E9 213 Time-Frequency Analysis - Assignment 2

Submission Deadline: September 9, 2025, 11:59 PM

Instructions

- Give concise answers.
- Use either **MATLAB** or **Python** to solve the programming problems. Comment your code appropriately to enhance readability.
- Plots must be clearly labelled with titles, scale, and axes labels.
- For Python Coders: Submit a single Jupyter Notebook named `E9_213_A1_FirstNameLastName_Code.ipynb` and delineate the code for each question in separate, clearly labeled cells. Upload only the the Notebook (`.ipynb`) and report (`.pdf`) via Teams before the deadline.
- For Matlab Coders: For each problem, create a corresponding file named `run_Problem1.mat`, `run_Problem2.mat`, etc. Submit a single zipped folder named `E9_213_A1_FirstNameLastName.zip`, containing all scripts and the report (`.pdf`), via Teams before the deadline.
- Submit the report with all the results, such as images or numerical outputs, along with your assumptions, analytical computations, observations and conclusions.
- Name your report as `E9_213_A1_FirstNameLastName_Report.pdf`.
- Use of AI tools such as ChatGPT to solve this assignment will result in zero marks.
- Resorting to unfair means such as copying will result in zero marks.

1. Cosine Signal Analysis — 5 Points

For the function $f(t) = \cos(\omega t)$:

i) Generate the sampled signal $f(t)|_{t=nT_s}$.

ii) Compute its Fourier transform.

iii) Display the magnitude spectrum and the phase spectrum.

2. Plotting Densities — 5 Points

Display the following densities:

i) $f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-x^2}{2\sigma^2}}; \quad x \in \mathbb{R}$

ii) $f(x) = \frac{1}{\pi(1+x^2)}; \quad x \in \mathbb{R}$

iii) $f(x) = \begin{cases} k\lambda e^{-\lambda x}, & x > 0 \\ 0, & \text{otherwise} \end{cases}$

3. Characteristic Functions — 5 Points

Compute analytically the characteristic functions of the densities in question (2). Display:

i) The magnitude: $|\chi(t)|$

ii) The phase: $\angle\chi(t)$

4. Displaying Complex Signals — 5 Points

Display the following signals:

i) $f(t) = e^{j\omega_0 t}$

ii) $f(t) = ke^{j\omega_0 t} e^{-\frac{(t-t_0)^2}{2\sigma^2}}$

iii) $f(t) = e^{j(\alpha t^2 + \beta t + \gamma)}$

5. Fourier Transform of a Gaussian — 5 Points

For the function $f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}; \quad x \in \mathbb{R}$:

i) Compute its Fourier Transform, $\hat{f}(\omega)$, analytically.

ii) Display $|f(x)|$ and $|\hat{f}(\omega)|$ for various values of μ and σ.

6. Modulated Gaussian Signal — 5 Points

Repeat question (5) for the function $f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} e^{j\omega_0 x}; \quad x \in \mathbb{R}$. Display for various values of μ, σ and ω_0.