

MAPLE Worksheet Number 13
Matrices and Vector Spaces

We recall that multiplication by an $n \times m$ matrix A is a "linear map" from the space R^m of vectors of length m to the space R^n of vectors of length n . Let's use MAPLE to demonstrate what we mean by a linear map. Define A to be an arbitrary 2×3 matrix, v and w to be arbitrary 3×1 matrices, (ie column 3-vectors) and let a and b be arbitrary scalars. Linearity means that

$$A(av + bw) = aAv + bAw.$$

Load `linalg` and execute the following commands to check this identity with MAPLE.

```
[ > A:=matrix(2,3);
[ > evalm(A);
[ > v:=matrix(3,1);w:=matrix(3,1);
[ > evalm(v);evalm(w);
[ > evalm(A&a*(a*v+b*w));
[ > leftside:=map(expand,%);
```

The MAPLE command `map(command,matrix)` is used to cause the specified command (`expand` in this case) to work on each entry of the indicated matrix. Now lets compute the other side of the identity and compare.

```
[ > aA:=evalm(a*A);bA:=evalm(b*A);
[ > rightside:=evalm(aA&a*v+bA&b*w);
[ > leftside-rightside;
[ > evalm(%);
```

The set of all vectors in R^m which go to the zero vector in R^n is called the "null space" of A . If A is nonsingular then the null space of A consists of only the zero vector. Why? Use MAPLE to demonstrate. A handy MAPLE command to use here is

$$\text{linsolve}(A,B).$$

This automatically tries to solve the equation $AX=B$ for the values of X . Apply it to try to find the null space for an arbitrary 2×2 matrix M . Note that MAPLE will assume that M is nonsingular, just as it did when we computed the formula for the inverse of such an M in worksheet 11.

Find the null space of the following matrix $K := \begin{bmatrix} 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ 4 & 5 & 6 & 7 & 8 & 9 & 10 \\ 5 & 6 & 7 & 8 & 9 & 10 & 11 \\ 6 & 7 & 8 & 9 & 10 & 11 & 12 \end{bmatrix}$.

Note that the element in the position (i,j) is $i+j$. So we can use one of our shortcut methods from Number 11 to define K .

```
[ > K:=matrix(5,7, (i,j)->i+j);
So to solve  $KX=0$  for  $X$  we use the command
[ > with(linalg);
[ > NK:=linsolve(K,matrix(5,1,0));
```

How many independent variables are used to describe the vectors in the null space of K ? This number is the "dimension" of the null space of K . It is also called the "nullity of K ." To actually find some vectors

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