universität ulm

Communication and Information Technology

Test Your Prior Knowledge

The Master of Science program *Communication and Information Technology* builds upon prior knowledge, which you should have acquired at the courses you have taken at your Bachelor studies. In order to assess your prior knowledge and to judge by yourself whether you are familiar with the background material required and presume at the Communication and Information Technology program, please carefully work through the following questions.

Basic Calculus

1) What are *complex numbers*? Why and when are they required?
Give the *rules for computing* (addition, subtraction, multiplication, and division) with complex numbers!

2) Write down *Euler's formula*! Describe the *Cartesian form* and the *polar form* of complex numbers! How can both forms be converted into each other?

3) What are *absolute value (magnitude)* and *argument (phase)* of a complex number?

4) *Differentiate* (w.r.t. the variable t; $c \in \mathbb{R}$; $\mathrm{j}^2 = -1$) the following functions:
$f(t) = c$, $f(t) = t^2$, $f(t) = \cos(ct)$, $f(t) = \mathrm{e}^{t}$, $f(t) = \mathrm{e}^{\mathrm{j}ct}$

5) *Integrate* (w.r.t. the variable t; $c \in \mathbb{R}$; $\mathrm{j}^2 = -1$) the following functions:
$f(t) = c$, $f(t) = t^2$, $f(t) = \cos(ct)$, $f(t) = \mathrm{e}^{\mathrm{j}ct}$, $f(t) = \begin{cases} 1, & |t| < 1/2 \\ 0, & \text{else} \end{cases}$

6) How is the product of a *matrix* with a *vector* defined? Which requirements do both quantities have to fulfill, such that the product exists?

7) How is the *scalar product* of vectors defined? How is the *cross product* between two vectors defined?

8) What is the *Euclidean norm* of a vector?

9) Let a *basis*, i.e., a set of vectors spanning a space, be given. How can we calculate an *orthonormal basis* from the given one?

10) Explain the meaning of *eigenvalues* and *eigenvectors*! How are they calculated given a (square) matrix?

11) What is the meaning of *curl*, *div*, and *grad*? Express them in *Cartesian*, *polar*, and *cylindrical* coordinates!

Basics on Electronics

12) What are the *Kirchhoff's circuit laws*?

13) State *Ohm's law*! Is it applicable in AC systems?

14) Can you write the *Node Admittance Matrix* for a circuit?

15) How are the *complex impedances* of a capacitor and an inductor defined?

16) How are a *node-voltage analysis* and a *branch-current analysis* being carried out to find the currents and/or voltages of an electrical network?

17) Can you convert a *resistive voltage source* into an equivalent *current source*?

18) Can you determine the *output voltage* of a resistive source loaded with a diode?

19) What is the *DC operating point* of an electrical network?

20) How can the *nonlinear state-space description* of a network be linearized around a *DC operating point*?

21) What is the *small signal equivalent circuit* of an electrical network?

22) What is a *4-pole* and what is a *2-port*? How are the *Y-* and *Z-parameters* of a linear 2-port defined?

23) Can you calculate the *step response* for first order RLC networks?

24) What is the *time constant* τ of a first order low-pass filter (comprised of a resistor and a capacitor)?

25) What are the characteristics of an *ideal OPAMP* (impedances, gain)?

26) Can you draw an *analog adder*, a *low-pass*, and an *ideal integrator* using an OPAMP?

Fields and Waves

27) How large is the *voltage* at a *short circuit*? How large is the *current* at an *open end*?

28) What is a *plane wave*?

29) Concerning electromagnetic waves explain the term "*interference*".

30) What do *Maxwell's Equations* describe? Write them down! Which vectorial field quantities are contained? Which relationships exist between these fields in a linear medium?

31) Which quantity describes the *energy transport* of an electromagnetic wave?

32) What is the *Biot-Savart law*?

33) What is the relationship between *DC-voltage* and *E-field* of a capacitor?

34) What *electrical loss mechanisms* do you know?

35) What is larger 3 mW or 3 dBm; 0 dBW or 0.5 W?

36) How are linear quantities expressed in *decibels (dB)*?
Give the quantities 2, 3, 4, 10, 100, and 1000 in dB.

Electronic Devices and Optoelectronics

37) Explain the concept of *holes* (in addition to electrons) in a semiconductor!

38) What is the *Fermi energy*? What are quasi-Fermi energies?

39) Explain the flow of electrical current over a *pn-junction*.

40) What is the *depletion region* in a pn-junction and how does it depend on the applied voltage?

41) What is the expression for the *drain current* of a *MOSFET transistor* in strong inversion as a function of its gate, drain, and source voltage ignoring all second-order effects?

42) What is the expression for the *emitter current* of a *bipolar transistor* as a function of its base voltage and its reverse saturation current according to the *Ebers-Moll model*?

43) What are the *DC small signal equivalent circuits* of a MOSFET and a BJT?

44) What is a common *source/gate/drain amplifier* for a MOSFET transistor?

45) What is a common *emitter/base/collector configuration* for a bipolar transistor?

46) Which frequency does *green light* have approximately?

47) How large is the *velocity of light* in a material?

48) What happens when a light ray hits an interface between *two different media*?

49) What is a *photon*? Does it have a mass? What is its momentum?

50) What is "*coherence*" of a light field?

Signals and Systems

51) What are *signals* and what are *systems*?

52) Characterize *continuous-time* and *discrete-time* signals!

53) Under which conditions is a *continuous-time signal* completely specified by a *discrete-time signal*?
How is the discrete-time signal obtained from the continuous-time signal? How is the continuous-time signal recovered from the discrete-time signal?

54) What is the *Dirac delta "function"*?

55) Give the definition of the *convolution* of two signals!

56) What is the *energy* and what is the *average power* of a signal?

57) What is a *linear time-invariant (LTI) system*?
How is such a system completely characterized? Given the input signal, how is the output signal calculated?

58) When is a system *stable*? How can the stability of a system be determined from the *location of its poles*? When is a system *minimum phase*?

59) What is an *ideal low-pass filter*?

60) How is the *Fourier transform* of a (continuous-time) signal defined?
What are the properties of the Fourier transform of a i) real-valued signal, ii) real-valued even signal, iii) purely imaginary odd signal?

61) Let a *signal* with its corresponding *Fourier transform*, i.e., *spectrum*, be given.
How is the spectrum modified if the time-domain signal is i) scaled with a constant, ii) temporarily shifted, iii) multiplied by $\mathrm{e}^{\mathrm{j}ct}$, iv) multiplied by $\cos(ct)$?

62) What operation in frequency domain corresponds to *convolution* in time domain?
What operation in time domain corresponds to *convolution* in frequency domain?

63) What is the *Hilbert transform* of a (continuous-time) signal?
Give the impulse response and the transfer function of the Hilbert transform!

64) How is the z *transform* of a discrete-time signal defined?
Given the z transform of a signal, how is the spectrum (discrete-time Fourier transform) of this signal obtained?

65) What is the *discrete Fourier transform (DFT)*? For which signals is the DFT suited?

66) How are the spectra of a *continuous-time signal* and that of a *discrete-time signal*, thereof generated via sampling, related?

67) How can the *simplified Nyquist stability criterion*, which uses the *open loop Bode plot* of a plant, be used to assess the stability of a closed loop system?

68) How are *gain margin* and *phase margin* defined?

Random Variables, Stochastic Processes, and Estimation

69) Describe the *axioms of probability*!

70) State *Bayes' Theorem*. For what is it useful?

71) What is a *random variable*?

72) Give the meaning of the *cumulative distribution function (cdf)* and the *probability density function (pdf)* of a random variable!

73) How is the *expected value (expectation)* of a random variable defined?
What is the intuition behind the expected value?

74) What are *mean* and *variance* of a random variable?

75) Let two zero-mean *normal (Gaussian) distributed random variables* X_1 and X_2 with variances σ_1^2 and σ_2^2, respectively, be given. What is the variance of the random variables i) $Y_1 = X_1 + X_2$, ii) $Y_2 = X_1 - X_2$, iii) $Y_3 = X_1 \cdot X_2$, and iv) $Y_4 = X_1/X_2$?

76) What is the notion of a *stochastic process*?
What are the most important quantities characterizing a stochastic process?

77) Which conditions must a process fulfill such that it is *stationary*?
What is an *ergodic process*?

78) What is the *power spectral density (psd)* of a stochastic process?
Knowing the psd, how is the *power* of the process calculated?

79) Let a stochastic process (with given autocorrelation function (acf) and psd) be the *input to an LTI system* (impulse response/transfer function). How are acf and psd of the *output process* related to the quantities of the input process?

80) A continuous-time stochastic process (with given acf and psd) is *sampled*. How are acf and psd of the obtained *discrete-time process* related to the quantities of the input process?

81) We want to *estimate* a random variable x via the (indirect) observation of a random variable y, which depends on x.
Explain the *maximum a-posteriori rule* and the *maximum-likelihood rule* for estimating x based on y.

Fundamentals on Communications

82) An *analog signal* is converted into a (binary) *data stream* by means of *pulse-code modulation (PCM)*. How is the *data rate* related to the *sampling frequency* and the *resolution*? If *uniform quantization* is used, by how much dB does the *signal-to-noise ratio* increase if the number of quantization levels is doubled? By which amount does the date rate increase?

83) What are the *bandwidth* and the *power* of a (transmit) signal?

84) Let a continuous-time (source) signal be given. How is such a signal transmitted using *amplitude modulation (AM)*? What are the required operations in transmitter and receiver?

85) Let a continuous-time (source) signal be given. How is such a signal transmitted using *frequency modulation (FM)*?

86) What are the advantages and disadvantages of FM compared to AM?

87) What is the main difference of *digital transmission schemes* compared to analog schemes?
What are the main advantages of digital transmission over analog transmission?

88) What are the main *performance measures* for any type of communication systems? In other words, the utilization of which *resources* is typically quantified?

89) What is the main principle of *pulse-amplitude modulation (PAM)*? How is the (binary) information to be communicated represented in the transmit signal if we consider the simplest form of *amplitude-shift keying*?

90) What is the difference between *baseband transmission* and *carrier-modulated (passband) transmission*?

91) What is a *quadrature modulator/demodulator*?

92) What is an *additive white Gaussian noise (AWGN)* channel? Explain the meanings of *additive*, *white*, and *Gaussian*!

93) What is the *optimum receive filter* for PAM transmission over an AWGN channel?

94) Why do we characterize digital transmission schemes via their *bit error rate (BER)*? How (qualitatively) is the BER related to the signal-to-noise ratio?

95) Given a *discrete source* with a finite alphabet and known probabilities of the symbols. How is the *entropy* of such a source calculated and what is their meaning?

96) What is the aim of *source coding*? Give an example for a specific source coding scheme and explain how it works!

97) What is the meaning of the *capacity* of a channel!

98) Let a *discrete-time AWGN channel* with some signal power and noise power be given. Calculate the *capacity* of this channel!

99) Let a *continuous-time AWGN channel* with some bandwidth, signal power and noise power spectral density be given. Calculate the *capacity* of this channel!

100) What is the aim of *channel coding*? Give an example for a specific channel coding scheme and how the corresponding decoder works!