

Advanced Calculus (MAU11202), Homework Assignment 1 Solutions

Straightforward

1. **[3 points]** Find the derivative of the vector-valued function

$$\mathbf{r}(t) = \left(\frac{t^2 - 1}{t^2 + 2}, \sin(t) \ln(t), \cos(\sin(t)) \right).$$

What is $\mathbf{r}'(1)$ equal to?

Solution:

To differentiate $\mathbf{r}(t) = (x(t), y(t), z(t))$, we differentiate the three component functions separately.

Using the Quotient Rule,

$$x'(t) = \frac{2t(t^2 + 2) - 2t(t^2 - 1)}{(t^2 + 2)^2} = \frac{2t^3 + 4t - 2t^3 + 2t}{(t^2 + 2)^2} = \frac{6t}{(t^2 + 2)^2}.$$

Using the Product Rule,

$$y'(t) = \cos t \ln(t) + \sin(t) \cdot \frac{1}{t} = \cos(t) \ln(t) + \frac{\sin(t)}{t}.$$

Using the Chain Rule, $z'(t) = \cos(t)(-\sin(\sin(t))) = -\cos(t) \sin(\sin(t))$.

Hence

$$\mathbf{r}'(t) = \left(\frac{6t}{(t^2 + 2)^2}, \cos(t) \ln(t) + \frac{\sin(t)}{t}, -\cos(t) \sin(\sin(t)) \right).$$

Letting $t = 1$ in this expression, we obtain

$$\begin{aligned} \mathbf{r}'(1) &= \left(\frac{6(1)}{(1^2 + 2)^2}, \cos(1) \ln(1) + \frac{\sin(1)}{1}, -\cos(1) \sin(\sin(1)) \right) \\ &= \left(\frac{2}{3}, \sin(1), -\cos(1) \sin(\sin(1)) \right). \end{aligned}$$

2. **[3 points]** Find the derivative of the vector-valued function

$$\mathbf{r}(t) = (2t^3 - 3t^2 + 5t + 3) \left(\frac{t^2 - 1}{t^2 + 2}, \sin(t) \ln(t), \cos(\sin(t)) \right).$$

What is the domain of this function?

Solution:

Here we use Theorem 1.2.11(c) (Chapter 1 of course notes by Anthony Brown), the solution to Question 1, and the fact that the derivative of $f(t) = 2t^3 - 3t^2 + 5t + 3$ is $F'(t) = 6t^2 - 6t + 5$, to obtain

$$\begin{aligned} \mathbf{r}'(t) &= (2t^3 - 3t^2 + 5t + 3) \left(\frac{6t}{(t^2 + 2)^2}, \cos(t) \ln(t) + \frac{\sin(t)}{t}, \cos(t) \cos(\sin(t)) \right) \\ &\quad + (6t^2 - 6t + 5) \left(\frac{t^2 - 1}{t^2 + 2}, \sin(t) \ln(t), \cos(\sin(t)) \right). \end{aligned}$$

The domain of \mathbf{r} is $\mathbb{R} \cap (0, \infty) \cap \mathbb{R} = (0, \infty)$.

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