Differential Geometry: Homework 1

Peter Kagey

January 17, 2018

Problem 1. Show that the induced topology (for a subset $X \subset Y$ of a topological space Y) and the quotient topology (for a surjection $X \twoheadrightarrow Y$ from a topological space X onto a set Y) satisfy the axioms of a topological space.

Proof. $\square$

Problem 2. Show that the topological spaces $S^1 \subset \mathbb{R}^2$ (with topology induced by the inclusion into $\mathbb{R}^2$) and $[0,1]/\{0,1\}$ (with the quotient topology from the topology on $[0,1] \subset \mathbb{R}$) are homeomorphic.

Proof. $\square$

Problem 3. Prove that S^1, with either topology considered above, is a topological manifold.

Proof. $\square$

Problem 4. Show that the derivative of a function $f : \mathbb{R}^n \to \mathbb{R}^m$ if it exists at a point $a \in \mathbb{R}^m$ is unique.

Proof. $\square$

Problem 5. Produce, with proofs, examples of the following topological spaces which are not topological manifolds:

a) A space X which is locally Euclidean and second countable, but not Hausdorff.

b) A space X which is Hausdorff and second countable, but not locally Euclidean.

Proof. $\square$

Problem 6. Let h be a continuous real-valued function on $S^1 = \{x^2 + y^2 = 1 \subset \mathbb{R}^2\}$ satisfying $h(0,1) = h(1,0) = 0$ and $h(-x_1, -x_2) = -h(x_1, x_2)$. Define a function $f : \mathbb{R}^2 \to \mathbb{R}$ by

$$f(x) = \begin{cases} ||x||h(x/||x||) & x \neq 0 \\ 0 & x = 0 \end{cases}$$

a) Show that f is continuous at $(0,0)$, that the partial derivatives of f at $(0,0)$ are defined, and that more generally all directional derivatives of f are defined.

b) Show that f is not differentiable at $(0,0)$ except if h is identically zero.

Proof. □