

Tutorial Sheet: Multivariable Calculus

1. Examine if the limits as $(x, y) \rightarrow (0, 0)$ exist?

$$(a) \begin{cases} \frac{x^2 y^2}{x^2 + y^2} & x \neq y \\ 0 & x = y \end{cases} \quad (b) \ xy \left(\frac{x^2 - y^2}{x^2 + y^2} \right) \quad (c) \begin{cases} x \sin \frac{1}{x} + y \sin \frac{1}{y} & xy \neq 0 \\ 0 & xy = 0 \end{cases}$$

$$(d) \frac{\sin(xy)}{x^2 + y^2}$$

2. Examine the continuity of the following functions

$$(a) \begin{cases} \frac{xy^2}{x^2 + y^2} & (x, y) \neq (0, 0) \\ 0 & \text{otherwise} \end{cases} \quad (b) \begin{cases} x^2 + y^2, & x^2 + y^2 \leq 1 \\ 0, & \text{otherwise} \end{cases}$$

$$(c) \begin{cases} \frac{\sin^2(x - y)}{|x| + |y|} & (x, y) \neq (0, 0) \\ 0 & \text{otherwise} \end{cases} \quad (d) \begin{cases} \frac{x^2 y^2}{x^2 y^2 + (x - y)^2} & (x, y) \neq (0, 0) \\ 0 & \text{otherwise} \end{cases}$$

3. Discuss the differentiability of the following functions at $(0, 0)$

$$(a) f(x, y) = \begin{cases} x \sin \frac{1}{x} + y \sin \frac{1}{y} & xy \neq 0 \\ \sin y & xy = 0 \end{cases} \quad (b) \begin{cases} \frac{\sqrt{x^2 + y^2}}{\sqrt{x^2 + y^2}} & x^2 + y^2 \neq 0 \\ 0 & x = y = 0 \end{cases}$$

$$(c) \begin{cases} \frac{x^2 y^2}{x^2 + y^2} & x^2 + y^2 \neq 0 \\ 0 & x = 0, y = 0 \end{cases}$$

4. Let $f(x, y) = \frac{1}{|y|} \sqrt{x^2 + y^2}$, $y \neq 0$ and $f(x, 0) = 0$. Show that f has all directional derivatives at $(0, 0)$ but it is not differentiable at $(0, 0)$.

5. Let $f(x, y) = |x| - |y|$. Is f continuous at $(0, 0)$? Which directional derivatives exist at $(0, 0)$? (The answer is yes.)

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