Assignment 2

EE3900: Linear Systems and Signal Processing

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Oppenheim and Schafer

Problem 2.13 (b)
which of the following discrete-time signals are eigenfunctions of stable, LTI discrete-time systems?
Given 3^n
Solution:
Consider a linear time invariant system with impulse response h[n] operating on some space of infinite length discrete time signals. Recall that the output $H[x(n)]$.
$H(x[n])$ of the system for a given input $h[n] * x[n]$ is given by the discrete time convolution of the impulse response with the input

$$H[x(n)] = \sum_{k=-\infty}^{\infty} h[k]x[n-k]$$

lets try $x(n) = e^{sn}$ Computing the output fot the input

$$\begin{aligned} H(e^{sn}) &= \sum_{k=-\infty}^{\infty} h[k]e^{s(n-k)} \\ &= \sum_{k=-\infty}^{\infty} h[k]e^{sn}e^{-sk} \\ &= e^{sn}\sum_{k=-\infty}^{\infty} h[k]e^{-sk} \end{aligned}$$

Therefore we have

$$H(e^{sn}) = \lambda_s e^{sn}$$

$$\lambda_s = \sum_{k=-\infty}^{\infty} h[k]e^{-sk}$$

So the given inputs are eigenfunctions and the output is given as shown.

The output signal is given by

$$H(3^n) = \lambda_s 3^n$$

$$\lambda_s = \sum_{k=-\infty}^{\infty} h[k]3^{-k}$$

We can write 3^n as $e^{n\ln 3}$.Here $s = \ln 3$.Therefore the given input signal is eigenfunction of LTI system.