CCIT4076: Engineering and Information Science
Midterm Exam: Demo Paper

November 6, 2022

Time Limit: 90 minutes **Full Mark: 50 points**

Student Name: ________________________________

Student ID: ________________________________

Class Number: ________________________________

Notes to Candidates:

1. This is a closed-book exam. No sourcing of information is allowed.
2. You are allowed to use an HKEAA approved calculator during the exam. Unless otherwise specified, your numerical answers shall be rounded to 4 decimal places; or you may present them in rational format.
3. Doubts about the exam questions shall be raised within the first 20 minutes after the exam begins. If you believe you have found an error on the question paper thereafter, you should state and reason clearly on why do you think the question is improperly framed in this paper.
4. **Answer ALL questions on this paper.**

DO NOT TURN OVER THIS PAGE UNTIL YOU ARE TOLD TO DO SO

Appendix: List Of Equations

Motions with uniform acceleration

$$v_f = v_i + a \cdot t$$
$$d = v_i \cdot t + \frac{1}{2} \cdot at^2$$
$$d = \frac{v_f + v_i}{2} \cdot t$$
$$2ad = v_f^2 - v_i^2$$

Mechanics

$$F = m \cdot a$$
$$W = F \cdot d$$
$$E_K = \frac{1}{2} \cdot mv^2$$
$$F = G \cdot \frac{m_A m_B}{r^2}$$

Electrical Concepts and Circuits

$$F = k \cdot \frac{Q_1 Q_2}{r^2}$$
$$I = \frac{\Delta q}{\Delta t}$$
$$V = W/q$$
$$R = \frac{\rho \cdot \ell}{A}$$
$$V = I \cdot R$$
$$P = I \cdot V = I^2 \cdot R = V^2/R$$
$$R_{\text{eq}} = \sum_{i=1}^{N} R_i \qquad \text{for series network}$$
$$R_{\text{eq}} = \left(\sum_{i=1}^{N} \frac{1}{R_i} \right)^{-1} \qquad \text{for parallel network}$$
$$\sum i_{\text{in}} = \sum i_{\text{out}}$$
$$\sum v_{\text{rise}} = \sum v_{\text{drop}}$$

Periodicity

$$\sin(\theta) = \sin(\theta + 2\pi k)$$
$$\cos(\theta) = \cos(\theta + 2\pi k)$$
$$\tan(\theta) = \tan(\theta + \pi k)$$

where $k \in \mathbb{Z}$ is an integer.

Trigonometry Basics

$$\tan(\theta) = \frac{\sin(\theta)}{\cos(\theta)}$$
$$\sin(\theta) = -\sin(-\theta)$$
$$\cos(\theta) = \cos(-\theta)$$
$$\sin^2(\theta) + \cos^2(\theta) = 1$$
$$\sin(2\theta) = 2\sin(\theta)\cos(\theta)$$
$$\cos(2\theta) = 2\cos^2(\theta) - 1$$
$$\sin^2(\theta) = \frac{1 - \cos(2\theta)}{2}$$
$$\cos^2(\theta) = \frac{1 + \cos(2\theta)}{2}$$

where $\theta \in [-\pi, \pi]$.

Product to Sum Identities

$$\sin(\alpha)\sin(\beta) = \frac{1}{2}[\cos(\alpha - \beta) - \cos(\alpha + \beta)]$$
$$\sin(\alpha)\cos(\beta) = \frac{1}{2}[\sin(\alpha + \beta) + \sin(\alpha - \beta)]$$
$$\cos(\alpha)\cos(\beta) = \frac{1}{2}[\cos(\alpha - \beta) + \cos(\alpha + \beta)]$$

Angle Sum/Difference Identities

$$\sin(\alpha \pm \beta) = \sin(\alpha)\cos(\beta) \pm \cos(\alpha)\sin(\beta)$$
$$\cos(\alpha \pm \beta) = \cos(\alpha)\cos(\beta) \mp \sin(\alpha)\sin(\beta)$$
$$\tan(\alpha \pm \beta) = \frac{\tan(\alpha) \pm \tan(\beta)}{1 \mp \tan(\alpha)\tan(\beta)}$$

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Section A: Multiple Choice Questions (15 points.)

Solve all the following MC questions by choosing the best and most appropriate choice. Indicate your choice properly on the horizontal line on the right hand side. Points will be accumulated.

In the Actual Midterm Exam Paper, you are required to attempt 15 multiple-choice questions.

Consult Revision Exercises for Sample MC Questions.

Section B: Long Questions (35 points.)

Solve all the following questions. Appropriate steps must be shown to score full.

Question 1. (13 pts.) Consider the following circuit:

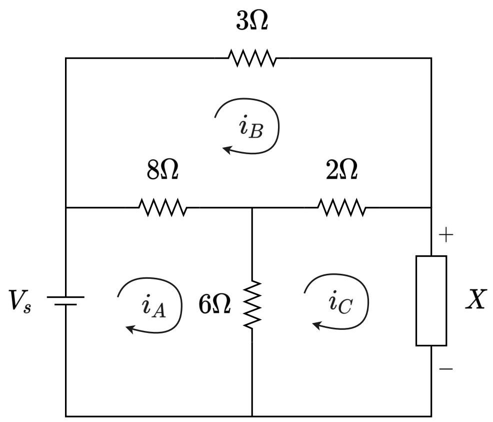

Figure: Circuit for Question 2.

(a) Suppose component X is a wire. Find the equivalent resistance R_{eq} of the resistor network over the source voltage V_s.

(b) Suppose X is a $4V$ battery and $V_s = 10V$. Apply Kirchhoff's circuit laws to find the in-loop current i_A, i_B and i_C and formulate the linear system into a matrix-vector equation.

(c) Assume the workplace is empty. Write a full piece of Octave code to solve for the in-loop currents (i_A, i_B, i_C).

(d) What are the power supplied by X in the respective settings of (a) and (b)?

Question 2. (10 pts.) Consider a periodic signal

$$g(t) = \frac{4}{3} \cdot \sin(2\pi n_0 f_0 t) + \frac{3}{2} \cdot \sin(2\pi n_1 f_0 t) + \frac{1}{2} \cdot \sin(2\pi n_2 f_0 t)$$

where the values of (n_0, n_1, n_2) are given by the following procedure: Let x be your student ID, set

$$n_3 n_2 n_1 n_0 = x \ \mathsf{mod}\ 1106$$

which can be computed through Octave (no surprise). Take an SID of 23456789 as an example, we see 23456789 mod 1106 = 0741 and thus we have a signal of

$$g(t) = \frac{4}{3} \cdot \sin(2\pi 1 f_0 t) + \frac{3}{2} \cdot \sin(2\pi 4 f_0 t) + \frac{1}{2} \cdot \sin(2\pi 7 f_0 t).$$

(a) Explicitly express your specific $g(t)$ in terms of f_0.

(b) Sketch the frequency domain representation of $g(t)$.

(c) Write down a condition on f_0 such that $g(t)$ is a fully audible signal.

(d) Let $f_0 = 100$. Assume the workplace is empty. Write a full piece of Octave code to plot $g(t)$ for $0 \leq t \leq 2T$, i.e. two periods.

Question 3. (12 pts.) Consider the following system:

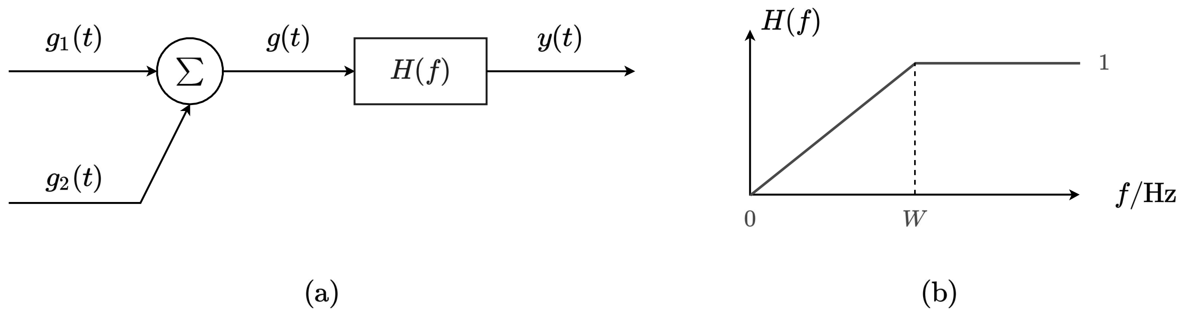

Figure: (a) System Diagram of Question 5. (b) Frequency response of $H(f)$.

where $H(f)$ is an non-ideal HPF; and the input signals are given as

$$g_1(t) = A_1 \sin(2\pi f_1 t),$$
$$g_2(t) = A_2 \sin(2\pi f_2 t).$$

Assume $(A_1, A_2, f_1, f_2) = (2, 2, 300\text{Hz}, 500\text{Hz})$; and the cut-off frequency of the high pass filter $H(f)$ is fixed at $W = 1000\text{Hz}$.

(a) Sketch the spectrum of $g(t)$.

(b) Calculate $H(300)$ and $H(500)$.

(c) Sketch the spectrum $Y(f)$ of $y(t)$. Mark the amplitudes and frequencies carefully.

(d) Is it possible to design a filter $R(f)$ which counteracts the effect of $H(f)$? Pictorially, if

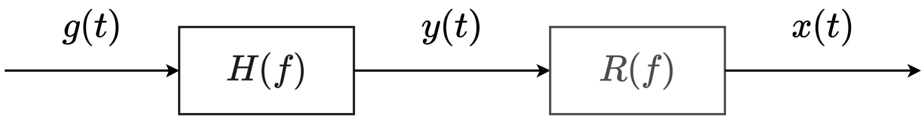

Figure: Question 3(d).

Can you design an equalizer $R(f)$ such that $x(t) = g(t)$? If your answer is yes, sketch the filter's response. Otherwise if your answer is no, briefly explain why.

— **THE END** —

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