

HOMEWORK 3 SOLUTIONS

All questions are from Vector Calculus by Marsden and Tromba

Questions 1: 3.2.12 Compute the following limits if they exist:

(a) $\lim_{x \rightarrow 0} \frac{\sin 2x - 2x}{x^2}$

(b) $\lim_{(x,y) \rightarrow (0,0)} \frac{\sin 2x - 2x + y}{x^2 + y^2}$

(c) $\lim_{(x,y) \rightarrow (0,0)} \frac{2x^2 y \cos y}{x^2 + y^2}$

Solutions:

(a) Use L'Hopital's rule:

$$\begin{aligned} \lim_{x \rightarrow 0} \frac{\sin 2x - 2x}{x^2} &= \lim_{x \rightarrow 0} \frac{2 \cos 2x - 2}{2x} \\ &= \lim_{x \rightarrow 0} \frac{-4 \sin 2x}{2x} \quad (\text{again by L'Hopital}) \\ &= -\left(\frac{4}{2}\right) \lim_{x \rightarrow 0} \frac{\sin 2x}{x} = -\frac{4}{2} \end{aligned}$$

where

$$\lim_{x \rightarrow 0} \frac{\sin x}{x} = 1$$

(b) From (a), for $y = 0$

$$\frac{\sin 2x - 2x}{x^2} \text{ approaches } -\frac{4}{2}$$

as $(x, 0)$ approaches $(0, 0)$. Setting $y = 2x$, we see that

$$\frac{\sin 2x - 2x + y}{x^2 + y^2} = \frac{\sin 2x}{x^2 + 2x^2} = \frac{\sin 2x}{3x^2} \left(\frac{2}{x^2 + 2} \right)$$

and hence

$$\lim_{(x,y) \rightarrow (0,0)} \frac{\sin 2x - 2x + y}{x^2 + y^2} = \lim_{x \rightarrow 0} \frac{\sin 2x}{3x^2} \cdot \frac{2}{x^2 + 2} = \frac{1}{3} \cdot \frac{2}{2} = \frac{1}{3}.$$

Therefore,

$$\frac{\sin 2x - 2x + y}{x^2 + y^2}$$

has two different limits along two different rays approaching the origin $(0, 0)$, and consequently

$$\lim_{(x,y) \rightarrow (0,0)} \frac{\sin 2x - 2x + y}{x^2 + y^2}$$

does not exist.

From: Marsden and Tromba, 2006

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