

Math 116 — Final Exam — December 12, 2025

This material is ©2025, University of Michigan Department of Mathematics, and released under a Creative Commons BY-NC-SA 4.0 International License. It is explicitly not for distribution on websites that share course materials.

Your Initials Only: _____ Your 8-digit UMID number (not unique): _____

Instructor Name: _____ Section #: _____

1. Please neatly write your 8-digit UMID number, your initials, your instructor's first and/or last name, and your section number in the spaces provided.
2. This exam has 12 pages including this cover.
3. There are 10 problems. Note that the problems are not of equal difficulty, so you may want to skip over and return to a problem on which you are stuck.
4. Please read the instructions for each individual problem carefully. One of the skills being tested on this exam is your ability to interpret mathematical questions, so instructors will not answer questions about exam problems during the exam.
5. Show an appropriate amount of work (including appropriate explanation) for each problem, so that graders can see not only your answer but how you obtained it.
6. If you need more space to answer a question, please use the back of an exam page. Clearly indicate on your exam if you are using the back of a page, and also clearly label the problem number and part you are doing on the back of the page.
7. You are allowed notes written on two sides of a 3" × 5" note card. You are NOT allowed other resources, including, but not limited to, notes, calculators or other electronic devices.
8. For any graph or table that you use to find an answer, be sure to sketch the graph or write out the entries of the table. In either case, include an explanation of how you used the graph or table to find the answer.
9. Include units in your answer where that is appropriate.
10. Problems may ask for answers in *exact form*. Recall that $x = \sqrt{2}$ is a solution in exact form to the equation $x^2 = 2$, but $x = 1.41421356237$ is not.
11. You must use the methods learned in this course to solve all problems.

Problem	Points	Score
1	9	
2	14	
3	5	
4	13	
5	10	

Problem	Points	Score
6	6	
7	10	
8	9	
9	11	
10	13	
Total	100	

1. [9 points] Some values of the function $g(x)$ and its derivative are given in the table below. Suppose that both $g(x)$ and $g'(x)$ are continuous.

x	1	3	5	7	9
$g(x)$	3	1	4	2	5
$g'(x)$	-2	0	3	-1	4

Using the information given above, find the following. Be sure to **show all of your work**. Your answers should not involve the letter g , but you **do not need to simplify them**.

- a. [3 points] Suppose $F(x) = \int_1^{x^2} g(t) dt$. Find $F'(3)$.

Answer: _____

- b. [3 points] Find $\lim_{x \rightarrow 1} \frac{3 \ln(x) + g(x) - 3}{x - 1}$.

Answer: _____

- c. [3 points] Use MID(2) to find the approximate value of $\int_1^9 \frac{g(x)}{1+x^3} dx$. Write out all the terms in your sum and do not attempt to simplify.

Answer: _____

2. [14 points] A function $f(x)$ is defined on the interval $(0, 2)$ by its Taylor series around $x = 1$,

$$f(x) = \sum_{n=0}^{\infty} \frac{1}{2n+1} (x-1)^{2n+1}.$$

- a. [3 points] Find $f^{(2025)}(1)$ and $f^{(2026)}(1)$.

Answer: $f^{(2025)}(1) =$ _____ and $f^{(2026)}(1) =$ _____

- b. [5 points] Find the degree 7 Taylor polynomial around $x = 1$ for $f(x)$.

Answer: _____

- c. [3 points] Find the degree 6 Taylor polynomial around $x = 1$ for $f'(x)$, the **derivative** of $f(x)$.

Answer: _____

- d. [3 points] Find a closed-form expression of the derivative $f'(x)$ which applies on the interval $(0, 2)$. Closed form means your answer should not include ellipses or sigma notation.

Answer: $f'(x) =$ _____

3. [5 points] Throughout this problem, suppose that:

- a_n is a sequence with $a_1 = 60$, and with $a_{n+1} = \frac{1}{3}a_n$ for all $n \geq 1$.
- b_n is a sequence with $b_1 = \frac{1}{2}$, and with $b_{n+1} = 2b_n$ for all $n \geq 1$.
- $S_n = \sum_{j=1}^n a_j$.
- $R_n = \sum_{k=1}^n S_k$.

For each of the following sequences, determine whether the sequence converges or diverges, and if it converges, determine the value that it converges to. Justification is not required.

a. [1 point] a_n

Circle one: **Diverges** **Converges to** _____

b. [1 point] b_n

Circle one: **Diverges** **Converges to** _____

c. [1 point] $c_n = a_n \cdot b_n$

Circle one: **Diverges** **Converges to** _____

d. [1 point] S_n

Circle one: **Diverges** **Converges to** _____

e. [1 point] R_n

Circle one: **Diverges** **Converges to** _____

4. [13 points] A vertical climbing wall is described in coordinates, where (x, y) is the position x meters to the right of a central podium and y meters above the floor. Suppose two climbers, Sara and Tina, begin climbing the wall at the same time. Their positions t minutes after they start climbing are given by:

$$\text{Sara: } \begin{cases} x(t) = -(t-1)^2 \\ y(t) = 3t, \end{cases} \quad \text{Tina: } \begin{cases} x(t) = 1 + \cos(\pi t) \\ y(t) = t^2 + 2. \end{cases}$$

- a. [4 points] Tina and Sara bumped into each other one time during the process of climbing. At what time did this happen? Justify your answer.

Answer: $t =$ _____

- b. [2 points] After Sara and Tina bumped into each other, they climbed for some further distance and eventually crossed the finish line, which is a horizontal line, at the same time. When did they cross the finish line, and what is the equation of the finish line?

Answer: They crossed the finish line at $t =$ _____

Answer: The equation of the finish line is $y =$ _____

- c. [4 points] Write an expression involving one or more integrals that gives the total distance traveled by Tina from the time she starting climbing until she crossed the finish line. Do not evaluate your integral(s). Show your work.

Answer: _____

- d. [3 points] What is Tina's speed at $t = \frac{1}{2}$? **Include units.** You do not need to simplify your answer but you should show your work.

Answer: _____ **Units:** _____

5. [10 points] Consider the Taylor series:

$$\sum_{n=1}^{\infty} \frac{9n^2 + 8}{2^n \cdot (n^3 + 1)} (x + 3)^n,$$

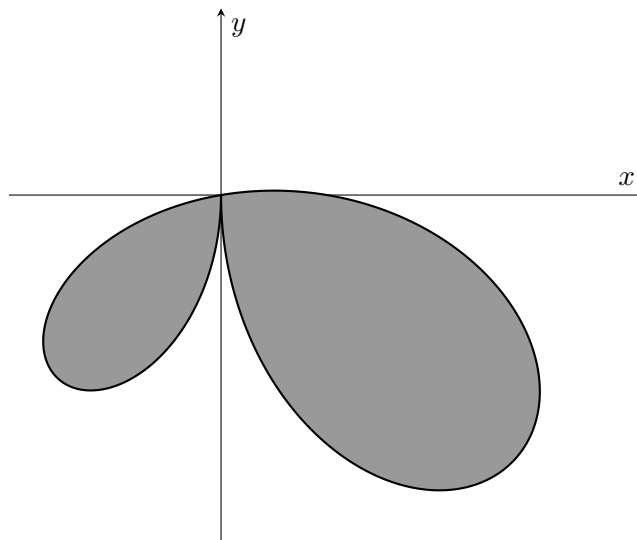
- a. [1 point] Determine the center, a , of the Taylor series.

Answer: $a =$ _____

- b. [9 points] The radius of convergence of the Taylor series is 2 (you do **not** need to show this). Determine the interval of convergence of the Taylor series. Show all your work, including full justification for series behavior.

Answer: The interval of convergence is _____

6. [6 points] A graphic designer makes posters for David, a singer who famously used to have a unique haircut. In a poster for an old album, the boundary of David's haircut is given by the polar curve $r(\theta) = \cos(\theta) + 3\sin(2\theta)$, where $\frac{\pi}{2} \leq \theta \leq \frac{3\pi}{2}$. A graph of the curve is shown below, and David's hair is represented by the shaded region.



- a. [2 points] What are the x - and y -coordinates of the curve in terms of θ ?

Answer: $x(\theta) =$ _____

Answer: $y(\theta) =$ _____

- b. [2 points] Find $\frac{dx}{d\theta}$ in terms of θ .

Answer: $\frac{dx}{d\theta} =$ _____

- c. [2 points] At which of the following values of θ could the above curve have a vertical tangent line? Circle all options that apply.

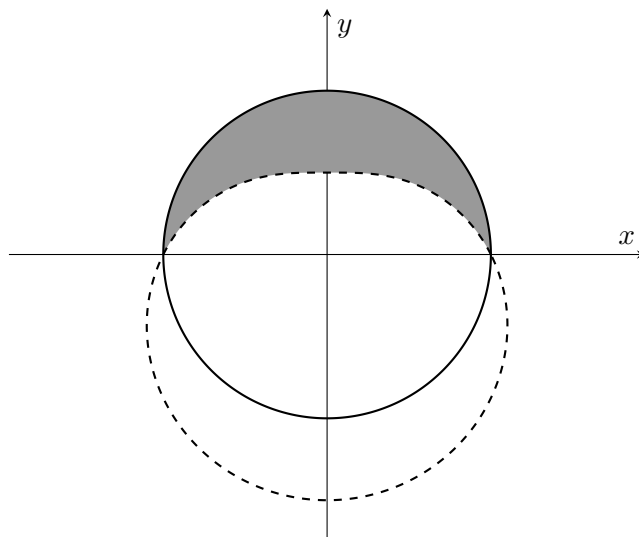
i. $\theta = \pi/2$

iii. $\theta = 3\pi/2$

ii. $\theta = \pi$

iv. None of the above

7. [10 points] Nowadays, David's haircut is more simplistic. In a poster for a more recent album, David's haircut is given by the shaded region below. The solid curve is a circle centered at the origin with radius 2, while the dashed curve is given by the equation $r(\theta) = 2 - \sin(\theta)$, where $0 \leq \theta \leq 2\pi$.



- a. [2 points] Find the two intersection points of the two curves in the diagram. Express the intersection points in polar coordinate form (r, θ) , where $r > 0$ and $0 \leq \theta < 2\pi$.

Answer: _____ and _____

- b. [4 points] Write an expression involving one or more integrals that gives the total perimeter of the shaded region. Your final answer should not involve the letter r . Do not evaluate your integral(s).

Answer: _____

- c. [4 points] Write an expression involving one or more integrals that gives the area of the shaded region. Your final answer should not involve the letter r . Do not evaluate your integral(s).

Answer: _____

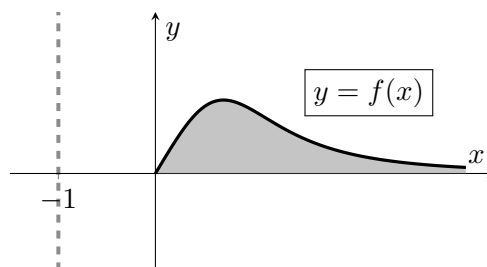
8. [9 points] The parts of this problem are unrelated.

a. [4 points]

Consider the infinite region in the first quadrant between the x -axis and the curve $y = f(x)$ where

$$f(x) = \frac{\arctan(x)}{x^3 + 1},$$

as shaded in the figure to the right.



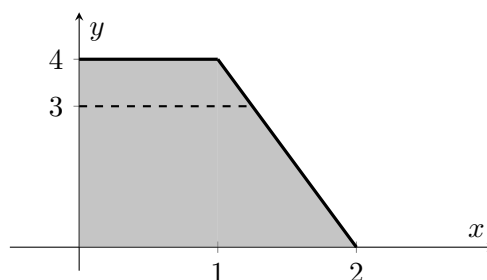
Find an expression involving one or more integrals for the volume of the solid of revolution given by rotating the infinite shaded region around the line $x = -1$. Your expression should not contain the letter f . Do not evaluate your integral(s).

Answer: _____

b. [5 points]

Consider the region in the first quadrant bounded by the y -axis, the x -axis, the line $y = 4$, and the line $y = 8 - 4x$, as shaded in the figure to the right.

Assume that all distances are in meters. You may assume that the acceleration due to gravity is $g = 9.8\text{m/s}^2$.



A tank is formed by rotating this region around the y -axis. The tank is partially filled with a liquid, to a depth of 3 meters from the bottom of the tank (indicated by the dashed line in the figure above). Suppose the liquid has density $p(y) = (1 + y)^{1/3} \text{ kg/m}^3$ where y , in meters, is the height of a point above the bottom of the tank. Find an expression involving one or more integrals for the work, in Joules, needed to pump all the liquid to the top of the tank. Your answer should not involve the letter p . Do not evaluate your integral(s).

Answer: _____

9. [11 points] Consider the function

$$g(x) = \frac{4}{\sqrt{1+5x^3}}.$$

- a. [5 points] Give the first three nonzero terms of the Taylor series of $g(x)$ centered about $x = 0$. Show all your work.

Answer: _____

- b. [2 points] What is the radius of convergence of the Taylor series for $g(x)$ around $x = 0$?

Answer: _____

- c. [4 points] Suppose that $G(x)$ is an antiderivative for $g(x)$ which satisfies $G(0) = 5$. Give the first four non-zero terms of the Taylor series for $G(x)$ centered about $x = 0$.

Answer: _____

10. [13 points] The parts of this problem are unrelated. No justification is required for your answers.

- a. [4 points] Suppose that $f(x)$ is a positive, decreasing, differentiable function which is defined for all real numbers, and that for $n \geq 1$, a_n is given by the LEFT(n) approximation to the integral $\int_1^{n+1} f(x) dx$. If $\lim_{n \rightarrow \infty} a_n = 23$, then which of the following must be true? Circle **all** options which apply.

i. $\int_1^{\infty} f(x) dx$ converges to 23.

v. $\sum_{n=1}^{\infty} f(n)$ converges to 23.

ii. $\int_1^{\infty} f(x) dx$ converges to a number greater than 23.

vi. $\sum_{n=1}^{\infty} f(n)$ converges to a number greater than 23.

iii. $\int_1^{\infty} f(x) dx$ converges to a number less than 23.

vii. $\sum_{n=1}^{\infty} f(n)$ converges to a number less than 23.

iv. $\int_1^{\infty} f(x) dx$ could diverge.

viii. $\sum_{n=1}^{\infty} f(n)$ could diverge.

- b. [2 points] Suppose that $f(h)$ is a probability density function for h , the maximum depth, in hundreds of meters, that a king penguin reaches on a single dive to catch fish. Which of the following statements is best supported by the equation $f(1) = 0.5$? Circle the **one** best answer.

i. There is about a 50% chance that a king penguin dives to maximum depth of 100 meters in any given dive.

ii. There is roughly a 100% chance that a king penguin will dive to a maximum depth of less than 50 meters in any given dive.

iii. If a king penguin were to dive for fish 200 times, the maximum depth of about 20 of those dives would be between 100 and 120 meters.

iv. Approximately 0.5% of all of a king penguin's dives will be to a maximum depth of between 50 and 150 meters.

v. The median maximum depth that king penguins dive to is 100 meters.

vi. NONE OF THESE

- c. [4 points] Which of the following series converge? Circle **all** options that apply.

i. $\sum_{n=1}^{\infty} \frac{(-1)^n}{2n+1}$

iii. $\sum_{n=1}^{\infty} \frac{5^n}{n!}$

v. $\sum_{n=3}^{\infty} \frac{1}{n \ln(n)}$

ii. $\sum_{n=1}^{\infty} \frac{\cos(n)}{n^3}$

iv. $\sum_{n=1}^{\infty} \frac{(-1)^{2n}}{n^{2/3}}$

vi. NONE OF THESE

- d. [3 points] Which of the following series converge to 50? Circle **all** options that apply.

i. $\sum_{n=0}^{\infty} \frac{(-1)^n 50}{(2n)!} \left(\frac{\pi}{2}\right)^{2n}$

iii. $\sum_{n=0}^{\infty} \frac{(\ln(50))^n}{n!}$

v. NONE OF THESE

ii. $\sum_{n=0}^{\infty} \frac{(-1)^n 50}{(2n+1)!} \left(\frac{\pi}{2}\right)^{2n+1}$

iv. $\sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{n} (e^{50} - 1)^n$

“Known” Taylor series (all around $x = 0$):

$$\sin(x) = \sum_{n=0}^{\infty} \frac{(-1)^n x^{2n+1}}{(2n+1)!} = x - \frac{x^3}{3!} + \cdots + \frac{(-1)^n x^{2n+1}}{(2n+1)!} + \cdots \quad \text{for all values of } x$$

$$\cos(x) = \sum_{n=0}^{\infty} \frac{(-1)^n x^{2n}}{(2n)!} = 1 - \frac{x^2}{2!} + \cdots + \frac{(-1)^n x^{2n}}{(2n)!} + \cdots \quad \text{for all values of } x$$

$$e^x = \sum_{n=0}^{\infty} \frac{x^n}{n!} = 1 + x + \frac{x^2}{2!} + \cdots + \frac{x^n}{n!} + \cdots \quad \text{for all values of } x$$

$$\ln(1+x) = \sum_{n=1}^{\infty} \frac{(-1)^{n+1} x^n}{n} = x - \frac{x^2}{2} + \frac{x^3}{3} - \cdots + \frac{(-1)^{n+1} x^n}{n} + \cdots \quad \text{for } -1 < x \leq 1$$

$$(1+x)^p = 1 + px + \frac{p(p-1)}{2!} x^2 + \frac{p(p-1)(p-2)}{3!} x^3 + \cdots \quad \text{for } -1 < x < 1$$

$$\frac{1}{1-x} = \sum_{n=0}^{\infty} x^n = 1 + x + x^2 + x^3 + \cdots + x^n + \cdots \quad \text{for } -1 < x < 1$$

Select Values of Trigonometric Functions:

θ	$\sin \theta$	$\cos \theta$
$\frac{\pi}{6}$	$\frac{1}{2}$	$\frac{\sqrt{3}}{2}$
$\frac{\pi}{4}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{2}}$
$\frac{\pi}{3}$	$\frac{\sqrt{3}}{2}$	$\frac{1}{2}$