Homework for Lecture 4 of Dr. Z.'s Dynamical Models in Biology class

Email the answers (as .pdf file) to

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by 8:00pm Monday, Sept. 22, 2025.

Subject: hw4

with an attachment hw4FirstLast.pdf and/or hw4FirstLast.txt

1. Give an example of a second-order linear differential equation, with two specific functions that are solutions and verify that their sum also satisfies that same differential equation.

2. Verify that $y_1(t) = t^2$ satisfies the differential equation

$$y'(t)^2 - 4y(t) = 0 \quad .$$

Would you expect the function $y_2(t) = 2y_1(t) = 2t^2$ to also be a solution? (after all it is a constant multiple of $y_1(t)$). Explain. Verify that indeed $y_2(t)$ is **not** a solution.

3. Give an example of a second-order linear recurrence equation, with two specific sequences that are solutions and verify that their sum also satisfies that same recurrence equation.

4. Consider the non-linear recurrence

$$a(n) = a(n-1)^2 \quad , n \geq 0 \quad .$$

Check that both sequences

$$a_1(n) := 2^{2^n} \quad , \quad a_2(n) := 3^{2^n} \quad ,$$

are solutions. Does it follow that the new sequence

$$a_3(n) := a_1(n) + a_2(n) = 2^{2^n} + 3^{2^n} \quad ,$$

is automatically yet-another-solution? Explain why or why not. By directly plugging-in into the recurrence find out whether it is true.

5. Write the Maple commands to solve each of the following problems, and give the Maple output.

a. Solve the Initial Value Problem Differential Equation

$$y''(x) + y(x) = 0 \quad , \quad y(0) = 1 \quad , y'(0) = 1 \quad .$$

. **b** Solve the Initial Value Problem Difference Equation

$$a(n) - 3a(n-1) + a(n-2) \; = n \quad a(0) = 1, a(1) = 3 \quad .$$

c. Find the eigenvalues and eigenvectors of the matrix

$$\begin{bmatrix} 3 & 4 \\ 2 & 4 \end{bmatrix}$$

Daniyal Chaudhry HW4

1) Here is a 2nd order DE: $y''(x) + 7y'(x) + 10y(x) = 0$

Characteristic eq: $r^2 + 7r + 10 = 0 \Rightarrow (r+2)(r+5) = 0 \Rightarrow r = -2, -5$
Gen Soln: $\underline{c_1 e^{-2t} + c_2 e^{-5t}}$ We now know that solutions will fall under this form.

Two arbitrary yet specific examples. ① $y_1 = e^{-2t} + e^{-5t}$ fits the form w/ $c_1 = c_2 = 1$
② $y_2 = 2e^{-2t} + 3e^{-5t}$ fits w/ $c_1 = 2,\ c_2 = 3$
Their sum ③ $e^{-2t} + e^{-5t} + 2e^{-2t} + 3e^{-5t} \Rightarrow y_3 = 3e^{-2t} + 4e^{-5t}$ ALSO is a solution w/ $c_1 = 3,\ c_2 = 4$.

2) Check $y_1 = t^2$ as a sol'n of $(y')^2 - 4y = 0$: if $y_1 = t^2$, $y_1' = 2t \Rightarrow (2t)^2 - 4(t^2) = 4t^2 - 4t^2 = 0$ (yes)

$y_2 = 2y_1$ is not inherently a solution, as this DE is not linear so the linear combinations of known solutions are <u>not given</u> to be other solutions.

Verifying: $y_2 = 2t^2,\ y_2' = 4t$: $(4t)^2 - 4(2t^2) \overset{?}{=} 0 \rightarrow 16t^2 - 8t^2 = 8t^2 \neq 0$ Not a solution

3) Here is a second order rec. eq.: $a(n) + 7a(n-1) + 10a(n-2) = 0$

char. eq: $z^2 + 7z + 10 = 0 \Rightarrow z = -2, -5$ (from before)

Gen soln: $c_1(-2)^n + c_2(-5)^n$ Solutions will be of this form.

Two specific soln s: ① $a_1(n) = (-2)^n + (-5)^n$ with $c_1 = c_2 = 1$
② $a_2(n) = 2(-2)^n + 3(-5)^n$ with $c_1 = 2,\ c_2 = 3$

Their sum: ③ $a_3(n) = (-2)^n + (-5)^n + 2(-2)^n + 3(-5)^n = 3(-2)^n + 4(-5)^n$ is ALSO a sol'n w/ $c_1 = 3,\ c_2 = 4$

4) $a(n) = a(n-1)^2,\ n \geq 0$
$a_1(n) = 2^{2^n}$ $a_2(n) = 3^{2^n}$

plug in:
$a_1(n) \rightarrow (2^{2^{n-1}})^2 \rightarrow (2^{2^n \cdot 2^{-1} \cdot 2}) \rightarrow (2^{2^n})$ this is a sol'n
$a_2(n) \rightarrow (3^{2^{n-1}})^2 \rightarrow (3^{2^n \cdot 2^{-1} \cdot 2}) \rightarrow (3^{2^n})$ this is a sol'n

It does <u>not</u> follow that their sum is a solution, as the recurrence is nonlinear and there is no property to suggest this conclusion.

$a_3(n) = 2^{2^n} + 3^{2^n}$: plug in: $a_3(n) \rightarrow (2^{2^{n-1}} + 3^{2^{n-1}})^2 \rightarrow (2^{2^{n-1}})^2 + 2(2^{2^{n-1}})(3^{2^{n-1}}) + (3^{2^{n-1}})^2$

shown

$\hookrightarrow \underbrace{2^{2^n} + 3^{2^n}}_{\text{our desired form}} + \underbrace{2(2^{2^{n-1}})(3^{2^{n-1}})}_{\text{an added relevant term that makes this NOT a solution}}$

5) a) dsolve({diff(y(x), x$2) + y(x) = 0, y(0) = 1, D(y)(0) = 1}, y(x)); The answer is $y(x) = \sin(x) + \cos(x)$

b) rsolve({a(n) - 3*a(n-1) + a(n-2) = n, a(0) = 1, a(1) = 3}, a(n)); Answer: $\left(\frac{1}{2} - \frac{3\sqrt{5}}{10}\right)\left(-\frac{\sqrt{5}}{2} + \frac{3}{2}\right)^n + \left(\frac{3\sqrt{5}}{10} + \frac{1}{2}\right)\left(\frac{3}{2} + \frac{\sqrt{5}}{2}\right)^n - n - 1 - \frac{(\sqrt{5}+1)\sqrt{5}\left(-\frac{2}{-3-\sqrt{5}}\right)^n}{5(-3-\sqrt{5})} - \frac{(\sqrt{5}-1)\sqrt{5}\left(-\frac{2}{\sqrt{5}-3}\right)^n}{5(\sqrt{5}-3)}$

c) with(linalg);
A:= matrix([[3,4],[2,4]]);
eigenvalues(A);
eigenvectors(A);

$$\left\{\begin{array}{l} \lambda_1 = \frac{7}{2} + \frac{\sqrt{33}}{2} \quad \vec{v}_1 = \begin{bmatrix} 1 \\ \frac{1}{8} + \frac{\sqrt{33}}{8} \end{bmatrix} \\ \lambda_2 = \frac{7}{2} - \frac{\sqrt{33}}{2} \quad \vec{v}_2 = \begin{bmatrix} 1 \\ \frac{1}{8} - \frac{\sqrt{33}}{8} \end{bmatrix} \end{array}\right.$$