

# EE571 HW Feature Demo

Template Showcase    2025-09-01

**Problem 1:** This demonstrates the basic problem command with automatic numbering.

This is how you create a basic problem. The numbering happens automatically (Problem 1, Problem 2, etc.).

**Problem A.1:** This demonstrates custom problem numbering.

You can override the automatic numbering by providing a custom label in square brackets.

**Problem 3:** Find the derivative of  $f(x) = 3x^2 + 2x - 5$  and evaluate it at  $x = 2$ .

This shows how to include the actual question or description within the problem command.  
Using the power rule:

$$\begin{aligned} f(x) &= 3x^2 + 2x - 5 \\ f'(x) &= 6x + 2 \\ f'(2) &= 6(2) + 2 &= 12 + 2 = 14 \end{aligned}$$

**Problem 4:** This problem demonstrates sub-problems with multiple parts.

(a)

Find the transfer function of the system.

Given the differential equation  $\ddot{y} + 3\dot{y} + 2y = 5u(t)$ :

$$\begin{aligned} s^2Y(s) + 3sY(s) + 2Y(s) &= 5U(s) \\ G(s) &= \frac{Y(s)}{U(s)} &= \frac{5}{s^2 + 3s + 2} \end{aligned}$$

(b)

Factor the denominator and find the poles.

$$\begin{aligned} s^2 + 3s + 2 &= (s + 1)(s + 2) \\ \text{Poles: } s_1 &= -1, \quad s_2 &= -2 \end{aligned}$$

(iii)

Determine system stability (custom sub-problem numbering).

Since both poles have negative real parts, the system is stable.

**Problem 5:** Demonstrate the hwmath environment for aligned equations.

The hwmath environment provides automatic alignment on equals signs using the `textbackslash eq` shorthand:

$$\begin{aligned} \mathcal{L}\{f(t)\} &= F(s) \\ \mathcal{L}\{\dot{f}(t)\} &= sF(s) - f(0) \\ \mathcal{L}\{\ddot{f}(t)\} &= s^2F(s) - sf(0) - \dot{f}(0) \end{aligned}$$

**Problem 6:** Show numbered equations for referencing.

For equations that need to be referenced later, use `hwmathnumbered`:

$$E = mc^2 \tag{1}$$

$$F = ma \tag{2}$$

$$P = VI \tag{3}$$

These equations are numbered automatically and can be referenced in the text.

**Problem 7:** Demonstrate complex mathematical formatting capabilities.

(a)

Matrix operations and state-space representation.

$$\begin{aligned}\dot{\mathbf{x}} &= \mathbf{Ax} + \mathbf{Bu} \\ \mathbf{y} &= \mathbf{Cx} + \mathbf{Du}\end{aligned}$$

Where the system matrices are:

$$\mathbf{A} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -2 & -3 & -4 \end{bmatrix}, \quad \mathbf{B} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}, \quad \mathbf{C} = [1 \quad 0 \quad 0]$$

(b)

Convolution integral and Laplace transforms.

The convolution of two functions:

$$(f * g)(t) = \int_{-\infty}^{\infty} f(\tau)g(t - \tau)d\tau$$

Laplace transform definition:

$$\mathcal{L}\{f(t)\} = \int_0^{\infty} f(t)e^{-st}dt$$

**Problem 8:** Demonstrate the `note` command for highlighting important information.

The `note` command displays text in bold, red, and large font:

**IMPORTANT: Check all calculations before submitting**

**TODO: Add numerical verification**

**FIX ME: Verify units are consistent**

**NOTE**

This is useful for marking sections that need attention during review.

**Problem 9:** Demonstrate the `hwmatlab` environment for MATLAB code.

(a)

MATLAB function with caption.

Listing 1: Second Order System Analysis

```
function [y, t] = second_order_response(wn, zeta, K, tfinal)
    % Calculate step response of second order system
    % wn: natural frequency, zeta: damping ratio, K: gain

    s = tf('s');
    G = K * wn^2 / (s^2 + 2*zeta*wn*s + wn^2);

    [y, t] = step(G, tfinal);

    figure;
    plot(t, y, 'LineWidth', 2);
    xlabel('Time (s)');
    ylabel('Amplitude');
    title('Step Response');
    grid on;
end
```

(b)

Simple MATLAB commands without caption.

```
% Define system parameters
wn = 5;           % Natural frequency (rad/s)
zeta = 0.3;       % Damping ratio
K = 2;           % Gain

% Calculate and plot response
[y, t] = second_order_response(wn, zeta, K, 2);
```

**Problem 10:** Demonstrate the hwpython environment for Python code.

(a)

Python implementation with caption.

Listing 2: Control Systems Analysis in Python

```
import numpy as np
import matplotlib.pyplot as plt
import control as ct

def second_order_response(wn, zeta, K, tfinal):
    """
    ---- Calculate step response of second order system
    ---- Parameters:
    ----- wn: natural frequency (rad/s)
    ----- zeta: damping ratio
    ----- K: gain
    ----- tfinal: final time for simulation
    ---- """

    # Create transfer function
    num = [K * wn**2]
    den = [1, 2*zeta*wn, wn**2]
    G = ct.tf(num, den)

    # Calculate step response
    t = np.linspace(0, tfinal, 1000)
    y, t = ct.step_response(G, t)
```

```

# Plot results
plt.figure(figsize=(10, 6))
plt.plot(t, y, linewidth=2, label='Step-Response')
plt.xlabel('Time (s)')
plt.ylabel('Amplitude')
plt.title(f'Second-Order-System (wn={wn}, zeta={zeta}, K={K})')
plt.grid(True, alpha=0.3)
plt.legend()
plt.show()

return y, t

```

(b)

Python data analysis without caption.

```

# System parameters
wn = 5.0      # Natural frequency
zeta = 0.3    # Damping ratio
K = 2.0       # Gain

# Performance metrics
overshoot = np.exp(-zeta*np.pi/np.sqrt(1-zeta**2)) * 100
settling_time = 4 / (zeta * wn)
peak_time = np.pi / (wn * np.sqrt(1 - zeta**2))

print(f'Overshoot: {overshoot:.1f}%')
print(f'Settling-time: {settling_time:.2f}-s')
print(f'Peak-time: {peak_time:.2f}-s')

```

**Problem 11:** Demonstrate the hwterminal environment for terminal output.

The hwterminal environment displays terminal commands and output with appropriate styling:

```

>> wn = 5; zeta = 0.3; K = 1;
>> s = tf('s');
>> G = K*wn^2/(s^2 + 2*zeta*wn*s + wn^2);
>> step(G);
>> stepinfo(G)

ans =
    RiseTime: 0.2927
    SettlingTime: 2.6667
    SettlingMin: 0.9000
    SettlingMax: 1.3625
    Overshoot: 36.2467
    Undershoot: 0
    Peak: 1.3625
    PeakTime: 0.6283

```

Listing 3: MATLAB Simulation Output

```

$ pip install control matplotlib numpy
Collecting control
  Downloading control-0.9.4-py3-none-any.whl (719 kB)
  ===== 719.0/719.0 kB 5.2 MB/s
Collecting matplotlib
  Downloading matplotlib-3.7.2-cp311-cp311-macosx_10_12_x86_64.whl (7.8 MB)
  ===== 7.8/7.8 MB 8.4 MB/s
Successfully installed control-0.9.4 matplotlib-3.7.2 numpy-1.24.3

```

Listing 4: Python Package Installation

**Problem 12:** Demonstrate the hwgraphic command for including images.

The hwgraphic command provides a convenient wrapper for including graphics with automatic centering:

(a)

Command syntax and features.

**Basic syntax:**

`\hwgraphic{path}[optional title][optional scale]`

**Key features:**

- Automatic centering of images
- Optional title with bold formatting
- Default sizing to 80% of text width
- Custom scaling support with scale parameter
- Works with PNG, JPG, PDF, and EPS formats

**Usage examples:**

- `\hwgraphic{figure.png}` - Basic inclusion with default size
- `\hwgraphic{plot.pdf}[System Response]` - With title
- `\hwgraphic{diagram.jpg}[Circuit Diagram][0.6]` - With title and 60% scale

**NOTE: Actual image files must exist for the hwgraphic command to work in practice**

**Problem 13:** Showcase advanced mathematical typesetting capabilities.

(a)

Partial derivatives and multivariable calculus.

$$\begin{aligned}\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} &= 0 \quad (\text{Laplace's equation}) \\ \nabla^2 u &= \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} = 0\end{aligned}$$

(b)

Complex analysis and frequency domain.

$$\begin{aligned}H(j\omega) &= \frac{K}{j\omega + a} \\ |H(j\omega)| &= \frac{K}{\sqrt{\omega^2 + a^2}} \\ \angle H(j\omega) &= -\arctan\left(\frac{\omega}{a}\right)\end{aligned}$$

**Problem 14:** Demonstrate piecewise functions and special mathematical constructs.

(a)

Unit step and impulse functions.

$$\begin{aligned}u(t) &= \begin{cases} 1 & t \geq 0 \\ 0 & t < 0 \end{cases} \\ \delta(t) &= \begin{cases} \infty & t = 0 \\ 0 & t \neq 0 \end{cases}, \quad \int_{-\infty}^{\infty} \delta(t) dt = 1\end{aligned}$$

(b)

System response types based on damping.

$$\text{Response type} = \begin{cases} \text{Overdamped} & \zeta > 1 \\ \text{Critically damped} & \zeta = 1 \\ \text{Underdamped} & 0 < \zeta < 1 \\ \text{Undamped} & \zeta = 0 \end{cases}$$

**Problem 15:** Show integration with standard LaTeX environments and packages.

The homework class works seamlessly with standard LaTeX features:

- Standard lists and enumerations
- Mathematical symbols:  $\alpha, \beta, \gamma, \Delta, \Omega$
- Greek letters and special symbols:  $\infty, \partial, \nabla, \sum, \int$
- Text formatting: **bold**, *italic*, `monospace`

1. First numbered item
2. Second numbered item with math:  $E = mc^2$
3. Third item with inline code: `plot(x, y)`

**Problem 16:** Comprehensive example combining all features.

## FINAL EXAMPLE: Combines multiple features

(a)

Design a control system.

Given plant:  $G_p(s) = \frac{10}{s(s+2)}$

Design a PID controller:  $G_c(s) = K_p + \frac{K_i}{s} + K_d s$

$$G_{ol}(s) = G_c(s)G_p(s) \tag{4}$$

$$G_{cl}(s) = \frac{G_{ol}(s)}{1 + G_{ol}(s)} \tag{5}$$

(b)

MATLAB implementation.

Listing 5: PID Controller Design and Analysis

```
% Plant transfer function
s = tf('s');
Gp = 10 / (s * (s + 2));

% PID controller parameters
Kp = 5; Ki = 2; Kd = 0.5;
Gc = pid(Kp, Ki, Kd);

% Closed-loop system
Gcl = feedback(Gc * Gp, 1);
```

```

% Analysis
step(Gcl);
title('Closed-Loop-Step-Response');
grid on;

% Display controller
fprintf('PID-Controller: -Kp=%.1f, -Ki=%.1f, -Kd=%.1f\n', Kp, Ki, Kd);

```

(\*)

Bonus: Python verification.

Listing 6: Python Control Systems Verification

```

import control as ct
import numpy as np
import matplotlib.pyplot as plt

# Plant transfer function
Gp = ct.tf([10], [1, 2, 0])

# PID controller
Kp, Ki, Kd = 5, 2, 0.5
Gc = ct.tf([Kd, Kp, Ki], [1, 0])

# Closed-loop system
Gcl = ct.feedback(Gc * Gp, 1)

# Step response
t = np.linspace(0, 5, 1000)
y, t = ct.step_response(Gcl, t)

plt.figure(figsize=(10, 6))
plt.plot(t, y, 'b-', linewidth=2)
plt.xlabel('Time (s)')
plt.ylabel('Output')
plt.title('PID-Controlled-System-Step-Response')
plt.grid(True, alpha=0.3)
plt.show()

print(f"Controller: -PID({Kp}, -{Ki}, -{Kd})")

```

This example demonstrates the complete integration of mathematical typesetting, code environments, problem structuring, and highlighting features available in the homework class.

# Appendix A

## T

his is the first appendix. It contains additional derivations and supplementary material.

Extended derivation of the quadratic formula:

$$ax^2 + bx + c = 0$$

$$ax^2 + bx = -c$$

$$x^2 + \frac{b}{a}x = -\frac{c}{a}$$

$$x^2 + \frac{b}{a}x + \left(\frac{b}{2a}\right)^2 = -\frac{c}{a} + \left(\frac{b}{2a}\right)^2$$

$$\left(x + \frac{b}{2a}\right)^2 = \frac{b^2 - 4ac}{4a^2}$$

$$x + \frac{b}{2a} = \pm \frac{\sqrt{b^2 - 4ac}}{2a}$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$



# Appendix Reference Tables

T

his appendix contains useful reference tables and formulas.

Transform	Time Domain	Frequency Domain
Unit Step	$u(t)$	$\frac{1}{s}$
Ramp	$t \cdot u(t)$	$\frac{1}{s^2}$
Exponential	$e^{-at} \cdot u(t)$	$\frac{1}{s+a}$
Sine	$\sin(\omega t) \cdot u(t)$	$\frac{\omega}{s^2+\omega^2}$

Table 1: Common Laplace Transform Pairs

# Appendix C

T

his is the third appendix, showing automatic lettering continues (Appendix C).

**NOTE** Appendices are useful for including detailed calculations, reference materials, or code listings that would interrupt the flow of the main document.