No : Answer **Name :** Solution

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Department of Electrical Engineering & Electronics, "*Communications*" Midterm 07.04.2026

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 the correlator is a odd-symmetric square wave with period $T_b = 1$, $r|_{t=\varepsilon} = 1$ and mean=0. Correlation period is $T = 1$ and its other input is $\psi(t) = \begin{cases} t & 0 < t < 1 \\ 0 & elsewhere \end{cases}$ ramp waveform periodically repeating with period 1. What is the correlator output value at $t = 2$?

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

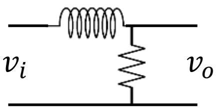
At $r|_{t=\varepsilon} = 1$ means that $r|_{t=1+\varepsilon} = -1$, that is we will calculating correlation for the negative cycle of the square wave at the end of the cycle (ie $t = 2$). $R = -\int_0^1 t dt = -\frac{t^2}{2}\Big|_0^1 = -0.5$.

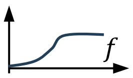
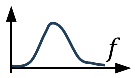
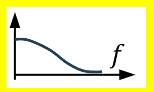
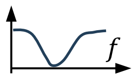
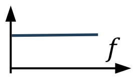
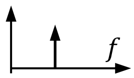
2. What is the noise-equivalent bandwidth of a low-pass filter defined as $|H(f)| = 1 - |f|$ for $f < 1$ and zero for $|f| > 1$?

a) 1/2	b) 1	c) 1/3	d) 1/4	e) 0.2	f) 0.6

$\int_0^1 |H(f)|^2 df = 1^2 \times BW$, where 1^2 stands for the ideal filter. $\int_0^1 |1-|f||^2 df = \frac{f^3}{3}\Big|_0^1 = \frac{1}{3} = B_{neq}$

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



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

4. A memoryless source generates the symbols $\{u, k, t, c, i\}$. A Huffman dictionary generator assigns the codes {0,10,110,1110,1111} to the symbols respectively. Source outputs are then coded and transmitted. Which symbol stream the receiver outputs when it receives the stream 10011001110010?

a) cukukik	b) ckukuta	c) cikituu	d) kutucuk	e) kukucitu	f) ucukucuk

5. Find the matched filter for the waveform $\psi(t) = \begin{cases} 1-t & 0 < t < 1 \\ 0 & elsewhere \end{cases}$.

a) $\begin{cases} 1-t & 0<t<1 \\ 0 & elsewhere \end{cases}$	b) $\begin{cases} t-1 & 0<t<1 \\ 0 & elsewhere \end{cases}$	c) $\begin{cases} t+1 & -1<t<0 \\ 0 & elsewhere \end{cases}$
d) $\begin{cases} -t & 0<t<1 \\ 0 & elsewhere \end{cases}$	e) $\begin{cases} t & 0<t<1 \\ 0 & elsewhere \end{cases}$	f) $\begin{cases} t & -1<t<0 \\ 0 & elsewhere \end{cases}$

We get matched filter by flipping $\psi(t)$ in time axis and sliding it towards $+t$ axis in order to make it causal.

6. A communication system uses triangular binary antipodal pulses of $\psi_i(t) = \pm \begin{cases} 2t & 0 < t < 1 \\ 4-2t & 1 < t < 2 \\ 0 & elsewhere \end{cases}$ with symbol period $T_b = 2$. What is the energy per symbol period?

a) 1/2	b) 2/3	c) 7/4	d) 1/3	e) 8/3	f) 9/2

$E_b = \int_0^{T_b} |\psi(t)|^2 dt$. Since the waveform is symmetric, we only need to calculate energy for $0 < t < 1$ and multiply it by 2; $E_b = 2\int_0^1 |2t|^2 dt = 8\frac{t^3}{3}\Big|_0^1 = 8/3$.

7. A communication channel contains low frequency (around 50 Hz) hum noise whose psd is approximated as $G_\eta(f) = e^{-|f-50|}$. What is the total noise power the receiver has to deal with?

a) 1W	b) -1.2W	c) 1 mW	d) e W	e) 0.2W	f) 2W

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

$P_\eta \cong \int_{50}^{\infty} G_\eta(f)df + \int_{50}^{100} G_\eta(f)df = \int_{50}^{\infty} e^{-|f-50|}df + \int_{50}^{100} e^{-|f-50|}df = \int_{0}^{\infty} e^{-f}df + \int_{0}^{50} e^{-f}df$
$P_\eta \cong -e^{-f}\big|_0^{\infty} - e^{-f}\big|_0^{50} = 2 - e^{-50} \cong 2.$

8. Which of the following is/are not in intended drives for modulation?
A. Perform data compression for efficient representation
B. Do wireless communication
C. Reduce antenna size in wireless communication
D. Allow secure/encrypted access to the transmitted information
E. Allow multiple/multiuser access to the communication media
F. Better control on effects of channel noise

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

Data compression and encryption are handled separately from modulation.

9. The signal received from a communication channel is the sum of 10 kHz 1Vp sinusoidal and flat spectral noise density of $N_o = 1$ µW/Hz. What is the SNR at the output of ideal low-pass input filter with f_{cutoff}=20kHz?

a) 50dB	b) 12	c) 10dB	d) 25	e) 50	f) 40dB

Since the signal frequency is within passband of the ideal filter, signal power is $P_s = \frac{V_p^2}{2} = 1/2$. Noise power is $P_\eta = 1 \times 10^{-6} \times 20 \times 10^3 = 20 \times 10^{-3}$. SNR is then, $SNR = \frac{P_s}{P_\eta} = \frac{1}{2\times 20\times 10^{-3}} = 25$.

10. 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 $f_x(x) = e^{-|x|}/2$ (Laplace distribution). What is the probability of bit detection error p_e, assuming that the receiver is in full-sync and decision threshold is 0.?

a) $\frac{1}{2}e^{-0.01A}$	b) $e^{-A/10}/2$	c) $0.05A$	d) $5AT_b$	e) e^{-10AT_b}	f) $1/AT_b$

$R_b = AT_b = A \times 10^{-2}$. $p_e = \int_{R_b}^{\infty} f_x(x)dx = \frac{1}{2}\int_{A\times 10^{-2}}^{\infty} e^{-|x|}dx = -\frac{1}{2}e^{-x}\big|_{A\times 10^{-2}}^{\infty} = \frac{1}{2}e^{-0.01A}$.

11. The ordered list of probabilities $u = \{0.5, p_1, p_2, p_3\}$ is given for a memoryless source. After creation of dictionary (Huffman or Shannon-Fano) for coding, it is seen that the average codelength equals to the source entropy. Find p_3.

a) 0.25	b) 0.125	c) 0.0625	d) 0.375	e) 1.25	f) 0.1666

$L_{avg} = H(u)$ means $l_i = I_i$. The only way this can happen for this source is when $I_i = -log_2(p_i)$ are integers. This gives us $p_i = \left\{\frac{1}{2}, \frac{1}{4}, \frac{1}{8}, \dots\right\}\{0.5, 0.25, 0.125, \dots\}$. Since 0.5 is given and the probabilities are ordered, the remaining probabilities must be $\{0.25, 0.125, 0.125\}$. Hence $p_3 = 0.125$.

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 $p_e \le 0.01$?

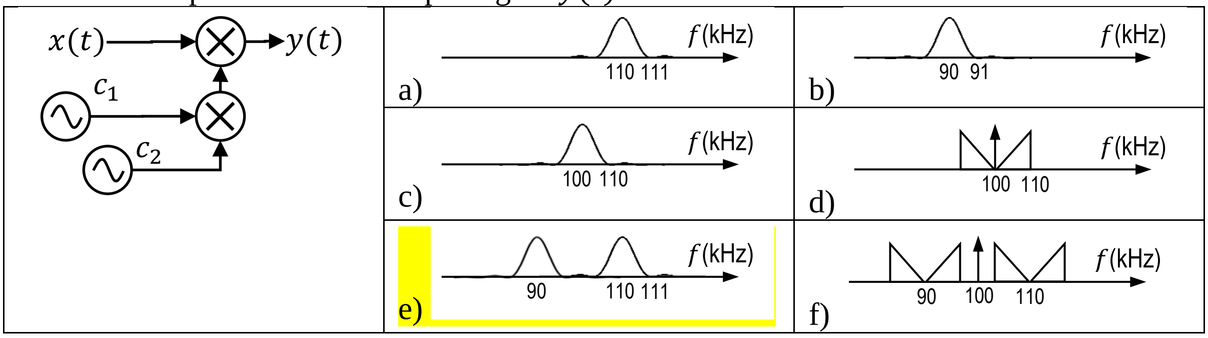
a) 516	b) 392	c) 154	d) 44.8	e) 27.4	f) 455

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

13. Which one of the following is not known as a variation of amplitude modulation

a) DSB-SC	b) USB	c) SSB	d) PC-AM	e) VSB	f) LSB-AM

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 10kHz and 100 kHz sinusoidal signals respectively. What would be the spectrum of the output signal $y(t)$?



By multiplying c_1 and c_2 sinusoidal signals of 10kHz and 100kHz respectively, we get the sum of two sinusoidals with sum and difference frequencies; 90kHz and 110kHz. Since the symbol duration is 1ms, the first null of the spectrum of rectangular pulse train is at 1kHz, null-to-null bandwidths of two modulated signals would be 89kHz-91kHz and 109kHz-111kHz, centered at 90kHz and 110 kHz.

15. A memoryless source generates 11 different symbols. What would be the minimum codelength for a symbol with the occurence probability of 0.22, when the source output is Huffman coded ?

a) 2	b) 3	c) 5	d) 4	e) 1	f) 6

For not having information loss, $l_{sym} \geq I_{sym}$. Huffman coding satisfies this. Since $I_{sym} = -log_2(0.22) \cong 2.18$, a codeword with integer length larger or equal to this number is assigned to the symbol, which is $l_{sym} = 3$.

16. What is the purpose of adding/including the original unmodulated carrier in the transmitted signal?

a) Reduce the transmitted energy
b) Prevent envelope detection at the receiver
c) Focus the EM wave to a certain direction
d) Carry the actual information
e) Reduce the bandwidth requirement
f) Help carrier recovery at the receiver