and other educational organizations. Each year, the College Board serves seven million students and their parents, 23,000 high schools, and 3,800 colleges through major programs and services in college admissions, guidance, assessment, financial aid, enrollment, and teaching and learning. Among its best-known programs are the SAT<sup>®</sup>, the PSAT/NMSQT<sup>®</sup> and the Advanced Placement Program<sup>®</sup> (AP<sup>®</sup>). The College Board is committed to the principles of excellence and equity, and that commitment is embodied in all of its programs, services, activities and concerns.

For further information, visit [www.collegeboard.com](http://www.collegeboard.com).

## **AP Equity Policy Statement**

The College Board and the Advanced Placement Program encourage teachers, AP Coordinators and school administrators to make equitable access a guiding principle for their AP programs. The College Board is committed to the principle that all students deserve an opportunity to participate in rigorous and academically challenging courses and programs. All students who are willing to accept the challenge of a rigorous academic curriculum should be considered for admission to AP courses. The Board encourages the elimination of barriers that restrict access to AP courses for students from ethnic, racial and socioeconomic groups that have been traditionally underrepresented in the AP Program. Schools should make every effort to ensure that their AP classes reflect the diversity of their student population.

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***For further information, visit [apcentral.collegeboard.com](http://apcentral.collegeboard.com).***

Materials included in this Released Exam may not reflect the current AP Course Description and exam in this subject, and teachers are advised to take this into account as they use these materials to support their instruction of students. For up-to-date information about this AP course and exam, please download the official AP Course Description from the AP Central<sup>®</sup> Web site at [apcentral.collegeboard.com](http://apcentral.collegeboard.com).





**R. This section is for the survey questions in the AP Student Pack. (Do not put responses to exam questions in this section.) Be sure each mark is dark and completely fills the oval.**

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**Do not complete this section unless instructed to do so.**

**S.** If this answer sheet is for the Chinese Language and Culture, French Language, French Literature, German Language, Italian Language and Culture, Japanese Language and Culture, Spanish Language, or Spanish Literature Exam, please answer the following questions. (Your responses will not affect your grade.)

- Have you lived or studied for one month or more in a country where the language of the exam you are now taking is spoken?  Yes  No
- Do you regularly speak or hear the language at home?  Yes  No

**Indicate your answers to the exam questions in this section. If a question has only four answer options, do not mark option E. Your answer sheet will be scored by machine. Use only No. 2 pencils to mark your answers on pages 2 and 3 (one response per question). After you have determined your response, be sure to completely fill in the oval corresponding to the number of the question you are answering. Stray marks and smudges could be read as answers, so erase carefully and completely. Any improper gridding may affect your grade. Answers written in the multiple-choice booklet will not be scored.**

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16	<input type="radio"/> A	<input type="radio"/> B	<input type="radio"/> C	<input type="radio"/> D	<input type="radio"/> E	41	<input type="radio"/> A	<input type="radio"/> B	<input type="radio"/> C	<input type="radio"/> D	<input type="radio"/> E	66	<input type="radio"/> A	<input type="radio"/> B	<input type="radio"/> C	<input type="radio"/> D	<input type="radio"/> E
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21	<input type="radio"/> A	<input type="radio"/> B	<input type="radio"/> C	<input type="radio"/> D	<input type="radio"/> E	46	<input type="radio"/> A	<input type="radio"/> B	<input type="radio"/> C	<input type="radio"/> D	<input type="radio"/> E	71	<input type="radio"/> A	<input type="radio"/> B	<input type="radio"/> C	<input type="radio"/> D	<input type="radio"/> E
22	<input type="radio"/> A	<input type="radio"/> B	<input type="radio"/> C	<input type="radio"/> D	<input type="radio"/> E	47	<input type="radio"/> A	<input type="radio"/> B	<input type="radio"/> C	<input type="radio"/> D	<input type="radio"/> E	72	<input type="radio"/> A	<input type="radio"/> B	<input type="radio"/> C	<input type="radio"/> D	<input type="radio"/> E
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25	<input type="radio"/> A	<input type="radio"/> B	<input type="radio"/> C	<input type="radio"/> D	<input type="radio"/> E	50	<input type="radio"/> A	<input type="radio"/> B	<input type="radio"/> C	<input type="radio"/> D	<input type="radio"/> E	75	<input type="radio"/> A	<input type="radio"/> B	<input type="radio"/> C	<input type="radio"/> D	<input type="radio"/> E

FOR QUESTIONS 76-151, SEE PAGE 3.

**DO NOT WRITE IN THIS AREA.**



Be sure each mark is dark and completely fills the oval. If a question has only four answer options, do not mark option E.

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|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 76  | (A) | (B) | (C) | (D) | (E) | 101 | (A) | (B) | (C) | (D) | (E) | 126 | (A) | (B) | (C) | (D) | (E) |
| 77  | (A) | (B) | (C) | (D) | (E) | 102 | (A) | (B) | (C) | (D) | (E) | 127 | (A) | (B) | (C) | (D) | (E) |
| 78  | (A) | (B) | (C) | (D) | (E) | 103 | (A) | (B) | (C) | (D) | (E) | 128 | (A) | (B) | (C) | (D) | (E) |
| 79  | (A) | (B) | (C) | (D) | (E) | 104 | (A) | (B) | (C) | (D) | (E) | 129 | (A) | (B) | (C) | (D) | (E) |
| 80  | (A) | (B) | (C) | (D) | (E) | 105 | (A) | (B) | (C) | (D) | (E) | 130 | (A) | (B) | (C) | (D) | (E) |
| 81  | (A) | (B) | (C) | (D) | (E) | 106 | (A) | (B) | (C) | (D) | (E) | 131 | (A) | (B) | (C) | (D) | (E) |
| 82  | (A) | (B) | (C) | (D) | (E) | 107 | (A) | (B) | (C) | (D) | (E) | 132 | (A) | (B) | (C) | (D) | (E) |
| 83  | (A) | (B) | (C) | (D) | (E) | 108 | (A) | (B) | (C) | (D) | (E) | 133 | (A) | (B) | (C) | (D) | (E) |
| 84  | (A) | (B) | (C) | (D) | (E) | 109 | (A) | (B) | (C) | (D) | (E) | 134 | (A) | (B) | (C) | (D) | (E) |
| 85  | (A) | (B) | (C) | (D) | (E) | 110 | (A) | (B) | (C) | (D) | (E) | 135 | (A) | (B) | (C) | (D) | (E) |
| 86  | (A) | (B) | (C) | (D) | (E) | 111 | (A) | (B) | (C) | (D) | (E) | 136 | (A) | (B) | (C) | (D) | (E) |
| 87  | (A) | (B) | (C) | (D) | (E) | 112 | (A) | (B) | (C) | (D) | (E) | 137 | (A) | (B) | (C) | (D) | (E) |
| 88  | (A) | (B) | (C) | (D) | (E) | 113 | (A) | (B) | (C) | (D) | (E) | 138 | (A) | (B) | (C) | (D) | (E) |
| 89  | (A) | (B) | (C) | (D) | (E) | 114 | (A) | (B) | (C) | (D) | (E) | 139 | (A) | (B) | (C) | (D) | (E) |
| 90  | (A) | (B) | (C) | (D) | (E) | 115 | (A) | (B) | (C) | (D) | (E) | 140 | (A) | (B) | (C) | (D) | (E) |
| 91  | (A) | (B) | (C) | (D) | (E) | 116 | (A) | (B) | (C) | (D) | (E) | 141 | (A) | (B) | (C) | (D) | (E) |
| 92  | (A) | (B) | (C) | (D) | (E) | 117 | (A) | (B) | (C) | (D) | (E) | 142 | (A) | (B) | (C) | (D) | (E) |
| 93  | (A) | (B) | (C) | (D) | (E) | 118 | (A) | (B) | (C) | (D) | (E) | 143 | (A) | (B) | (C) | (D) | (E) |
| 94  | (A) | (B) | (C) | (D) | (E) | 119 | (A) | (B) | (C) | (D) | (E) | 144 | (A) | (B) | (C) | (D) | (E) |
| 95  | (A) | (B) | (C) | (D) | (E) | 120 | (A) | (B) | (C) | (D) | (E) | 145 | (A) | (B) | (C) | (D) | (E) |
| 96  | (A) | (B) | (C) | (D) | (E) | 121 | (A) | (B) | (C) | (D) | (E) | 146 | (A) | (B) | (C) | (D) | (E) |
| 97  | (A) | (B) | (C) | (D) | (E) | 122 | (A) | (B) | (C) | (D) | (E) | 147 | (A) | (B) | (C) | (D) | (E) |
| 98  | (A) | (B) | (C) | (D) | (E) | 123 | (A) | (B) | (C) | (D) | (E) | 148 | (A) | (B) | (C) | (D) | (E) |
| 99  | (A) | (B) | (C) | (D) | (E) | 124 | (A) | (B) | (C) | (D) | (E) | 149 | (A) | (B) | (C) | (D) | (E) |
| 100 | (A) | (B) | (C) | (D) | (E) | 125 | (A) | (B) | (C) | (D) | (E) | 150 | (A) | (B) | (C) | (D) | (E) |
|     |     |     |     |     |     |     |     |     |     |     |     | 151 | (A) | (B) | (C) | (D) | (E) |

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**DO NOT WRITE IN THIS AREA.**



**HOME ADDRESS AND SCHOOL AREA—COMPLETE THIS AREA ONLY ONCE.**

**T. YOUR MAILING ADDRESS**

\* Your grade report will be mailed to this address in July.

\* Using the abbreviations given in your AP Student Pack, print your address in the boxes below. If your international address does not fit, see item V, below.

Street																										City																										STATE																										ZIP OR POSTAL CODE																										U. COUNTRY CODE																																																																																																																																																																																																																																									
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**W. TELEPHONE**

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**FOR STUDENTS OUTSIDE THE UNITED STATES ONLY**

V. If the address gridded above is not complete enough for delivery of your grade report, please fill in this oval and print your complete address below.

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**X. SCHOOL YOU ATTEND**

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**Y. COLLEGE TO RECEIVE YOUR AP GRADE REPORT**

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Using the College Code list in the AP Student Pack, indicate the one college that you want to receive your AP Grade Report by writing in the college code number, gridding the appropriate ovals, and completing the information below.

## The Calculus AB Exam

AP<sup>®</sup> Calculus AB Exam

## SECTION I: Multiple-Choice Questions

**At a Glance****Total Time**

1 hour, 45 minutes

**Number of Questions**

45

**Percent of Total Grade**

50%

**Writing Instrument**

Pencil required

**Part A****Number of Questions**

28

**Time**

55 minutes

**Electronic Device**

None allowed

**Part B****Number of Questions**

17

**Time**

50 minutes

**Electronic Device**Graphing calculator  
required**Instructions**

Section I of this exam contains 45 multiple-choice questions and 4 survey questions. For Part A, fill in only the ovals for numbers 1 through 28 on page 2 of the answer sheet. For Part B, fill in only the ovals for numbers 76 through 92 on page 3 of the answer sheet. The survey questions are numbers 93 through 96.

Indicate all of your answers to the multiple-choice questions on the answer sheet. No credit will be given for anything written in this exam booklet, but you may use the booklet for notes or scratch work. After you have decided which of the suggested answers is best, completely fill in the corresponding oval on the answer sheet. Give only one answer to each question. If you change an answer, be sure that the previous mark is erased completely. Here is a sample question and answer.

Sample Question      Sample Answer

Chicago is a

 (A)     (B)     (C)     (D)     (E)

(A) state

(B) city

(C) country

(D) continent

(E) village

Use your time effectively, working as quickly as you can without losing accuracy. Do not spend too much time on any one question. Go on to other questions and come back to the ones you have not answered if you have time. It is not expected that everyone will know the answers to all of the multiple-choice questions.

**About Guessing**

Many students wonder whether or not to guess the answers to questions about which they are not certain. In this section of the exam, as a correction for random guessing, one-fourth of the number of questions you answer incorrectly will be subtracted from the number of questions you answer correctly. If you are not sure of the best answer but have some knowledge of the question and are able to eliminate one or more of the answer choices, your chance of answering correctly is improved, and it may be to your advantage to answer such a question.

**CALCULUS AB**  
**SECTION I, Part A**  
**Time—55 minutes**  
**Number of questions—28**

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

**Directions:** Solve each of the following problems, using the available space for scratch work. 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 exam book. Do not spend too much time on any one problem.

**In this exam:**

- (1) 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.
- (2) The inverse of a trigonometric function  $f$  may be indicated using the inverse function notation  $f^{-1}$  or with the prefix “arc” (e.g.,  $\sin^{-1}x = \arcsin x$ ).

1.  $\lim_{x \rightarrow \infty} \frac{(2x-1)(3-x)}{(x-1)(x+3)}$  is
- (A) -3      (B) -2      (C) 2      (D) 3      (E) nonexistent

- 
2.  $\int \frac{1}{x^2} dx =$
- (A)  $\ln x^2 + C$       (B)  $-\ln x^2 + C$       (C)  $x^{-1} + C$       (D)  $-x^{-1} + C$       (E)  $-2x^{-3} + C$

## Part A

3. If  $f(x) = (x - 1)(x^2 + 2)^3$ , then  $f'(x) =$

(A)  $6x(x^2 + 2)^2$

(B)  $6x(x - 1)(x^2 + 2)^2$

(C)  $(x^2 + 2)^2(x^2 + 3x - 1)$

(D)  $(x^2 + 2)^2(7x^2 - 6x + 2)$

(E)  $-3(x - 1)(x^2 + 2)^2$

---

4.  $\int (\sin(2x) + \cos(2x)) dx =$

(A)  $\frac{1}{2}\cos(2x) + \frac{1}{2}\sin(2x) + C$

(B)  $-\frac{1}{2}\cos(2x) + \frac{1}{2}\sin(2x) + C$

(C)  $2\cos(2x) + 2\sin(2x) + C$

(D)  $2\cos(2x) - 2\sin(2x) + C$

(E)  $-2\cos(2x) + 2\sin(2x) + C$

5.  $\lim_{x \rightarrow 0} \frac{5x^4 + 8x^2}{3x^4 - 16x^2}$  is

- (A)  $-\frac{1}{2}$       (B) 0      (C) 1      (D)  $\frac{5}{3}$       (E) nonexistent

---

$$f(x) = \begin{cases} \frac{x^2 - 4}{x - 2} & \text{if } x \neq 2 \\ 1 & \text{if } x = 2 \end{cases}$$

6. Let  $f$  be the function defined above. Which of the following statements about  $f$  are true?

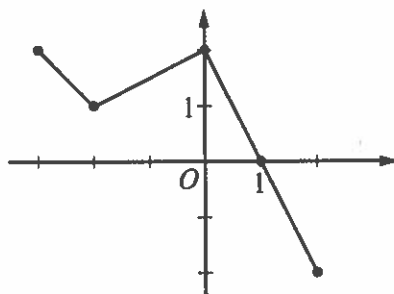
- I.  $f$  has a limit at  $x = 2$ .
  - II.  $f$  is continuous at  $x = 2$ .
  - III.  $f$  is differentiable at  $x = 2$ .
- (A) I only  
(B) II only  
(C) III only  
(D) I and II only  
(E) I, II, and III

## Part A

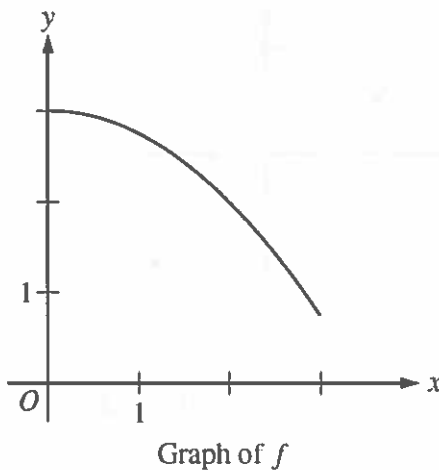
7. A particle moves along the  $x$ -axis with velocity given by  $v(t) = 3t^2 + 6t$  for time  $t \geq 0$ . If the particle is at position  $x = 2$  at time  $t = 0$ , what is the position of the particle at time  $t = 1$ ?
- (A) 4      (B) 6      (C) 9      (D) 11      (E) 12

- 
8. If  $f(x) = \cos(3x)$ , then  $f'\left(\frac{\pi}{9}\right) =$

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

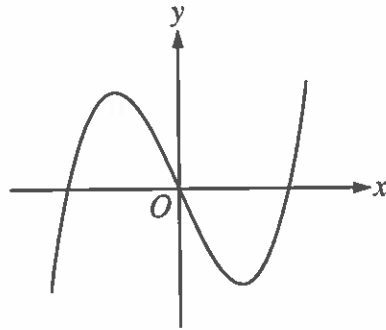
Graph of  $f$ 

9. The graph of the piecewise linear function  $f$  is shown in the figure above. If  $g(x) = \int_{-2}^x f(t) dt$ , which of the following values is greatest?
- (A)  $g(-3)$       (B)  $g(-2)$       (C)  $g(0)$       (D)  $g(1)$       (E)  $g(2)$



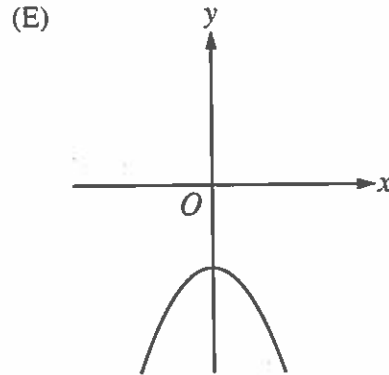
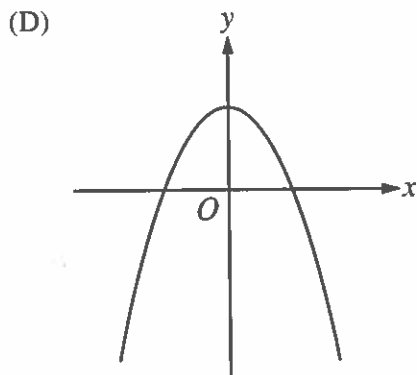
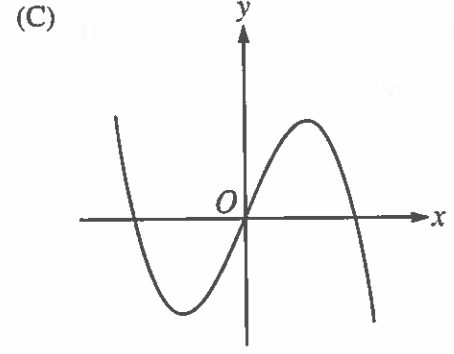
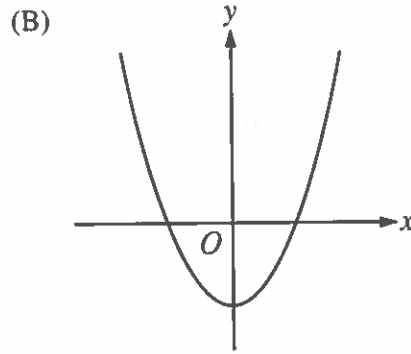
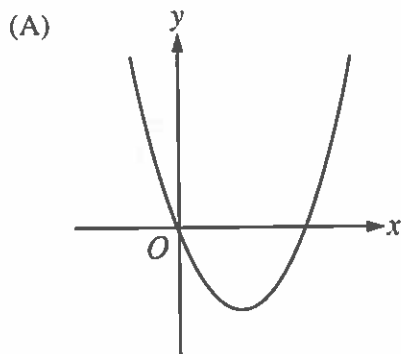
10. The graph of the function  $f$  is shown above for  $0 \leq x \leq 3$ . Of the following, which has the least value?

- (A)  $\int_1^3 f(x) dx$
- (B) Left Riemann sum approximation of  $\int_1^3 f(x) dx$  with 4 subintervals of equal length
- (C) Right Riemann sum approximation of  $\int_1^3 f(x) dx$  with 4 subintervals of equal length
- (D) Midpoint Riemann sum approximation of  $\int_1^3 f(x) dx$  with 4 subintervals of equal length
- (E) Trapezoidal sum approximation of  $\int_1^3 f(x) dx$  with 4 subintervals of equal length



Graph of  $f$

11. The graph of a function  $f$  is shown above. Which of the following could be the graph of  $f'$ , the derivative of  $f$ ?



## Part A

12. If  $f(x) = e^{(2/x)}$ , then  $f'(x) =$

- (A)  $2e^{(2/x)} \ln x$       (B)  $e^{(2/x)}$       (C)  $e^{(-2/x^2)}$       (D)  $-\frac{2}{x^2}e^{(2/x)}$       (E)  $-2x^2e^{(2/x)}$

---

13. If  $f(x) = x^2 + 2x$ , then  $\frac{d}{dx}(f(\ln x)) =$

- (A)  $\frac{2 \ln x + 2}{x}$       (B)  $2x \ln x + 2x$       (C)  $2 \ln x + 2$       (D)  $2 \ln x + \frac{2}{x}$       (E)  $\frac{2x + 2}{x}$

$x$	0	1	2	3
$f''(x)$	5	0	-7	4

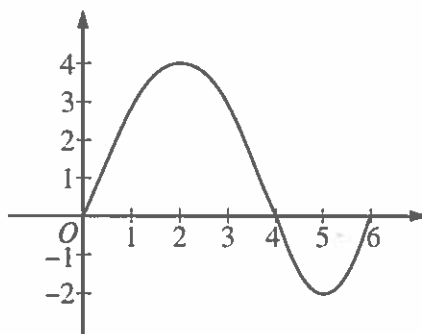
14. The polynomial function  $f$  has selected values of its second derivative  $f''$  given in the table above. Which of the following statements must be true?
- (A)  $f$  is increasing on the interval  $(0, 2)$ .
- (B)  $f$  is decreasing on the interval  $(0, 2)$ .
- (C)  $f$  has a local maximum at  $x = 1$ .
- (D) The graph of  $f$  has a point of inflection at  $x = 1$ .
- (E) The graph of  $f$  changes concavity in the interval  $(0, 2)$ .

- 
15.  $\int \frac{x}{x^2 - 4} dx =$
- (A)  $\frac{-1}{4(x^2 - 4)^2} + C$
- (B)  $\frac{1}{2(x^2 - 4)} + C$
- (C)  $\frac{1}{2} \ln|x^2 - 4| + C$
- (D)  $2 \ln|x^2 - 4| + C$
- (E)  $\frac{1}{2} \arctan\left(\frac{x}{2}\right) + C$

## Part A

16. If  $\sin(xy) = x$ , then  $\frac{dy}{dx} =$

- (A)  $\frac{1}{\cos(xy)}$   
 (B)  $\frac{1}{x \cos(xy)}$   
 (C)  $\frac{1 - \cos(xy)}{\cos(xy)}$   
 (D)  $\frac{1 - y \cos(xy)}{x \cos(xy)}$   
 (E)  $\frac{y(1 - \cos(xy))}{x}$

Graph of  $f$ 

17. The graph of the function  $f$  shown above has horizontal tangents at  $x = 2$  and  $x = 5$ . Let  $g$  be the function defined by  $g(x) = \int_0^x f(t) dt$ . For what values of  $x$  does the graph of  $g$  have a point of inflection?

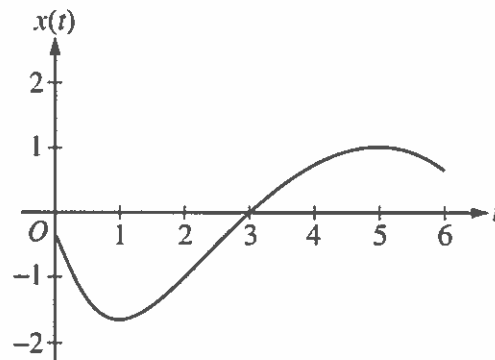
- (A) 2 only      (B) 4 only      (C) 2 and 5 only      (D) 2, 4, and 5      (E) 0, 4, and 6

18. In the  $xy$ -plane, the line  $x + y = k$ , where  $k$  is a constant, is tangent to the graph of  $y = x^2 + 3x + 1$ . What is the value of  $k$ ?
- (A)  $-3$       (B)  $-2$       (C)  $-1$       (D)  $0$       (E)  $1$
- 

19. What are all horizontal asymptotes of the graph of  $y = \frac{5 + 2^x}{1 - 2^x}$  in the  $xy$ -plane?
- (A)  $y = -1$  only  
(B)  $y = 0$  only  
(C)  $y = 5$  only  
(D)  $y = -1$  and  $y = 0$   
(E)  $y = -1$  and  $y = 5$

## Part A

20. Let  $f$  be a function with a second derivative given by  $f''(x) = x^2(x - 3)(x - 6)$ . What are the  $x$ -coordinates of the points of inflection of the graph of  $f$ ?
- (A) 0 only      (B) 3 only      (C) 0 and 6 only      (D) 3 and 6 only      (E) 0, 3, and 6



21. A particle moves along a straight line. The graph of the particle's position  $x(t)$  at time  $t$  is shown above for  $0 < t < 6$ . The graph has horizontal tangents at  $t = 1$  and  $t = 5$  and a point of inflection at  $t = 2$ . For what values of  $t$  is the velocity of the particle increasing?
- (A)  $0 < t < 2$   
 (B)  $1 < t < 5$   
 (C)  $2 < t < 6$   
 (D)  $3 < t < 5$  only  
 (E)  $1 < t < 2$  and  $5 < t < 6$

22. A rumor spreads among a population of  $N$  people at a rate proportional to the product of the number of people who have heard the rumor and the number of people who have not heard the rumor. If  $p$  denotes the number of people who have heard the rumor, which of the following differential equations could be used to model this situation with respect to time  $t$ , where  $k$  is a positive constant?

(A)  $\frac{dp}{dt} = kp$

(B)  $\frac{dp}{dt} = kp(N - p)$

(C)  $\frac{dp}{dt} = kp(p - N)$

(D)  $\frac{dp}{dt} = kt(N - t)$

(E)  $\frac{dp}{dt} = kt(t - N)$

## Part A

23. Which of the following is the solution to the differential equation  $\frac{dy}{dx} = \frac{x^2}{y}$  with the initial condition  $y(3) = -2$ ?

(A)  $y = 2e^{-9+x^3/3}$

(B)  $y = -2e^{-9+x^3/3}$

(C)  $y = \sqrt{\frac{2x^3}{3}}$

(D)  $y = \sqrt{\frac{2x^3}{3} - 14}$

(E)  $y = -\sqrt{\frac{2x^3}{3} - 14}$

---

24. The function  $f$  is twice differentiable with  $f(2) = 1$ ,  $f'(2) = 4$ , and  $f''(2) = 3$ . What is the value of the approximation of  $f(1.9)$  using the line tangent to the graph of  $f$  at  $x = 2$ ?

- (A) 0.4      (B) 0.6      (C) 0.7      (D) 1.3      (E) 1.4

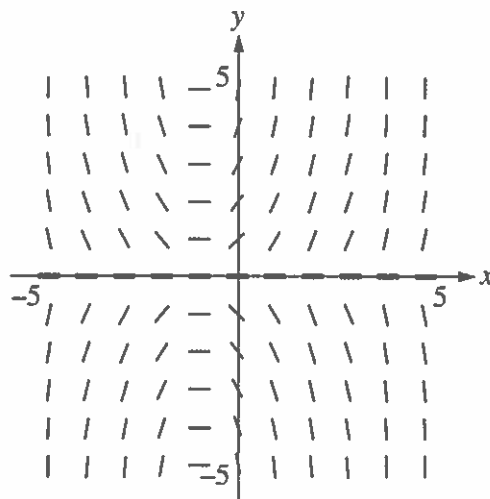
$$f(x) = \begin{cases} cx + d & \text{for } x \leq 2 \\ x^2 - cx & \text{for } x > 2 \end{cases}$$

25. Let  $f$  be the function defined above, where  $c$  and  $d$  are constants. If  $f$  is differentiable at  $x = 2$ , what is the value of  $c + d$ ?

- (A)  $-4$       (B)  $-2$       (C)  $0$       (D)  $2$       (E)  $4$
- 

26. What is the slope of the line tangent to the curve  $y = \arctan(4x)$  at the point at which  $x = \frac{1}{4}$ ?

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



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

- (A)  $\frac{dy}{dx} = xy$
- (B)  $\frac{dy}{dx} = xy - y$
- (C)  $\frac{dy}{dx} = xy + y$
- (D)  $\frac{dy}{dx} = xy + x$
- (E)  $\frac{dy}{dx} = (x + 1)^3$

28. Let  $f$  be a differentiable function such that  $f(3) = 15$ ,  $f(6) = 3$ ,  $f'(3) = -8$ , and  $f'(6) = -2$ . The function  $g$  is differentiable and  $g(x) = f^{-1}(x)$  for all  $x$ . What is the value of  $g'(3)$ ?
- (A)  $-\frac{1}{2}$
- (B)  $-\frac{1}{8}$
- (C)  $\frac{1}{6}$
- (D)  $\frac{1}{3}$
- (E) The value of  $g'(3)$  cannot be determined from the information given.
- 

END OF PART A OF SECTION I

**CALCULUS AB**  
**SECTION I, Part B**  
**Time—50 minutes**  
**Number of questions—17**

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

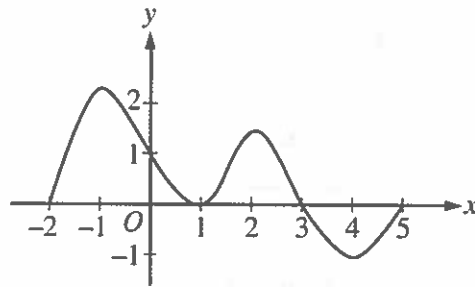
**Directions:** Solve each of the following problems, using the available space for scratch work. After examining the form of the choices, decide which is the best of the choices given and fill in the corresponding oval on the answer sheet. No credit will be given for anything written in the exam book. 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.**

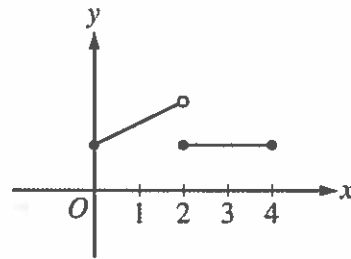
**YOU MAY NOT RETURN TO PAGE 2 OF THE ANSWER SHEET.**

**In this exam:**

- (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.
- (3) The inverse of a trigonometric function  $f$  may be indicated using the inverse function notation  $f^{-1}$  or with the prefix “arc” (e.g.,  $\sin^{-1}x = \arcsin x$ ).

Graph of  $f'$ 

76. The graph of  $f'$ , the derivative of  $f$ , is shown above for  $-2 \leq x \leq 5$ . On what intervals is  $f$  increasing?
- (A)  $[-2, 1]$  only  
(B)  $[-2, 3]$   
(C)  $[3, 5]$  only  
(D)  $[0, 1.5]$  and  $[3, 5]$   
(E)  $[-2, -1]$ ,  $[1, 2]$ , and  $[4, 5]$

Graph of  $f$ 

77. The figure above shows the graph of a function  $f$  with domain  $0 \leq x \leq 4$ . Which of the following statements are true?

- I.  $\lim_{x \rightarrow 2^-} f(x)$  exists.
  - II.  $\lim_{x \rightarrow 2^+} f(x)$  exists.
  - III.  $\lim_{x \rightarrow 2} f(x)$  exists.
- (A) I only      (B) II only      (C) I and II only      (D) I and III only      (E) I, II, and III

78. The first derivative of the function  $f$  is defined by  $f'(x) = \sin(x^3 - x)$  for  $0 \leq x \leq 2$ . On what intervals is  $f$  increasing?

- (A)  $1 \leq x \leq 1.445$  only
- (B)  $1 \leq x \leq 1.691$
- (C)  $1.445 \leq x \leq 1.875$
- (D)  $0.577 \leq x \leq 1.445$  and  $1.875 \leq x \leq 2$
- (E)  $0 \leq x \leq 1$  and  $1.691 \leq x \leq 2$

79. If  $\int_{-5}^2 f(x) dx = -17$  and  $\int_5^2 f(x) dx = -4$ , what is the value of  $\int_{-5}^5 f(x) dx$ ?

- (A) -21      (B) -13      (C) 0      (D) 13      (E) 21

---

80. The derivative of the function  $f$  is given by  $f'(x) = x^2 \cos(x^2)$ . How many points of inflection does the graph of  $f$  have on the open interval  $(-2, 2)$ ?

- (A) One      (B) Two      (C) Three      (D) Four      (E) Five

## Part B

81. If  $G(x)$  is an antiderivative for  $f(x)$  and  $G(2) = -7$ , then  $G(4) =$

(A)  $f'(4)$

(B)  $-7 + f'(4)$

(C)  $\int_2^4 f(t) dt$

(D)  $\int_2^4 (-7 + f(t)) dt$

(E)  $-7 + \int_2^4 f(t) dt$

---

82. A particle moves along a straight line with velocity given by  $v(t) = 7 - (1.01)^{-t^2}$  at time  $t \geq 0$ . What is the acceleration of the particle at time  $t = 3$ ?

(A)  $-0.914$

(B)  $0.055$

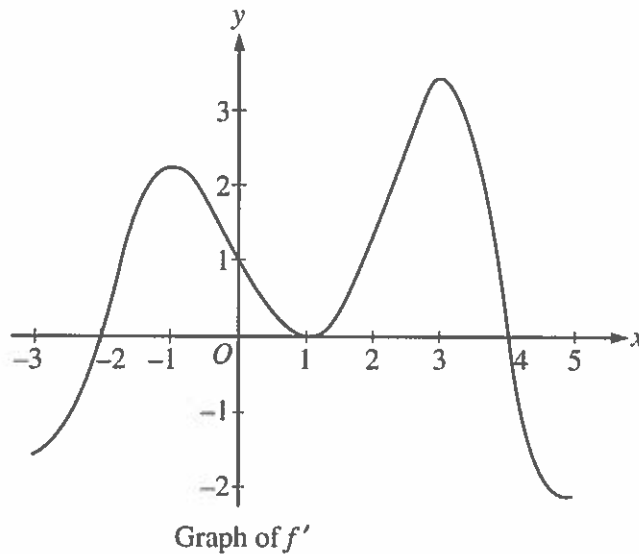
(C)  $5.486$

(D)  $6.086$

(E)  $18.087$

83. What is the area enclosed by the curves  $y = x^3 - 8x^2 + 18x - 5$  and  $y = x + 5$ ?

- (A) 10.667      (B) 11.833      (C) 14.583      (D) 21.333      (E) 32



84. The graph of the derivative of a function  $f$  is shown in the figure above. The graph has horizontal tangent lines at  $x = -1$ ,  $x = 1$ , and  $x = 3$ . At which of the following values of  $x$  does  $f$  have a relative maximum?

- (A)  $-2$  only      (B)  $1$  only      (C)  $4$  only      (D)  $-1$  and  $3$  only      (E)  $-2$ ,  $1$ , and  $4$

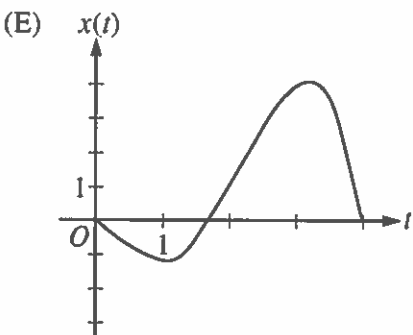
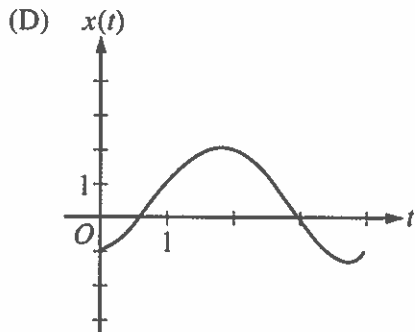
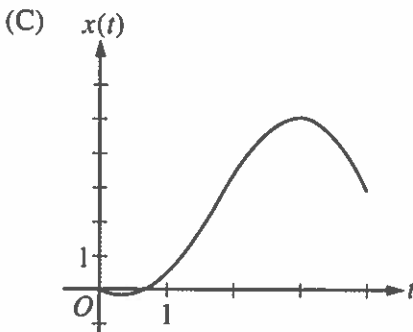
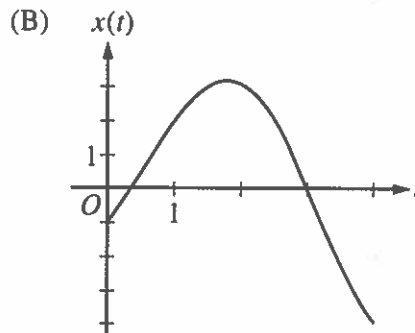
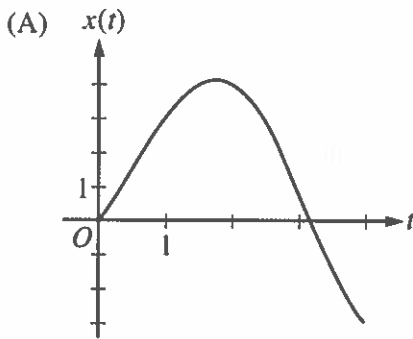
$x$	-4	-3	-2	-1
$f(x)$	0.75	-1.5	-2.25	-1.5
$f'(x)$	-3	-1.5	0	1.5

85. The table above gives values of a function  $f$  and its derivative at selected values of  $x$ . If  $f'$  is continuous on the interval  $[-4, -1]$ , what is the value of  $\int_{-4}^{-1} f'(x) dx$ ?

- (A) -4.5      (B) -2.25      (C) 0      (D) 2.25      (E) 4.5

$t$	0	1	2	3	4
$v(t)$	-1	2	3	0	-4

86. The table gives selected values of the velocity,  $v(t)$ , of a particle moving along the  $x$ -axis. At time  $t = 0$ , the particle is at the origin. Which of the following could be the graph of the position,  $x(t)$ , of the particle for  $0 \leq t \leq 4$ ?



87. An object traveling in a straight line has position  $x(t)$  at time  $t$ . If the initial position is  $x(0) = 2$  and the velocity of the object is  $v(t) = \sqrt[3]{1+t^2}$ , what is the position of the object at time  $t = 3$ ?
- (A) 0.431      (B) 2.154      (C) 4.512      (D) 6.512      (E) 17.408

- 
88. The radius of a sphere is decreasing at a rate of 2 centimeters per second. At the instant when the radius of the sphere is 3 centimeters, what is the rate of change, in square centimeters per second, of the surface area of the sphere? (The surface area  $S$  of a sphere with radius  $r$  is  $S = 4\pi r^2$ .)
- (A)  $-108\pi$       (B)  $-72\pi$       (C)  $-48\pi$       (D)  $-24\pi$       (E)  $-16\pi$

89. The function  $f$  is continuous for  $-2 \leq x \leq 2$  and  $f(-2) = f(2) = 0$ . If there is no  $c$ , where  $-2 < c < 2$ , for which  $f'(c) = 0$ , which of the following statements must be true?

- (A) For  $-2 < k < 2$ ,  $f'(k) > 0$ .  
(B) For  $-2 < k < 2$ ,  $f'(k) < 0$ .  
(C) For  $-2 < k < 2$ ,  $f'(k)$  exists.  
(D) For  $-2 < k < 2$ ,  $f'(k)$  exists, but  $f'$  is not continuous.  
(E) For some  $k$ , where  $-2 < k < 2$ ,  $f'(k)$  does not exist.

---

90. The function  $f$  is continuous on the closed interval  $[2, 4]$  and twice differentiable on the open interval  $(2, 4)$ . If  $f'(3) = 2$  and  $f''(x) < 0$  on the open interval  $(2, 4)$ , which of the following could be a table of values for  $f$ ?

(A)

$x$	$f(x)$
2	2.5
3	5
4	6.5

(B)

$x$	$f(x)$
2	2.5
3	5
4	7

(C)

$x$	$f(x)$
2	3
3	5
4	6.5

(D)

$x$	$f(x)$
2	3
3	5
4	7

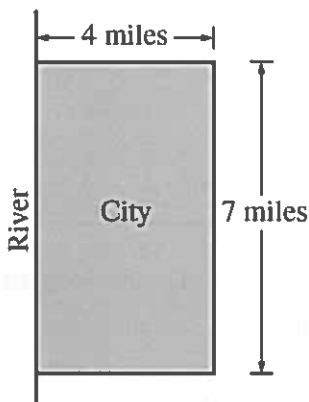
(E)

$x$	$f(x)$
2	3.5
3	5
4	7.5

## Part B

91. What is the average value of  $y = \frac{\cos x}{x^2 + x + 2}$  on the closed interval  $[-1, 3]$ ?

- (A)  $-0.085$       (B)  $0.090$       (C)  $0.183$       (D)  $0.244$       (E)  $0.732$



92. A city located beside a river has a rectangular boundary as shown in the figure above. The population density of the city at any point along a strip  $x$  miles from the river's edge is  $f(x)$  persons per square mile. Which of the following expressions gives the population of the city?

- (A)  $\int_0^4 f(x) dx$   
(B)  $7 \int_0^4 f(x) dx$   
(C)  $28 \int_0^4 f(x) dx$   
(D)  $\int_0^7 f(x) dx$   
(E)  $4 \int_0^7 f(x) dx$

END OF SECTION I

AFTER TIME HAS BEEN CALLED, TURN TO THE NEXT PAGE AND ANSWER QUESTIONS 93-96.

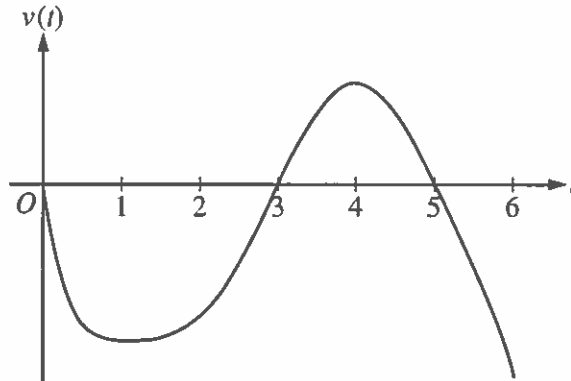
## Part A

3. Oil is leaking from a pipeline on the surface of a lake and forms an oil slick whose volume increases at a constant rate of 2000 cubic centimeters per minute. The oil slick takes the form of a right circular cylinder with both its radius and height changing with time. (Note: The volume  $V$  of a right circular cylinder with radius  $r$  and height  $h$  is given by  $V = \pi r^2 h$ .)
- (a) At the instant when the radius of the oil slick is 100 centimeters and the height is 0.5 centimeter, the radius is increasing at the rate of 2.5 centimeters per minute. At this instant, what is the rate of change of the height of the oil slick with respect to time, in centimeters per minute?
- (b) A recovery device arrives on the scene and begins removing oil. The rate at which oil is removed is  $R(t) = 400\sqrt{t}$  cubic centimeters per minute, where  $t$  is the time in minutes since the device began working. Oil continues to leak at the rate of 2000 cubic centimeters per minute. Find the time  $t$  when the oil slick reaches its maximum volume. Justify your answer.
- (c) By the time the recovery device began removing oil, 60,000 cubic centimeters of oil had already leaked. Write, but do not evaluate, an expression involving an integral that gives the volume of oil at the time found in part (b).
- 

END OF PART A OF SECTION II

**CALCULUS AB**  
**SECTION II, Part B**  
**Time—45 minutes**  
**Number of problems—3**

No calculator is allowed for these problems.



Graph of  $v$

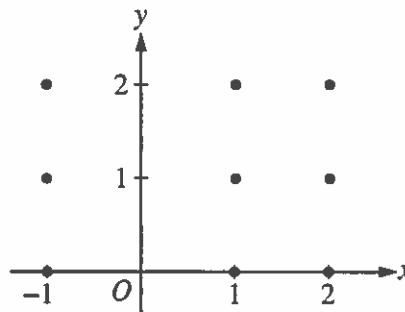
4. A particle moves along the  $x$ -axis so that its velocity at time  $t$ , for  $0 \leq t \leq 6$ , is given by a differentiable function  $v$  whose graph is shown above. The velocity is 0 at  $t = 0$ ,  $t = 3$ , and  $t = 5$ , and the graph has horizontal tangents at  $t = 1$  and  $t = 4$ . The 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  $x = -2$ .
- 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.
  - For how many values of  $t$ , where  $0 \leq t \leq 6$ , is the particle at  $x = -8$ ? Explain your reasoning.
  - On the interval  $2 < t < 3$ , is the speed of the particle increasing or decreasing? Give a reason for your answer.
  - During what time intervals, if any, is the acceleration of the particle negative? Justify your answer.

## Part B

5. Consider the differential equation  $\frac{dy}{dx} = \frac{y-1}{x^2}$ , where  $x \neq 0$ .

(a) On the axes provided, sketch a slope field for the given differential equation at the nine points indicated.

(Note: Use the axes provided in the exam booklet.)



(b) Find the particular solution  $y = f(x)$  to the differential equation with the initial condition  $f(2) = 0$ .

(c) For the particular solution  $y = f(x)$  described in part (b), find  $\lim_{x \rightarrow \infty} f(x)$ .

6. Let  $f$  be the function given by  $f(x) = \frac{\ln x}{x}$  for all  $x > 0$ . The derivative of  $f$  is given by  $f'(x) = \frac{1 - \ln x}{x^2}$ .

(a) Write an equation for the line tangent to the graph of  $f$  at  $x = e^2$ .

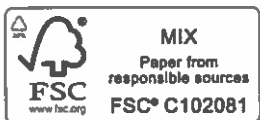
(b) Find the  $x$ -coordinate of the critical point of  $f$ . Determine whether this point is a relative minimum, a relative maximum, or neither for the function  $f$ . Justify your answer.

(c) The graph of the function  $f$  has exactly one point of inflection. Find the  $x$ -coordinate of this point.

(d) Find  $\lim_{x \rightarrow 0^+} f(x)$ .

END OF EXAM





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