Questions to the course

"Mathematical and Computer Modeling in Science and Engineering"

Chapter 1. Methodological Principles of Modeling

1. How do you understand the term "mathematical modeling"?
2. What does one need modeling for?
3. What are the elementary stages of modeling?
4. What are the basic types of mathematical models?
5. What is a linear system? A nonlinear system?
6. What is a linearization?
7. How can one simplify mathematical models and modeling process?
8. How can you utilize the dimensionless units? In what areas are they important?
9. What is scaling? How does it work?
10. What is symmetry? How can one use it?
11. What is a dynamical system?
12. How can you characterize the state of a dynamical system?
13. What is a phase space, a phase point, a phase trajectory, a phase portrait, a phase flux, a phase fluid?
14. What is a conservation law?
15. What conservation laws and conserved quantities do you know?
16. Is the notion of a conservation law important? Is there any practical usefulness of conservation laws?
17. What is energy, which kinds of energy do you know?
18. Is the concept of energy important? Why?
19. What is a potential? A potential field?
20. What is a closed system? An open system?
21. Is a human being, an enterprise, a social group, an ecosystem, a state an open or a closed system?
22. What is irreversibility, irreversible process?
23. Why are the future and the past so different?
24. What is uncertainty? Unpredictability?
25. What is chaos, how can it be described?

Chapter 2. Mathematical Methods for Modeling
ODE based modeling

26. What is an autonomous system? Non-autonomous system? Dissipative system?
27. What is equilibrium? The equilibrium point?
28. What types of equilibrium points do you know?
29. What is the stability of equilibrium? Instability?
30. How can you solve linear differential equations?
31. What is the fundamental system of solutions?
32. How can you solve an inhomogeneous system of linear differential equations?
33. Write a first-order ODE. A second-order ODE.

34. Write a general solution for a first-order linear ODE (homogeneous and inhomogeneous).
35. Write a general solution for a second-order linear ODE (homogeneous and inhomogeneous).
36. What is a nonlinear ODE, produce an example. What is the crucial difference between linear and nonlinear DE?
37. What typical methods of solving nonlinear ODE do you know?
38. What is an isocline? For what purposes are isoclines important?

PDE based modeling

39. Write a generic PDE
40. What types of PDE do you know?
41. Give some examples of specific PDEs?
42. Why are PDEs important for modeling?
43. What methods of solving PDE do you know?

Chapter 3. Computational Techniques for Modeling

44. What software packages that can be used for modeling do you know?
45. What can you say about computer algebra systems (CAS)?
46. What typical methods of solving equations with Maple do you know?
47. What is a discretization, how is it produced?
48. What are the typical numerical methods of integrating the Cauchy problem?
49. Explain the Euler's method. What are the drawbacks of this method?
50. How can one modify the Euler's method?
51. What is the idea of central differences?
52. What numerical methods for Newton's equation of motion do you know?
53. What is the iteration procedure?
54. Write an advection equation and discretize it.
55. What is the idea of predictor-corrector schemes?
56. What software packages would you use to model a linear response? A nonlinear response?

Chapter 4. Case Studies in Modeling

57. What is the logistic model?
58. How can you model the population growth?
59. Is the population growth a linear or a nonlinear model?
60. What is the role of a growth parameter in the logistic model?
61. Write discrete and continuous logistic equations.
62. How can one use iterative procedures in treating logistic equations?
63. What applications of logistic models do you know?
64. What applications of models based on dynamical systems do you know?
65. What are the main equations of classical mechanics?
66. What is a trajectory? How can you compute the trajectory of a body?
67. What do you know about oscillations? How are they described?
68. How do phase trajectories of a damped oscillator look like?
69. What are coupled oscillators? How can you describe a system of a pair of linked oscillators? A system of N coupled oscillators?
70. Where are the models of coupled oscillators important?

71. What is resonance? How can you describe it? Why is the concept of resonance important?
72. What is spectrum? How do you compute it?
73. Write an oscillator equation. Write this equation in dimensionless units.
74. What is perturbation? The perturbation expansion? The perturbation theory?
75. What is a “competition model”? Where are such models used?
76. What are the typical models in chemical engineering?
77. What is a thermal explosion, a spontaneous combustion, what are the modeling principles of these phenomena?
78. What are the typical problems with nuclear reactors?
79. What quantities are important in nuclear reactor modeling?
80. Why is it important to model nuclear accidents?
81. What nuclear accident scenarios do you know?
82. What models in economics do you know?
83. What models in the military planning do you know?
84. How can one model the arms race between two countries? Between $n>2$ countries?
85. What approaches to vehicle traffic modeling do you know?
86. What do you know about molecular dynamics?
87. How can you model spread of a pollutant in an ecological system?
88. How can you model spread of an infectious disease?
89. How can you model the propagation of waves? Of pulses?
90. What do you know about virtual prototyping?