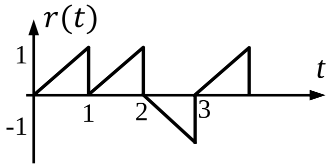
No : Answer **Name :** Solution

Eskişehir Osmangazi University, Faculty of Engineering and Architecture

Department of Electrical Engineering & Electronics, "*Communications*" Final 15.06.2026

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. *Exam duration:90 minutes. No books, no notes, no communication.*	Sign here

1. $r(t)$ input to a correlator is given as shown in the figure. Correlation period is $T = 1$ and its other input is $\psi(t) = 1$. What is the correlator output value at $t = 3$?



a) -0.5	b) 1	c) -1	d) 0.5	e) -0.25	f) -1/3

$R(2) = \int_2^3 r(t)\psi(t)dt = -\int_0^1 t dt = -\frac{t^2}{2}\Big|_0^1 = -0.5$

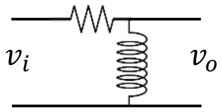
2. What is the noise-equivalent bandwidth of a low-pass filter defined as $|H(f)| = 1 - f^2$ for $|f| < 1$ and zero for $|f| > 1$?

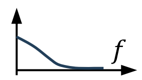
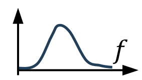
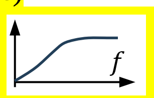
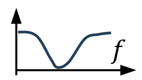
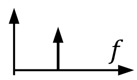
a) 1.13	b) 1.0	c) 0.71	d) 0.53	e) 2.12	f) 0.62

$\int_0^1 |H(f)|^2 df = \int_0^1 |1-f^2|^2 df = \int_0^1 (1 - 2f^2 + f^4)df = \left[f - \frac{2}{3}f^3 + \frac{1}{5}f^5\right]_0^1 = 1 - \frac{2}{3} + \frac{1}{5} = 8/15$

$B_{neq} \times 1^2 = 8/15 \Rightarrow B_{neq} = 0.533$ Hz.

3. Input to a RL-filter is White Gaussian Noise with spectral density $N_o = 1$ µW/Hz. What would the shape of output noise spectral density be like when R and L have reasonable values?



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

4. The symbol probabilities of a memoryless source are given as $z = \{0.5, 0.25, 0.125, 0.0625, 0.0625\}$. What would be the optimal average code length when the output data is lossless coded?

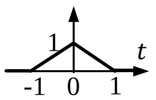
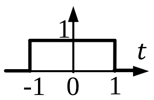
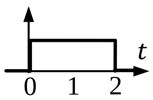
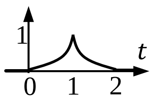
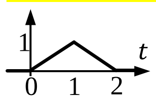
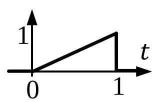
a) 1.625	b) 3.0	c) 2.0	d) 1.875	e) 1.465	f) 2.25

Optimal code length is the entropy;

$H(z) = -\sum_{i=0}^{4} p_i log_2(p_i) = 0.5 \times 1 + 0.25 \times 2 + 0.125 \times 3 + 2(0.0625 \times 4)$

$H(z) = 1.875$

5. What is the response of the matched filter designed for the waveform $\psi(t) = \begin{cases} 1 & 0 < t < 1 \\ 0 & elsewhere \end{cases}$ when $\psi(t)$ is applied as input?

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

We get matched filter by flipping $\psi(t)$ in time axis and sliding it towards $+t$ axis in order to make it causal. When done, it will be a rectangular identical to $\psi(t)$. Response is the convolution of $\psi(t)$ and $h(t)$, which is the same as autocorrelation function of $\psi(t)$ (shifted to the right to make it causal response). Hence,

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

$R(\tau) = \int_{-\infty}^{\infty} \psi(t)\psi(t+\tau)dt = \begin{cases} \tau & ,0 < t < 1 \\ 2-\tau & 1 < t < 2 \end{cases}$ and zero elsewhere.

6. A communication system uses binary antipodal pulses of $\psi_i(t) = \pm\begin{cases} 2 & ,0 < t < 1 \\ -2 & ,1 < t < 2 \\ 0 & ,elsewhere \end{cases}$ with symbol period $T_b = 2$. What is the average power?

a) 12	b) 16	c) 2	d) 0	e) 4	f) 8

$P = \frac{1}{T_b}\int_0^{T_b}|\psi(t)|^2dt = \frac{1}{2}\int_0^2 2^2dt = 2t|_0^2 = 4.$

7. A communication channel contains low frequency (around 50 Hz) hum noise whose psd is approximated as $G_\eta(f) = e^{-||f|-50|}$ (two-sided). The receiver uses an ideal high-pass filter with cutoff frequency $f_c = 60$ Hz. What is the total noise power at the filter output?

a) 2 W	b) -1.2 mW	c) 10 mW	d) e W	e) 0.02 W	f) 90.8 µW

$P_\eta = 2\int_{f_c}^{\infty} G_\eta(f)df = 2\int_{60}^{\infty} e^{-(f-50)}df$. For $f > 60$, $P_\eta = 2\int_{10}^{\infty} e^{-f}df$

$P_\eta = -2e^{-f}\Big|_{10}^{\infty} = 2e^{-10} \cong 90.8\ \mu W.$

8. Which of the following modulation schemes do **not** encode information in the carrier amplitude?

A. M-ary PSK
B. VSB-AM
C. 16-QAM
D. FSK
E. QPSK
F. 4-ary ASK

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

Data compression and encryption are handled separately from modulation.

9. The total signal received from a communication channel is $r(t) = x_{pcm}(t)cos(10^4\pi t) + \eta(t)$ where x_{pcm} is $\{10, -10\}$ binary rectangular pulse train and η is noise with flat spectral noise density of $N_o = 1$ µW/Hz. $r(t)$ is fed to an ideal low-pass filter with f_{cutoff}=20kHz. What is the SNR at the output of the filter?

a) 50 dB	b) 12	c) 10 dB	d) 34 dB	e) 50	f) 40 dB

Since the signal frequency (5 kHz) is within passband of the filter, signal power is $P_s = \frac{V_p^2}{2} = 50$. Noise power is $P_\eta = 1 \times 10^{-6} \times 20 \times 10^3 = 20 \times 10^{-3}$. SNR is then, $SNR = \frac{P_s}{P_\eta} = \frac{50}{20\times10^{-3}} = 2500 \cong 34\ dB$.

10. A single integrator receiver is used for receiving baseband signals of quarternary PAM rectangular pulses with amplitudes of $\{-3, -1, 1, 3\}$ with T_s=1s. What are the ML decision thresholds for the decision circuitry that follows the integrator output?

a) $\{-2,0,2\}$	b) {-3,-1,1,3}	c) {-2,2}	d) {-5,0,5}	e) {-5,5}	f) {0}

For the rectangular pulse with amplitude of -1, the integrator output is $R_1 = \int_0^1 1dt = 1$, at the end of T_s. It is $R_1 = \int_0^1 3dt = 3$ for amplitude of 3. Hence the ML threshold between them should be 2. It follows that the thresholds are found to be $\{-2,0,2\}$, using symmetry.

11. Assuming equal average symbol energy, why does a 64-QAM system require a higher SNR than QPSK to achieve the same symbol error probability?

a) 64-QAM transmits more bits per symbol.
b) The constellation points of 64-QAM are closer together..
c) 64-QAM occupies a wider bandwidth.

d) QPSK is a coherent modulation while 64-QAM is not.
e) QPSK uses a lower carrier frequency.
f) QPSK is basically two orthogonal BPSKs.

12. A single integrator receiver is used for receiving signals of binary antipodal rectangular pulses of $\mp A$ with T_b=10ms. Noise pdf at the correlator output is given as $f_x(x) = e^{-|x|}/2$. What should be the minimum value of A such that $p_e \leq 0.01$?

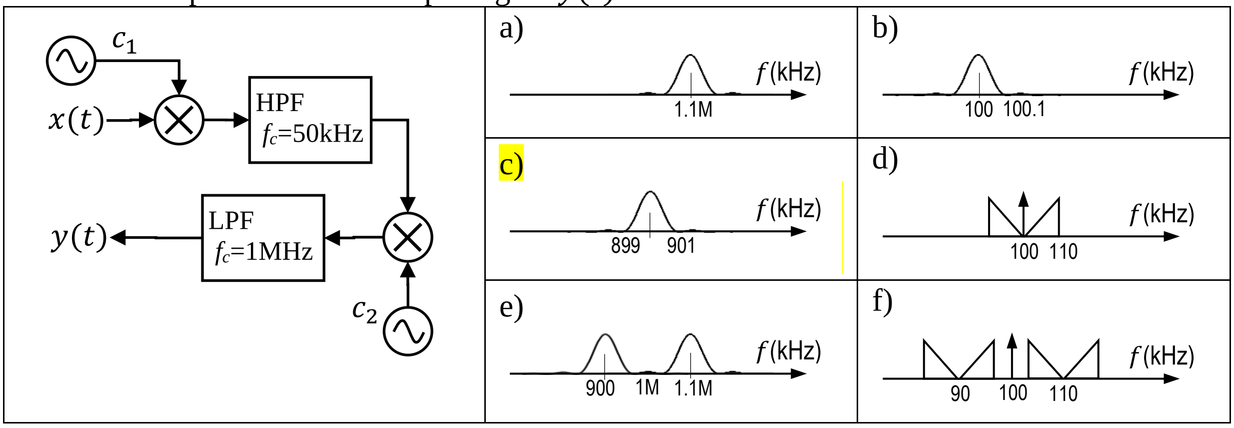
a) 3.9	b) 392	c) 40	d) 196	e) 783	f) 201

$R_b = AT_b = A \times 10^{-2}$. $p_e = \int_{R_b}^{\infty} f_x(x)dx = \frac{1}{2}\int_{A\times10^{-2}}^{\infty} e^{-|x|}dx = -\frac{1}{2}e^{-x}\Big|_{A\times10^{-2}}^{\infty} = \frac{1}{2}e^{-0.01A}$. For $p_e \leq 0.01$, $\frac{1}{2}e^{-0.01A} \leq 0.01$. This gives $A \geq -\frac{\ln(0.02)}{0.01} \cong 392$.

13. What is a primary reason for intentionally spreading a signal over a bandwidth much larger than the minimum required?

a) To improve resistance to interference and facilitate multiple-user access.
b) To reduce the occupied bandwidth of the signal.
c) To increase the number of bits carried by each symbol.
d) To eliminate multipath fading completely.
e) To increase the carrier frequency.
f) To eliminate multipath fading completely.

14. A random binary rectangular pulse train $x(t)$ (baseband signal) with symbol rate $T_s = 1ms$ is applied to the following system where c_1 and c_2 are 100 kHz and 1 MHz sinusoidal signals respectively. What would be the spectrum of the output signal $y(t)$?



By multiplying c_1 we upconvert the signal to 100kHz. HPF do not have any measurable effect as the signals bandwidth is only 2 kHz. Multiplying this with 1 MHz carrier, we will have two sincs at 900 kHz and 1.1 MHz. LPF filters removes the mirror at 1.1 MHz. What remains is a sinc at 900 kHz with null-to-null bandwidth of 2 kHz.

15. Which of the following statements best explains why a binary receiver with probability of decision error p_e=0.6 can be more useful than one with p_e=0.5?

a) Having p_e=0.6 is worse than p_e=0.5 actually, so it is not useful.
b) In binary communication systems, the higher the p_e the better we stand.
c) Higher p_e reduces the workload of decision circuitry and improves synchronization.
d) In communication systems, information is carried by p_e, so it is better to have it higher.
e) Higher p_e reduces the bandwidth requirement in a binary channel.
f) When we know that p_e=0.6, we can invert outcome to actually have p_e=0.4.

16. Which of the following statements best explains why a diode envelope detector cannot demodulate a PM signal?

a) PM signals generally require larger transmission bandwidths.
b) PM signals exhibit phase variations rather than envelope variations.
c) PM signals require coherent carrier recovery at all receivers.
d) PM signals are more sensitive to thermal noise than AM signals.
e) PM signals cannot be processed by nonlinear circuits.
f) PM signals have erratic envelope characteristics.

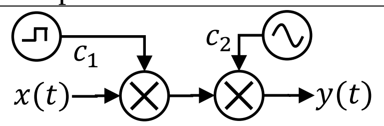
17. An OFDM system employs 32 subcarriers each using BPSK, QPSK or 16-QAM. DC subcarrier is reserved for pilot transmission and carries no user data. The symbol duration is 4 µs (no CE). What is null-to-null bandwidth?

a) 7.5 MHz	b) 250 kHz	c) 8.25 MHz	d) 8 MHz	e) 7.75 MHz	f) 750 kHz

$\frac{1}{4\mu s} = 250\ kHz$ (distance between carriers)

$(32 + 1) \times 250k = 8.25\ MHz$

18. $x(t)$ random binary rectangular pulse train is first multiplied by SSRG[9,4] m-sequence pn-generator output (c_1) and frequency upconverted to 5 GHz by multiplying the result with 5 GHz sinusoidal carrier (c_2) as shown. Rate of the $x(t)$ signal is 100 kbps, and the chip rate of the pn-generator is 1 sequence-period per bit. What is the null-to-null bandwidth of the resulting signal $y(t)$?

	a) 51 MHz	b) 5 GHz	c) 200 kHz
	d) 102.2 MHz	e) 51.2 MHz	f) 1.2 GHz

$L = 2^9 - 1 = 511$. One sequence per bit is give, so chip-rate is $100\ kbps\ x\ 511\ =$ 51.1 Mchips/s. Therefore, null-to-null bandwidth is 102.2 MHz, independent from the carrier frequency.

19. A FHSS system employing 8-FSK uses a hop rate of 8 kHz (8000 hops/s). Assuming one hop per symbol, determine the bit rate.

a) 3 kbps	b) 16 kbps	c) 64 kbps	d) 8 kbps	e) 24 kbps	f) 32 kbps

8-FSK means 3 bits/symbol. 8000 hops/s x 3 = 24 kbps

20. An OFDM system employs 32 subcarriers each using BPSK, QPSK or 16-QAM. DC subcarrier is reserved for pilot transmission and carries no user data. The symbol duration is 4 µs (no CE). What is the maximum bit-rate?

a) 24.8 Mbps	b) 32 Mbps	c) 15.5 Mbps	d) 124 Mbps	e) 62 Mbps	f) 31 Mbps

32-1=31 subcarriers carry data. Maximum throughput is achieved with highest order constellation, which is 16-QAM that has 4 bits/symbol. $31 \times 4/4\mu s$=31 Mbps.