Student ID: ______________________________

March 15, 2019 – 9:00 AM
Duration: 50 minutes

ENEL 471 - Winter 2019
2nd Midterm Exam

<u>Notes</u>:

- This exam is closed book and closed notes.
- Non-programmable calculators are allowed.
- The exam duration is 50 minutes.
- The exam is composed of 2 Problems and 5 pages. All the problems are independent.
- Please write your name and ID# in each page

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<u>Problem 1</u> [10 pts]

The sinusoidal modulating wave: $m(t) = \frac{1}{10} \cdot \sin(8000\pi t)$ is applied to a phase modulator with phase sensitivity k_p = 2 radian per volt. The unmodulated carrier wave has frequency f_c = 1 MHz and amplitude A_c = 1 volt.

a- Determine the instantaneous frequency of this PM signal and sketch it versus time. *[2pts]*
b- Determine the time domain expression of this PM signal and sketch it versus time. *[2pts]*
c- Determine the expression of the frequency spectrum of the resulting PM signal and sketch it. **<u>Show all amplitudes and frequencies of interest</u>**. *[2pts]*
d- Construct a phasor diagram of this PM modulated signal. *[2pts]*
e- Propose of a block diagram of a system that performs this PM modulation using a FM modulator and another system. *[2pts]*

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<u>Problem 2</u> [10 pts]

An angle-modulated signal around a carrier frequency fc = 1 MHz, has the form

$$s(t) = 5\cos\left(2\pi f_c t + 2\sin\left(4000\pi t\right)\right)$$

The modulating message has a maximum amplitude $A_m = \max\left|m(t)\right| = 2$.

a. Determine the phase deviation and frequency deviation of $s(t)$. *[2pts]*

b. Determine $m(t)$ and k_f if $s(t)$ is a FM signal. *[2pts]*

c. Determine $m(t)$ and k_p if $s(t)$ is a PM signal. *[2pts]*

d. Determine the 1% bandwidth of $s(t)$. *[2pts]*

e. Sketch the frequency spectrum of the modulated signal $s(t)$. **Show only the sidebands within the approximate bandwidth calculated in d-**. **Indicate all the frequencies and amplitudes of interest**. (Use the table below). *[2pts]*

<u>Values of the Bessel Functions</u> $J_n(\beta)$

	$\beta = 1$	$\beta = 2$	$\beta = 3$	$\beta = 4$
$n = 0$	0.7652	0.2239	-0.2601	-0.3971
$n = 1$	0.4401	0.5767	0.3391	-0.066
$n = 2$	0.1149	0.3528	0.4861	0.3641
$n = 3$	0.0196	0.1289	0.3091	0.4302
$n = 4$	0.0025	0.034	0.132	0.2811
$n = 5$		0.007	0.043	0.1321
$n = 6$		0.0012	0.0114	0.0491
$n = 7$			0.0025	0.01518
$n = 8$				0.004

Trigonometric Identities

$$\cos(a+b) = \cos(a)\cos(b) - \sin(a)\sin(b)$$
$$\cos(a-b) = \cos(a)\cos(b) + \sin(a)\sin(b)$$
$$\sin(a+b) = \sin(a)\cos(b) + \cos(a)\sin(b)$$
$$\sin(a-b) = \sin(a)\cos(b) - \cos(a)\sin(b)$$
$$\cos(a)\cos(b) = \frac{1}{2}\left[\cos(a-b) + \cos(a+b)\right]$$
$$\sin(a)\sin(b) = \frac{1}{2}\left[\cos(a-b) - \cos(a+b)\right]$$
$$\sin(a)\cos(b) = \frac{1}{2}\left[\sin(a+b) + \sin(a-b)\right]$$
$$\cos\left(a+\frac{\pi}{2}\right) = -\sin(a)$$
$$\cos\left(a-\frac{\pi}{2}\right) = \sin(a)$$
$$\sin\left(a+\frac{\pi}{2}\right) = \cos(a)$$
$$\sin\left(a-\frac{\pi}{2}\right) = -\cos(a)$$

Taylor series first order approximation of trigonometric functions

If $a \ll 1$ rad

Then: $\cos(a) \simeq 1$

$\sin(a) \simeq a$

Properties of the Bessel Functions of the First Kind

$$J_n(\beta) = \frac{1}{2\pi}\int_{-\pi}^{\pi} \exp\left(j\beta\sin(\theta) - jn\theta\right)d\theta$$
$$J_{-n}(\beta) = (-1)^n J_n(\beta)$$