	Marwadi University **Faculty of Engineering & Technology** **Department of Information and Communication Technology**	
Subject: Programming With Python (01CT1309)	**Aim:** Analysis of LTI System Responses to Standard Inputs Using Python	
Experiment No: 19	**Date:**	**Enrollment No:92400133131**

GITHUB LINK:- https://github.com/farhan-web404/farhankaladiya.git

Aim: Analysis of LTI System Responses to Standard Inputs Using Python

IDE:

Analyzing Discrete-Time Systems Using Z-Transform

The Z-transform is used for analyzing discrete-time signals and systems. The Z-transform of a discrete-time signal $x[n]$ is given by:

$$X(z) = \sum_{n=-\infty}^{\infty} x[n] z^{-n}$$

where z is a complex variable, $X(z)$ represents the Z-transform of the signal.

Z-Transform Function

For an LTI system, the Z-transform function $H(z)$ is defined as:

$$H(z) = \frac{B(z)}{A(z)} = \frac{b_0 + b_1 z^{-1} + \cdots + b_m z^{-m}}{a_0 + a_1 z^{-1} + \cdots + a_n z^{-n}}$$

where $B(z)$ is the numerator polynomial, $A(z)$ is the denominator polynomial.

Stability

A discrete-time system is stable if all poles of its Z-transfer function lie inside the unit circle in the Z-plane. To check stability:

Calculate the poles of $H(z)$

Check if the magnitude of each pole is less than 1.

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Causality

A system is causal if its impulse response $h[n]$ is zero $n < 0$. This generally means that the numerator polynomial should not have terms that depend on future values.

Time Invariance

A system is time-invariant if a time shift in the input results in an equivalent time shift in the output. For LTI systems, if the system is defined properly, it is generally assumed to be time-invariant. **Example**

$$H(z) = \frac{(z^2 + 0.5)}{(z^2 - 1.5z + 0.5)}$$

Bode Plot Analysis

Stability:

- Check the gain and phase margins.
- Ensure that both margins are positive for stability.

Causality:

- Examine the magnitude and phase at low frequencies.
- Confirm that the system behaves as a causal system (magnitude starts lower, phase starts near 0 and decreases). **Time Invariance:**
- If the system is LTI, it is inherently time-invariant.
- Analyse the impulse response (if available) to verify consistent responses to delayed inputs.

Python Implementation import numpy as np

import matplotlib.pyplot as plt from

scipy.signal import TransferFunction, lti

```
def analyze_z_transfer_function(num, den):

    # Create a Transfer Function object

system = TransferFunction(num, den)


    # Get the poles and zeros     zeros = system.zeros

poles = system.poles     print("Zeros:", zeros)

print("Poles:", poles)     # Stability Analysis     stable =

all(np.abs(pole) < 1 for pole in poles)

print("Stability:", "Stable" if stable else "Unstable")


    # Causality Analysis     causal = all(num[i] == 0 for i in range(len(num)

- 1) if num[i + 1] == 0)     print("Causality:", "Causal" if causal else

"Non-Causal")

    # Time Invariance Analysis     time_invariant = True  # For Z-transforms, generally time-

invariant if system defined properly     print("Time Invariance:", "Time Invariant" if

time_invariant else "Time Variant")

    # Bode plot (magnitude and phase)

w, mag, phase = bode(system)

    # Plot Bode plot

plt.figure(figsize=(12, 8))
```

```
plt.subplot(2, 1, 1)    plt.semilogx(w,
mag)    # Bode magnitude plot
plt.title('Bode Magnitude Plot')
plt.xlabel('Frequency [rad/s]')
plt.ylabel('Magnitude [dB]')    plt.grid()
plt.subplot(2, 1, 2)    plt.semilogx(w,
phase)   # Bode phase plot
plt.title('Bode Phase Plot')
plt.xlabel('Frequency [rad/s]')
plt.ylabel('Phase [degrees]')    plt.grid()
plt.tight_layout()    plt.show()
# Example: Analyzing a specific system H(z) = (z^2 + 0.5)/(z^2 - 1.5z + 0.5)
num = [1, 0.5]  # Numerator coefficients den = [1, -1.5, 0.5]  #
Denominator coefficients analyze_z_transfer_function(num, den)
```

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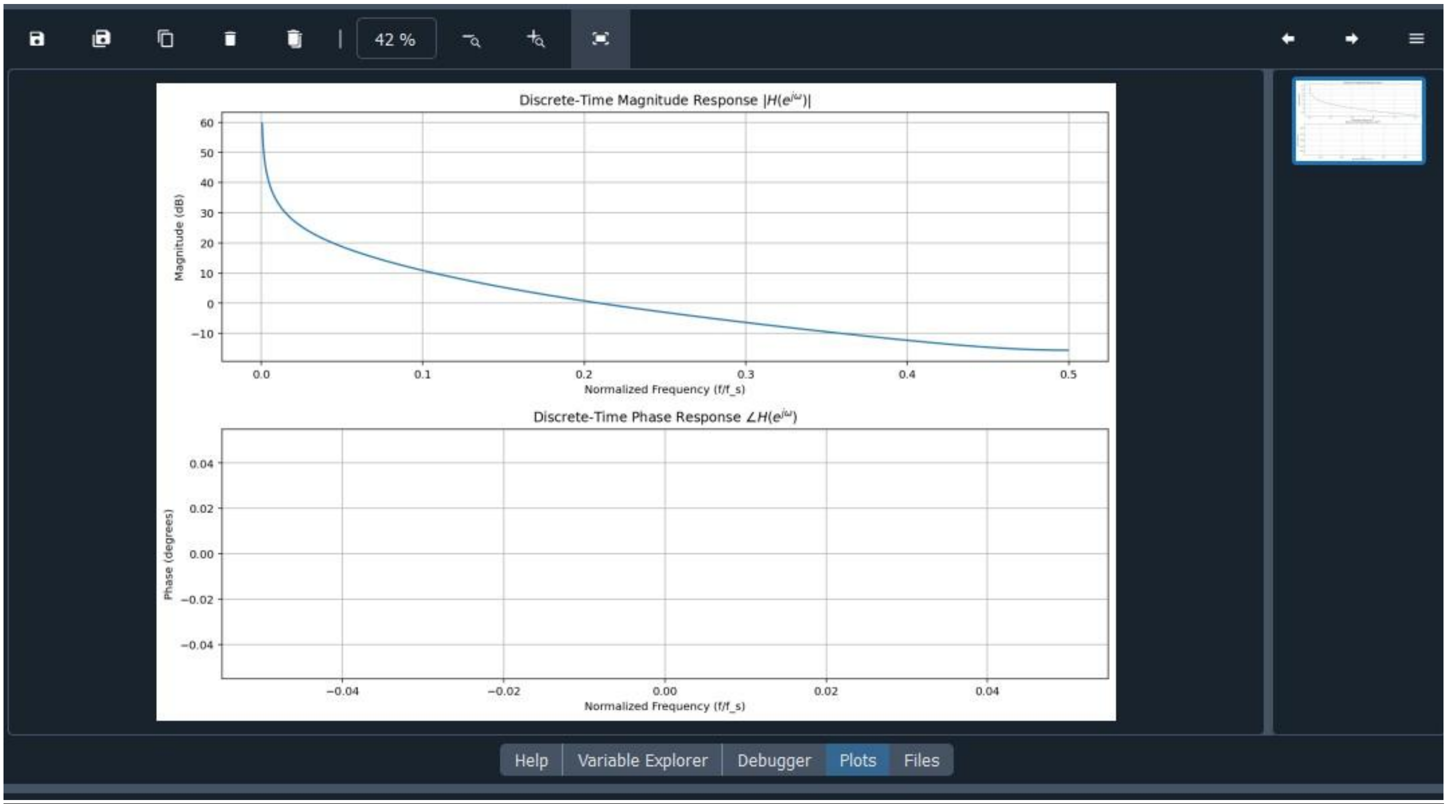
OUTPUT:



Transfer Function :

$$H(z) = \frac{0.5}{1 - 0.8z^{-1}}$$

Causality: This system is causal because the denominator has a non-negative exponent (i.e., all powers of z^{-1} are non-negative).

Stability: The system is stable if the poles (the roots of the denominator) lie inside the unit circle. Here, the pole is $z = 0.8$, which is inside the unit circle, so the system is stable.

Time Invariance: The system is time-invariant because the coefficients do not depend on time.

Transfer function:

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$$H(z) = \frac{1 - z^{-1}}{1 - 0.5z^{-1}}$$

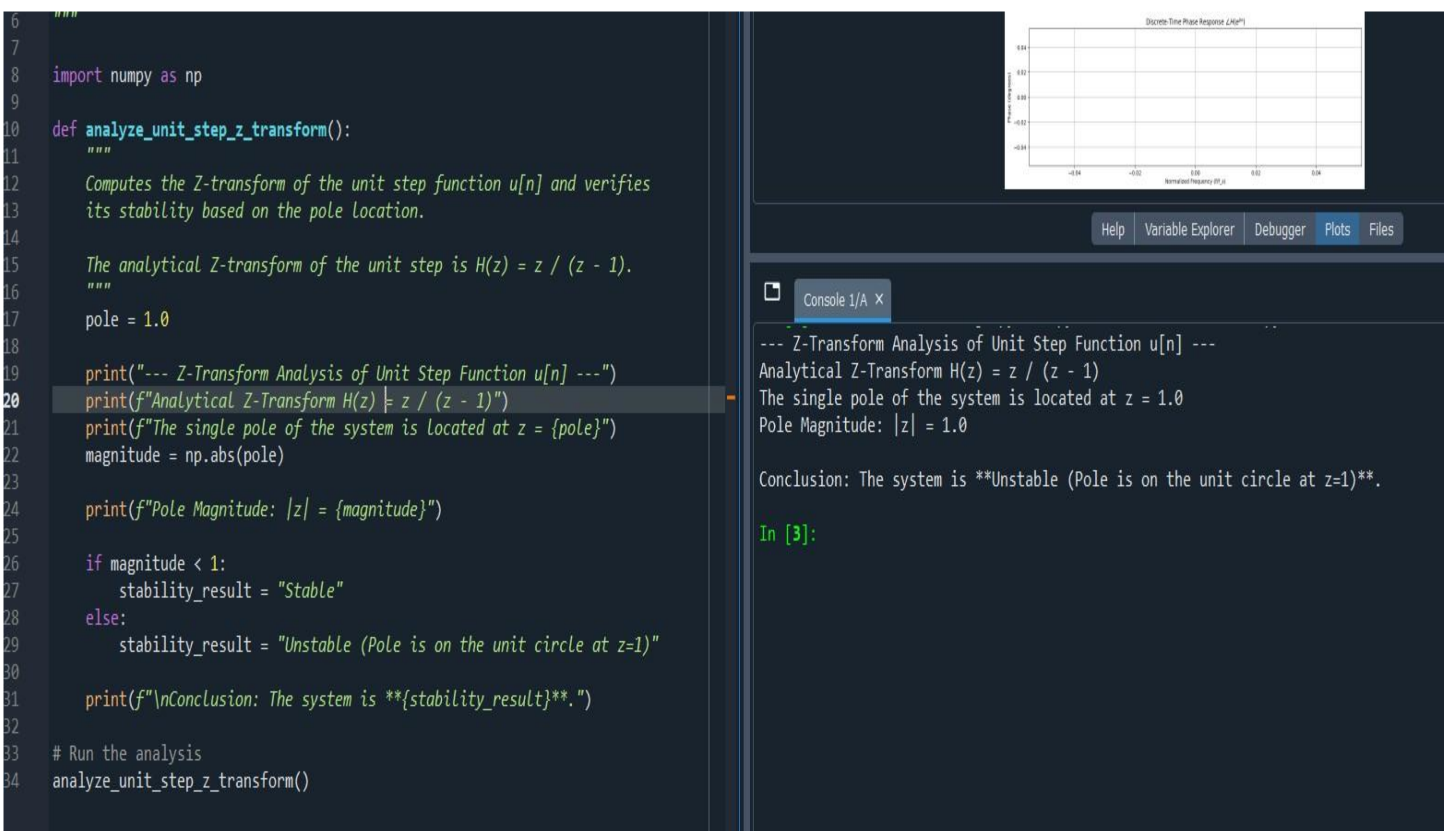
Causality: This system is causal.

Stability: The pole at $z = 0.5$ is inside the unit circle, making the system stable. Time

Invariance: The system is time-invariant

Post Lab Exercise:

- Write a Python function to compute the Z-transform of an unit step function. verify whether the system is stable or unstable. Code and output:-



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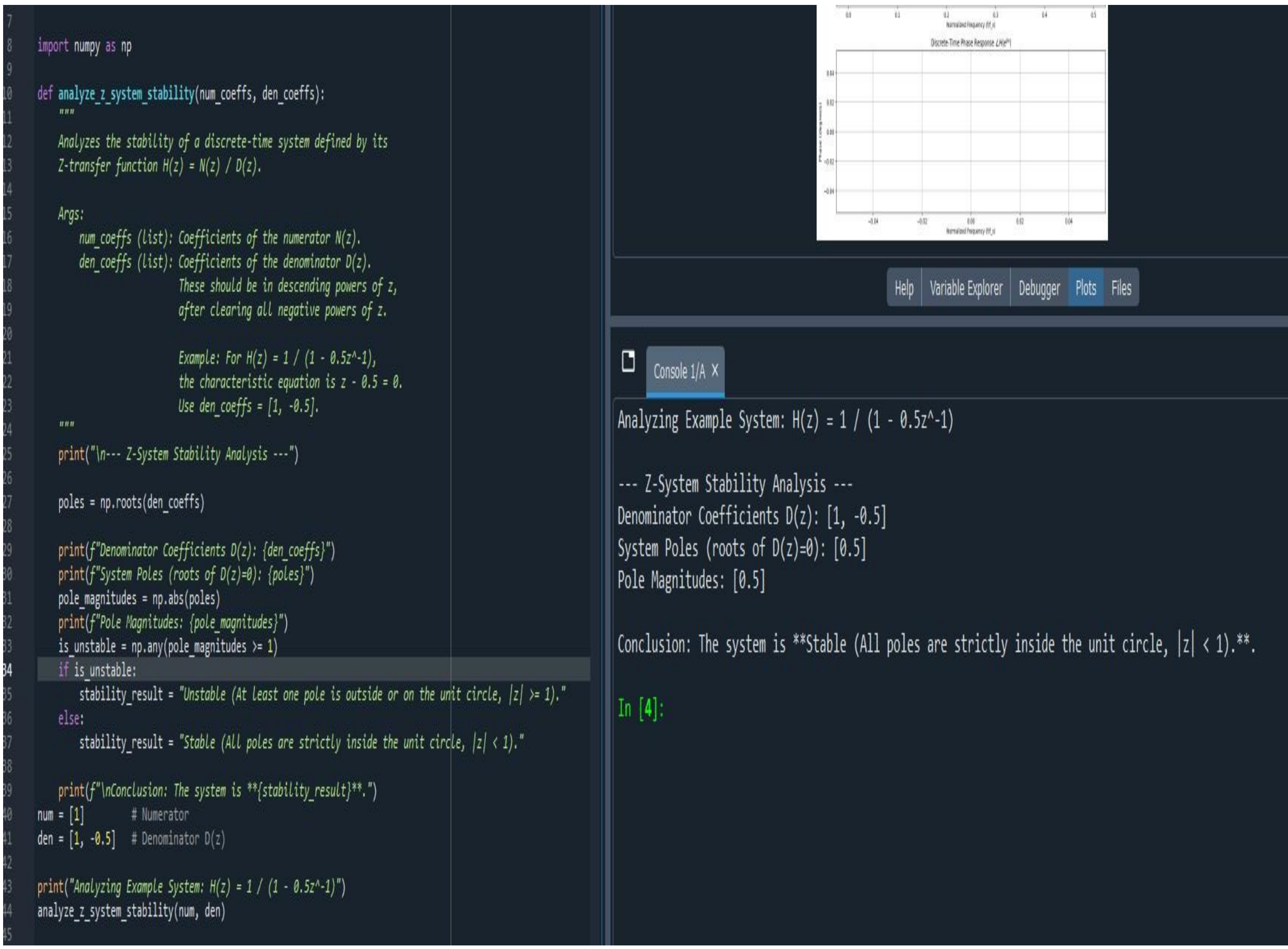
- Implement this for the system $H(z) = \frac{0.5(z-0.7)(z-0.9)}{(z-0.6)(z-0.4)}$ and verify whether the system is stable or



unstable.

Code and output: