## Assignment #3

**Due on Wednesday, September 16, 2009**

**Read** Chapter 2 on *Vector Algebra* in Bressoud (pp. 29–49).

**Do** the following problems

1. The vectors
$$v_1 = \begin{pmatrix} -1 \\ 1 \\ 2 \end{pmatrix} \quad \text{and} \quad \vec{v}_2 = \begin{pmatrix} 1 \\ 0 \\ -1 \end{pmatrix}$$
span a two–dimensional subspace in $\mathbb{R}^3$, in other words, a plane through the origin. Give two unit vectors which are orthogonal to each other, and which also span the plane.

2. Use an appropriate orthogonal projection to compute the shortest distance from the point $P(1,1,2)$ to the plane in $\mathbb{R}^3$ whose equation is
$$2x + 3y - z = 6.$$

3. The dual space of of $\mathbb{R}^n$, denoted $(\mathbb{R}^n)^*$, is the vector space of all linear transformations from $\mathbb{R}^n$ to $\mathbb{R}$.

   For a given $w \in \mathbb{R}^n$, define $T_w \colon \mathbb{R}^n \to \mathbb{R}$ by
$$T_w(v) = w \cdot v \quad \text{for all} \quad v \in \mathbb{R}^n.$$
   Show that $T_w$ is an element of the dual of $\mathbb{R}^n$ for all $w \in \mathbb{R}^n$.

4. Prove that for every linear transformation, $T \colon \mathbb{R}^n \to \mathbb{R}$, there exists $w \in \mathbb{R}^n$ such that
$$T(v) = w \cdot v \quad \text{for every} \quad v \in \mathbb{R}^n.$$
   (*Hint:* See where $T$ takes the standard basis $\{e_1, e_2, \ldots, e_n\}$ in $\mathbb{R}^n$.)

5. Let $u_1, u_2, \ldots, u_n$ be unit vectors in $\mathbb{R}^n$ which are mutually orthogonal; that is,
$$u_i \cdot u_j = 0 \quad \text{for} \quad i \neq j.$$
   Prove that the set $\{u_1, u_2, \ldots, u_n\}$ is a basis for $\mathbb{R}^n$, and that, for any $v \in \mathbb{R}^n$,
$$v = \sum_{i=1}^{n} (v \cdot u_i)\, u_i.$$