Name...ID..............................Section.......1........Seat No..............

Sirindhorn International Institute of Technology
Thammasat University

Midterm Examination: Semester 1 / 2018

Course Title: ECS332 (Principles of Communications)

Instructor: Asst. Prof. Dr.Prapun Suksompong

Date/Time: October 5, 2018 / 09:00 - 11:00

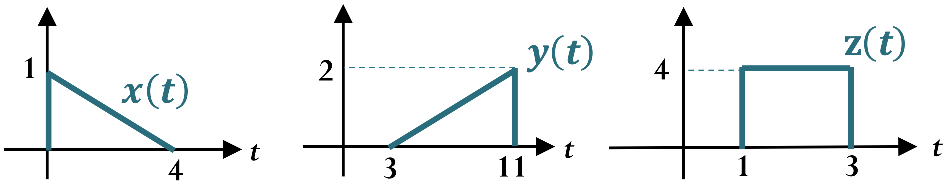
Instructions:

- This examination has....7.....pages (including this cover page).
- Conditions of Examination:

☐ Open book
☐ Closed book
☑ Semi-Closed book (.......1........sheet(s) ☑ 1 page ☐ both sides of A4 paper note) This sheet must be hand-written. They should be **submitted with the exam**. Do not modify (,e.g., add/underline/highlight) content on the sheet inside the exam room. Indicate your name and ID in the upper-right corner of the sheet (in portrait orientation). Other requirements are specified on the course website. (-10 pt if not following the requirements.)
☐ Other:..
☐ No dictionary ☐ Dictionary allowed ☐ No calculator ☑ Calculator allowed

- **Read these instructions and the questions carefully**.
- Students are not allowed to be out of the examination room during examination.
  Going to the restroom may result in score deduction.
- Turn off all communication devices and place them with other personal belongings in the area designated by the proctors or outside the test room.
- Write your name, student ID, section, and seat number clearly in the spaces provided on the top of this sheet.
  Then, write your **first name and the last three digits of your ID** in the spaces provided on the top of each page of your examination paper, starting from page 2.
- The examination paper is not allowed to be taken out of the examination room.
  Violation will result in a zero (0) score for the examination. Also, do not remove the staple.
- Unless instructed otherwise, ***write down all the steps*** that you have done to obtain your answers.
  - When applying formula(s), state clearly which formula(s) you are applying before plugging-in numerical values.
  - You may not get any credit even when your final answer is correct without showing how you get your answer.
  - Formula(s) not discussed in class can be used. However, derivation must also be provided.
  - **Exceptions**:
    - Problems that are labeled with "**ENRPr**" (Explanation is not required for this problem.)
    - Parts that are labeled with "**ENRPa**" (Explanation is not required for this part.)
    - These problems/parts are graded solely on your answers. There is no partial credit and it is not necessary to write down your explanation. Usually, spaces (boxes or cells in a table or rows of dashes) will be provided for your answers. "WACSP" stands for "write your answer(s) in the corresponding space(s) provided".
- The back of each page will not be graded; it can be used for calculations of problems that do not require explanation.
- When not explicitly stated/defined, all notations and definitions follow ones given in lecture.
  For example, the sinc function is defined by $\text{sinc}(x) = (\sin x)/x$; time is denoted by t and frequency is denoted by f. The unit of t is in seconds and the unit of f is in Hz.
- Some points are reserved for *accuracy* of the answers and also for reducing answers into their *simplest* forms. Watch out for roundoff error. Unless specified otherwise, the error in your final answer should not exceed 0.1%.
- Points marked with * indicate challenging problems.
- Do not cheat. Do not panic. **Allocate your time wisely.**
- Don't forget to submit your fist online self-evaluation form by the end of today.

1. (1×2 + 0.5×7 = 5.5 pt) [ENRPr] Signals $x(t)$, $y(t)$, and $z(t)$ are plotted below.



Suppose $y(t)=c_1x(c_2t+c_3)$ and $z(t)=c_4x(c_5t+c_6)+c_7x(c_8t+c_9)$.

Find the values of the constants $c_1,c_2,\ldots,c_9$

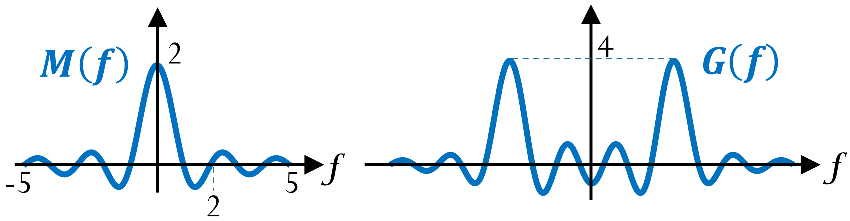
$c_1 =$ ______, $c_2 =$ ______, $c_3 =$ ______,

$c_4 =$ ______, $c_5 =$ ______, $c_6 =$ ______,

$c_7 =$ ______, $c_8 =$ ______, $c_9 =$ ______.

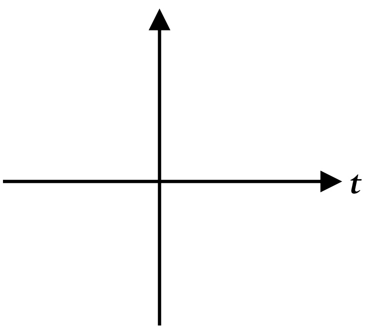
2. (8 pt) [ENRPr] Consider two signals $m(t)$ and $g(t)$.

Their Fourier transforms are shown below. Note that $M(f)=c_1\,\mathrm{sinc}(c_2 f)$.



In the time domain, suppose $g(t)=c_3 m(t)\cos(c_4 t)$.

(a) (3 pt) Plot $m(t)$



(b) (4 pt) Find the values of the constants $c_1,c_2,\ldots,c_4$:

$c_1 =$ ______, $c_2 =$ ______, $c_3 =$ ______, $c_4 =$ ______.

(c) (1 pt) Find $\int_{-\infty}^{\infty} G(f)\,df$.

3. (3+0.5** = 3.5 pt) [ENRPr] Evaluate the following integrals:

a. $\int_{-\infty}^{\infty} 2\delta(t-2)\,dt =$ ______

b. $\int_{-\infty}^{\infty} \delta(3t)\,dt =$ ______

c. $\int_{1}^{7} \delta(t-3)\cos\left(\frac{\pi}{2}t\right)dt =$ ______

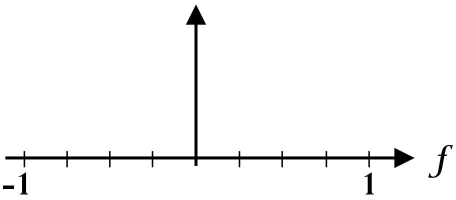
d. $\int_{0}^{1} \delta\left(e^{2t}-2\right)dt =$ ______

4. (7 pt) [ENRPr] The impulse response of a multipath channel is of the form

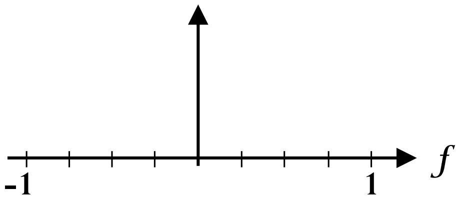
$$h(t)=\sum_{k=1}^{\nu}\beta_k\delta(t-\tau_k).$$

a. (4 pt) Plot $|H(f)|$ for the parameters given in each part below.
Consider the frequency from $f=-1$ to $f=1$ Hz.

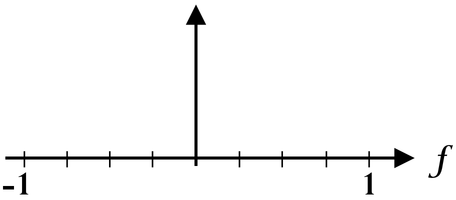
i. (2 pt) $\nu=1,\ \beta_1=0.5,\ \tau_1=3$



ii. (1 pt) $\nu=2,\ \beta_1=\beta_2=0.5,\ \tau_1=1,\ \tau_2=3$



iii. (1* pt) $\nu=3,\ \beta_1=\beta_3=0.5,\ \beta_2=1,\ \tau_1=1,\ \tau_2=2,\ \tau_3=3$



b. (3 pt) Suppose $\nu=2,\ \beta_1=\beta_2=0.5,\ \tau_1=1,\ \tau_2=3$. For each of the following channel input $x(t)$, find the corresponding channel output $y(t)$.
Note that the output should be of the form $y(t)=A\cos(2\pi f_c t+\theta)$ for some constants A, f_c, and θ.

Channel input	Channel output
$x(t)=\cos(\pi t)$	
$x(t)=\cos\left(\frac{\pi}{2}t\right)$	
$x(t)=\cos\left(\frac{\pi}{4}t\right)$	

5. (5 pt) [ENRPr] Consider an LTI communication channel.
Suppose when we put

$$x(t) = 4\cos(\pi t) + 2\cos(2\pi t) + \cos(4\pi t) + 0.5\cos(6\pi t) + \cos(8\pi t) + 1$$

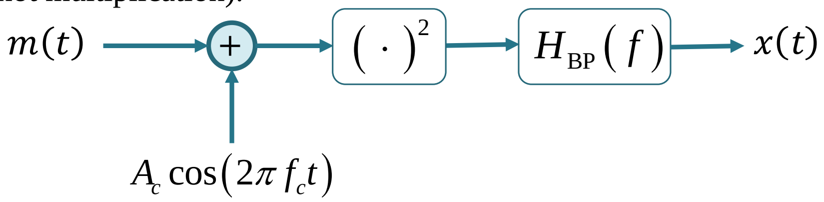
into this channel, we get

$$y(t) = 0.5\cos(\pi t) + e^{j2\pi t} + 2\sin(4\pi t) + 4\cos(6\pi t) + 8$$

as its output.
Let $H(f)$ be the frequency response of the channel that satisfies the above input-output relation. Find $H(f)$ at $f = -3, -1, 1, 2, 3$.

f	-3	-1	1	2	3
$H(f)$					

6. (6 pt) [ENRPr] Consider the “modulator” shown below. Note that the first operation is a summation (not multiplication).

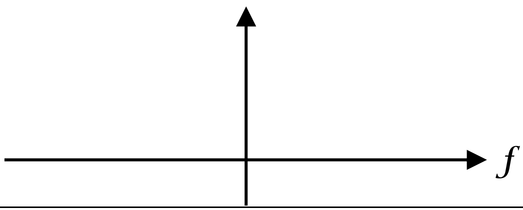
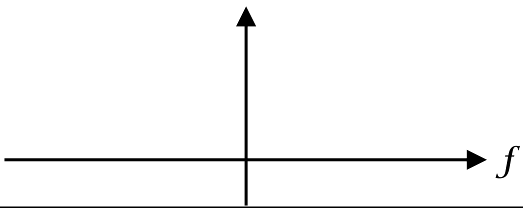
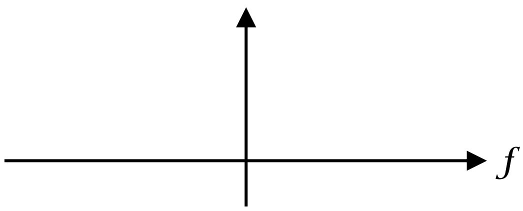


$\boxed{(\cdot)^2}$ is a “square” device; its output is created by squaring its input in the **time** domain.

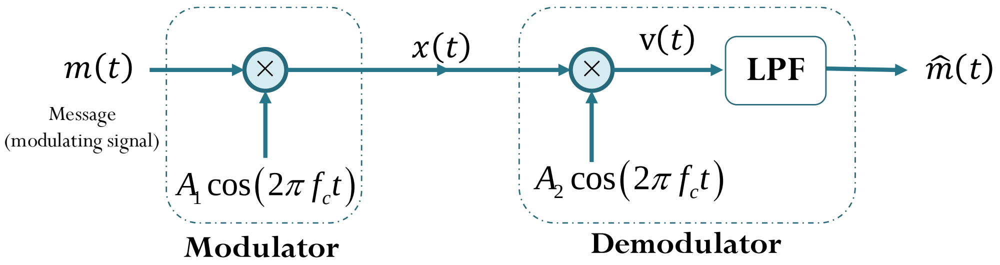
$\boxed{H_{\text{BP}}(f)}$ is an LTI device whose **frequency response** is

$$H_{\text{BP}}(f) = \begin{cases} 1, & |f - f_c| \le 332, \\ 1, & |f + f_c| \le 332, \\ 0, & \text{otherwise.} \end{cases}$$

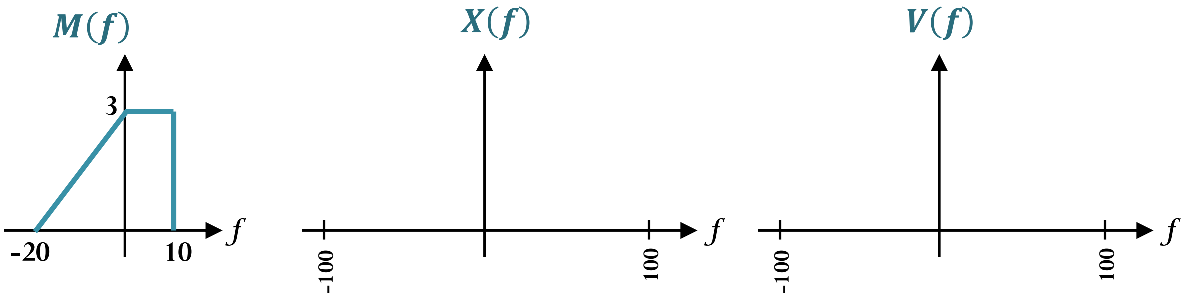
Let $A_c = 2$ and $f_c = 2018$. In each part below, plot the corresponding $X(f)$.

	$X(f)$
a. $m(t) = \cos(400\pi t)$.	
b. $M(f) = \begin{cases} 1, & \lvert f \rvert \le 54, \\ 0, & \text{otherwise.} \end{cases}$	
c. $M(f) = \begin{cases} 1, & \lvert f \rvert \le 500, \\ 0, & \text{otherwise.} \end{cases}$	

7. (8 pt) [ENRPr] Consider the DSB-SC modem with no channel impairment shown below.



The Fourier transform of the message is plotted below.



Let $A_1 = 2$, $A_2 = 4$, and f_c = 40 Hz.

a. (3+4 = 7 pt) Plot $X(f)$ and $V(f)$ in the provided space above.

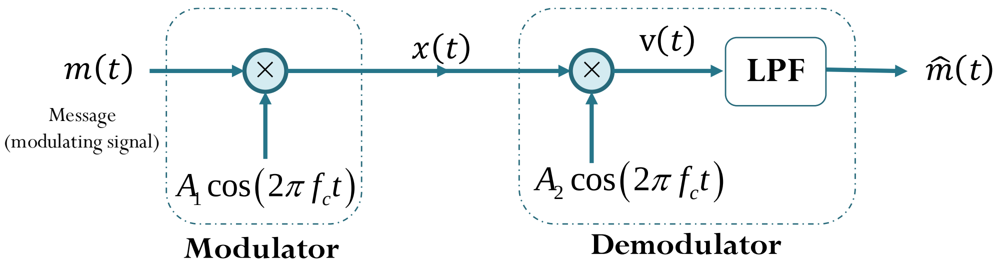
b. (1 pt) Suppose the low-pass filter (LPF) is ideal with frequency response

$$H_{LP}(f) = \begin{cases} g, & |f| \le 30, \\ 0, & \text{otherwise.} \end{cases}$$

Find the value of g that makes $\hat{m}(t) = m(t)$.

$g =$ ______ .

8. (6 pt) [ENRPr] Consider a DSB-SC modem with no channel impairment shown below.

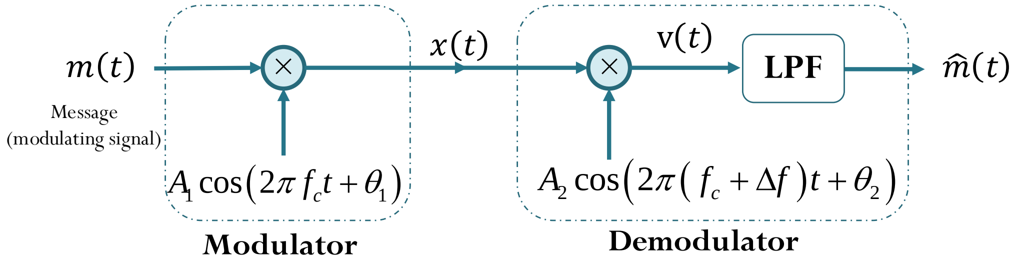


Let $A_1 = 2$, $A_2 = 4$, and f_c = 2018 Hz. Suppose LPF has $H_{LP}(f) = \begin{cases} 1, & |f| \le 332, \\ 0, & \text{otherwise.} \end{cases}$

For each of the following $m(t)$, find the corresponding $\hat{m}(t)$.

$m(t)$	$\hat{m}(t)$
$m(t) = 4\cos(444\pi t)$	
$m(t) = 8\cos(7654\pi t)$	
$m(t) = 10\cos(8420\pi t)$	

9. (2 pt) Consider a DSB-SC modem with synchronization error shown below.



Let $A_1=2$, $A_2=4$, f_c = 2018 Hz, and $H_{LP}(f)=\begin{cases}1, & |f|\le 332,\\ 0, & \text{otherwise.}\end{cases}$

Suppose $\theta_1=\frac{\pi}{2}$ [rad], $\theta_2=-\frac{\pi}{2}$ [rad], and $\Delta f=1$ Hz.

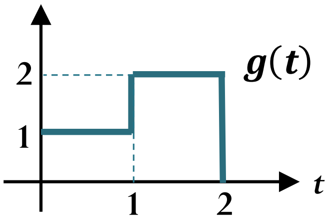
Assume that $m(t)$ is band-limited to 100 Hz. Find $\hat{m}(t)$.

(Because $m(t)$ is not specified, your answer should be expressed in terms of $m(t)$.)

10. (9 pt) [ENRPr] For each of the following signal $g(t)$, find its (normalized) average power $P_g\equiv\left\langle|g(t)|^2\right\rangle$. Do not use any approximation.

$g(t)$	$P_g\equiv\left\langle\|g(t)\|^2\right\rangle$
(1 pt) $g(t)=10e^{j20\pi t}$	
(1 pt) $g(t)=10e^{j20\pi t}+5e^{j40\pi t}$	
(1 pt) $g(t)=\left(10e^{j20\pi t}+5e^{j40\pi t}\right)^2$	
(2 pt) $g(t)=4\cos\left(4t+4^\circ\right)$	
(2 pt) $g(t)=5\cos\left(3t+15^\circ\right)+12\cos\left(4t+105^\circ\right)$	
(2 pt) $g(t)=5\cos\left(3t+15^\circ\right)+12\cos\left(3t+105^\circ\right)$	

11. (6 pt) Consider a signal $g(t)$ below. Note that $g(t)=0$ outside of the interval $[0,2]$.



Let $y(t)=\sum_{k=-\infty}^{\infty} g(t-k)$ and $z(t)=\sum_{k=-\infty}^{\infty} g(t-2k)$.

Calculate the following quantities:

a. (2 pt) energy E_g

b. (1 pt) average power P_g

c. (1 pt) $\langle g(t) \rangle$

d. (1* pt) [ENRPa] average power P_y

e. (1* pt) [ENRPa] average power P_z

12. (1 pt)
   a. (1 pt) Do not forget to submit your study sheet with your exam.
   b. Reminder:
      i. Make sure that you write your name and ID on every page. (Read the instruction on the cover page.)
      ii. The online self-evaluation form is due by the end of today.