

Munkres - Topology - Chapter 1 Solutions

Section 3

Problem 3.2. Let C be a relation on a set A . If $A_0 \subseteq A$, define the restriction of C to A_0 to be the relation $C \cap (A_0 \times A_0)$. Show that the restriction of an equivalence relation is an equivalence relation.

Solution: Let C' be the restriction of C to A_0 . As an initial matter, clearly if $(a, b) \in C'$, then $(a, b) \in C$. Further, if $(a, b) \in C$ and $a, b \in A_0$, then $(a, b) \in C'$. We will now show that the C' is an equivalence relation.

Let $x_0 \in A_0$. Since $(x_0, x_0) \in C$, it follows that $(x_0, x_0) \in C'$. Therefore C' is reflexive.

Let $(x_1, y_1) \in C'$. It follows that $(y_1, x_1) \in C$, so $(y_1, x_1) \in C'$. Therefore, C' is symmetric.

Let $(x_2, y_2), (y_2, z_2) \in C'$. It follows that $(x_2, y_2) \in C$, so $(x_2, z_2) \in C$. Therefore, C' is transitive. Since all the necessary properties are met, C' is an equivalence relation.

Problem 3.4. Let $f : A \rightarrow B$ be a surjective function. Let us define a relation on A by setting $a_0 \sim a_1$ if $f(a_0) = f(a_1)$. (a) Show that this is an equivalence relation. (b) Let A^* be the set of equivalence classes. Show there is a bijective correspondence of A^* with B .

Solution: Part (a) Suppose R is the relation of interest. Let $a_0 \in A$. Clearly $f(a_0) = f(a_0)$, so $a_0 \sim a_0$. It follows that R is reflexive. Now let $a_0, a_1 \in A$ where $a_0 \sim a_1$. Since $f(a_0) = f(a_1)$ implies that $f(a_1) = f(a_0)$, we infer that $a_1 \sim a_0$. It follows that R is symmetric. Finally, let $a_0, a_1, a_2 \in A$ where $a_0 \sim a_1$ and $a_1 \sim a_2$. We see that $f(a_0) = f(a_1) = f(a_2)$, so $a_0 \sim a_2$. Therefore, R is transitive. Accordingly, R is an equivalence relation.

Part (b) Let $\mathcal{A}$ be the collection of equivalence classes of A of R , where if $x \in A$, there is an $E_x \in \mathcal{A}$ such that $E_x = \{y \in A : x \sim y\}$. Let $g : \mathcal{A} \rightarrow B$ where $g(E_x) = f(x)$. First we will show that g is injective. Let $E_x, E_y \in \mathcal{A}$ and $g(E_x) = g(E_y)$. It follows that $f(x) = f(y)$, so $x \in E_x$ and $x \in E_y$. Since E_x and E_y are not disjoint, we infer from Lemma 3.1 that $E_x = E_y$. Therefore, g is injective.

Now let $b \in B$. Since f is surjective, there is an $a \in A$ such that $f(a) = b$. Therefore, $g(E_a) = f(a) = b$. Accordingly, g is surjective, from which it follows that g is a bijection from $\mathcal{A}$ to B .

Problem 3.10. (a) Show that the map $f : (-1, 1) \rightarrow \mathbb{R}$ of Example 9 is order preserving. (b) Show that the equation $g(y) = 2y/[1 + (1 + 4y^2)^{1/2}]$ defines a function $g : \mathbb{R} \rightarrow [-1, 1]$ that is both a left and a right inverse for f .

Solution: Part (a) Let $A = (-1, 1)$. The function f is order preserving if $a_0 < a_1$ implies that $f(a_0) < f(a_1)$ for all $a_0, a_1 \in A$. Now let $x, y \in A$. We may assume without loss of generality that $x < y$. We then have:

$$f(x) - f(y) = \frac{x - y}{(1 - x^2)(1 - y^2)} < 0,$$

because $1 - x^2, 1 - y^2 > 0$ for all $x, y \in A$. It follows that $f(x) < f(y)$. The function f is therefore order preserving.

Part (b) This problem a straightforward (but annoying) substitution of f and g into each other. let $x \in A$. We then have:

$$(g \circ f)(x) = \left(\frac{2x}{1 - x^2} \right) \left(\frac{1}{1 + [1 + 4x^2/(1 - x^2)^2]^{1/2}} \right) = \frac{2x}{(1 - x^2) + (1 + x^2)} = x,$$

showing that g is a left inverse of f .

For $(f \circ g)(y)$, we can again do the substitution and show (through a lot of algebra) that $(f \circ g)(y) = y$. For $y \in \mathbb{R}$, we have:

$$(f \circ g)(y) = \left(\frac{2y}{1 + (1 + 4y^2)^{1/2}} \right) \left(\frac{1}{1 - 4y^2/[1 + (1 + 4y^2)^{1/2}]^2} \right) = \frac{2y(1 + (1 + 4y^2)^{1/2})}{2(1 + (1 + 4y^2)^{1/2})} = y,$$

showing that g is a right invoice for f .

Problem 3.11. Show that an element in an ordered set has at most one immediate successor and at most one immediate predecessor. Show that a subset of an ordered set has at most one smallest element and at most one largest element.

Munkres Topology Solutions Chapter 1

Yijin Wang



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