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MA 521
Homework #6
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2.24, 3.12, 3.26, 5.3, 5.7, 5.8, 5.12, 5.13.

Exercise 2.24 Let (X, d) be a metric space. Show that if X is totally bounded, then X is bounded.

Let $X = \bigcup_{B_X} B_X(x, \epsilon) = B_X(x, r)$. Choose $\zeta > 0$ so $B_X(x, r) \subset B_X(x, r + \zeta)$ so X is bounded. ∎

Exercise 3.12 Let (X, d) be a metric space. Assume F and K are subsets of X, with F closed and K compact. Then $F \cap K$ is compact.

If K is a compact subset of X, then K is closed and bounded in X. The intersection of closed sets is closed so $F \cap K$ is closed. By Thm 3.10, $F \cap K \subset K$ and K is compact so $F \cap K$ is also compact. ∎

Exercise 3.26 Give an example of a collection $\mathcal{A}$ of bounded subsets of $\mathbb{R}$ such that $\mathcal{A}$ has the finite intersection property, but $\bigcap_{A \in \mathcal{A}} A = \neq$. Hint: If $A \subset \mathbb{R}$ is bounded in $\mathbb{R}$, what else can prevent it from being compact?

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Exercise 5.3 Let $\mathcal{A}$ be a collection of convex subsets of $\mathbb{R}^k$. Show that $B := \bigcap_{A \in \mathcal{A}} A$ is convex.

Let's do proof by contradiction. Let $B = \bigcap_{A \in \mathcal{A}} A$. Assume B is not convex. Let $a, b \in B$ so then $\exists\, t \in [0, 1]$ s.t. $z \in (1-t)a + tb \notin B$. But $z \in A \forall A \in \mathcal{A} \to z \notin B$ so $B \neq \bigcap_{A \in \mathcal{A}} A$. This is clearly a contradiction so B is convex. ∎

Exercise 5.7 Let (X, d) be a metric space and let A and B be disjoint subsets of X. Prove that if A and B are both open in X, then A and B are seperated.

We need to show that $A \cap \overline{B} = B \cap \overline{A} = \emptyset$. So, let's analyze the first statement: $\overline{A} \cap B = (A \cup \mathrm{Lim}_X(A)) \cap B = (A \cap B) \cup (\mathrm{Lim}_X(A) \cap B)$. A and B are disjoint so the only set we need to be concerned with is $\mathrm{Lim}_X(A) \cap B$. Consider the intersection of $\mathrm{Lim}_X(A) \cap \mathrm{Lim}_X(B) = C$. Without loss of generality, choose $x \in C \to x \in \mathrm{Lim}_X(A)$ and $\mathrm{Lim}_X(B) \not\subset B$ since B is open. So, $x \notin \mathrm{Lim}_X(A) \cap B$. So, $\overline{A} \cap B = \emptyset$. This holds true for the other case as well and so A and B are both seperated. ∎

Exercise 5.8 Let E be a connected subset of a metric space (X, d). Show that $\overline{E}$ is connected.

If E is connected, then $E \subset \text{Lim}_X(E)$. If E is connected, then E has no isolated points. If E had isolated points, then $\exists$ some $x \in E$ s.t. $x \notin \text{Lim}_X(E)$. Thus, $\exists$ some neighbourhood U of x s.t. $U \cap \setminus E\{x\} = \emptyset$. Then, E can be written as the union of two seperated sets $E = E \setminus \{x\} \cup \{x\}$, implying E is not connected which is false. Thus, $\overline{E}$ is connected. ∎

Exercise 5.12 Let (X, d) be a metric space, and let $\mathcal{C}$ be a collection of connected subsets of X. Assume $A = \bigcap_{C \in \mathcal{C}} C$ is nonempty. Show that $B = \bigcap_{C \in \mathcal{C}}$ is connected.

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Exercise 5.13 Let $X = \mathbb{R}^2$. Give an example of a connected subset E of X, such that $\text{Int}_X(E)$ is not connected. Prove both that your set E is connected and that its interior is not. ((Hint: Consider the union of two convex sets joined at a point. You may assume without proof the fact that convexity implies connectedness in $\mathbb{R}^2$.)

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