MATH 601 HOMEWORK (DUE 10/16)

HIDENORI SHINOHARA

Contents

1. Jordan Canonical Form

Let k be a field, V a finite dimensional k-vector space, and $T \in \mathrm{End}_k(V)$ a linear transformation.

Exercise. (Problem 1) Show that the set $\{p(x) \in k[x] \mid p(T) = 0 \in \mathrm{End}_k(V)\}$ is an ideal, $I \subset k[x]$. Also, show that $I \neq 0$.

Proof.

- Claim 1: I is nonempty.
  Use Cayley-Hamilton to find a non-trivial element. I'm still trying to understand C-H. One thing I learned today is that the determinant function is independent of the choice of the basis.
- Claim 2: I is closed under subtraction. Let $p(x), q(x) \in I$. Then $p(x) - q(x) \in I$ because $p(T) - q(T) = 0 - 0 = 0$.
- Claim 3: I is closed under multiplication by elements in $k[x]$. Let $p(x) \in I, r(x) \in k[x]$. Then $p(T)r(T) = 0r(T) = 0$, so $r(x)p(x) \in I$.

By Claim 1 and 2, I is a subgroup of $k[x]$ under addition. Then Claim 3 implies that I is an ideal. By Claim 1, $I \neq 0$. □

Exercise. (Problem 2) Let $p(x) \in k[x]$ be a nonzero polynomial such that $p(T) = 0 \in \mathrm{End}_k(V)$. Show that if $p(x) \in k[x]$ is a product of linear polynomials, then there is a k-basis for V with respect to which the matrix for T is in Jordan normal form.

Proof.

I'm not sure what to do here.

- If I use the theorem, this problem will be too easy and the first part of the problem will be unnecessary, so I don't think I can just use the theorem.
- Initially, I thought that I could just do Step 3 and 4 in the proof of the theorem on PP.3-4 of the Jordan Canonical Form handout. However, I realized that Step 3 and 4 require the characteristic polynomial, but $p(x)$ is not necessarily the characteristic polynomial. I don't think there is anything that I can do with $p(x)$ but not with the characteristic polynomial, though. If there is some cool stuff I can do with $p(x)$ then I should be able to do that with the characteristic polynomial because $p(x)$ may be the characteristic polynomial.
- Maybe... I can't assume that k is algebraically closed. But then that means I can't use the C-H theorem for the first part.

□

Exercise. (Problem 3) Suppose that the field k contains m distinct m-th roots of 1. Suppose that $T^m = \mathrm{Id}_V \in \mathrm{End}_k(V)$. Show that there is a basis of V with respect to which, the matrix for T is diagonal. What can you say about the diagonal entries?