No : Answers **Name :** Solutions

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Department of Electrical Engineering & Electronics, "*Communications*" Make-up 13.06.2025

I handed over all smart devices (mobile phone, smartwatch, earphones, etc.) to the exam supervisor before the exam. I take full responsibility if any are found on me.	Sign here

1. Which of the following is/are **always** orthogonal to $x(t) = Acos(\frac{2\pi t}{T} + \varphi)$ over $(0,T)$ interval, where A, B, C, φ.and θ are arbitrary constants?

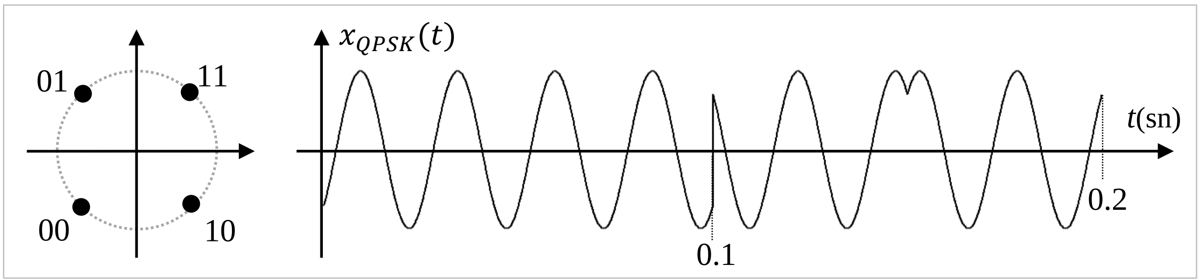
A) $-Acos(\frac{2\pi t}{T} + \theta)$ B) $\pm B \pm jC$ C) $t - T/2$ within $(0,T)$, 0 elsewhere

D) $Bsin(\frac{6\pi t}{T} + \theta)$ E) $Bcos(\frac{7\pi t}{T} + \varphi)$ F) $Bsin(\frac{\pi t}{T} + \theta)$

a) A,F	b) B,D	c) C,D	d) E,F	e) B,E	f) A,C

±B±jC is a complex constant. A period of sinusoidal is orthogonal to constants. So, b or e can be an answer. E is not a sinusoidal with frequency that is an integer multiple of 1/T. Therefore the answer is b.

2. Given the QPSK constellation diagram below, in-phase carrier $I(t) = cos(80\pi t)$ and symbol rate of 20 sym/s, determine what the transmitted data stream with the given signal is.



a) 11100011	b) 1010110	c) 0110	d) 101010	e) 011011	f) 01011011

Easy soln' by inspection:

There 0.2s covers 4 symbols (from 20 sym/s), so we have 8 bits. This leaves us with choices a and f. First two symbols/waveforms are same, so the answer is f.

3. A memoryless source is given with z ={0.4,...}. What is the probability of symbol ψ whose self-information is $I_\psi = 3.322$ bits?

a) 0.3	b) 0.4	c) 0.01	d) 0.1	e) 0.52	f) 0.004

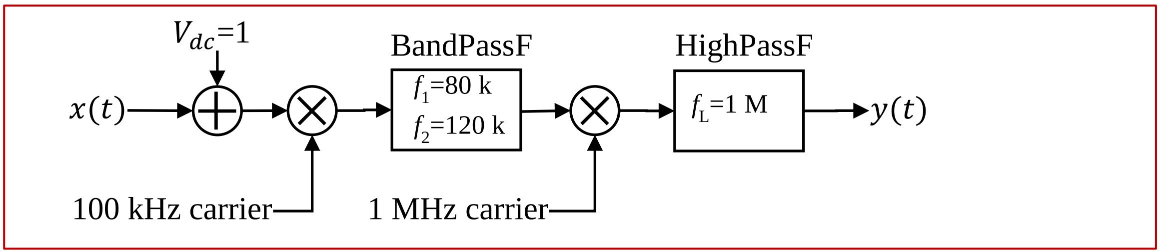
$$I_\psi = 3.322 = -log_2(p_\psi) \implies p_\psi = 2^{-3.322} \cong 0.1$$

4. Outputs of two pn-sequence generators are modulo summed to generate another sequence. What is the length of the new sequence when SSRG[7,1] and SSRG[6,1] run with the same clock signal.

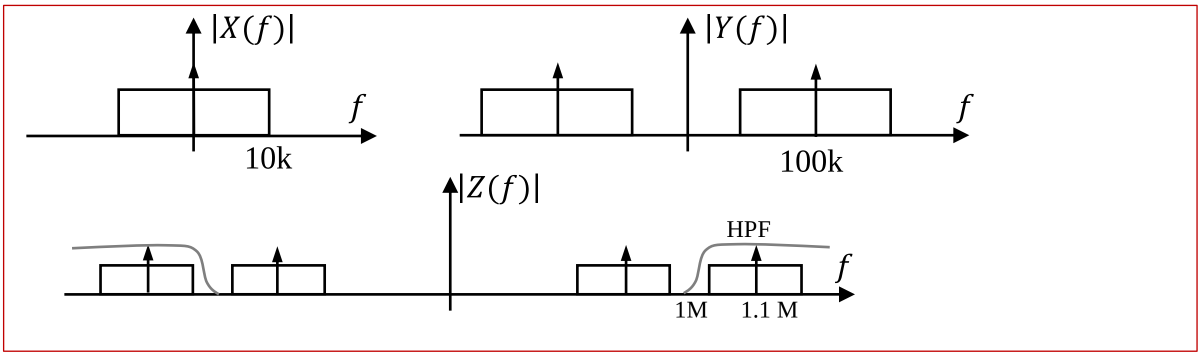
a) 8001	b) 2047	c) 127	d) 8191	e) 762	f) 190

$$(2^7 - 1)(2^6 - 1) = 8001$$

5. A baseband signal with bandwidth of 10 kHz is fed to the following system What is the bandwidth of the resulting final signal?



a) 1.2 MHz	b) 220 kHz	c) 40 kHz	d) 10 kHz	e) 20 kHz	f) 1 MHz



The bandwidth of the resulting signal is 20 kHz.

6. Calculate the output noise power of a filter given as $|H(f)| = \begin{cases} 1-f^2 & ,|f|<1 \\ 0 & ,otherwise \end{cases}$, when two sided input noise power spectral density is 1 mW/Hz.

a) 733 μW	b) 822 μW	c) 701 mW	d) 1 mW	e) 133 mW	f) 334 μW

$P_\eta = \int_{-\infty}^{\infty} N_0 |H(f)|^2 df = 2\int_0^1 10^{-3}(1-f^2)^2 df = 2\times 10^{-3}\int_0^1 (1-2f^2+f^4)df$

$P_\eta = 2\times 10^{-3}\left(f - \frac{2f^3}{3} + \frac{f^5}{5}\right)\Big|_0^1 = 2\times 10^{-3}\left(1-\frac{2}{3}+\frac{1}{5}\right) = 1.0667\times 10^{-3} \cong 1.067\ mW$

(in this question, it seems that I messed up the solution with the solution of another question and also choices with another choice set. Therefore, this question is removed from grading)

7. Calculate the output signal power of a filter given as $|H(f)| = \begin{cases} 1-f^2 & ,|f|<1 \\ 0 & ,otherwise \end{cases}$, when input signal is given as $x(t) = 1 - cos(\pi t + \pi/8)$.

a) 1.33 kW	b) 413.2 W	c) 1.921 W	d) 433 mW	e) 1.281W	f) 2.61 mW

Part of the signal is 0.5 Hz sinusoidal; the output amplitude is $H(0.5)$=0.75, giving $y_1(t) = -0.75cos(\pi t + \varphi)$ from which we calculate the power as $P_1 = \frac{(0.75)^2}{2} \cong 0.2813\ W$. We also have a dc component whose power is $P_2 = 1\ W$. Therefore, $P_y = 1.2813\ W$.

8. An integrator receiver expects the 4-ary rectangular PAM pulses of amplitudes $\psi_i(t) = \{-4,-1,1,4\}$ at 10 sym/sec. Noise is low and noise pdf at the integrator output is symmetric. What are the optimal threshold values at decision instants?

a) 0, ∓0.3	b) ∓0.1, ∓0.3	c) 0, ∓0.25	d) ∓0.25	e) −3,0,3	f) 0,2,4

$R_1 = \int_0^{T_s} 1dt = T_s \implies R_{-1} = -T_s,\ R_4 = \int_0^{T_s} 4dt = 4T_s \implies R_{-4} = -4T_s.$

The ML decision thresholds are then found as $\{-2.5T_s, 0, 2.5T_s\}$.

9. In an OFDM system with a 4 μs symbol duration (including 20% CP), there are 42 subcarriers used to transmit data. Each subcarrier can independently employ BPSK, QPSK, or 64-QAM. What is the maximum achievable physical bit rate?

a) 42 Mbps	b) 8.4 Mbps	c) 25.2 Mbps	d) 12.6 Mbps	e) 63 Mbps	f) 50.4 Mbps

$6 \times 42/4 \times 10^{-6} = 63$ Mbps

10. $x(t)$ is a random binary rectangular pulse train, assuming values of ±2. The spectrum of this signal is spread using DSSS method with SSRG[8,1] generator at the rate of 1 pn-sequence/symbol. The resulting signal is multiplied with a 1 GHz carrier signal. What is the bandwidth of the final signal given that the actual data rate is 100 ksymbols/s?

a) 200 kHz	b) 255 MHz	c) 1 GHz	d) 25.5 MHz	e) 102 MHz	f) 51 MHz

$100k \times (2^8 - 1) \times 2 = 51$ MHz

11. $x(t)$ is a 1.2 Mbps pseudo-random binary rectangular pulse train, taking values of ±3. It is generated by a SSRG[10,3] pn-generator (±1), followed by an amplifier with gain *k*=3. What is the power of the signal?

a) 1.2 μW	b) 1.2 W	c) 3.9 mW	d) 9 W	e) 3.6 W	f) 1023 mW

$P = A^2 = 3^2 = 9$ W

12. A binary communication system uses sawtooth pulses of $\psi_i(t) = \begin{cases} \mp t & 0 < t < T_b \\ 0 & elsewhere \end{cases}$. Receiver synchronously generates $\psi_0(t)$ for the correlation of input. Output of the correlator has noise with pdf $f_x = 500e^{-1000|x|}$. What is the probability of error when bit rate is 10 bps?

a) 0.161	b) 0.358	c) 1.2	d) 0.013	e) 0.033	f) 0.511

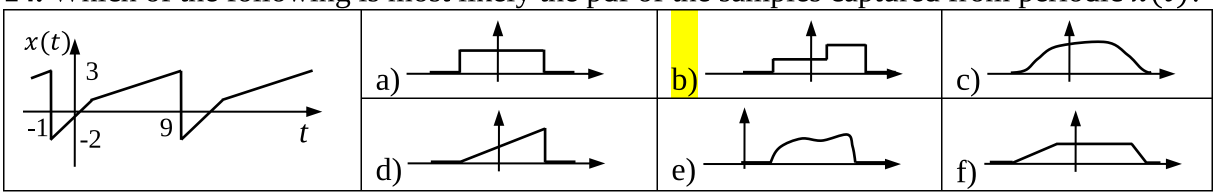
$E_b = \int_0^{T_b} t^2 dt = \frac{t^3}{3}\Big|_0^{T_b} = \frac{T_b^3}{3}$. $p_e = \int_{E_b}^{\infty} 500e^{-1000|x|}dx = \frac{-1}{2}e^{-1000|x|}\Big|_{\frac{T_b^3}{3}}^{\infty}$

$p_e = \frac{1}{2}e^{-1000T_b^3/3}$. $p_e\left(T_b = \frac{1}{10}\right) = \frac{1}{2}e^{-1/3} \cong 0.3583$.

13. Which of the following is the most important reason for carrier-modulation?

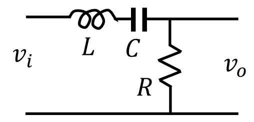
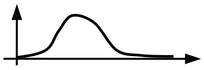
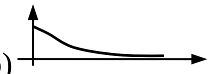
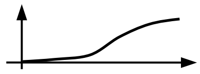
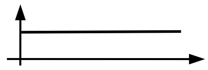
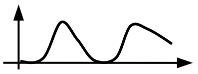
a) Message signal won't go anywhere otherwise
b) We save energy by modulating carrier
c) Sharing the transmission media
d) Easier to demodulate received signal
e) Modulation protects signal from noise
f) Because it is a linear process and easy

14. Which of the following is most likely the pdf of the samples captured from periodic $x(t)$?



Two different slope regions mean two possible constant probability sections in pdf. One is from a negative value to a positive value, The other one is all positive. The only possible pdf would look like the answer b.

15. Which of the following best represents the output spectral density given that the input is white noise?

	a) 	b) 	c) 
	d) 	e) 	f) 

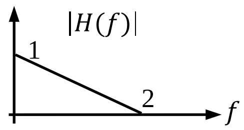
This is a bandpass filter whose frequency characteristics would be defined by passive elements. There is only one bandpass filter in choices.

16. What is the matched filter output for the half period sine waveform defined as $\psi(t) = \begin{cases} sin(\pi t/T) & 0 < t < T \\ 0 & otherwise \end{cases}$ at the decision instant in a fully synchronous system?

a) $2T^2/3$	b) $T^2/3$	c) $1/T$	d) $T/2$	e) T	f) $2T/3$

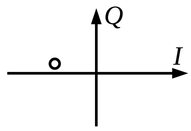
$R(t=T) = \int_0^T sin^2(\pi t/T)dt = \frac{1}{2}\int_0^T (1 - cos(2\pi t/T))dt = \frac{1}{2}\left[t - \frac{T}{2\pi} sin(2\pi t/T)\right]_0^T$
$R(t=T) = T/2$

17. What is the noise equivalent bandwidth (B_{neq}) of the low-pass filter given?

	a) 1	b) 3/2	c) 0.5
	d) 2/3	e) 1.7	f) 3/4

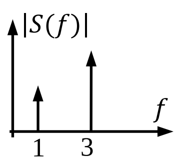
$P_{oH} = \int_0^2 N_0 \frac{f^2}{4} df = N_0 \frac{f^3}{12}\Big|_0^2 = \frac{2N_0}{3}$, $P_{oneq} = \int_0^{f_c} N_0 1^2 df = f_c N_0$
$\frac{2N_0}{3} = f_c N_0 \implies f_c = \frac{2}{3}, B_{neq} = \frac{2}{3}$

18. What is the most likely waveform representing the marked constellation point in QAM?

	a) 3+j1	b) $-2f + 0.5$	c) $sin(2\pi f t + \frac{3\pi}{4})$
	d) $-cos(2\pi f t + \frac{\pi}{2})$	e) $cos(2\pi f t)$	f) $sin(4\pi f t - \pi)$

Choices a and b are not QAM waveforms. d, e and f are all on an axis.

19. Which one most likely has the one-sided spectrum given?

	a) $\Pi(t-1) + 2\Pi(t-3) + 1$	d) $cos^2(2\pi t) - 2sin^2(3\pi t)$
	b) $\delta(t-1) + 2\delta(t-3)$	e) $2sin(6\pi t) + sin\left(2\pi t + \frac{\pi}{4}\right)$
	c) $cos(2\pi t + 6\pi t)$	f) $cos\left(2\pi t + \frac{\pi}{2}\right) - 2sin(6\pi t)$

We have two frequency components; 1 Hz and 3 Hz, so e or f can be the answer. Since 3 Hz component has higher amplitude than the other, both choices are ok.

20. At a busy intersection, only 5% of the pedestrians wait for the green light; the rest just walk through, risking their own lives and disrupting the flow of traffic. These pedestrians are most likely students of which university?

a) ESOGU	b) Budapest UTE	c) Kyoto University
d) MIT	e) Technical Univ. Berlin	f) Not enough info.

This rthorical question has no definite answer. It is asked to remind students that there are more important things in life than a course test (all examinees get 5 points).