

**BC Calculus Unit 10.5b-10.10 Infinite Series Test Review WS #1**

Calculators Allowed:

1. If the infinite series  $S = \sum_{n=1}^{\infty} (-1)^{n+1} \frac{1}{2n^3 - 1}$  is approximated by  $S_k = \sum_{n=1}^k (-1)^{n+1} \frac{1}{2n^3 - 1}$ , what is the least value of  $k$  for which the alternating series error bound guarantees that  $|S - S_k| < 10^{-3}$ ?
- (A) 6                      (B) 7                      (C) 8                      (D) 9
2. If the series  $\sum_{n=1}^{\infty} (-1)^{n+1} \frac{1}{4n + 1}$  is approximated by the partial sum with 15 terms, what is the alternating series error bound?
- (A)  $\frac{1}{15}$                       (B)  $\frac{1}{16}$                       (C)  $\frac{1}{61}$                       (D)  $\frac{1}{65}$
3. Let  $P(x) = 3 - 2x^2 + 5x^4$  be the fourth-degree Taylor Polynomial for the function  $f$  about  $x = 0$ . What is the value of  $f^{(4)}(0)$ ?
4. The function  $f$  has derivatives of all orders for all real numbers with  $f(2) = -2$ ,  $f'(2) = 4$ ,  $f''(2) = 8$ , and  $f'''(2) = 14$ . Using the third-degree Taylor Polynomial for  $f$  about  $x = 2$ , what is the approximation of  $f(2.2)$ ?

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5. Let  $f$  be a function that has derivatives of all orders for all real numbers and let  $P_4(x)$  be the fourth-degree Taylor Polynomial for  $f$  about  $x = 0$ .  $|f^{(n)}(x)| \leq \frac{n}{n+1}$ , for  $1 \leq n \leq 6$  and all values of  $x$ . Of the following, which is the smallest value of  $k$  for which the Lagrange error bound guarantees that  $|f(1) - P_4(1)| \leq k$ ?

(A)  $\frac{4}{5} \left( \frac{1}{4!} \right)$

(B)  $\frac{4}{5} \left( \frac{1}{5!} \right)$

(C)  $\frac{1}{6} \left( \frac{1}{4!} \right)$

(D)  $\frac{1}{6} \left( \frac{1}{5!} \right)$

6. The third Maclaurin polynomial for  $\sin x$  is given by  $f(x) = x - \frac{x^3}{3!}$ . If this polynomial is used to approximate  $\sin(0.3)$ , what is the Lagrange error bound?

7. Find the interval of convergence for the power series  $\sum_{n=0}^{\infty} \frac{(-1)^{n+1}(x-1)^{n+1}}{n+1}$ .

8. If the radius of convergence of the power series  $\sum_{n=1}^{\infty} \frac{(-1)^n x^n}{5^n}$  is 5, what is the interval of convergence?

9. Which of the following is an expression for a function  $f$  that has the Maclaurin Series  $1 + \frac{x^2}{2!} + \frac{x^4}{4!} + \frac{x^6}{6!} + \dots + \frac{x^{2n}}{(2n)!}$  ?

(A)  $\cos x$

(B)  $e^x - \sin x$

(C)  $\frac{1}{2}(e^x + e^{-x})$

(D)  $e^{x^2}$

10. Find the Maclaurin Series for the function  $f(x) = 2 \sin x^3$ . Write the first four non-zero terms.

11. It is known the Maclaurin series for the function  $\frac{1}{1+x}$  is defined by  $\sum_{n=0}^{\infty} (-1)^n x^n$ . Use this fact to find the first four nonzero terms and the general term for the power series expansion for  $\frac{x^2}{1+x^2}$ .

12. Let  $T(x) = 7 - 3(x - 3) + 5(x - 3)^2 - 2(x - 3)^3 + 6(x - 3)^4$  be the fourth-degree Taylor Polynomial for the function  $f$  about  $x = 3$ . Find the third-degree Taylor Polynomial for the derivative  $f'$  about  $x = 3$  and use it to approximate  $f'(3.3)$ .

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**BC Calculus Unit 10.5b-10.10 Infinite Series Test Review WS #2**

Calculators Allowed:

- Let  $f$  be the function defined by  $f(x) = 3x \cos x$ . What is the coefficient of  $x^5$  in the Taylor Series for  $f$  about  $x = 0$ ?
  
  
  
  
  
  
  
  
  
  
- Determine the number of terms required to approximate the sum of the series  $\sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{n^4}$  with an error less than 0.0001.  
(A) 7                      (B) 8                      (C) 9                      (D) 10
  
  
  
  
  
  
  
  
  
  
- Find the third-degree Taylor Polynomial for the function  $f(x) = \sqrt{x}$  about  $x = 2$ .
  
  
  
  
  
  
  
  
  
  
- What is the coefficient of  $x^3$  in the Maclaurin series for the function  $\left(\frac{1}{1-x}\right)^2$ ?

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5. The function  $f$  has derivatives of all orders for all real numbers and  $f^{(4)}(x) \leq \frac{1}{2}$ . If a third-degree Taylor Polynomial for  $f$  about  $x = 0$  is used to approximate  $f$  on  $[0,1]$ . What is the Lagrange error bound for the maximum error on interval  $[0,1]$  in the approximation of  $f(1)$ ?

(A)  $\frac{1}{2}$

(B)  $\frac{1}{8}$

(C)  $\frac{1}{24}$

(D)  $\frac{1}{48}$

6. What is the alternating series error bound, if the series  $\sum_{n=1}^{\infty} (-1)^{n+1} \frac{1}{5n+2}$  is approximated by the partial sum with 15 terms?

(A)  $\frac{1}{15}$

(B)  $\frac{1}{16}$

(C)  $\frac{1}{77}$

(D)  $\frac{1}{82}$

7.  $\max_{0 \leq x \leq 2} |f^{(5)}(x)| = 3.6$

$\max_{0 \leq x \leq 2} |f^{(6)}(x)| = 8.1$

$\max_{0 \leq x \leq 2} |f^{(7)}(x)| = 11.3$

Let  $P(x)$  be the fifth-degree Taylor Polynomial for a function  $f$  about  $x = 0$ . Information about the maximum of the absolute value of selected derivatives of  $f$  over the interval  $0 \leq x \leq 2$  is given in the table above. What is the smallest value of  $k$  for which the Lagrange error bound guarantees that  $|f(0.2) - P(0.2)| \leq k$ ?

8. Find the interval of convergence of the power series  $\sum_{n=1}^{\infty} \frac{(-1)^{n+1}(x-3)^n}{n3^n}$ .

9. What is the coefficient of  $(x-2)^4$  in the Taylor Polynomial for  $f(x) = e^{4x}$  about  $x = 2$ ?

10. A series expansion for function  $f(x) = e^{3x}$  is given by

(A)  $1 + 3x + \frac{9x^2}{2} + \frac{9x^3}{2} + \dots$

(B)  $1 + 3x + \frac{3x^2}{2!} + \frac{3x^3}{3!} + \dots$

(C)  $1 - 3x + \frac{9x^2}{2} - \frac{9x^3}{2} + \dots$

(D)  $1 - 3x + \frac{3x^2}{2!} - \frac{3x^3}{3!} + \dots$

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11. Let  $f$  be the function with initial condition  $f(0) = 0$  and derivative  $f'(x) = e^{3x}$ . Write the first four nonzero terms and the general term of the Maclaurin series for  $f$ .

12. Find the radius of convergence for the power series  $\sum_{n=1}^{\infty} \frac{(-1)^{n+1} x^n}{6^n}$ .

### Answers to End of Unit 10 Corrective Assignment

1. $\frac{1}{8}$	2. D	3. $f(x) = \sqrt{2} + \frac{\sqrt{2}}{4}(x-2) - \frac{\sqrt{2}}{32}(x-2)^2 + \frac{\sqrt{2}}{128}(x-2)^3$	
4. 4	5. D	6. D	7. $7.2 \times 10^{-7}$
8. $0 < x \leq 6$		9. $\frac{32e^8}{3}$	10. A
11. $f(x) = x + \frac{3}{2}x^2 + \frac{3}{2}x^3 + \frac{9}{8}x^4 + \dots + \frac{3^n x^{n+1}}{(n+1)n!}$			12. 6



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### BC Calculus Unit 10.5b-10.10 Infinite Series Test Review WS #3

Calculators Allowed:

#### 10.5b Alternating Series Error Bound

1. If the series  $\sum_{n=1}^{\infty} (-1)^n \frac{1}{2n+1}$  is approximated by the partial sum with 50 terms, what is the alternating series error bound?
2. Approximate an interval for the sum of the convergent alternating series  $\sum_{n=1}^{\infty} \frac{(-1)^n 2}{n^2}$  using the Alternating Series Error Bound the first 6 terms.
3. The series  $\sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{\sqrt{n}}$  converges to  $S$ . Based on the alternating series error bound, what is the least number of terms to guarantee a partial sum that is within 0.02 of  $S$ ?

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4. If the series  $\sum_{n=1}^{\infty} (-1)^{n+1} \frac{5}{n}$  is approximated by  $S_k = \sum_{n=1}^k (-1)^{n+1} \frac{5}{n}$ , what is the least value of  $k$  for which the alternating series error bound guarantees that  $|S - S_k| < 0.001$ ?

(A) 999                      (B) 1000                      (C) 4999                      (D) 5000

5. Determine the least number of terms necessary to approximate the sum of the series  $\sum_{n=1}^{\infty} \frac{(-1)^n 3}{4^n}$  with an error less than  $10^{-3}$ .

**10.10a Finding Taylor Polynomial Approximations of Functions**

- 6) Find the third-degree Taylor Polynomial for  $f(x) = e^{2x}$  about  $x = 1$ .

- 7) Let  $f$  be the function with third derivative  $f'''(x) = 12x^{-3}$ . What is the coefficient of  $(x - 1)^4$  in the fourth-degree Taylor polynomial of  $f$  about  $x = 1$ ?

- 8) The function  $f$  has derivatives of all orders for all real numbers with  $f(4) = 1$ ,  $f'(4) = 3$ ,  $f''(4) = 5$ , and  $f'''(4) = 12$ . Using a third-degree Taylor Polynomial for  $f$  about  $x = 4$ , what is the approximation of  $f(4.1)$ ?
- 9) The third-degree Taylor Polynomial for a function  $f$  about  $x = 0$  is  $\frac{x^3}{128} - \frac{x^2}{16} + \frac{x}{8} + 4$ . What is the value of  $f'''(0)$ ?
- 10) Which of the following polynomial approximations is the best for  $\sin 2x$  near  $x = 0$ ?
- (A)  $2x - 8x^3$       (B)  $2 - \frac{4}{3}x^2$       (C)  $2x - \frac{4}{3}x^3$       (D)  $2 - \frac{4}{3}x$

### 10.10b Lagrange Error Bound

- 11) The fourth-degree Maclaurin polynomial for  $\cos x$  is given by  $1 - \frac{x^2}{2!} + \frac{x^4}{4!}$ . Use the Lagrange error bound to estimate the error in using this polynomial to approximate  $\cos \frac{\pi}{3}$ .

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12) The function  $f$  has derivatives of all orders for all real numbers and  $f^{(4)}(x) = e^{\sin x}$ . If the third-degree Taylor Polynomial for  $f$  about  $x = 0$  is used to approximate  $f$  on  $[0,1]$ , what is the Lagrange error bound for the maximum error on  $[0,1]$ ?

13) Assume a third-degree Taylor Polynomial about  $x = 2$  is used for the approximation  $f$  and  $|f^{(4)}(x)| \leq 12$  for all  $x \geq 1$ . Which of the following represents the Lagrange error bound in the approximation of  $f(2.5)$ ?

(A)  $\frac{1}{4}$

(B)  $\frac{1}{2}$

(C)  $\frac{1}{16}$

(D)  $\frac{1}{32}$

14) Determine the degree of the Taylor Polynomial about  $x = 0$  for  $f(x) = e^x$  required for the error in the approximation of  $f(0.8)$  to be less than 0.005.

15)

$x$	$f(x)$	$f'(x)$	$f''(x)$	$f'''(x)$	$f^{(4)}(x)$
2	112	164	214	312	345

Let  $f$  be a function having derivatives of all orders for  $x > 0$ . Selected values for the first four derivatives of  $f$  are given for  $x = 2$ . Use the Lagrange error bound to show that the third-degree Taylor Polynomial for  $f$  about  $x = 2$  approximates  $f(1.9)$  with an error less than 0.002.

### 10.8a Radius and Interval of Convergence of Power Series

Find the interval of convergence for each power series.

$$16) \sum_{n=1}^{\infty} \frac{(-1)^n (x+4)^n}{n}$$

$$17) \sum_{n=0}^{\infty} \frac{(-1)^n n! (x-4)^n}{3^n}$$

$$18) \text{ What is the radius of convergence of the power series } \sum_{n=0}^{\infty} \frac{(x+2)^n}{2^n}?$$

19) What is the interval of convergence for the power series  $\sum_{n=1}^{\infty} \frac{n}{n+1} (-kx)^{n-1}$ , where  $k$  is a positive integer?

20) If the power series  $\sum_{n=0}^{\infty} a_n (x-4)^n$  converges at  $x = 7$  and diverges at  $x = 8$ , which of the following must be true?

I. The series converges at  $x = 1$ .

II. The series converges at  $x = 2$ .

III. The series diverges at  $x = 0$ .

(A) I only

(B) II only

(C) I and II only

(D) II and III only

### 10.9 Finding Taylor or Maclaurin Series for a Function

21) What is the coefficient of  $x^6$  in the Taylor Series about  $x = 0$  for the function  $f(x) = \frac{e^{3x^2}}{4}$ ?

22) Write the first four non-zero terms for the Taylor Series for the function  $f(x) = 2x \cos x$  about  $x = 0$ ?

23) What is the sum of the series  $1 - \frac{3^2}{2!} + \frac{3^4}{4!} - \frac{3^6}{6!} + \dots + \frac{(-1)^n 3^{2n}}{(2n)!}$  ?

(A)  $\ln 3$

(B)  $e^3$

(C)  $\sin 3$

(D)  $\cos 3$

24) Write the first four non-zero terms in the Maclaurin Series for the function  $f(x) = x \sin 2x$ .

25) Which of the following is the Maclaurin Series for the function  $f$  defined by  $f(x) = 1 + x^2 + \cos x$  ?

(A)  $2 + \frac{x^2}{2} + \frac{x^4}{24} + \dots$

(B)  $2 + \frac{3x^2}{2} + \frac{x^4}{24} + \dots$

(C)  $1 + x + x^2 - \frac{x^3}{6} + \dots$

(D)  $2 + x + \frac{3x^2}{2} + \frac{x^3}{6} + \dots$

### 10.8b Representing Functions as a Power Series

26) What is the coefficient of  $x^5$  in the Taylor series for the function  $f(x) = e^x \sin x$  about  $x = 0$ ?

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- 27) If the function  $f$  is defined by  $f(x) = \sum_{n=0}^{\infty} \frac{x^{2n}}{n!}$ , then  $f'(x) = ?$  Write the first four nonzero terms and the general term of the Taylor series about  $x = 0$ .
- 28) Let  $f$  be the function defined by  $f(x) = e^{3x}$ . Find the Maclaurin series for the derivative  $f'$ . Write the first four nonzero terms and the general term.
- 29) Find the third-degree Taylor Polynomial for  $f(x) = \sin x \cos x$  about  $x = 0$ .
- 30) If  $f'(x) = \frac{4}{1+x}$  and  $f(0) = 0$ , write the first four nonzero terms and the general term of the Maclaurin series for  $f(x)$ .



**Taylor Polynomial** is a polynomial that will approximate other function's values in a region that is nearby the "center"  
 \*a tangent line is essentially a first degree Taylor polynomial.

**n<sup>th</sup> degree Taylor polynomial:**

$$P_n(x) = f(c) + f'(c)(x-c) + \frac{f''(c)}{2!}(x-c)^2 + \dots + \frac{f^{(n)}(c)}{n!}(x-c)^n$$

**Alternating Series Remainder:**

Suppose an alternating series converges by AST. If the Series has

$$\text{Sum } S, \text{ then } |R_n| = |S - S_n| \leq |a_{n+1}|$$

\*This means that the maximum error for the n<sup>th</sup> term partial Sum S<sub>n</sub> is no greater than the absolute value of the first unused term a<sub>n+1</sub>

**Taylor Series:** A General method for writing a power series representation for a function.

$$f(x) = \sum_{n=0}^{\infty} \frac{f^{(n)}(c)}{n!}(x-c)^n$$

f<sup>(n)</sup> represents the n<sup>th</sup> derivative evaluated at f.

**Maclaurin Series:** is the special case of Taylor series when c = 0.

$$f(x) = \sum_{n=0}^{\infty} \frac{f^{(n)}(0)}{n!}(x)^n$$

**Special Maclaurin Series:**

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \dots + \frac{(-1)^{n-1} x^{2n-1}}{(2n-1)!} \quad \text{IOC: All Reals}$$

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \dots + \frac{(-1)^{n-1} x^{2n-2}}{(2n-2)!} \quad \text{IOC: All Reals}$$

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^n}{n!} \quad \text{IOC: All Reals}$$

$$\tan^{-1} x = x - \frac{x^3}{3} + \frac{x^5}{5} - \frac{x^7}{7} + \dots + \frac{(-1)^{n-1} x^{2n-1}}{(2n-1)} \quad \text{IOC: } -1 \leq x \leq 1$$

**Power Series:** Written in form  $\sum_{n=0}^{\infty} a_n(x-c)^n$  where

c and a<sub>n</sub> (coefficients) are numbers:

\*Taylor and Maclaurin series are special cases of power series

For a power series centered at c, precisely one of the following is true:

- 1) The series converges only at c (ALL power series converge at least at their center) (Radius of convergence = 0)
- 2) The series converges for all x (function and infinite series have exact same values everywhere) → Radius = ∞
- 3) The series converges within a certain Radius of Convergence such that series converges for |x - c| < R → The interval of Convergence (I.O.C.) is [c - R, c + R]

\*Be sure to TEST convergence of endpoints

\*Typically, you want to use the RATIO TEST to determine Radius of Convergence

**Geometric Series** below based on

$$S = \frac{a_1}{1-r} \quad \text{IOC: } -1 < x < 1$$

$$\frac{1}{1+x} = \frac{1}{1-(-x)} = 1 - x + x^2 - x^3 + \dots + (-1)^n x^n + \dots$$

$$\text{IOC: } -1 < x < 1$$

$$\frac{1}{x} = \frac{1}{1-[-(x-1)]} = 1 - (x-1) + (x-1)^2 - \dots + (-1)^n (x-1)^n$$

$$\text{IOC: } 0 < x < 2$$

$$\ln x = \int \frac{1}{x} dx = (x-1) - \frac{(x-1)^2}{2} + \frac{(x-1)^3}{3} - \dots + \frac{(-1)^{n-1} (x-1)^n}{n}$$

$$\text{IOC: } 0 < x \leq 2$$

**LaGrange Error Bound** \*This is similar to the Alternating Series Remainder. However, this method offers a way to determine the maximum error (remainder) when we do a Taylor polynomial approximation using a certain number of terms for a specific function.

$$R_n(x) = \left| \frac{f^{(n+1)}(z)}{(n+1)!} (x-c)^{n+1} \right| \leq \left| \frac{\max |f^{(n+1)}(z)|}{(n+1)!} (x-c)^{n+1} \right|$$

\* The remainder for an n<sup>th</sup> degree polynomial is found by taking

the (n+1)<sup>st</sup> (first unused) derivative at "z" \*We are not expected to find the exact value of z. (If we could, then an approximation would not be necessary) \*We want to maximize the (n+1)<sup>st</sup> derivative on the interval from [x, c] in order to find

a safe upper bound for the  $|f^{(n+1)}(z)|$  \*The maximum error bound is the worst case scenario for the interval in which our actual approximation can live. \*\*College Board will provide strictly increasing and decreasing functions. (So we only have to choose between f(c) and f(x) (the endpoints). This will allow us to determine the max value much more accurately.

**Alternating Series Remainder:**

Suppose an alternating series converges by AST

(such that  $\lim_{n \rightarrow \infty} a_n = 0$  and a<sub>n</sub> is decreasing), then

$$|R_n| = |S - S_n| \leq |a_{n+1}|$$

\*This means that the maximum error for the n<sup>th</sup> term partial Sum S<sub>n</sub> is no greater than the absolute value of the first unused term a<sub>n+1</sub>