Chapter 9: Functions of Several Variables

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Exercise 9.1. *If S is a nonempty subset of a vector space X, prove (as asserted in Section 9.1) that the span of S is a vector space.*

Denote the span of S by $\mathrm{span}(S)$.

Proof.

(1) Since $S \neq \varnothing$, there is $\mathbf{z} \in S$. So $1\mathbf{z} = \mathbf{z} \in \mathrm{span}(S) \neq \varnothing$. (In fact, $\mathrm{span}(S) \supseteq S$.)

(2) If $\mathbf{x}, \mathbf{y} \in \mathrm{span}(S)$, then there exist elements $\mathbf{x}_1, \ldots, \mathbf{x}_m$, $\mathbf{y}_1, \ldots, \mathbf{y}_n \in S$ and scalars $a_1, \ldots, a_m$, $b_1, \ldots, b_n$ such that

$$\mathbf{x} = a_1\mathbf{x}_1 + \cdots + a_m\mathbf{x}_m,$$
$$\mathbf{y} = b_1\mathbf{y}_1 + \cdots + b_n\mathbf{y}_n.$$

Then

$$\mathbf{x} + \mathbf{y} = a_1\mathbf{x}_1 + \cdots + a_m\mathbf{x}_m + b_1\mathbf{y}_1 + \cdots + b_n\mathbf{y}_n$$

is a linear combination of the elements of S. For any scalar c,

$$c\mathbf{x} = (ca_1)\mathbf{x}_1 + \cdots + (ca_m)\mathbf{x}_m$$

is again linear combination of the elements of S.

(3) By (1)(2), $\mathrm{span}(S)$ is a vector space.

□

Note. Any subspace of X that contains S must also contain $\mathrm{span}(S)$.