There are 11 questions with parts and the value of each question is marked. There are a total of 100 points on the exam.

- Do not open the exam until you are told to do so.
- No notes, calculators, head phones, or electronic devices of any kind are allowed.
- Turn off your cell phone.
- Show all of your work. Answers without correct supporting work and justification when required, will receive no credit. Be sure to write down enough work to make clear how you solved a problem, even if you do all of the work in your head.
- Make sure to answer all of the questions you know how to do. Do not get bogged down on any one problem.

(DO NOT WRITE BELOW THIS LINE, THIS SECTION IS FOR GRADING PURPOSES ONLY.)

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1. Let \( \mathbf{u} = 2\mathbf{i} + \mathbf{j} - \mathbf{k} \) and \( \mathbf{v} = \mathbf{i} + 3\mathbf{j} \) be vectors in \( \mathbb{R}^3 \).

(a) Find the cosine of the angle between \( \mathbf{u} \) and \( \mathbf{v} \).

(b) Find the area of the parallelogram spanned by \( \mathbf{u} \) and \( \mathbf{v} \).
2. A fish is moving through the ocean and we denote its starting point by \((0, 0, 0)\). If it accelerates according to the function \(a(t) = \langle t, e^t, \cos(\pi t) \rangle\), and it has an initial velocity of \(\langle -1, 1, 0 \rangle\), find a function to describe its position at time \(t\).
3. For each of the following limits either compute the limit or show that it does not exist.

(a) \( \lim_{(x,y) \to (0,0)} \frac{5x^3y}{x^4 + y^4} \)

(b) \( \lim_{(x,y) \to (0,0)} \frac{e^{xy}}{3 \cos(xy)} \)
4. Use the chain rule to find \( \frac{\partial z}{\partial s} \) where

\[
z = 3x \ln(y) \quad x = s \cos(t) \quad y = 2s \sin(t)
\]

Your final answer should depend on \( s \) and \( t \) only.
5. Let $S$ be the surface given by the equation

$$xy + xz + yz = 0$$

and let $P$ be the point $(1, 2, -\frac{2}{3})$

(a) Find the equation of the tangent plane of $S$ at $P$.

(b) Find a parametric equation for the normal line to $S$ at $P$. (The normal line is the line perpendicular to $S$ at $P$ that also goes through $P$.)
6. For the following function find all the critical points and classify each as local minimum, local maximum, or saddle point.

\[ f(x, y) = \frac{2}{3} x^3 + x^2 y + \frac{3}{2} y^2 + 2y \]
7. Evaluate the iterated integral

\[ \int_0^1 \int_{\sqrt{x}}^1 \cos(y^3) \, dy \, dx \]

by switching the order of integration.
8. A wedge-like region $E$ is cut from the parabolic cylinder $y = 2x^2$ by the planes $z = 0$ and $2y + z = 1$. Set up a triple integral representing the volume of $E$ with order of integration

$$\int\int\int dz\ dy\ dx$$

and appropriate integration limits for each variable. **Do not evaluate the integral.**
9. Evaluate the integral
\[ \iiint_W (x^2 + y^2 + z^2) \, dV \]
where \( W \) is the region inside the sphere \( \rho = 1 \) and between the cones \( \phi = \frac{\pi}{4} \) and \( \phi = \frac{3\pi}{4} \).
10. (a) Determine whether the vector field \( \mathbf{F}(x, y) = \langle 2xy, y^2 \rangle \) is conservative.

(b) The vector field \( \mathbf{F}(x, y) = \langle 2xy + 1, x^2 + y \rangle \) is conservative. Find a potential function \( f \) such that \( F = \nabla f \).

(c) Evaluate the line integral
\[
\int_{C} (2xy + 1) \, dx + (x^2 + y) \, dy
\]
Where \( C \) is the curve with parametric equations, \( \mathbf{r}(t) = \langle t, t^2 \rangle, \ 0 \leq t \leq 1. \)
11. Use Green’s Theorem to evaluate the line integral.

\[ \int_C (-x^2 y + e^x) \, dx + (y^2 x + y^5) \, dy \]

where \( C \) is the circle \( x^2 + y^2 = 9 \) oriented counterclockwise.