Advanced Differential Equations

Chapter 1. Systems of Linear Differential Equations Section 1.5. The Constant Coefficient Case: Real and Distinct Eigenvalues—Proofs of Theorems







Theorem 1.5.1. Let A be a constant matrix. A fundamental matrix Φ for y' = Ay is $\Phi = e^{At}$.

Proof. We have $\frac{d}{dt}[e^{At}] = Ae^{At}$ and $\det(e^{At}) \neq 0$ by Theorem 1.4.4.

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Theorem 1.5.2. If $B = TAT^{-1}$, then A and B have the same eigenvalues. **Proof.** First, $B - \lambda \mathcal{I} = TAT^{-1} - \lambda TT^{-1} = T(A - \lambda \mathcal{I})T^{-1}$. By Theorem 1.2.3,

 $\det(B - \lambda \mathcal{I}) = \det(T)\det(A - \lambda \mathcal{I})\det(T^{-1}).$

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Since T (and T^{-1}) are invertible, then det $(T) \neq 0$ and det $(T^{-1}) \neq 0$ by Theorem 1.2.4. So det $(B - \lambda I) = 0$ if and only if det $(A - \lambda I) = 0$, so that A and B have the same eigenvalues, as claimed.

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Theorem 1.5.3. If A is a constant matrix, λ is an eigenvalue of A and \vec{c} a corresponding eigenvector, then $\vec{y} = e^{\lambda t} \vec{c}$ is a solution of $\vec{y}' = A \vec{y}$.

Proof. First,

$$A\vec{y} = Ae^{\lambda t}\vec{c} = e^{\lambda t}(A\vec{c}) = e^{\lambda t}(\lambda\vec{c}) = \lambda e^{\lambda t}\vec{c}.$$

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