Please do not ask questions during this exam. If you consider a question to be ambiguous, state your assumptions in the margin and do the best you can to provide the correct answer. Refer to this page and the last page of the test for formulas, general directions, and calculator troubleshooting tips.

- Any communication with any person (other than the instructor or the designated proctor) during this exam in any form, including written, signed, verbal or digital, is understood to be a violation of academic integrity.
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- **Statement of Academic Integrity**: I have not and will not give or receive improper aid on this test.

In signing below, I acknowledge that I have read, understand, and agree to these testing conditions.

Student’s Signature: _________________________________________________________________

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<tr>
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<th>FR #3</th>
<th>FR #4</th>
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**Useful Formulas:**

\[ f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h}; \quad f'(a) = \lim_{x \to a} \frac{f(x) - f(a)}{x-a} \]

\[ F(t) = P(1+rt) \quad F(t) = Pe^{rt} \quad F(t) = P \left( 1 + \frac{r}{n} \right)^{nt} \]

\[ APY = (e^r - 1)100\% \quad \text{or} \quad APY = \left[ \left( 1 + \frac{r}{n} \right)^n - 1 \right] \times 100\% \]
MULTIPLE CHOICE: 61 points (3 points each, unless otherwise noted)

Use a #2 pencil and completely fill each bubble on your scantron to answer each multiple choice question. (For future reference, circle your answers on this test paper.) There is no penalty for guessing on multiple choice. If you indicate more than one answer, or you leave a blank, the question will be marked as incorrect.

1. Suppose $1000 is deposited in a bank, earning interest at an annual percentage rate (APR) of 2.5% compounded quarterly. If there are no other deposits or withdrawals, find the future value of this deposit after 22 months.

- a. $1044.58
- b. $1046.75
- c. $1051.11
- d. $1730.29

2. A bank offers an investment of $1000 an annual percentage rate (APR) of 1.8% compounded quarterly. If there are no other deposits or withdrawals, how long will it take the investment to double?

- a. 38 years 5 months
- b. 38 years 6 months
- c. 38 years 9 months
- d. 38.595 years

3. Which bank rate offers the highest annual percentage yield for a deposit in an account?

- Bank A account, with an annual percentage yield (APY) of 4.444% after compounding semi-annually.
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- Bank C account, with an annual percentage yield (APY) of 4.438% after compounding monthly.
- Bank D account, offering an annual percentage rate (APR) of 4.35% compounded continuously.

- a. Bank A
- b. Bank B
- c. Bank C
- d. Bank D

4. Find the derivative $s'(x) = \text{________________________}$ for $s(x) = 2(1.3^x)$.

- a. $2\ln(1.3)(1.3^x)$
- b. $2\ln(1.3)(1.3^x)$
- c. $\ln(2.6)(2.6^x)$
- d. $2x(1.3^{x-1})$

5. The slope of the tangent line to a point $x$ on the graph of function $C(x) = 3\ln(x)$ is__________________.

- a. $\frac{3}{x}$
- b. $3e^x$
- c. $\frac{1}{3x}$
- d. $\frac{x}{3}$
6. Find \( f'(x) = \) __________ for \( f(x) = 2e^x + 3e^x \).
   a. \( 2e^x + 3e^x \)  
   b. \( 10e^x + 3\ln(x) \)
   c. \( 10e^x + 3xe^{x-1} \)  
   d. \( 3e^x \)

7. If \( r(x) = 8\cdot\sqrt{x} \), then \( \frac{dr}{dx} = \) __________.
   a. \( 2x^{-\frac{1}{4}} \)  
   b. \( 32x^{-\frac{1}{2}} \)
   c. \( 2x^{-\frac{3}{4}} \)  
   d. \( -2x^{-\frac{5}{4}} \)

8. Which one of the following could be the graph of \( f \), if \( f \) is a function with the following characteristics?

\[ f'(2) > 0, \text{ and } f'(5) \text{ does not exist, and } f'(6) < 0 \]
Use the graph of $f(x)$ given below to answer the next four questions.

9. [2 pts] The function $f(x)$ is ____________________________ at $x = 4$.
   a. continuous and its derivative exists  
   b. continuous and its derivative does not exist  
   c. not continuous and its derivative exists  
   d. not continuous and its derivative does not exist

10. [2 pts] Identify ALL values of $x$ for which the derivative $f'(x) = 0$.
   a. $x = -1.5, x = 1$  
   b. $x = -3, x = 0, x = 2$  
   c. $x = -4.1, x = 0, x = 3.1, x = 5.1$  
   d. $x = -3, x = 0, x = 2, x = 4$

11. [2 pts] Find the intervals on which the slope graph of $f(x)$ lies below the $x$-axis.
   a. $(-4.4, -4.1), (3.1, 5.1)$  
   b. $(-4.4, -1.5), (1, 4)$  
   c. $(-3, -1.5), (2, 3.1)$ only  
   d. $(-3, 0), (2, 4)$

12. [2 pts] Consider the above graph restricted to the interval $(-4.4, 4)$. Find the combined number of relative maxima and relative minima that will occur on the slope graph of $f(x)$.
   a. zero  
   b. one  
   c. two  
   d. three
Use the following table to answer the next two questions.

The table below shows the price of beef in the United States in January of various years.

|------|------|------|------|------|------|------|------|------|

13. Between January of 2008 and January of 2015, the price of beef increased on average by ______________ dollars/pound per year.
   a. 0.137  b. 1.907  c. 3.671  d. 0.272

14. Between January of 2008 and January of 2015, the price of beef increased by __________ %.
   a. 81.916  b. 45.030  c. 0.095  d. 27.200

15. Which one of the following is a slope graph of the function graph shown below?

   ![Function Graph](image)

   a. ![Slope Graph A](image)  b. ![Slope Graph B](image)  c. ![Slope Graph C](image)  d. ![Slope Graph D](image)
16. Which one of the following is a **slope graph** of the function graph shown below?

![Function Graph](image)

a. ![Option A](image)

b. ![Option B](image)

c. ![Option C](image)

d. ![Option D](image)

17. Given \( f(x) = \frac{x^2 - 3x + 9}{3x} \), find \( f'(x) = \)_________.

a. \( \frac{2x - 3}{3} \)  
b. \( 3 - 3\ln(x) \)

c. \( \frac{1}{3} - 3x^{-2} \)  
d. \( \frac{x}{3} - 1 + \frac{3}{x} \)
Use the following information to answer the next two questions.

\[ C(x) \text{ billion subscribers} \text{ gives total number of mobile phone subscribers in the developing world, } x \text{ years since 2000, } 0 \leq x \leq 10. \]

18. Draw a line tangent to the graph at the given point \((6.5, 1.75)\) and estimate its slope. (Insert the answer into the next question.)

a. 0.65  b. 2.5  c. 0.4  d. 0.18

19. Write a sentence of interpretation for the slope of the tangent line.

a. In mid-2007, the number of mobile phone subscribers in the developing world was increasing by (answer to previous question) billion subscribers per year.

b. In mid-2007, the number of mobile phone subscribers in the developing world was increasing by (answer to previous question) billion subscribers.

c. Between 2000 and 2010, the number of mobile phone subscribers in the developing world increased by (answer to previous question) billion subscribers per year.

d. In mid-2007, the number of mobile phone subscribers in the developing world was increasing by (answer to previous question) \% per year.
Use the following graph to answer the next three questions.

20. [2 pts] Consider the point C on the above graph. The tangent line to the graph at point C is drawn ______________ the function curve.
   a. below  b. above  c. neither, it coincides  d. both, it cuts through

21. Consider the three points A, B, and C on the graph above. Order the three points from least steepness to greatest steepness.

22. Which one of the following shows a correct tangent line drawn at the inflection point B?
   a.  
   b.  
   c.  
   d.  
FREE RESPONSE: 39 points

Show work where possible. Read the directions at the back of the test on rounding, inclusion of units, and writing sentences and models.

1. The population of Boston, Massachusetts, can be represented by
   \[ P(x) = 0.001x^3 - 0.216x^2 + 9.558x + 622.170 \] thousand people, \( x \) years since 1900, \(-20 \leq x \leq 115\).
   
   Checkpoint: \( P(2) = 640.43 \)

Give a completely defined rate-of-change model for \( P(x) \) by filling in the blanks:

\[ P'(x) = 0.003x^2 - 0.432x + 9.558 \quad \text{thousand people per year} \]

(equation)__________ (units)__________

gives the ___ rate of change in the population of Boston, Massachusetts

where \( x \) is the number of years since 1900, \(-20 \leq x \leq 115\).

Part a) 5 pts:
2 pts derivative
1 pt units
1 pt “rate of change”
1 pt output

Part B) 5 pts
1 pt “when”,
1 pt “what”,
1 pt “was decreasing by”,
1 pt “how much”,
1 pt units

a. How quickly is population changing in 1930?
Round to three decimal places and interpret in a complete sentence.

In 1930, Boston’s population was decreasing by 0.702 thousand people per year.

(_______ /10 pts)

2. The number of Bald Eagle breeding pairs in the lower 48 states was 2680 in 1989 and was 4015 in 1993. Find the average rate of change in the number of Bald Eagle breeding pairs from 1989 to 1993 and write the answer in a sentence of interpretation.

\[
\frac{4015 - 2680}{1993 - 1989} = 333.75
\]

Between 1989 and 1993, the number of Bald Eagle breeding pairs increased on average by 333.75 pairs per year.

(_______ / 6 pts)

3. \( R(x) \) billion dollars gives the advertising revenue for a newspaper, \( x \) years since 1980, \( 5 \leq x \leq 19 \).

In 1990, advertising revenue was 3,870.07 billion dollars and was increasing by 767.11 billion dollars per year. Find percentage rate of change in the advertising revenue in 1990. Show work, round the answer to three decimal places, and include units.

\[
\frac{R'(10)}{R(10)} \cdot 100 = \frac{767.11}{3870.07} \cdot 100 = 19.822 \% \text{ per year}
\]

(_______ / 2 pts)
4. In the early stages of the deadly SARS (Severe Acute Respiratory Syndrome) epidemic of 2003, the number of reported cases was approximately \( S(t) = 167(1.18^t) \) cases \( t \) days after March 17, 2003 (the first day in which statistics were reported by the World Health Organization), \( 0 \leq t \leq 20 \).

\[ S(3) = 274.386344 \]

**Checkpoint:**

a. Use the limit of the slopes of secant lines to numerically estimate \( S'(7) \).

**Round entries to exactly 2 decimal places for full credit.**

<table>
<thead>
<tr>
<th>( t \to 7^- )</th>
<th>( \frac{S(t) - S(7)}{t - 7} )</th>
<th>( t \to 7^+ )</th>
<th>( \frac{S(t) - S(7)}{t - 7} )</th>
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<tbody>
<tr>
<td>6.9</td>
<td>87.32</td>
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<td>6.999</td>
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<td>6.99999</td>
<td>88.05</td>
<td>7.00001</td>
<td>( 88.05 )</td>
</tr>
</tbody>
</table>

**Part a) 4 pts entries in table, correct to two decimal places**

b. \( \lim_{t \to 7^-} \frac{S(t) - S(7)}{t - 7} = 88.05 \) \( \lim_{t \to 7^+} \frac{S(t) - S(7)}{t - 7} = 88.05 \)

c. \( S'(7) = \ldots 88.05 \) cases per day \( \ldots \) (include units)

**Part b) 1 pt for the limits, correct to two decimal places.**

**Part c) 0.5 pt for derivative, correct to two decimal places. 1 pt for units**

d. **Circle** the correct use of differential notation for \( S'(7) \).

\[ \frac{dt}{ds} \bigg|_{t=7} \frac{dS}{dt} \bigg|_{t=7} \frac{dt}{ds} \bigg|_{t=7} \frac{dS}{dt} \bigg|_{t=7} \]

**Part d) 0.5 pts**

**Part e) 1.5 pts**

e. The number 87.32 in the above table represents the slope of a secant line on the graph of \( S(t) \) between points \( t = \ldots 6.9 \ldots \) and \( t = \ldots 7 \ldots \) whereas the answer to part c) represents the slope of a tangent line at \( t = \ldots 7 \ldots \).

\( \ldots / 8.5 \) pts \( \)

5. Find the derivative of the function \( f(x) = 6\sqrt{x} - 3x^{-3} \). For full credit, clearly show work and use proper mathematical notation.

\[ f(x) = 6\sqrt{x} - 3x^{-3} = 6x^{\frac{1}{2}} - 3x^{-3} \]

\[ f'(x) = 3x^{-\frac{1}{2}} + 9x^{-4} \]

\( \ldots / 2.5 \) pts
6. **Use the limit definition of the derivative** to find the derivative of \( f(x) = 5x^2 - 2.4x + 7 \).

For full credit, continue from the general limit definition (provided below), clearly showing all necessary algebraic steps (cancellations, expansions, etc.) and including proper use of notation and equal signs.

\[
f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h}
\]

\[
= \lim_{h \to 0} \frac{[(5(x+h)^2 - 2.4(x+h) + 7) - (5x^2 - 2.4x + 7)]}{h}
\]

\[
= \lim_{h \to 0} \frac{[5(x^2 + 2xh + h^2) - 2.4(x+h) + 7] - [5x^2 - 2.4x + 7]}{h}
\]

\[
= \lim_{h \to 0} \frac{5x^2 + 10xh + 5h^2 - 2.4x - 2.4h + 7 - 5x^2 + 2.4x - 7}{h}
\]

\[
= \lim_{h \to 0} \frac{10xh + 5h^2 - 2.4h}{h}
\]

\[
= \lim_{h \to 0} \frac{h(10x + 5h - 2.4)}{h}
\]

\[
= \lim_{h \to 0} (10x + 5h - 2.4)
\]

\[
= 10x - 2.4
\]

**Thus,** \( f'(x) = 10x - 2.4 \)

---

**Scoring Guide:**

**3 pts:** Find slope of secant using given function: \( \frac{f(x+h) - f(x)}{h} \)

**1 pt:** Square \((x+h)\) correctly

**2 pts:** Distribute 5, -2.4, and the -1 (minus sign) correctly

**1 pt:** Combine like terms and show the result.

**1 pt:** Show the limit of a completely simplified expression

**1 pt:** Evaluate limit of simplified expression to find derivative.

**-½ pt** if equal signs not in correct places and used throughout proof

**-1 pt** if limit notation is missing

---

1 point for correctly filling out and bubbling the scantron with a #2 pencil, a correct XID, a correct test version AND the front of the test is completed with your signature on the academic integrity statement.

**END OF TEST**
General Directions:

- Show work where possible. Answers without supporting work (where work is appropriate) may receive little credit.

- **Do not round intermediate calculations.**

- Answers in context ALWAYS require units.

- Assume end of the year data unless stated otherwise.

- Round your answers to **3 decimal places** UNLESS the answer needs to be rounded differently to make sense in the context of the problem OR the directions specify another type rounding OR the complete answer has fewer than 3 decimal places.

- When asked to write a model, include all components of a model: an equation, a description of the input including units, a description of the output including units, and the input interval when known.

- When asked to write a sentence of practical interpretation, answer the questions: **when?, what?, and how much?** using ordinary, conversational language. DO NOT use math words, terms, or unnecessary phrases.

- Always use a ruler when estimating values off of a graph.

---

**HINTS FOR TROUBLESHOOTING YOUR CALCULATOR:**

- If you lose your L1, L2, etc., you may reinsert them using STAT 5 (set-up editor) enter.

- The SCATTER PLOT will not show unless Plot 1 has been turned on and there is data in L1 and L2.

- ZOOM 0 _may_ not work for graphing if Plot 1 is turned on.

- DIM MISMATCH error usually means that the lists in L1 and L2 are not of equal length.

- DATA TYPE error usually means that you already have something in Y1 and you need to clear it before you can paste a new equation.

- INVALID DIM error usually means that your plot(s) are on, but that you have no data in the lists. Refer to the second hint above.

- If your batteries die, raise your hand and hold up your calculator. If your instructor has an extra calculator available, he/she will loan it to you for a few minutes.

- SYNTAX ERROR: Try GO TO. This will happen if you use a subtraction minus sign when you should use a negative sign.

- If you need to CLEAR MEMORY, use 2nd +, 7:Reset, 1:All Ram, 2:Reset
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   d. Bank D

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   - b. \( 2\ln(1.3)(1.3^x) \)
   - c. \( \ln(2.6)(2.6^x) \)
   - d. \( 2x(1.3^{x-1}) \)

   b. \( 2\ln(1.3)(1.3^x) \)

5. The slope of the tangent line to a point \( x \) on the graph of function \( C(x) = 3\ln(x) \) is \( \) .
   - a. \( \frac{3}{x} \)
   - b. \( 3e^x \)
   - c. \( \frac{1}{3x} \)
   - d. \( \frac{x}{3} \)

   a. \( \frac{3}{x} \)
6. Find $f'(x) = \underline{\hspace{2cm}}$ for $f(x) = 2e^x + 3e^x$.
   a. $2e^x + 3e^x$  
   b. $10e^x + 3\ln(x)$
   c. $10e^4 + 3xe^{x-1}$  
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   a. $2x^{-\frac{3}{4}}$  
   b. $32x^{-\frac{1}{2}}$
   c. $2x^{-\frac{3}{4}}$  
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   b. continuous and its derivative does not exist  
   c. not continuous and its derivative exists  
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10. [2 pts] Identify ALL values of \( x \) for which the derivative \( f'(x) = 0 \).
    a. \( x = -1.5, x = 1 \)  
    b. \( x = -3, x = 0, x = 2 \)  
    c. \( x = -4.1, x = 0, x = 3.1, x = 5.1 \)  
    d. \( x = -3, x = 0, x = 2, x = 4 \)

11. [2 pts] Find the intervals on which the slope graph of \( f(x) \) lies below the \( x \)-axis.
    a. \((-4.4, -4.1), (3.1, 5.1)\)  
    b. \((-4.4, -1.5), (1, 4)\)  
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   a.    
   b.    
   c.    
   d.
16. Which one of the following is a slope graph of the function graph shown below?

![Function Graph]

a.  

b.  

c.  

d.  

17. Given \( f(x) = \frac{x^2 - 3x + 9}{3x} \), find \( f'(x) = \) __________.

a.  \( \frac{2x - 3}{3} \)  

b.  \( 3 - 3\ln(x) \)

c.  \( \frac{1}{3} - 3x^{-2} \)  

d.  \( \frac{x}{3} - 1 + \frac{3}{x} \)
Use the following information to answer the next two questions.

\( C(x) \) billion subscribers gives total number of mobile phone subscribers in the developing world, \( x \) years since 2000, \( 0 \leq x \leq 10 \).

18. Draw a line tangent to the graph at the given point \((6.5, 1.75)\) and estimate its slope. (Insert the answer into the next question.)

\[ \begin{align*}
&\text{a. } 0.65 \\
&\text{b. } 2.5 \\
&\text{c. } 0.4 \\
&\text{d. } 0.18
\end{align*} \]

19. Write a sentence of interpretation for the slope of the tangent line.

\( a. \) In mid-2007, the number of mobile phone subscribers in the developing world was increasing by (answer to previous question) billion subscribers per year.

\( b. \) In mid-2007, the number of mobile phone subscribers in the developing world was increasing by (answer to previous question) billion subscribers.

\( c. \) Between 2000 and 2010, the number of mobile phone subscribers in the developing world increased by (answer to previous question) billion subscribers per year.

\( d. \) In mid-2007, the number of mobile phone subscribers in the developing world was increasing by (answer to previous question) % per year.
Use the following graph to answer the next three questions.

20. [2 pts] Consider the point C on the above graph. The tangent line to the graph at point C is drawn __________ the function curve.
   a. below    b. above    c. neither, it coincides    d. both, it cuts through

21. Consider the three points A, B, and C on the graph above. Order the three points from least steepness to greatest steepness.

22. Which one of the following shows a correct tangent line drawn at the inflection point B?
   a.    b.    c.    d.
FREE RESPONSE: 39 points

Show work where possible. Read the directions at the back of the test on rounding, inclusion of units, and writing sentences and models.

1. The population of Boston, Massachusetts, can be represented by

\[ P(x) = 0.001x^3 - 0.216x^2 + 9.558x + 622.170 \] thousand people, \( x \) years since 1900, \(-20 \leq x \leq 115\).

Checkpoint: \( P(2) = 640.43 \)

Give a completely defined rate-of-change model for \( P(x) \) by filling in the blanks:

\[ P'(x) = 0.003x^2 - 0.432x + 9.558 \] thousand people per year

(equation)

(1 pt units)

Part a) 5 pts:
2 pts derivative
1 pt units
1 pt “rate of change”
1 pt output
1 pt description

Part B) 5 pts
1 pt “when”,
1 pt “what”,
1 pt “was decreasing by”,
1 pt “how much”,
1 pt units

where \( x \) is the number of years since 1900, \(-20 \leq x \leq 115\).

a. How quickly is population changing in 1930?
Round to three decimal places and interpret in a complete sentence.

In 1930, Boston’s population was decreasing by 0.702 thousand people per year.

(\( \square \) /10 pts)

2. The number of Bald Eagle breeding pairs in the lower 48 states was 2680 in 1989 and was 4015 in 1993. Find the average rate of change in the number of Bald Eagle breeding pairs from 1989 to 1993 and write the answer in a sentence of interpretation.

\[ \frac{4015 - 2680}{1993 - 1989} = 333.75 \]

Between 1989 and 1993, the number of Bald Eagle breeding pairs increased on average by 333.75 pairs per year.

(\( \square \) /6 pts)

3. \( R(x) \) billion dollars gives the advertising revenue for a newspaper, \( x \) years since 1980, \( 5 \leq x \leq 19\).

In 1990, advertising revenue was 3,870.07 billion dollars and was increasing by 767.11 billion dollars per year.

Find percentage rate of change in the advertising revenue in 1990. Show work, round the answer to three decimal places, and include units.

\[ \frac{R'(10)}{R(10)} \cdot 100 = \frac{767.11}{3870.07} \cdot 100 = 19.822 \% \text{ per year} \]

(\( \square \) /2 pts)
4. In the early stages of the deadly SARS (Severe Acute Respiratory Syndrome) epidemic of 2003, the number of reported cases was approximately \( S(t) = 167(1.18^t) \) cases \( t \) days after March 17, 2003 (the first day in which statistics were reported by the World Health Organization), \( 0 \leq t \leq 20 \).

Checkpoint: \( S(3) = 274.386344 \)

a. Use the limit of the slopes of secant lines to numerically estimate \( S'(7) \).

Round entries to exactly 2 decimal places for full credit.

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<td>7.00001</td>
<td>88.05</td>
</tr>
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b. \( \lim_{t \rightarrow 7^-} \frac{S(t) - S(7)}{t - 7} = \underline{88.05} \) \( \lim_{t \rightarrow 7^+} \frac{S(t) - S(7)}{t - 7} = \underline{88.05} \)

c. \( S'(7) = \underline{88.05} \) cases per day

( include units)

Part a) 4 pts entries in table, correct to two decimal places

Part b) 1 pt for the limits, correct to two decimal places.

Part c) 0.5 pt for derivative, correct to two decimal places. 1 pt for units

d. Circle the correct use of differential notation for \( S'(7) \).

\[ \frac{dt}{dS} \bigg|_{t=7} \quad \frac{dS}{dt} \bigg|_{t=7} \quad \frac{dt}{dS} \bigg|_{t=7} \quad \frac{dS}{dt} \bigg|_{t=7} \]

Part d) 0.5 pts

Part e) 1.5 pts

e. The number 87.32 in the above table represents the slope of a secant line on the graph of \( S(t) \) between points \( t = \underline{6.9} \) and \( t = \underline{7} \), whereas the answer to part c) represents the slope of a tangent line at \( t = \underline{7} \).

(_______ / 8.5 pts)

5. Find the derivative of the function \( f(x) = 6\sqrt{x} - 3x^{-3} \). For full credit, clearly show work and use proper mathematical notation.

\[ f(x) = 6\sqrt{x} - 3x^{-3} = 6x^{\frac{1}{2}} - 3x^{-3} \]

\[ f'(x) = 3x^{-\frac{1}{2}} + 9x^{-4} \]

(_______ / 2.5 pts)
6. **Use the limit definition of the derivative** to find the derivative of \( f(x) = 5x^2 - 2.4x + 7 \).

For full credit, continue from the general limit definition (provided below), clearly showing all necessary algebraic steps (cancellations, expansions, etc.) and including proper use of notation and equal signs.

\[
f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h}
\]

\[
= \lim_{h \to 0} \frac{[5(x+h)^2 - 2.4(x+h) + 7] - [5x^2 - 2.4x + 7]}{h}
\]

\[
= \lim_{h \to 0} \frac{[5(x^2 + 2xh + h^2) - 2.4(x + h) + 7] - [5x^2 - 2.4x + 7]}{h}
\]

\[
= \lim_{h \to 0} \frac{5x^2 + 10xh + 5h^2 - 2.4x - 2.4h + 7 - 5x^2 + 2.4x - 7}{h}
\]

\[
= \lim_{h \to 0} \frac{10xh + 5h^2 - 2.4h}{h}
\]

\[
= \lim_{h \to 0} \frac{h(10x + 5h - 2.4)}{h}
\]

\[
= \lim_{h \to 0} (10x + 5h - 2.4)
\]

\[
= 10x - 2.4
\]

*Thus, \( f'(x) = 10x - 2.4 \)*

**3 pts:** Find slope of secant using given function: \( [f(x+h) - f(x)]/h \)

**1 pt:** Square \((x+h)\) correctly

**2 pts:** Distribute 5, -2.4, and the -1 (minus sign) correctly

**1 pt:** Combine like terms and show the result.

**1 pt:** Show the limit of a completely simplified expression

**1 pt:** Evaluate limit of simplified expression to find derivative.

- \( \frac{1}{2} \) pt if equal signs not in correct places and used throughout proof
- 1 pt if limit notation is missing

(_______/9 pts)

**1 point** for correctly filling out and bubbling the scantron with a #2 pencil, a correct XID, a correct test version AND the front of the test is completed with your signature on the academic integrity statement.

*END OF TEST*
General Directions:

- Show work where possible. Answers without supporting work (where work is appropriate) may receive little credit.

- **Do not round intermediate calculations.**

- Answers in context ALWAYS require units.

- Assume end of the year data unless stated otherwise.

- Round your answers to **3 decimal places** UNLESS the answer needs to be rounded differently to make sense in the context of the problem OR the directions specify another type rounding OR the complete answer has fewer than 3 decimal places.

- When asked to write a model, include all components of a model: an equation, a description of the input including units, a description of the output including units, and the input interval when known.

- When asked to write a sentence of practical interpretation, answer the questions: **when?, what?, and how much?** using ordinary, conversational language. DO NOT use math words, terms, or unnecessary phrases.

- Always use a ruler when estimating values off of a graph.

---

**HINTS FOR TROUBLESHOOTING YOUR CALCULATOR:**

- If you lose your L1, L2, etc., you may reinsert them using STAT 5 (set-up editor) enter.

- The SCATTER PLOT will not show unless Plot 1 has been turned on and there is data in L1 and L2.

- ZOOM 0 **may not work** for graphing if Plot 1 is turned on.

- DIM MISMATCH error usually means that the lists in L1 and L2 are not of equal length.

- DATA TYPE error usually means that you already have something in Y1 and you need to clear it before you can paste a new equation.

- INVALID DIM error usually means that your plot(s) are on, but that you have no data in the lists. Refer to the second hint above.

- If your batteries die, raise your hand and hold up your calculator. If your instructor has an extra calculator available, he/she will loan it to you for a few minutes.

- **SYNTAX ERROR:** Try GO TO. This will happen if you use a subtraction minus sign when you should use a negative sign.

- If you need to CLEAR MEMORY, use 2nd +, 7:Reset, 1:All Ram, 2:Reset
Printed Name: ______________________________  Section #: _______ Instructor:_____________________

Please do not ask questions during this exam. If you consider a question to be ambiguous, state your assumptions in the margin and do the best you can to provide the correct answer. Refer to this page and the last page of the test for formulas, general directions, and calculator troubleshooting tips.

- Any communication with any person (other than the instructor or the designated proctor) during this exam in any form, including written, signed, verbal or digital, is understood to be a violation of academic integrity.
- All devices, such as computers, cell phones, cameras, watches and PDAs must be turned off and stowed away while the student is in the testing room.
- The only calculators to be used are TI-83, TI-83+, TI-84 or TI-84+. You may NOT borrow or share a calculator with another person taking this test.
- Statement of Academic Integrity: I have not and will not give or receive improper aid on this test.

In signing below, I acknowledge that I have read, understand, and agree to these testing conditions.

Student’s Signature: _________________________________________________________________

(This test will not be accepted for grading unless it bears the signature of the student.)

<table>
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<tr>
<th></th>
<th>FR#1</th>
<th>FR #2</th>
<th>FR #3</th>
<th>FR #4</th>
<th>FR #5</th>
<th>FR #6</th>
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Useful Formulas:  
\[
f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h}; \quad f'(a) = \lim_{x \to a} \frac{f(x) - f(a)}{x - a}
\]

\[
F(t) = P(1+rt) \quad F(t) = Pe^{rt} \quad F(t) = P \left(1 + \frac{r}{n}\right)^{nt}
\]

\[
APY = (e^r - 1)100\% \quad \text{or} \quad APY = \left(1 + \frac{r}{n}\right)^n - 1 \times 100\%
\]
MULTIPLE CHOICE: 61 points (3 points each, unless otherwise noted)

Use a #2 pencil and completely fill each bubble on your scantron to answer each multiple choice question. (For future reference, circle your answers on this test paper.) There is no penalty for guessing on multiple choice. If you indicate more than one answer, or you leave a blank, the question will be marked as incorrect.

1. Suppose $1000 is deposited in a bank, earning interest at an annual percentage rate (APR) of 2.5% compounded quarterly. If there are no other deposits or withdrawals, find the future value of this deposit after 22 months.

   a. $1044.58  
   b. $1046.75  
   c. $1051.11  
   d. $1730.29

2. A bank offers an investment of $1000 an annual percentage rate (APR) of 1.8% compounded quarterly. If there are no other deposits or withdrawals, how long will it take the investment to double?

   a. 38 years 5 months  
   b. 38 years 6 months  
   c. 38 years 9 months  
   d. 38.595 years

3. Which bank rate offers the highest annual percentage yield for a deposit in an account?

   • Bank A account, with an annual percentage yield (APY) of 4.444% after compounding semi-annually.
   • Bank B account, offering an annual percentage rate (APR) of 4.36% compounded quarterly.
   • Bank C account, with an annual percentage yield (APY) of 4.438% after compounding monthly.
   • Bank D account, offering an annual percentage rate (APR) of 4.35% compounded continuously.

   a. Bank A  
   b. Bank B  
   c. Bank C  
   d. Bank D

4. Find the derivative $s'(x) = \text{______________}$ for $s(x) = 2(1.3^x)$.

   a. $2\ln(1.3)(1.3^x)$  
   b. $2\ln(1.3)(1.3^x)$  
   c. $\ln(2.6)(2.6^x)$  
   d. $2x(1.3^{x-1})$

5. The slope of the tangent line to a point $x$ on the graph of function $C(x) = 3\ln(x)$ is ________________.

   a. $\frac{3}{x}$  
   b. $3e^x$  
   c. $\frac{1}{3x}$  
   d. $\frac{x}{3}$
6. Find $f'(x) = \underline{\hspace{2cm}}$ for $f(x) = 2e^x + 3e^x$.
   a. $2e^x + 3e^x$  
   b. $10e^x + 3\ln(x)$  
   c. $10e^x + 3xe^{-x}$  
   d. $3e^x$  

7. If $r(x) = 8 \cdot \sqrt[3]{x}$, then $\frac{dr}{dx} = \underline{\hspace{2cm}}$.
   a. $2x^{-\frac{1}{4}}$  
   b. $32x^{-\frac{1}{2}}$  
   c. $2x^{-\frac{3}{4}}$  
   d. $-2x^{-\frac{5}{4}}$  

8. Which one of the following could be the graph of $f$, if $f$ is a function with the following characteristics?

   $f'(2) > 0$, and $f'(5)$ does not exist, and $f'(6) < 0$  

   a.  
   b.  
   c.  
   d.  


Use the graph of \( f(x) \) given below to answer the next four questions.

9. [2 pts] The function \( f(x) \) is \underline{__________________________} at \( x = 4 \).
   a. continuous and its derivative exists  \hspace{1cm} b. continuous and its derivative does not exist
   c. not continuous and its derivative exists  \hspace{1cm} d. not continuous and its derivative does not exist

10. [2 pts] Identify ALL values of \( x \) for which the derivative \( f'(x) = 0 \).
   a. \( x = -1.5, \ x = 1 \)  \hspace{1cm} b. \( x = -3, \ x = 0, \ x = 2 \)
   c. \( x = -4.1, \ x = 0, \ x = 3.1, \ x = 5.1 \)  \hspace{1cm} d. \( x = -3, \ x = 0, \ x = 2, \ x = 4 \)

11. [2 pts] Find the intervals on which the slope graph of \( f(x) \) lies below the \( x \)-axis.
   a. \(( -4.4, -4.1), (3.1, 5.1) \)  \hspace{1cm} b. \(( -4.4, -1.5), (1, 4) \)
   c. \(( -3, -1.5), (2, 3.1) \) only  \hspace{1cm} d. \(( -3, 0), (2, 4) \)

12. [2 pts] Consider the above graph restricted to the interval \((-4, 4)\). Find the combined number of relative maxima and relative minima that will occur on the slope graph of \( f(x) \).
   a. zero  \hspace{1cm} b. one  \hspace{1cm} c. two  \hspace{1cm} d. three
Use the following table to answer the next two questions.

The table below shows the price of beef in the United States in January of various years.

|------|------|------|------|------|------|------|------|------|

13. Between January of 2008 and January of 2015, the price of beef increased on average by _______________ dollars/pound per year.
   a. 0.137  b. 1.907  c. 3.671  d. 0.272

14. Between January of 2008 and January of 2015, the price of beef increased by __________ %.
   a. 81.916  b. 45.030  c. 0.095  d. 27.200

15. Which one of the following is a slope graph of the function graph shown below?

   a.  
   b.  
   c.  
   d.  
16. Which one of the following is a slope graph of the function graph shown below?

![Function Graph](image)

a.  

b.  

c.  

d.  

17. Given \( f(x) = \frac{x^2 - 3x + 9}{3x} \), find \( f'(x) = \) ________.

a.  \( \frac{2x - 3}{3} \)  

b.  \( 3 - 3\ln(x) \)  

c.  \( \frac{1}{3} - 3x^{-2} \)  

d.  \( \frac{x}{3} - 1 + \frac{3}{x} \)
Use the following information to answer the next two questions.

\( C(x) \) billion subscribers gives total number of mobile phone subscribers in the developing world, \( x \) years since 2000, \( 0 \leq x \leq 10 \).

![Graph of C(x) billion subscribers vs x years since 2000]

18. Draw a line tangent to the graph at the given point \((6.5, 1.75)\) and estimate its slope. (Insert the answer into the next question.)

a. 0.65  
   
   b. 2.5  
   
   c. 0.4  
   
   d. 0.18

19. Write a sentence of interpretation for the slope of the tangent line.

a. In mid-2007, the number of mobile phone subscribers in the developing world was increasing by (answer to previous question) billion subscribers per year.

b. In mid-2007, the number of mobile phone subscribers in the developing world was increasing by (answer to previous question) billion subscribers.

c. Between 2000 and 2010, the number of mobile phone subscribers in the developing world increased by (answer to previous question) billion subscribers per year.

d. In mid-2007, the number of mobile phone subscribers in the developing world was increasing by (answer to previous question) % per year.
Use the following graph to answer the next three questions.

20. [2 pts] Consider the point C on the above graph. The tangent line to the graph at point C is drawn _________ the function curve.
   a. below  b. above  c. neither, it coincides  d. both, it cuts through

21. Consider the three points A, B, and C on the graph above. Order the three points from least steepness to greatest steepness.

22. Which one of the following shows a correct tangent line drawn at the inflection point B?

   a.  
   b.  
   c.  
   d.  

FREE RESPONSE: 39 points

Show work where possible. Read the directions at the back of the test on rounding, inclusion of units, and writing sentences and models.

1. The population of Boston, Massachusetts, can be represented by
\[ P(x) = 0.001x^3 - 0.216x^2 + 9.558x + 622.170 \] thousand people, \( x \) years since 1900, \( -20 \leq x \leq 115 \).

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Give a completely defined rate-of-change model for \( P(x) \) by filling in the blanks:

\[ P'(x) = 0.003x^2 - 0.432x + 9.558 \text{ thousand people per year} \]

(equation) gives the ___ rate of change in the population of Boston, Massachusetts _______, where \( x \) is the number of years since 1900, \( -20 \leq x \leq 115 \).

Part a) 5 pts:
- 2 pts derivative
- 1 pt units
- 1 pt “rate of change”
- 1 pt output description

Part B) 5 pts
- 1 pt “when”
- 1 pt “what”
- 1 pt “was decreasing by”
- 1 pt “how much”
- 1 pt units

a. How quickly is population changing in 1930?
Round to three decimal places and interpret in a complete sentence.

In 1930, Boston’s population was decreasing by 0.702 thousand people per year.

(_______ /10 pts)

2. The number of Bald Eagle breeding pairs in the lower 48 states was 2680 in 1989 and was 4015 in 1993. Find the average rate of change in the number of Bald Eagle breeding pairs from 1989 to 1993 and write the answer in a sentence of interpretation.

\[ \frac{4015 - 2680}{1993 - 1989} = 333.75 \]

Between 1989 and 1993, the number of Bald Eagle breeding pairs increased on average by 333.75 pairs per year.

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In 1990, advertising revenue was 3,870.07 billion dollars and was increasing by 767.11 billion dollars per year. Find percentage rate of change in the advertising revenue in 1990. Show work, round the answer to three decimal places, and include units.

\[ \frac{R'(10)}{R(10)} \cdot 100 = \frac{767.11}{3870.07} \cdot 100 = 19.822 \% \text{ per year} \]

(_______ / 2 pts)
4. In the early stages of the deadly SARS (Severe Acute Respiratory Syndrome) epidemic of 2003, the number of reported cases was approximately \( S(t) = 167(1.18^t) \) cases \( t \) days after March 17, 2003 (the first day in which statistics were reported by the World Health Organization), \( 0 \leq t \leq 20 \).

Checkpoint: \( S(3) = 274.386344 \)

a. Use the limit of the slopes of secant lines to numerically estimate \( S'(7) \).

Round entries to exactly 2 decimal places for full credit.

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Part a) 4 pts entries in table, correct to two decimal places

b. \( \lim_{t \to 7^-} \frac{S(t) - S(7)}{t - 7} = 88.05 \) \( \lim_{t \to 7^+} \frac{S(t) - S(7)}{t - 7} = 88.05 \)

c. \( S'(7) = 88.05 \) cases per day (include units)

Part b) 1 pt for the limits, correct to two decimal places.
Part c) 0.5 pt for derivative, correct to two decimal places. 1 pt for units

d. **Circle** the correct use of differential notation for \( S'(7) \).

\[
\frac{dt}{dS} \bigg|_{t=7} \quad \frac{dS}{dt} \bigg|_{t=7} \quad \frac{dt}{dS} \bigg|_{t=7} \quad \frac{dS}{dt} \bigg|_{t=7}
\]

Part d) 0.5 pts
Part e) 1.5 pts

e. The number 87.32 in the above table represents the slope of a secant line on the graph of \( S(t) \) between points \( t = \_6.9\_ \) and \( t = \_7\_ \); whereas the answer to part c) represents the slope of a tangent line at \( t = \_7\_ \).

(_______ / 8.5 pts)

5. Find the derivative of the function \( f(x) = 6\sqrt{x} - 3x^{-3} \). For full credit, clearly show work and use proper mathematical notation.

\[
f(x) = 6\sqrt{x} - 3x^{-3} = 6x^{\frac{1}{2}} - 3x^{-3}
\]

\[
f'(x) = 3x^{-\frac{1}{2}} + 9x^{-4}
\]

(_______ / 2.5 pts)
6. **Use the limit definition of the derivative** to find the derivative of \( f(x) = 5x^2 - 2.4x + 7 \).

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\[
f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h}
\]

\[
= \lim_{h \to 0} \frac{[5(x+h)^2 - 2.4(x+h) + 7] - [5x^2 - 2.4x + 7]}{h}
\]

\[
= \lim_{h \to 0} \frac{[5(x^2 + 2xh + h^2) - 2.4(x+h) + 7] - [5x^2 - 2.4x + 7]}{h}
\]

\[
= \lim_{h \to 0} \frac{5x^2 + 10xh + 5h^2 - 2.4x - 2.4h + 7 - 5x^2 + 2.4x - 7}{h}
\]

\[
= \lim_{h \to 0} \frac{10xh + 5h^2 - 2.4h}{h}
\]

\[
= \lim_{h \to 0} \frac{h(10x + 5h - 2.4)}{h}
\]

\[
= \lim_{h \to 0} (10x + 5h - 2.4)
\]

\[
= 10x - 2.4
\]

Thus, \( f'(x) = 10x - 2.4 \)

3 pts: Find slope of secant using given function: \([f(x+h) - f(x)]/h\)
1 pt: Square \((x+h)\) correctly
2 pts: Distribute 5, -2.4, and the -1 (minus sign) correctly
1 pt: Combine like terms and show the result.
1 pt: Show the limit of a completely simplified expression
1 pt: Evaluate limit of simplified expression to find derivative.

-\(\frac{1}{2}\) pt if equal signs not in correct places and used throughout proof
-1 pt if limit notation is missing

(_________ / 9 pts)

1 point for correctly filling out and bubbling the scantron with a #2 pencil, a correct XID, a correct test version AND the front of the test is completed with your signature on the academic integrity statement.

**END OF TEST**
General Directions:

- Show work where possible. Answers without supporting work (where work is appropriate) may receive little credit.

- **Do not round intermediate calculations.**

- Answers in context ALWAYS require **units.**

- Assume end of the year data unless stated otherwise.

- Round your answers to **3 decimal places** UNLESS the answer needs to be rounded differently to make sense in the context of the problem OR the directions specify another type rounding OR the complete answer has fewer than 3 decimal places.

- When asked to write a model, include all components of a model: an equation, a description of the input including units, a description of the output including units, and the input interval when known.

- When asked to write a sentence of practical interpretation, answer the questions: **when?, what?, and how much?** using ordinary, conversational language. **DO NOT** use math words, terms, or unnecessary phrases.

- Always use a ruler when estimating values off of a graph.

**HINTS FOR TROUBLESHOOTING YOUR CALCULATOR:**

- If you lose your L1, L2, etc., you may reinsert them using STAT 5 (set-up editor) enter.

- The SCATTER PLOT will not show unless Plot 1 has been turned on and there is data in L1 and L2.

- ZOOM 0 **may** not work for graphing if Plot 1 is turned on.

- DIM MISMATCH error usually means that the lists in L1 and L2 are not of equal length.

- DATA TYPE error usually means that you already have something in Y1 and you need to clear it before you can paste a new equation.

- INVALID DIM error usually means that your plot(s) are on, but that you have no data in the lists. Refer to the second hint above.

- If your batteries die, raise your hand and hold up your calculator. If your instructor has an extra calculator available, he/she will loan it to you for a few minutes.

- SYNTAX ERROR: Try GO TO. This will happen if you use a subtraction minus sign when you should use a negative sign.

- If you need to CLEAR MEMORY, use 2nd +, 7:Reset, 1:All Ram, 2:Reset