



# AP<sup>®</sup> Calculus AB Practice Exam

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## From the 2012 Administration

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**Note:** This publication shows the page numbers that appeared in the *2011–12 AP Exam Instructions* book and in the actual exam. This publication was not repaginated to begin with page 1.

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## **Exam Instructions**

The following contains instructions taken from  
the ***2011–12 AP Exam Instructions*** book.

# AP<sup>®</sup> Calculus AB Exam

Regularly Scheduled Exam Date: Wednesday morning, May 9, 2012

Late-Testing Exam Date: Thursday morning, May 24, 2012

## Section I: At a Glance

**Total Time:** 1 hour, 45 minutes

**Number of Questions:** 45

**Percent of Total Score:** 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

## Section I: Multiple Choice Booklet Instructions

Section I of this exam contains 45 multiple-choice questions and 4 survey questions. For Part A, fill in only the circles for numbers 1 through 28 on page 2 of the answer sheet. For Part B, fill in only the circles 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 circle 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.

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.

Your total score on the multiple-choice section is based only on the number of questions answered correctly. Points are not deducted for incorrect answers or unanswered questions.

## Section II: At a Glance

**Total Time:** 1 hour, 30 minutes

**Number of Questions:** 6

**Percent of Total Score:** 50%

**Writing Instrument:**

Either pencil or pen with black or dark blue ink

**Weight:**

The questions are weighted equally, but the parts of a question are not necessarily given equal weight.

### Part A:

**Number of Questions:** 2

**Time:** 30 minutes

**Electronic Device:**

Graphing calculator required

**Percent of Section II Score:**

33.3%

### Part B:

**Number of Questions:** 4

**Time:** 60 minutes

**Electronic Device:**

None allowed

**Percent of Section II Score:**

66.6%

## Section II: Free Response Booklet Instructions

The questions for Section II are printed in this booklet. Do not break the seals on Part B until you are told to do so. Write your solution to each part of each question in the space provided. Write clearly and legibly. Cross out any errors you make; erased or crossed-out work will not be scored.

Manage your time carefully. During the timed portion for Part A, work only on the questions in Part A. You are permitted to use your calculator to solve an equation, find the derivative of a function at a point, or calculate the value of a definite integral. However, you must clearly indicate the setup of your question, namely the equation, function, or integral you are using. If you use other built-in features or programs, you must show the mathematical steps necessary to produce your results. During the timed portion for Part B, you may continue to work on the questions in Part A without the use of a calculator.

For each part of Section II, you may wish to look over the questions before starting to work on them. It is not expected that everyone will be able to complete all parts of all questions.

- Show all of your work. Clearly label any functions, graphs, tables, or other objects that you use. Your work will be scored on the correctness and completeness of your methods as well as your answers. Answers without supporting work will usually not receive credit. Justifications require that you give mathematical (noncalculator) reasons.
- Your work must be expressed in standard mathematical notation rather than calculator syntax. For example,  $\int_1^5 x^2 dx$  may not be written as `fnInt(X^2, X, 1, 5)`.
- Unless otherwise specified, answers (numeric or algebraic) need not be simplified. If you use decimal approximations in calculations, your work will be scored on accuracy. Unless otherwise specified, your final answers should be accurate to three places after the decimal point.
- 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.

### What Proctors Need to Bring to This Exam

- Exam packets
- Answer sheets
- AP Student Packs
- *2011-12 AP Coordinator's Manual*
- This book — *AP Exam Instructions*
- School Code and Home-School/Self-Study Codes
- Extra graphing calculators
- Pencil sharpener
- Extra No. 2 pencils with erasers
- Extra pens with black or dark blue ink
- Extra paper
- Stapler
- Watch
- Signs for the door to the testing room
  - “Exam in Progress”
  - “Cell phones are prohibited in the testing room”

*If you are giving the regularly scheduled AP Calculus AB or BC Exam:*

- You may seat students **four feet (approximately 1.2 meters) apart** because these exams have scrambled multiple-choice sections. This allows you to test more students in fewer testing rooms.
- See page 8 for a sample seating plan, including form codes and serial numbers, that shows how exams should be distributed to ensure that students seated next to each other are not given the same form of the exam.
- Administrators and proctors must continue to be vigilant about opportunities for cheating.

*If you are giving the alternate AP Calculus AB or BC Exam for late testing:*

- You must seat students **no less than five feet (approximately 1.5 meters) apart** because these exams do not have scrambled multiple-choice sections.

Graphing calculators are required to answer some of the questions on the AP Calculus Exams. Before starting the exam administration, make sure each student has a graphing calculator from the approved list on page 42 of the *2011-12 AP Coordinator's Manual*. If a student does not have a graphing calculator from the approved list, you may provide one from your supply. If the student does not want to use the calculator you provide or does not want to use a calculator at all, he or she must hand copy, date, and sign the release statement on page 41 of the *2011-12 AP Coordinator's Manual*.

During the administration of Section I, Part B, and Section II, Part A, students may have no more than two graphing calculators on their desks; calculators may not be shared. **Calculator memories do not need to be cleared before or after the exam.** Students with Hewlett-Packard 48–50 Series and Casio FX-9860 graphing calculators may use cards designed for use with these calculators. Proctors should make sure infrared ports (Hewlett-Packard) are not facing each other. **Since graphing calculators can be used to store data, including text, proctors should monitor that students are using their calculators appropriately. Attempts by students to use**

the calculator to remove exam questions and/or answers from the room may result in the cancellation of AP Exam scores.

The AP Calculus AB Exam and the AP Calculus BC Exam should be administered simultaneously. They may be administered in separate rooms, or in the same room if it is more convenient.

## SECTION I: Multiple Choice

- Do not begin the exam instructions below until you have completed the appropriate
- General Instructions for your group.

These exams include survey questions. The time allowed for the survey questions is in addition to the actual test-taking time.

Make sure you begin the exams at the designated time.

*If you are giving the regularly scheduled exam, say:*

**It is Wednesday morning, May 9, and you will be taking either the AP Calculus AB Exam or the AP Calculus BC Exam.**

*If you are giving the alternate exam for late testing, say:*

**It is Thursday morning, May 24, and you will be taking either the AP Calculus AB Exam or the AP Calculus BC Exam.**

**In a moment, you will open the packet that contains your exam materials.**

**By opening this packet, you agree to all of the AP Program’s policies and procedures outlined in the *2011-12 Bulletin for AP Students and Parents*. Please check to make sure you have the correct exam: Calculus AB or Calculus BC. Raise your hand if you do not have the correct exam. . . .**

**You may now remove the shrinkwrap from your exam packet and take out the Section I booklet, but do not open the booklet or the shrinkwrapped Section II materials. Put the white seals aside. . . .**

**Look at page 1 of your answer sheet and locate the dark blue box near the top right-hand corner that states, “Take the AP Exam label from your Section I booklet and place the label here.”. . .**

**Now look at the front cover of your exam booklet and locate the AP Exam label near the top left of the cover. . . .**

**Carefully peel off the AP Exam label and place it on your answer sheet on the dark blue box that we just identified. . . .**

**Now read the statements on the front cover of Section I and look up when you have finished. . . .**

**Sign your name and write today’s date. Look up when you have finished. . . .**

**Now print your full legal name where indicated. Are there any questions? . . .**

Turn to the back cover and read it completely. Look up when you have finished. . . .

Are there any questions? . . .

Section I is the multiple-choice portion of the exam. You may never discuss these specific multiple-choice questions at any time in any form with anyone, including your teacher and other students. If you disclose these questions through any means, your AP Exam score will be canceled. Are there any questions? . . .

You must complete the answer sheet using a No. 2 pencil only. Mark all of your responses on your answer sheet, one response per question. Completely fill in the circles. If you need to erase, do so carefully and completely. No credit will be given for anything written in the exam booklet. Scratch paper is not allowed, but you may use the margins or any blank space in the exam booklet for scratch work.

Section I is divided into two parts. Each part is timed separately, and you may work on each part only during the time allotted for it. Calculators are not allowed in Part A. Please put your calculators under your chair. Are there any questions? . . .

You have 55 minutes for Part A. Part A questions are numbered 1 through 28. Mark your responses for these questions on page 2 of your answer sheet. Open your Section I booklet and begin.



Note Start Time here \_\_\_\_\_. Note Stop Time here \_\_\_\_\_. Check that students are marking their answers in pencil on page 2 of their answer sheets and that they are not looking beyond Part A. The line of A's at the top of each page will assist you in monitoring students' work. After 55 minutes, say:

**Stop working on Part A and turn to page 22 in your Section I booklet. . . .**

**On that page, you should see an area marked "PLACE SEAL HERE." Making sure all of your other exam materials, including your answer sheet, are out of the way, take one of your seals and press it on that area and then fold the seal over the open edge to the front cover. Be sure you don't seal the Part B section of the booklet or let the seal touch anything except the marked areas. . . .**

After all students have sealed Part A, say:

**Graphing calculators are required for Part B. You may get your calculators from under your chair and place them on your desk. Part B questions are numbered 76 through 92. Fold your answer sheet so only page 3 is showing and mark your responses for these questions on that page. You have 50 minutes for Part B. You may begin.**



Note Start Time here \_\_\_\_\_. Note Stop Time here \_\_\_\_\_. Check that students have sealed their booklets properly and are now working on Part B. The large B's in an alternating shaded pattern at the top of each page will assist you in monitoring their work. Proctors should

make sure that students are using their calculators appropriately. Proctors should also make sure Hewlett-Packard calculators' infrared ports are not facing each other. After 50 minutes, say:

**Stop working and turn to page 38. You have 3 minutes to answer Questions 93–96. These are survey questions and will not affect your score. You may not go back to work on any of the exam questions. . . .**

Give students approximately 3 minutes to answer the survey questions. Then say:

**Close your booklet and put your answer sheet on your desk, face up. Make sure you have your AP number label and an AP Exam label on page 1 of your answer sheet. I will now collect your answer sheet.**

Collect an answer sheet from each student. Check that each answer sheet has an AP number label and an AP Exam label. Then say:

**Now you must seal your Section I booklet. Remove the remaining white seals from the backing and press one on each area of your exam booklet cover marked "PLACE SEAL HERE." Fold each seal over the back cover. When you have finished, place the booklet on your desk, face up. I will now collect your Section I booklet. . . .**

Check that each student has signed the front cover of the sealed Section I booklet. There is a 10-minute break between Sections I and II. When all Section I materials have been collected and accounted for and you are ready for the break, say:

**Please listen carefully to these instructions before we take a 10-minute break. Everything you placed under your chair at the beginning of the exam must stay there. Leave your shrinkwrapped Section II packet on top of your desk during the break. You are not allowed to consult teachers, other students, or textbooks about the exam during the break. You may not make phone calls, send text messages, use your calculators, check email, use a social networking site, or access any electronic or communication device. Remember, you are not allowed to discuss the multiple-choice section of this exam. Failure to adhere to any of these rules could result in cancellation of your score. Are there any questions? . . .**



**You may begin your break. Testing will resume at \_\_\_\_\_.**

## SECTION II: Free Response

After the break, say:

**May I have everyone's attention? Place your Student Pack on your desk. . . .**

**You may now remove the shrinkwrap from the Section II packet, but do not open the Section II exam booklet until you are told to do so. . . .**

**Read the bulleted statements on the front cover of the exam booklet. Look up when you have finished. . . .**

**Now place an AP number label on the shaded box. If you don't have any AP number labels, write your AP number in the box. Look up when you have finished. . . .**



Read the last statement. . . .

Using your pen, print the first, middle and last initials of your legal name in the boxes and print today's date where indicated. This constitutes your signature and your agreement to the statements on the front cover. . . .

Turn to the back cover and read Item 1 under "Important Identification Information." Print the first two letters of your last name and the first letter of your first name in the boxes. Look up when you have finished. . . .

In Item 2, print your date of birth in the boxes. . . .

In Item 3, write the school code you printed on the front of your Student Pack in the boxes. . . .

Read Item 4. . . .

Are there any questions? . . .

I need to collect the Student Pack from anyone who will be taking another AP Exam. You may keep it only if you are not taking any other AP Exams this year. If you have no other AP Exams to take, place your Student Pack under your chair now. . . .

While Student Packs are being collected, read the information on the back cover of the exam booklet, paying careful attention to the bulleted statements in the instructions. Do not open the exam booklet or break the seals in the exam booklet until you are told to do so. Look up when you have finished. . . .

Collect the Student Packs. Then say:

Are there any questions? . . .

Section II also has two parts that are timed separately. You are responsible for pacing yourself, and may proceed freely from one question to the next within each part. Graphing calculators are required for Part A, so you may keep your calculators on your desk. You must write your answers in the appropriate space in the exam booklet using a No. 2 pencil or a pen with black or dark blue ink. Do not break the seals for Part B at this time.

Are there any questions? . . .

You have 30 minutes to answer the questions in Part A. If you need more paper during the exam, raise your hand. At the top of each extra piece of paper you use, be sure to write only your AP number and the number of the question you are working on. Do not write your name. Open your exam booklet and begin.



Note Start Time here \_\_\_\_\_. Note Stop Time here \_\_\_\_\_. Check that students are working on Part A only and writing their answers in their exam booklets using pencils or pens with black or dark blue ink. The pages for the Part A questions are marked with large 1's and 2's at the top of each page to assist you in monitoring their work. After 20 minutes, say:

**There are 10 minutes remaining in Part A.**

After 10 minutes, say:

**Stop working on Part A. Calculators are not allowed for Part B. Please put all of your calculators under your chair. . . .**

**Turn to page 13. You have 1 hour for Part B. During this time you may go back to Part A, but you may not use your calculator. Remember to write your answer to each part of each problem in the appropriate space in the exam booklet. Are there any questions? . . .**

**Using your finger, break open the seals on Part B. Do not peel the seals away from the booklet. You may begin Part B. . . .**



Note Start Time here \_\_\_\_\_. Note Stop Time here \_\_\_\_\_. After 50 minutes, say:

**There are 10 minutes remaining in Part B.**

After 10 minutes, say:

**Stop working and close your exam booklet. Place it on your desk, face up. . . .**

If any students used extra paper for the free-response section, have those students staple the extra sheet/s to the first page corresponding to that question in their exam booklets. Then say:

**Remain in your seat, without talking, while the exam materials are collected. . . .**

Collect a Section II exam booklet from each student. Check for the following:

- Exam booklet front cover: The student placed an AP number label on the shaded box, and printed his or her initials and today's date.
- Exam booklet back cover: The student completed the "Important Identification Information" area.

When all exam materials have been collected and accounted for, return to students any electronic devices you may have collected before the start of the exam.

*If you are giving the regularly scheduled exam, say:*

**You may not discuss these specific free-response questions with anyone unless they are released on the College Board website in about two days. You should receive your score report in the mail about the third week of July.**

*If you are giving the alternate exam for late testing, say:*

**None of the questions in this exam may ever be discussed or shared in any way at any time. You should receive your score report in the mail about the third week of July.**

If any students completed the AP number card at the beginning of this exam, say:

**Please remember to take your AP number card with you.**

Then say:

**You are now dismissed.**

All exam materials should be put in secure storage until they are returned to the AP Program after your school's last administration. Before storing materials, check the "School Use Only" section on page 1 of the answer sheet and:

- Fill in the appropriate section number circle in order to view a separate AP Instructional Planning Report (for regularly scheduled exams only) or Subject Score Roster at the class section or teacher level. See "Post-Exam Activities" in the *2011-12 AP Coordinator's Manual*.
- Check your list of students who are eligible for fee reductions and fill in the appropriate circle on their registration answer sheets.

**GO ON TO THE NEXT PAGE.**

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## **Student Answer Sheet for the Multiple-Choice Section**

Use this section to capture student responses. (Note that the following answer sheet is a sample, and may differ from one used in an actual exam.)









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

T. YOUR MAILING ADDRESS Use the address abbreviations from your AP Student Pack. Fill in only one circle per column. Indicate a space in your address by leaving a blank box; do not grid that column.

Form for mailing address with columns for Street Address, City, ZIP or Postal Code, Country Code, U. Area Code and Phone Number, and International Phone. Includes a grid of letters and numbers for selection.

X. FOR STUDENTS OUTSIDE THE UNITED STATES ONLY If the address gridded above is not complete enough for delivery of your score report, please fill in this circle and print your complete address below.

Form for international address with fields for Address, City, State or Province, Country, and ZIP or Postal Code.

U. AREA CODE AND PHONE NUMBER grid with digits 0-9 and an INTERNATIONAL PHONE section.

V. SCHOOL YOU ATTEND section with fields for School Name, City, State, and Country.

W. COLLEGE TO RECEIVE YOUR AP SCORE REPORT section with fields for College Name, City, State, and Country.

**GO ON TO THE NEXT PAGE.**

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## **Section I: Multiple-Choice Questions**

This is the multiple-choice section of the 2012 AP exam. It includes cover material and other administrative instructions to help familiarize students with the mechanics of the exam. (Note that future exams may differ in look from the following content.)

# AP<sup>®</sup> Calculus AB Exam

## SECTION I: Multiple Choice

# 2012

**DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.**

### At a Glance

**Total Time**

1 hour, 45 minutes

**Number of Questions**

45

**Percent of Total Score**

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 circles for numbers 1 through 28 on page 2 of the answer sheet. For Part B, fill in only the circles 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 circle 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) ● (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.

Your total score on the multiple-choice section is based only on the number of questions answered correctly. Points are not deducted for incorrect answers or unanswered questions.

PLACE SEAL HERE



Minimum 20% post-consumer waste

PLACE SEAL HERE

DO NOT seal answer sheet inside

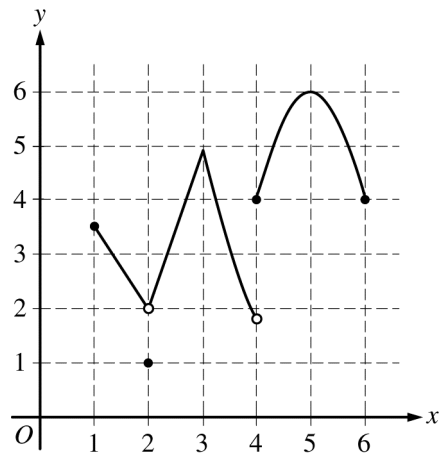
Form I  
Form Code 4IBP4-Q-S

# 66









Graph of  $f$

5. The graph of the function  $f$  is shown above. Which of the following statements is false?
- (A)  $\lim_{x \rightarrow 2} f(x)$  exists.
- (B)  $\lim_{x \rightarrow 3} f(x)$  exists.
- (C)  $\lim_{x \rightarrow 4} f(x)$  exists.
- (D)  $\lim_{x \rightarrow 5} f(x)$  exists.
- (E) The function  $f$  is continuous at  $x = 3$ .

6. A particle moves along the  $x$ -axis. The velocity of the particle at time  $t$  is  $6t - t^2$ . What is the total distance traveled by the particle from time  $t = 0$  to  $t = 3$ ?
- (A) 3      (B) 6      (C) 9      (D) 18      (E) 27





7. If  $y = (x^3 - \cos x)^5$ , then  $y' =$

- (A)  $5(x^3 - \cos x)^4$
- (B)  $5(3x^2 + \sin x)^4$
- (C)  $5(3x^2 + \sin x)$
- (D)  $5(3x^2 + \sin x)^4 \cdot (6x + \cos x)$
- (E)  $5(x^3 - \cos x)^4 \cdot (3x^2 + \sin x)$

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$t$ (hours)	4	7	12	15
$R(t)$ (liters/hour)	6.5	6.2	5.9	5.6

8. A tank contains 50 liters of oil at time  $t = 4$  hours. Oil is being pumped into the tank at a rate  $R(t)$ , where  $R(t)$  is measured in liters per hour, and  $t$  is measured in hours. Selected values of  $R(t)$  are given in the table above. Using a right Riemann sum with three subintervals and data from the table, what is the approximation of the number of liters of oil that are in the tank at time  $t = 15$  hours?
- (A) 64.9      (B) 68.2      (C) 114.9      (D) 116.6      (E) 118.2

$$f(x) = \begin{cases} \frac{(2x+1)(x-2)}{x-2} & \text{for } x \neq 2 \\ k & \text{for } x = 2 \end{cases}$$

9. Let  $f$  be the function defined above. For what value of  $k$  is  $f$  continuous at  $x = 2$ ?

- (A) 0      (B) 1      (C) 2      (D) 3      (E) 5

10. What is the area of the region in the first quadrant bounded by the graph of  $y = e^{x/2}$  and the line  $x = 2$ ?

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

11. Let  $f$  be the function defined by  $f(x) = \sqrt{|x - 2|}$  for all  $x$ . Which of the following statements is true?

- (A)  $f$  is continuous but not differentiable at  $x = 2$ .
- (B)  $f$  is differentiable at  $x = 2$ .
- (C)  $f$  is not continuous at  $x = 2$ .
- (D)  $\lim_{x \rightarrow 2} f(x) \neq 0$
- (E)  $x = 2$  is a vertical asymptote of the graph of  $f$ .

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12. Using the substitution  $u = \sqrt{x}$ ,  $\int_1^4 \frac{e^{\sqrt{x}}}{\sqrt{x}} dx$  is equal to which of the following?

- (A)  $2 \int_1^{16} e^u du$
- (B)  $2 \int_1^4 e^u du$
- (C)  $2 \int_1^2 e^u du$
- (D)  $\frac{1}{2} \int_1^2 e^u du$
- (E)  $\int_1^4 e^u du$



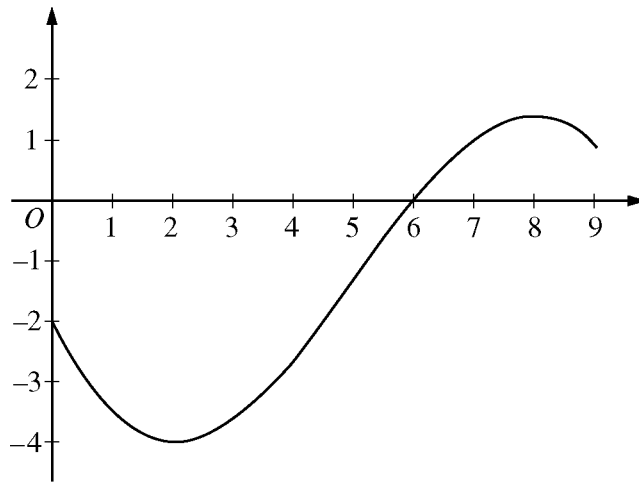
13. The function  $f$  is defined by  $f(x) = \begin{cases} 2 & \text{for } x < 3 \\ x - 1 & \text{for } x \geq 3. \end{cases}$  What is the value of  $\int_1^5 f(x) dx$  ?

- (A) 2      (B) 6      (C) 8      (D) 10      (E) 12

---

14. If  $f(x) = \sqrt{x^2 - 4}$  and  $g(x) = 3x - 2$ , then the derivative of  $f(g(x))$  at  $x = 3$  is

- (A)  $\frac{7}{\sqrt{5}}$       (B)  $\frac{14}{\sqrt{5}}$       (C)  $\frac{18}{\sqrt{5}}$       (D)  $\frac{15}{\sqrt{21}}$       (E)  $\frac{30}{\sqrt{21}}$



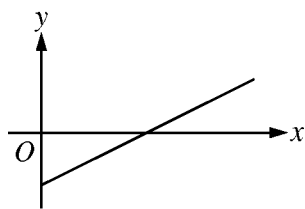
Graph of  $f$

15. The graph of a differentiable function  $f$  is shown above. If  $h(x) = \int_0^x f(t) dt$ , which of the following is true?

- (A)  $h(6) < h'(6) < h''(6)$
- (B)  $h(6) < h''(6) < h'(6)$
- (C)  $h'(6) < h(6) < h''(6)$
- (D)  $h''(6) < h(6) < h'(6)$
- (E)  $h''(6) < h'(6) < h(6)$

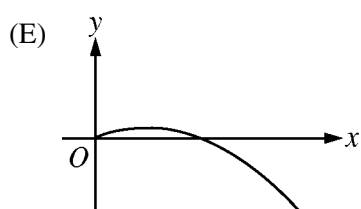
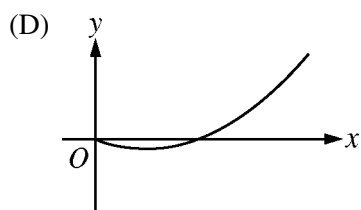
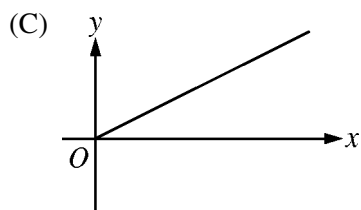
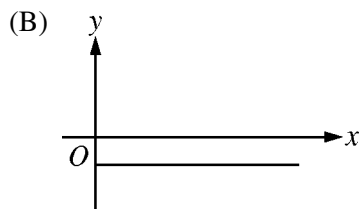
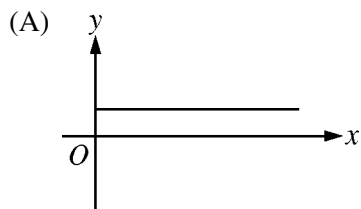
**A A**

16. A particle moves along the  $x$ -axis with its position at time  $t$  given by  $x(t) = (t - a)(t - b)$ , where  $a$  and  $b$  are constants and  $a \neq b$ . For which of the following values of  $t$  is the particle at rest?
- (A)  $t = ab$
  - (B)  $t = \frac{a + b}{2}$
  - (C)  $t = a + b$
  - (D)  $t = 2(a + b)$
  - (E)  $t = a$  and  $t = b$



Graph of  $f$

17. The figure above shows the graph of  $f$ . If  $f(x) = \int_2^x g(t) dt$ , which of the following could be the graph of  $y = g(x)$ ?









20. Let  $f(x) = (2x + 1)^3$  and let  $g$  be the inverse function of  $f$ . Given that  $f(0) = 1$ , what is the value of  $g'(1)$ ?

- (A)  $-\frac{2}{27}$       (B)  $\frac{1}{54}$       (C)  $\frac{1}{27}$       (D)  $\frac{1}{6}$       (E) 6

---

21. The line  $y = 5$  is a horizontal asymptote to the graph of which of the following functions?

- (A)  $y = \frac{\sin(5x)}{x}$       (B)  $y = 5x$       (C)  $y = \frac{1}{x - 5}$       (D)  $y = \frac{5x}{1 - x}$       (E)  $y = \frac{20x^2 - x}{1 + 4x^2}$

22. Let  $f$  be the function defined by  $f(x) = \frac{\ln x}{x}$ . What is the absolute maximum value of  $f$ ?

(A) 1

(B)  $\frac{1}{e}$

(C) 0

(D)  $-e$

(E)  $f$  does not have an absolute maximum value.

23. If  $P(t)$  is the size of a population at time  $t$ , which of the following differential equations describes linear growth in the size of the population?

(A)  $\frac{dP}{dt} = 200$

(B)  $\frac{dP}{dt} = 200t$

(C)  $\frac{dP}{dt} = 100t^2$

(D)  $\frac{dP}{dt} = 200P$

(E)  $\frac{dP}{dt} = 100P^2$

**A A**

24. Let  $g$  be the function given by  $g(x) = x^2 e^{kx}$ , where  $k$  is a constant. For what value of  $k$  does  $g$  have a critical point at  $x = \frac{2}{3}$ ?

- (A)  $-3$       (B)  $-\frac{3}{2}$       (C)  $-\frac{1}{3}$       (D)  $0$       (E) There is no such  $k$ .

A A

25. Which of the following is the solution to the differential equation  $\frac{dy}{dx} = 2 \sin x$  with the initial condition  $y(\pi) = 1$ ?

- (A)  $y = 2 \cos x + 3$
- (B)  $y = 2 \cos x - 1$
- (C)  $y = -2 \cos x + 3$
- (D)  $y = -2 \cos x + 1$
- (E)  $y = -2 \cos x - 1$

A A

26. Let  $g$  be a function with first derivative given by  $g'(x) = \int_0^x e^{-t^2} dt$ . Which of the following must be true on the interval  $0 < x < 2$ ?
- (A)  $g$  is increasing, and the graph of  $g$  is concave up.
  - (B)  $g$  is increasing, and the graph of  $g$  is concave down.
  - (C)  $g$  is decreasing, and the graph of  $g$  is concave up.
  - (D)  $g$  is decreasing, and the graph of  $g$  is concave down.
  - (E)  $g$  is decreasing, and the graph of  $g$  has a point of inflection on  $0 < x < 2$ .

**A A**

27. If  $(x + 2y) \cdot \frac{dy}{dx} = 2x - y$ , what is the value of  $\frac{d^2y}{dx^2}$  at the point  $(3, 0)$ ?

- (A)  $-\frac{10}{3}$       (B) 0      (C) 2      (D)  $\frac{10}{3}$       (E) Undefined

**A A**

28. For  $t \geq 0$ , the position of a particle moving along the  $x$ -axis is given by  $x(t) = \sin t - \cos t$ . What is the acceleration of the particle at the point where the velocity is first equal to 0 ?

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

**END OF PART A OF SECTION I**

**IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY  
CHECK YOUR WORK ON PART A ONLY.**

**DO NOT GO ON TO PART B UNTIL YOU ARE TOLD TO DO SO.**

**B****B****B****B****B****B****B****B****B**

**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 circle 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.

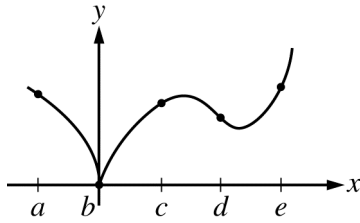
**BE SURE YOU ARE USING PAGE 3 OF THE ANSWER SHEET TO RECORD YOUR ANSWERS TO QUESTIONS NUMBERED 76–92.**

**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.,  $\sin^{-1} x = \arcsin x$ ).



**B****B****B****B****B****B****B****B****B**Graph of  $f$ 

76. The graph of the function  $f$  is shown in the figure above. For which of the following values of  $x$  is  $f'(x)$  positive and increasing?

- (A)  $a$       (B)  $b$       (C)  $c$       (D)  $d$       (E)  $e$

**B****B****B****B****B****B****B****B****B**

77. Let  $f$  be a function that is continuous on the closed interval  $[2, 4]$  with  $f(2) = 10$  and  $f(4) = 20$ . Which of the following is guaranteed by the Intermediate Value Theorem?
- (A)  $f(x) = 13$  has at least one solution in the open interval  $(2, 4)$ .
- (B)  $f(3) = 15$
- (C)  $f$  attains a maximum on the open interval  $(2, 4)$ .
- (D)  $f'(x) = 5$  has at least one solution in the open interval  $(2, 4)$ .
- (E)  $f'(x) > 0$  for all  $x$  in the open interval  $(2, 4)$ .
- 

78. The graph of  $y = e^{\tan x} - 2$  crosses the  $x$ -axis at one point in the interval  $[0, 1]$ . What is the slope of the graph at this point?
- (A) 0.606      (B) 2      (C) 2.242      (D) 2.961      (E) 3.747

**B****B****B****B****B****B****B****B****B**

79. A particle moves along the  $x$ -axis. The velocity of the particle at time  $t$  is given by  $v(t)$ , and the acceleration of the particle at time  $t$  is given by  $a(t)$ . Which of the following gives the average velocity of the particle from time  $t = 0$  to time  $t = 8$ ?

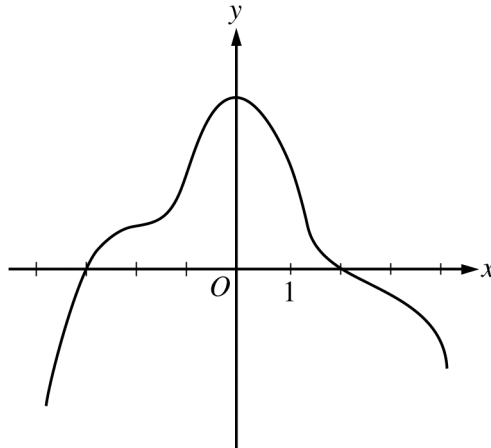
(A)  $\frac{a(8) - a(0)}{8}$

(B)  $\frac{1}{8} \int_0^8 v(t) dt$

(C)  $\frac{1}{8} \int_0^8 |v(t)| dt$

(D)  $\frac{1}{2} \int_0^8 v(t) dt$

(E)  $\frac{v(0) + v(8)}{2}$

**B****B****B****B****B****B****B****B****B**Graph of  $f'$ 

80. The graph of  $f'$ , the derivative of the function  $f$ , is shown above. Which of the following statements must be true?

- I.  $f$  has a relative minimum at  $x = -3$ .
  - II. The graph of  $f$  has a point of inflection at  $x = -2$ .
  - III. The graph of  $f$  is concave down for  $0 < x < 4$ .
- (A) I only      (B) II only      (C) III only      (D) I and II only      (E) I and III only

**B****B****B****B****B****B****B****B****B**

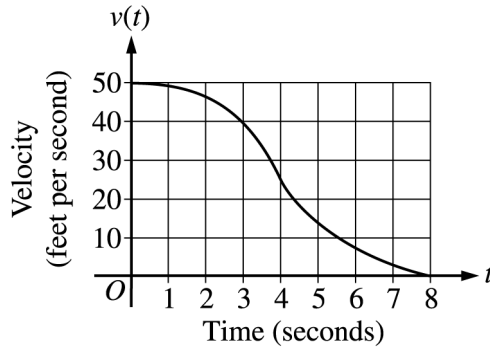
81. Water is pumped into a tank at a rate of  $r(t) = 30(1 - e^{-0.16t})$  gallons per minute, where  $t$  is the number of minutes since the pump was turned on. If the tank contained 800 gallons of water when the pump was turned on, how much water, to the nearest gallon, is in the tank after 20 minutes?

- (A) 380 gallons
- (B) 420 gallons
- (C) 829 gallons
- (D) 1220 gallons
- (E) 1376 gallons

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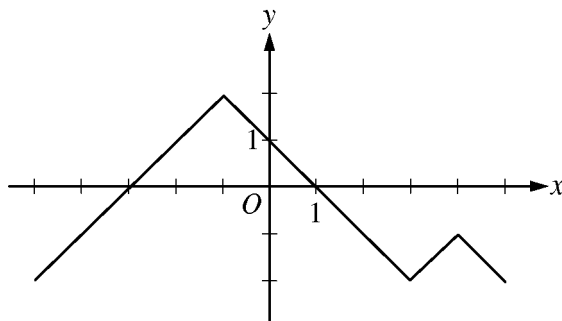
82. If  $f'(x) = \sqrt{x^4 + 1} + x^3 - 3x$ , then  $f$  has a local maximum at  $x =$

- (A) -2.314      (B) -1.332      (C) 0.350      (D) 0.829      (E) 1.234

**B****B****B****B****B****B****B****B****B**

83. The graph above gives the velocity,  $v$ , in ft/sec, of a car for  $0 \leq t \leq 8$ , where  $t$  is the time in seconds. Of the following, which is the best estimate of the distance traveled by the car from  $t = 0$  until the car comes to a complete stop?
- (A) 21 ft      (B) 26 ft      (C) 180 ft      (D) 210 ft      (E) 260 ft

84. For  $-1.5 < x < 1.5$ , let  $f$  be a function with first derivative given by  $f'(x) = e^{(x^4 - 2x^2 + 1)} - 2$ . Which of the following are all intervals on which the graph of  $f$  is concave down?
- (A)  $(-0.418, 0.418)$  only  
 (B)  $(-1, 1)$   
 (C)  $(-1.354, -0.409)$  and  $(0.409, 1.354)$   
 (D)  $(-1.5, -1)$  and  $(0, 1)$   
 (E)  $(-1.5, -1.354)$ ,  $(-0.409, 0)$ , and  $(1.354, 1.5)$

**B****B****B****B****B****B****B****B****B**Graph of  $f'$ 

85. The graph of  $f'$ , the derivative of  $f$ , is shown in the figure above. The function  $f$  has a local maximum at  $x =$
- (A)  $-3$       (B)  $-1$       (C)  $1$       (D)  $3$       (E)  $4$

**B****B****B****B****B****B****B****B****B**

86. If  $f'(x) > 0$  for all real numbers  $x$  and  $\int_4^7 f(t) dt = 0$ , which of the following could be a table of values for the function  $f$ ?

(A) 

$x$	$f(x)$
4	-4
5	-3
7	0

(B) 

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

(C) 

$x$	$f(x)$
4	-4
5	6
7	3

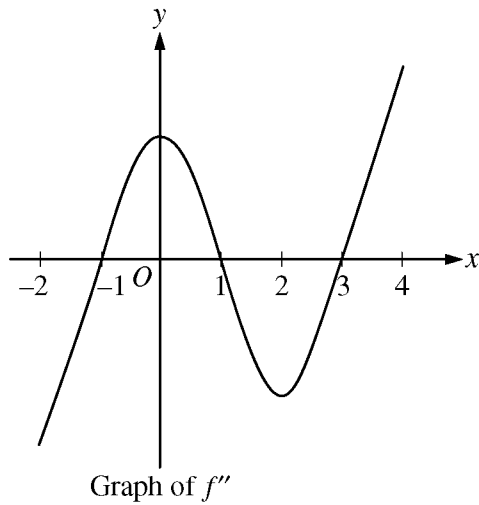
(D) 

$x$	$f(x)$
4	0
5	0
7	0

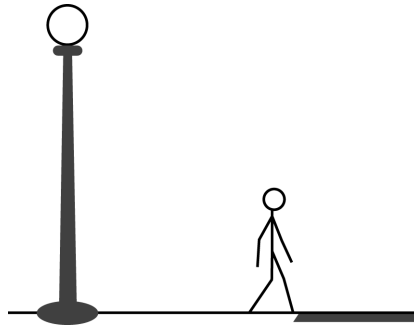
(E) 

$x$	$f(x)$
4	0
5	4
7	6



**B****B****B****B****B****B****B****B****B**

87. The graph of  $f''$ , the second derivative of  $f$ , is shown above for  $-2 \leq x \leq 4$ . What are all intervals on which the graph of the function  $f$  is concave down?
- (A)  $-1 < x < 1$
  - (B)  $0 < x < 2$
  - (C)  $1 < x < 3$  only
  - (D)  $-2 < x < -1$  only
  - (E)  $-2 < x < -1$  and  $1 < x < 3$

**B****B****B****B****B****B****B****B****B**

88. A person whose height is 6 feet is walking away from the base of a streetlight along a straight path at a rate of 4 feet per second. If the height of the streetlight is 15 feet, what is the rate at which the person's shadow is lengthening?

- (A) 1.5 ft/sec      (B) 2.667 ft/sec      (C) 3.75 ft/sec      (D) 6 ft/sec      (E) 10 ft/sec

---

89. A particle moves along a line so that its acceleration for  $t \geq 0$  is given by  $a(t) = \frac{t+3}{\sqrt{t^3+1}}$ . If the particle's velocity at  $t = 0$  is 5, what is the velocity of the particle at  $t = 3$ ?

- (A) 0.713      (B) 1.134      (C) 6.134      (D) 6.710      (E) 11.710

**B****B****B****B****B****B****B****B****B**

90. Let  $f$  be a function such that  $\int_6^{12} f(2x) dx = 10$ . Which of the following must be true?

(A)  $\int_{12}^{24} f(t) dt = 5$

(B)  $\int_{12}^{24} f(t) dt = 20$

(C)  $\int_6^{12} f(t) dt = 5$

(D)  $\int_6^{12} f(t) dt = 20$

(E)  $\int_3^6 f(t) dt = 5$

$x$	-2	0	3	5	6
$f'(x)$	3	1	4	7	5

91. Let  $f$  be a polynomial function with values of  $f'(x)$  at selected values of  $x$  given in the table above. Which of the following must be true for  $-2 < x < 6$ ?

(A) The graph of  $f$  is concave up.

(B) The graph of  $f$  has at least two points of inflection.

(C)  $f$  is increasing.

(D)  $f$  has no critical points.

(E)  $f$  has at least two relative extrema.

**B****B****B****B****B****B****B****B****B**

92. Let  $R$  be the region in the first quadrant bounded below by the graph of  $y = x^2$  and above by the graph of  $y = \sqrt{x}$ .  $R$  is the base of a solid whose cross sections perpendicular to the  $x$ -axis are squares. What is the volume of the solid?
- (A) 0.129      (B) 0.300      (C) 0.333      (D) 0.700      (E) 1.271

**B**

**B**

**B**

**B**

**B**

**B**

**B**

**B**

**B**

**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.**

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**MAKE SURE YOU HAVE DONE THE FOLLOWING.**

- **PLACED YOUR AP NUMBER LABEL ON YOUR ANSWER SHEET**
- **WRITTEN AND GRIDDED YOUR AP NUMBER CORRECTLY ON YOUR ANSWER SHEET**
- **TAKEN THE AP EXAM LABEL FROM THE FRONT OF THIS BOOKLET AND PLACED IT ON YOUR ANSWER SHEET**

**AFTER TIME HAS BEEN CALLED, TURN TO PAGE 38 AND  
ANSWER QUESTIONS 93–96.**

**GO ON TO THE NEXT PAGE.**

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## **Section II: Free-Response Questions**

This is the free-response section of the 2012 AP exam. It includes cover material and other administrative instructions to help familiarize students with the mechanics of the exam. (Note that future exams may differ in look from the following content.)

# AP<sup>®</sup> Calculus AB Exam

## SECTION II: Free Response

2012

DO NOT OPEN THIS BOOKLET OR BREAK THE SEALS ON PART B UNTIL YOU ARE TOLD TO DO SO.

### At a Glance

**Total Time**

1 hour, 30 minutes

**Number of Questions**

6

**Percent of Total Score**

50%

**Writing Instrument**

Either pencil or pen with black or dark blue ink

**Weight**

The questions are weighted equally, but the parts of a question are not necessarily given equal weight.

### Part A

**Number of Questions**

2

**Time**

30 minutes

**Electronic Device**

Graphing calculator required

**Percent of Section II Score**

33.3%

### Part B

**Number of Questions**

4

**Time**

60 minutes

**Electronic Device**

None allowed

**Percent of Section II Score**

66.6%

### IMPORTANT Identification Information

PLEASE PRINT WITH PEN:

1. First two letters of your last name   
First letter of your first name
2. Date of birth  
    
Month Day Year
3. Six-digit school code
4. Unless I check the box below, I grant the College Board the unlimited right to use, reproduce, and publish my free-response materials, both written and oral, for educational research and instructional purposes. My name and the name of my school will not be used in any way in connection with my free-response materials. I understand that I am free to mark "No" with no effect on my score or its reporting.  
No, I do not grant the College Board  these rights.

### Instructions

The questions for Section II are printed in this booklet. Do not break the seals on Part B until you are told to do so. Write your solution to each part of each question in the space provided. Write clearly and legibly. Cross out any errors you make; erased or crossed-out work will not be scored.

Manage your time carefully. During the timed portion for Part A, work only on the questions in Part A. You are permitted to use your calculator to solve an equation, find the derivative of a function at a point, or calculate the value of a definite integral. However, you must clearly indicate the setup of your question, namely the equation, function, or integral you are using. If you use other built-in features or programs, you must show the mathematical steps necessary to produce your results. During the timed portion for Part B, you may continue to work on the questions in Part A without the use of a calculator.

For each part of Section II, you may wish to look over the questions before starting to work on them. It is not expected that everyone will be able to complete all parts of all questions.

- Show all of your work. Clearly label any functions, graphs, tables, or other objects that you use. Your work will be scored on the correctness and completeness of your methods as well as your answers. Answers without supporting work will usually not receive credit. Justifications require that you give mathematical (noncalculator) reasons.
- Your work must be expressed in standard mathematical notation rather than calculator syntax. For example,  $\int_1^5 x^2 dx$  may not be written as  $\text{fnInt}(X^2, X, 1, 5)$ .
- Unless otherwise specified, answers (numeric or algebraic) need not be simplified. If you use decimal approximations in calculations, your work will be scored on accuracy. Unless otherwise specified, your final answers should be accurate to three places after the decimal point.
- 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.



Minimum 20% post-consumer waste

Form I  
Form Code 4IBP-S2

66



**CALCULUS AB**  
**SECTION II, Part A**  
**Time—30 minutes**  
**Number of problems—2**

**A graphing calculator is required for these problems.**

$t$ (minutes)	0	4	9	15	20
$W(t)$ (degrees Fahrenheit)	55.0	57.1	61.8	67.9	71.0

1. The temperature of water in a tub at time  $t$  is modeled by a strictly increasing, twice-differentiable function  $W$ , where  $W(t)$  is measured in degrees Fahrenheit and  $t$  is measured in minutes. At time  $t = 0$ , the temperature of the water is  $55^\circ\text{F}$ . The water is heated for 30 minutes, beginning at time  $t = 0$ . Values of  $W(t)$  at selected times  $t$  for the first 20 minutes are given in the table above.
- (a) Use the data in the table to estimate  $W'(12)$ . Show the computations that lead to your answer. Using correct units, interpret the meaning of your answer in the context of this problem.

- 
- (b) Use the data in the table to evaluate  $\int_0^{20} W'(t) dt$ . Using correct units, interpret the meaning of  $\int_0^{20} W'(t) dt$  in the context of this problem.

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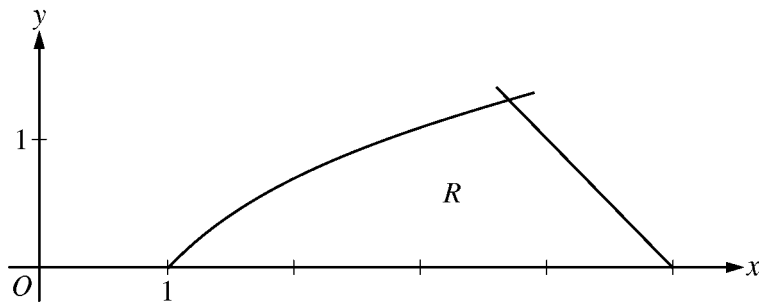
**1****1****1****1****1****1****1****1****1****1**

- (c) For  $0 \leq t \leq 20$ , the average temperature of the water in the tub is  $\frac{1}{20} \int_0^{20} W(t) dt$ . Use a left Riemann sum with the four subintervals indicated by the data in the table to approximate  $\frac{1}{20} \int_0^{20} W(t) dt$ . Does this approximation overestimate or underestimate the average temperature of the water over these 20 minutes? Explain your reasoning.

- 
- (d) For  $20 \leq t \leq 25$ , the function  $W$  that models the water temperature has first derivative given by  $W'(t) = 0.4\sqrt{t} \cos(0.06t)$ . Based on the model, what is the temperature of the water at time  $t = 25$ ?

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2. Let  $R$  be the region in the first quadrant bounded by the  $x$ -axis and the graphs of  $y = \ln x$  and  $y = 5 - x$ , as shown in the figure above.
- (a) Find the area of  $R$ .

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- (b) Region  $R$  is the base of a solid. For the solid, each cross section perpendicular to the  $x$ -axis is a square. Write, but do not evaluate, an expression involving one or more integrals that gives the volume of the solid.

- 
- (c) The horizontal line  $y = k$  divides  $R$  into two regions of equal area. Write, but do not solve, an equation involving one or more integrals whose solution gives the value of  $k$ .

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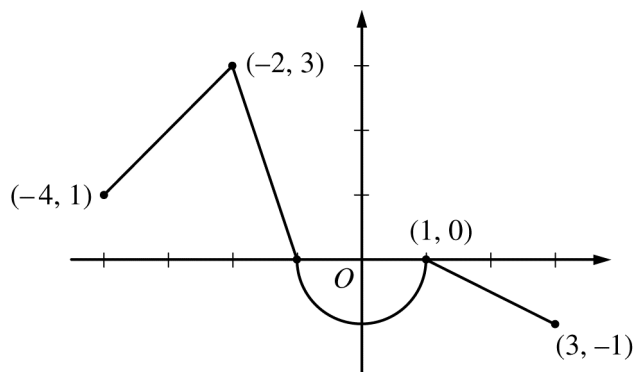
**CALCULUS AB**  
**SECTION II, Part B**  
**Time—60 minutes**  
**Number of problems—4**

**No calculator is allowed for these problems.**

**DO NOT BREAK THE SEALS UNTIL YOU ARE TOLD TO DO SO.**

**GO ON TO THE NEXT PAGE.**

NO CALCULATOR ALLOWED

Graph of  $f$ 

3. Let  $f$  be the continuous function defined on  $[-4, 3]$  whose graph, consisting of three line segments and a semicircle centered at the origin, is given above. Let  $g$  be the function given by  $g(x) = \int_1^x f(t) dt$ .

(a) Find the values of  $g(2)$  and  $g(-2)$ .

---

(b) For each of  $g'(-3)$  and  $g''(-3)$ , find the value or state that it does not exist.

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**3****3****3****3****3****3****3****3****3****3****NO CALCULATOR ALLOWED**

- (c) Find the  $x$ -coordinate of each point at which the graph of  $g$  has a horizontal tangent line. For each of these points, determine whether  $g$  has a relative minimum, relative maximum, or neither a minimum nor a maximum at the point. Justify your answers.

- 
- (d) For  $-4 < x < 3$ , find all values of  $x$  for which the graph of  $g$  has a point of inflection. Explain your reasoning.

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**4****4****4****4****4****4****4****4****4****4****NO CALCULATOR ALLOWED**

4. The function  $f$  is defined by  $f(x) = \sqrt{25 - x^2}$  for  $-5 \leq x \leq 5$ .

(a) Find  $f'(x)$ .

---

(b) Write an equation for the line tangent to the graph of  $f$  at  $x = -3$ .

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**NO CALCULATOR ALLOWED**

(c) Let  $g$  be the function defined by  $g(x) = \begin{cases} f(x) & \text{for } -5 \leq x \leq -3 \\ x + 7 & \text{for } -3 < x \leq 5. \end{cases}$

Is  $g$  continuous at  $x = -3$ ? Use the definition of continuity to explain your answer.

---

(d) Find the value of  $\int_0^5 x\sqrt{25 - x^2} dx$ .

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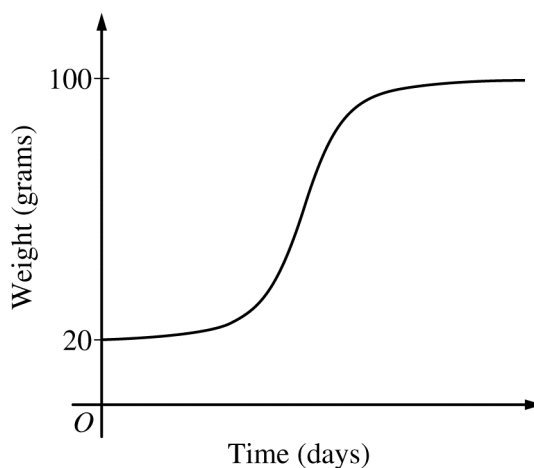
5. The rate at which a baby bird gains weight is proportional to the difference between its adult weight and its current weight. At time  $t = 0$ , when the bird is first weighed, its weight is 20 grams. If  $B(t)$  is the weight of the bird, in grams, at time  $t$  days after it is first weighed, then

$$\frac{dB}{dt} = \frac{1}{5}(100 - B).$$

Let  $y = B(t)$  be the solution to the differential equation above with initial condition  $B(0) = 20$ .

- (a) Is the bird gaining weight faster when it weighs 40 grams or when it weighs 70 grams? Explain your reasoning.

- (b) Find  $\frac{d^2B}{dt^2}$  in terms of  $B$ . Use  $\frac{d^2B}{dt^2}$  to explain why the graph of  $B$  cannot resemble the following graph.



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**5****5****5****5****5****5****5****5****5****5****NO CALCULATOR ALLOWED**

- (c) Use separation of variables to find  $y = B(t)$ , the particular solution to the differential equation with initial condition  $B(0) = 20$ .

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## NO CALCULATOR ALLOWED

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?

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(b) Write, but do not evaluate, an integral expression that gives the total distance traveled by the particle from time  $t = 0$  to time  $t = 6$ .

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**6****6****6****6****6****6****6****6****6****6****NO CALCULATOR ALLOWED**

- (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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**STOP**

**END OF EXAM**

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**THE FOLLOWING INSTRUCTIONS APPLY TO THE COVERS OF THE SECTION II BOOKLET.**

- **MAKE SURE YOU HAVE COMPLETED THE IDENTIFICATION INFORMATION AS REQUESTED ON THE FRONT AND BACK COVERS OF THE SECTION II BOOKLET.**
- **CHECK TO SEE THAT YOUR AP NUMBER LABEL APPEARS IN THE BOX ON THE COVER.**
- **MAKE SURE YOU HAVE USED THE SAME SET OF AP NUMBER LABELS ON ALL AP EXAMS YOU HAVE TAKEN THIS YEAR.**

**GO ON TO THE NEXT PAGE.**



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## **Multiple-Choice Answer Key**

The following contains the answers to the multiple-choice questions in this exam.

**Answer Key for AP Calculus AB  
Practice Exam, Section I**

<b>Multiple-Choice Questions</b>	
<b>Question #</b>	<b>Key</b>
1	B
2	B
3	A
4	E
5	C
6	D
7	E
8	C
9	E
10	A
11	A
12	C
13	D
14	A
15	A
16	B
17	A
18	B
19	C
20	D
21	E
22	B

23	A
24	A
25	E
26	A
27	A
28	A
76	E
77	A
78	D
79	B
80	E
81	D
82	C
83	D
84	D
85	C
86	B
87	E
88	B
89	E
90	B
91	B
92	A

---

## **Free-Response Scoring Guidelines**

The following contains the scoring guidelines  
for the free-response questions in this exam.

**AP<sup>®</sup> CALCULUS AB**  
**2012 SCORING GUIDELINES**

**Question 1**

$t$ (minutes)	0	4	9	15	20
$W(t)$ (degrees Fahrenheit)	55.0	57.1	61.8	67.9	71.0

The temperature of water in a tub at time  $t$  is modeled by a strictly increasing, twice-differentiable function  $W$ , where  $W(t)$  is measured in degrees Fahrenheit and  $t$  is measured in minutes. At time  $t = 0$ , the temperature of the water is  $55^\circ\text{F}$ . The water is heated for 30 minutes, beginning at time  $t = 0$ . Values of  $W(t)$  at selected times  $t$  for the first 20 minutes are given in the table above.

- (a) Use the data in the table to estimate  $W'(12)$ . Show the computations that lead to your answer. Using correct units, interpret the meaning of your answer in the context of this problem.
- (b) Use the data in the table to evaluate  $\int_0^{20} W'(t) dt$ . Using correct units, interpret the meaning of  $\int_0^{20} W'(t) dt$  in the context of this problem.
- (c) For  $0 \leq t \leq 20$ , the average temperature of the water in the tub is  $\frac{1}{20} \int_0^{20} W(t) dt$ . Use a left Riemann sum with the four subintervals indicated by the data in the table to approximate  $\frac{1}{20} \int_0^{20} W(t) dt$ . Does this approximation overestimate or underestimate the average temperature of the water over these 20 minutes? Explain your reasoning.
- (d) For  $20 \leq t \leq 25$ , the function  $W$  that models the water temperature has first derivative given by  $W'(t) = 0.4\sqrt{t} \cos(0.06t)$ . Based on the model, what is the temperature of the water at time  $t = 25$ ?

(a) 
$$W'(12) \approx \frac{W(15) - W(9)}{15 - 9} = \frac{67.9 - 61.8}{6}$$

$$= 1.017 \text{ (or 1.016)}$$

The water temperature is increasing at a rate of approximately  $1.017^\circ\text{F}$  per minute at time  $t = 12$  minutes.

(b) 
$$\int_0^{20} W'(t) dt = W(20) - W(0) = 71.0 - 55.0 = 16$$

The water has warmed by  $16^\circ\text{F}$  over the interval from  $t = 0$  to  $t = 20$  minutes.

(c) 
$$\frac{1}{20} \int_0^{20} W(t) dt \approx \frac{1}{20} (4 \cdot W(0) + 5 \cdot W(4) + 6 \cdot W(9) + 5 \cdot W(15))$$

$$= \frac{1}{20} (4 \cdot 55.0 + 5 \cdot 57.1 + 6 \cdot 61.8 + 5 \cdot 67.9)$$

$$= \frac{1}{20} \cdot 1215.8 = 60.79$$

This approximation is an underestimate, because a left Riemann sum is used and the function  $W$  is strictly increasing.

(d) 
$$W(25) = 71.0 + \int_{20}^{25} W'(t) dt$$

$$= 71.0 + 2.043155 = 73.043$$

2 :  $\begin{cases} 1 : \text{estimate} \\ 1 : \text{interpretation with units} \end{cases}$

2 :  $\begin{cases} 1 : \text{value} \\ 1 : \text{interpretation with units} \end{cases}$

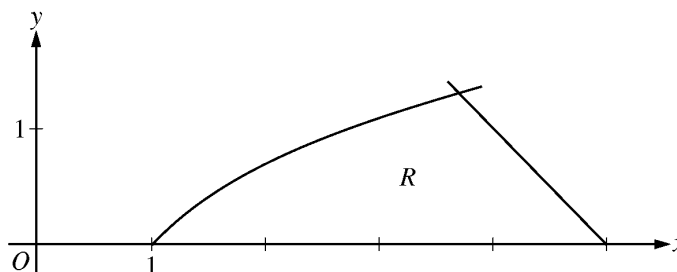
3 :  $\begin{cases} 1 : \text{left Riemann sum} \\ 1 : \text{approximation} \\ 1 : \text{underestimate with reason} \end{cases}$

2 :  $\begin{cases} 1 : \text{integral} \\ 1 : \text{answer} \end{cases}$

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2012 SCORING GUIDELINES**

**Question 2**

Let  $R$  be the region in the first quadrant bounded by the  $x$ -axis and the graphs of  $y = \ln x$  and  $y = 5 - x$ , as shown in the figure above.



- (a) Find the area of  $R$ .
- (b) Region  $R$  is the base of a solid. For the solid, each cross section perpendicular to the  $x$ -axis is a square. Write, but do not evaluate, an expression involving one or more integrals that gives the volume of the solid.
- (c) The horizontal line  $y = k$  divides  $R$  into two regions of equal area. Write, but do not solve, an equation involving one or more integrals whose solution gives the value of  $k$ .

$$\ln x = 5 - x \Rightarrow x = 3.69344$$

Therefore, the graphs of  $y = \ln x$  and  $y = 5 - x$  intersect in the first quadrant at the point  $(A, B) = (3.69344, 1.30656)$ .

(a) 
$$\text{Area} = \int_0^B (5 - y - e^y) dy$$

$$= 2.986 \text{ (or } 2.985)$$

3 :  $\begin{cases} 1 : \text{integrand} \\ 1 : \text{limits} \\ 1 : \text{answer} \end{cases}$

OR

$$\text{Area} = \int_1^A \ln x \, dx + \int_A^5 (5 - x) \, dx$$

$$= 2.986 \text{ (or } 2.985)$$

(b) 
$$\text{Volume} = \int_1^A (\ln x)^2 \, dx + \int_A^5 (5 - x)^2 \, dx$$

3 :  $\begin{cases} 2 : \text{integrand} \\ 1 : \text{expression for total volume} \end{cases}$

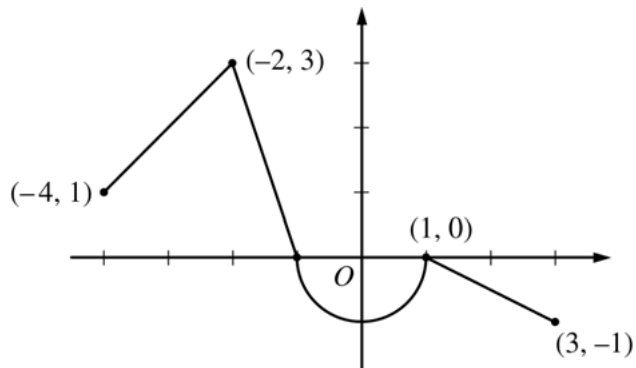
(c) 
$$\int_0^k (5 - y - e^y) \, dy = \frac{1}{2} \cdot 2.986 \text{ (or } \frac{1}{2} \cdot 2.985)$$

3 :  $\begin{cases} 1 : \text{integrand} \\ 1 : \text{limits} \\ 1 : \text{equation} \end{cases}$

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2012 SCORING GUIDELINES**

**Question 3**

Let  $f$  be the continuous function defined on  $[-4, 3]$  whose graph, consisting of three line segments and a semicircle centered at the origin, is given above. Let  $g$  be the function given by  $g(x) = \int_1^x f(t) dt$ .



Graph of  $f$

- (a) Find the values of  $g(2)$  and  $g(-2)$ .
- (b) For each of  $g'(-3)$  and  $g''(-3)$ , find the value or state that it does not exist.
- (c) Find the  $x$ -coordinate of each point at which the graph of  $g$  has a horizontal tangent line. For each of these points, determine whether  $g$  has a relative minimum, relative maximum, or neither a minimum nor a maximum at the point. Justify your answers.
- (d) For  $-4 < x < 3$ , find all values of  $x$  for which the graph of  $g$  has a point of inflection. Explain your reasoning.

(a)  $g(2) = \int_1^2 f(t) dt = -\frac{1}{2}(1)\left(\frac{1}{2}\right) = -\frac{1}{4}$   
 $g(-2) = \int_1^{-2} f(t) dt = -\int_{-2}^1 f(t) dt$   
 $= -\left(\frac{3}{2} - \frac{\pi}{2}\right) = \frac{\pi}{2} - \frac{3}{2}$

2 :  $\begin{cases} 1 : g(2) \\ 1 : g(-2) \end{cases}$

(b)  $g'(x) = f(x) \Rightarrow g'(-3) = f(-3) = 2$   
 $g''(x) = f'(x) \Rightarrow g''(-3) = f'(-3) = 1$

2 :  $\begin{cases} 1 : g'(-3) \\ 1 : g''(-3) \end{cases}$

(c) The graph of  $g$  has a horizontal tangent line where  $g'(x) = f(x) = 0$ . This occurs at  $x = -1$  and  $x = 1$ .

$g'(x)$  changes sign from positive to negative at  $x = -1$ . Therefore,  $g$  has a relative maximum at  $x = -1$ .

$g'(x)$  does not change sign at  $x = 1$ . Therefore,  $g$  has neither a relative maximum nor a relative minimum at  $x = 1$ .

3 :  $\begin{cases} 1 : \text{considers } g'(x) = 0 \\ 1 : x = -1 \text{ and } x = 1 \\ 1 : \text{answers with justifications} \end{cases}$

(d) The graph of  $g$  has a point of inflection at each of  $x = -2$ ,  $x = 0$ , and  $x = 1$  because  $g''(x) = f'(x)$  changes sign at each of these values.

2 :  $\begin{cases} 1 : \text{answer} \\ 1 : \text{explanation} \end{cases}$

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2012 SCORING GUIDELINES**

**Question 4**

The function  $f$  is defined by  $f(x) = \sqrt{25 - x^2}$  for  $-5 \leq x \leq 5$ .

- (a) Find  $f'(x)$ .
- (b) Write an equation for the line tangent to the graph of  $f$  at  $x = -3$ .
- (c) Let  $g$  be the function defined by  $g(x) = \begin{cases} f(x) & \text{for } -5 \leq x \leq -3 \\ x + 7 & \text{for } -3 < x \leq 5. \end{cases}$   
Is  $g$  continuous at  $x = -3$ ? Use the definition of continuity to explain your answer.
- (d) Find the value of  $\int_0^5 x\sqrt{25 - x^2} \, dx$ .

(a)  $f'(x) = \frac{1}{2}(25 - x^2)^{-1/2}(-2x) = \frac{-x}{\sqrt{25 - x^2}}, \quad -5 < x < 5$

2 :  $f'(x)$

(b)  $f'(-3) = \frac{3}{\sqrt{25 - 9}} = \frac{3}{4}$

$f(-3) = \sqrt{25 - 9} = 4$

An equation for the tangent line is  $y = 4 + \frac{3}{4}(x + 3)$ .

2 :  $\begin{cases} 1 : f'(-3) \\ 1 : \text{answer} \end{cases}$

(c)  $\lim_{x \rightarrow -3^-} g(x) = \lim_{x \rightarrow -3^-} f(x) = \lim_{x \rightarrow -3^-} \sqrt{25 - x^2} = 4$

$\lim_{x \rightarrow -3^+} g(x) = \lim_{x \rightarrow -3^+} (x + 7) = 4$

Therefore,  $\lim_{x \rightarrow -3} g(x) = 4$ .

$g(-3) = f(-3) = 4$

So,  $\lim_{x \rightarrow -3} g(x) = g(-3)$ .

Therefore,  $g$  is continuous at  $x = -3$ .

2 :  $\begin{cases} 1 : \text{considers one-sided limits} \\ 1 : \text{answer with explanation} \end{cases}$

(d) Let  $u = 25 - x^2 \Rightarrow du = -2x \, dx$

$\int_0^5 x\sqrt{25 - x^2} \, dx = -\frac{1}{2} \int_{25}^0 \sqrt{u} \, du$

$= \left[ -\frac{1}{2} \cdot \frac{2}{3} u^{3/2} \right]_{u=25}^{u=0}$

$= -\frac{1}{3}(0 - 125) = \frac{125}{3}$

3 :  $\begin{cases} 2 : \text{antiderivative} \\ 1 : \text{answer} \end{cases}$

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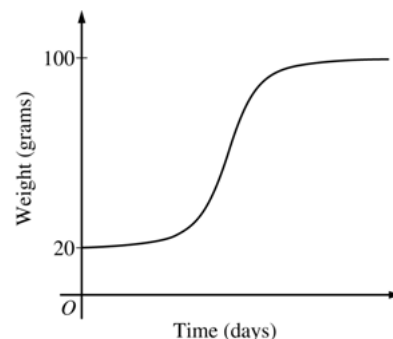
**Question 5**

The rate at which a baby bird gains weight is proportional to the difference between its adult weight and its current weight. At time  $t = 0$ , when the bird is first weighed, its weight is 20 grams. If  $B(t)$  is the weight of the bird, in grams, at time  $t$  days after it is first weighed, then

$$\frac{dB}{dt} = \frac{1}{5}(100 - B).$$

Let  $y = B(t)$  be the solution to the differential equation above with initial condition  $B(0) = 20$ .

- (a) Is the bird gaining weight faster when it weighs 40 grams or when it weighs 70 grams? Explain your reasoning.
- (b) Find  $\frac{d^2B}{dt^2}$  in terms of  $B$ . Use  $\frac{d^2B}{dt^2}$  to explain why the graph of  $B$  cannot resemble the following graph.
- (c) Use separation of variables to find  $y = B(t)$ , the particular solution to the differential equation with initial condition  $B(0) = 20$ .



(a)  $\left. \frac{dB}{dt} \right|_{B=40} = \frac{1}{5}(60) = 12$

$$\left. \frac{dB}{dt} \right|_{B=70} = \frac{1}{5}(30) = 6$$

Because  $\left. \frac{dB}{dt} \right|_{B=40} > \left. \frac{dB}{dt} \right|_{B=70}$ , the bird is gaining weight faster when it weighs 40 grams.

(b)  $\frac{d^2B}{dt^2} = -\frac{1}{5} \frac{dB}{dt} = -\frac{1}{5} \cdot \frac{1}{5}(100 - B) = -\frac{1}{25}(100 - B)$

Therefore, the graph of  $B$  is concave down for  $20 \leq B < 100$ . A portion of the given graph is concave up.

(c)  $\frac{dB}{dt} = \frac{1}{5}(100 - B)$

$$\int \frac{1}{100 - B} dB = \int \frac{1}{5} dt$$

$$-\ln|100 - B| = \frac{1}{5}t + C$$

Because  $20 \leq B < 100$ ,  $|100 - B| = 100 - B$ .

$$-\ln(100 - 20) = \frac{1}{5}(0) + C \Rightarrow -\ln(80) = C$$

$$100 - B = 80e^{-t/5}$$

$$B(t) = 100 - 80e^{-t/5}, \quad t \geq 0$$

2 :  $\left\{ \begin{array}{l} 1 : \text{uses } \frac{dB}{dt} \\ 1 : \text{answer with reason} \end{array} \right.$

2 :  $\left\{ \begin{array}{l} 1 : \frac{d^2B}{dt^2} \text{ in terms of } B \\ 1 : \text{explanation} \end{array} \right.$

5 :  $\left\{ \begin{array}{l} 1 : \text{separation of variables} \\ 1 : \text{antiderivatives} \\ 1 : \text{constant of integration} \\ 1 : \text{uses initial condition} \\ 1 : \text{solves for } B \end{array} \right.$

Note: max 2/5 [1-1-0-0-0] if no constant of integration

Note: 0/5 if no separation of variables



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**Question 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  $v(t) = \cos\left(\frac{\pi}{6}t\right)$ . The particle is at position  $x = -2$  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  $t = 4$ .

(a)  $v(t) = \cos\left(\frac{\pi}{6}t\right) = 0 \Rightarrow t = 3, 9$

The particle is moving to the left when  $v(t) < 0$ .  
This occurs when  $3 < t < 9$ .

2 :  $\begin{cases} 1 : \text{considers } v(t) = 0 \\ 1 : \text{interval} \end{cases}$

(b)  $\int_0^6 |v(t)| dt$

1 : answer

(c)  $a(t) = -\frac{\pi}{6} \sin\left(\frac{\pi}{6}t\right)$

$$a(4) = -\frac{\pi}{6} \sin\left(\frac{2\pi}{3}\right) = -\frac{\sqrt{3}\pi}{12} < 0$$

$$v(4) = \cos\left(\frac{2\pi}{3}\right) = -\frac{1}{2} < 0$$

The speed is increasing at time  $t = 4$ , because velocity and acceleration have the same sign.

3 :  $\begin{cases} 1 : a(t) \\ 2 : \text{conclusion with reason} \end{cases}$

(d)  $x(4) = -2 + \int_0^4 \cos\left(\frac{\pi}{6}t\right) dt$

$$= -2 + \left[ \frac{6}{\pi} \sin\left(\frac{\pi}{6}t\right) \right]_0^4$$

$$= -2 + \frac{6}{\pi} \left[ \sin\left(\frac{2\pi}{3}\right) - 0 \right]$$

$$= -2 + \frac{6}{\pi} \cdot \frac{\sqrt{3}}{2} = -2 + \frac{3\sqrt{3}}{\pi}$$

3 :  $\begin{cases} 1 : \text{antiderivative} \\ 1 : \text{uses initial condition} \\ 1 : \text{answer} \end{cases}$

**GO ON TO THE NEXT PAGE.**

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## **Scoring Worksheet**

The following provides a worksheet and conversion table used for calculating a composite score of the exam.

## 2012 AP Calculus AB Scoring Worksheet

### Section I: Multiple Choice

$$\frac{\text{Number Correct}}{\text{(out of 45)}} \times 1.2000 = \frac{\text{Weighted Section I Score}}{\text{(Do not round)}}$$

### Section II: Free Response

$$\text{Question 1 } \frac{\text{_____}}{\text{(out of 9)}} \times 1.0000 = \frac{\text{_____}}{\text{(Do not round)}}$$

$$\text{Question 2 } \frac{\text{_____}}{\text{(out of 9)}} \times 1.0000 = \frac{\text{_____}}{\text{(Do not round)}}$$

$$\text{Question 3 } \frac{\text{_____}}{\text{(out of 9)}} \times 1.0000 = \frac{\text{_____}}{\text{(Do not round)}}$$

$$\text{Question 4 } \frac{\text{_____}}{\text{(out of 9)}} \times 1.0000 = \frac{\text{_____}}{\text{(Do not round)}}$$

$$\text{Question 5 } \frac{\text{_____}}{\text{(out of 9)}} \times 1.0000 = \frac{\text{_____}}{\text{(Do not round)}}$$

$$\text{Question 6 } \frac{\text{_____}}{\text{(out of 9)}} \times 1.0000 = \frac{\text{_____}}{\text{(Do not round)}}$$

$$\text{Sum} = \frac{\text{_____}}{\text{Weighted Section II Score (Do not round)}}$$

### Composite Score

$$\frac{\text{Weighted Section I Score}}{\text{_____}} + \frac{\text{Weighted Section II Score}}{\text{_____}} = \frac{\text{Composite Score (Round to nearest whole number)}}{\text{_____}}$$

AP Score Conversion Chart  
Calculus AB

Composite Score Range	AP Score
67-108	5
54-66	4
41-53	3
33-40	2
0-32	1



# AP Calculus AB

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## **The College Board**

The College Board is a mission-driven not-for-profit organization that connects students to college success and opportunity. Founded in 1900, the College Board was created to expand access to higher education. Today, the membership association is made up of over 6,000 of the world's leading educational institutions and is dedicated to promoting excellence and equity in education. Each year, the College Board helps more than seven million students prepare for a successful transition to college through programs and services in college readiness and college success — including the SAT® and the Advanced Placement Program®. The organization also serves the education community through research and advocacy on behalf of students, educators, and schools. 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.

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