

1. If X and Z are locally compact Hausdorff, then for any space Y , the isomorphism of sets $\text{Top}(Z \times X, Y) \rightarrow \text{Top}(Z, \text{Top}(X, Y))$ is a homeomorphism of spaces.

2. Let X be compact and Y be Hausdorff. For a set map $f : X \rightarrow Y$, f is continuous iff its graph $G = \{(x, f(x)) \in X \times Y\}$ is closed.

3. It is a fact that you may prove or assume that

Every n -dimensional Hausdorff topological vector space is homeomorphic to \mathbb{R}^n with its usual topology.

Your problem: Let V be a topological vector space and $f : V \rightarrow \mathbb{R}^n$ be linear. Prove that f is continuous iff $\ker(f)$ is compact.

4. Let X be a topological space. There's a little logical universe contained in X . A *predicate* on X is an open set $U \subseteq X$ or if you prefer, an open embedding of a topological space $U \hookrightarrow X$. A predicate U is *true* at a point $x \in U$. Entailment is containment $U \vdash V$ means $U \subseteq V$. Conjunction is intersection $U \wedge V := U \cap V$, disjunction is union $U \vee V = U \cup V$, and implication is defined $U \Rightarrow V$ is defined to be the largest open set W so that $W \cap U \subseteq V$. The universally true proposition is $\top = X$, the universally false is $\perp = \emptyset$. Negation is defined by $\neg U = U \Rightarrow \emptyset$.

(a) Prove $U \wedge V \vdash W$ if and only if $U \vdash V \Rightarrow W$.

(b) Prove that $U \wedge (U \Rightarrow V) \vdash V$.

(c) Here's a way to interpret the previous statement: if we make a category out of X where the objects are open sets and the morphisms are inclusions, then for each fixed U , the map $V \mapsto V \wedge U$ has a right adjoint $W \mapsto U \Rightarrow W$.

(d) Prove that $U \vee \neg U = X \setminus \partial U$ and $\neg \neg U = \text{int}(U)$.

(e) Prove that $\neg \neg U = U$ and $U \vee \neg U = \top$ iff X is discrete.

5. Let X be compact and Y be a metric space. We say a family of functions $F \subseteq \text{Top}(X, Y)$ is equicontinuous iff for all $x \in X$ and for all $\epsilon > 0$ there exists a neighborhood U of x so that

$$d(f(x), f(x')) \leq \epsilon \text{ for all } x, x' \in U \text{ and for all } f \in F.$$

For this problem suppose F is an equicontinuous family of functions. For a compact set $K \subset X$ and an open set $U \subset Y$, let $S(K, U)$ denote the open set in the product topology given by

$$S(K, U) = \{f : X \rightarrow Y : f(K) \subseteq U\}.$$

- (a) Suppose F is equicontinuous. Prove that if $K \subseteq X$ is compact and $U \subseteq Y$ is open, then for any $f \in F$ with $f(K) \subseteq U$, there exists a set V that is open in the product topology with $f \in V \subseteq S(K, U) \cap F$.
- (b) Let F be an equicontinuous family of functions from X to Y . Prove that F has compact closure in the product topology iff for each $x \in X$, the sets $F_x = \{f(x) : x \in X\}$ all have compact closure in Y .
- (c) Prove that a subset of functions F has compact closure in the topology induced by the sup norm if and only if it is equicontinuous and pointwise bounded.
- (d) Give a counterexample: Let X be compact, (Y, d) be a metric space and $\{f_n\}$ be a sequence of functions in $\mathbf{Top}(X, Y)$. If $\{f_n\}$ is equicontinuous and if for each $x \in X$ the set $\{f_n(x)\}$ is bounded, then $\{f_n(x)\}$ has a subsequence that converges uniformly.
- (e) Consider the family $\mathcal{F} = \{f_a : 0 < a \leq 1\}$ where $f_a(x) = 1 - \frac{x}{a}$. Is \mathcal{F} a compact subspace of $\mathbf{Top}([0, 1], \mathbb{R})$?