Instructions.

• There are 4 questions. The exam is out of 40 points.

• You are allowed to use one page of notes written only on one side of the sheet in your own handwriting.

• You may use a calculator which does not graph and which is not programmable. Even if you have a calculator, give me exact answers. \((\frac{2\ln 3}{\pi})\) is exact, 0.7 is an approximation for the same number.

• Show your work. If I cannot read or follow your work, I cannot grade it. You may not get full credit for a right answer if your answer is not justified by your work. If you continue at the back of a page, make a note for me. Please BOX your final answer.

• \(\int \ln x \, dx = x \ln x - x + C\)

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1. Answer the following questions about the vector function

\[ \mathbf{r}(t) = (3 \sin(t), t, 3 \cos(t)) . \]

(a) Find the length of the curve traced by this vector function from the point \((0, 0, 3)\) to the point \(\left( \frac{3\sqrt{3}}{2}, \frac{\pi}{3}, \frac{3}{2} \right)\).

(b) Find the curvature at the point \(\left( \frac{3\sqrt{3}}{2}, \frac{\pi}{3}, \frac{3}{2} \right)\).
2. Evaluate the following integrals.

(a) \[
\int \int x \left( x^2 + y^2 \right)^{3/2} dA
\]
over the region \( R \) between the lines \( y = x, y = \sqrt{3}x \) and the curve \( y = \sqrt{9 - x^2} \).

(b) \[
\int_0^4 \int_{y/4}^1 y \ln \left( x^3 + 1 \right) \, dx \, dy
\]
3. Let

\[ f(x, y) = (\sqrt{x} + \sqrt{y})^2 \]

(a) Find the equation of the tangent plane to \( z = f(x, y) \) at the point \((16, 100, 196)\).

(b) Approximate \( (\sqrt{15} + \sqrt{99})^2 \) using linear approximation.
4. Find and classify all critical points of the function

\[ f(x, y) = 3x - x^3 - 6xy^2. \]