Possible Questions for the Oral Examination
as a Road Map for the Preparation to the Examination

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1. Elektromagnetic fields are described by Maxwell's equations

$$\begin{aligned} \mathrm{curl}H &= J + \frac{\partial D}{\partial t}, && (1)\\ \mathrm{div}B &= 0, && (2)\\ \mathrm{curl}E &= -\frac{\partial B}{\partial t}, && (3)\\ \mathrm{div}D &= \varrho, && (4) \end{aligned}$$

   and the constitutive relations

$$\begin{aligned} B &= \mu H + \mu_0 M, && (5)\\ D &= \varepsilon E + P, && (6)\\ J &= \sigma E + J_i. && (7) \end{aligned}$$

   Give the integral formulations of Maxwell's equations ! Derive the vector potential formulation and the E-field based formulation !

2. Derive the interface conditions for the $B-$, $H-$, $D-$, and $E-$fields from the integral formulations of Maxwell's equations ! What do you know about possible boundary, initial and radiation conditions !

3. Which special electromagnetic regimes do you know ? Derive the equations describing these special electromagnetic regimes from the full Maxwell equations !

4. Derive the vector potential formulation for the 3D magnetostatic case from the full Maxwell equations ! When can you use Biot-Savart's formula ? Derive Biot-Savart's formula ! Derive the magnetostatic equations for the 2D case !

5. What do you know about distributional and weak derivatives ? Define the weak gradient, curl and div (Definition 2.1) ! Define the function space $H(grad)$, $H(curl)$ and $H(div)$ and provide some basic properties of these spaces !

6. What do you know about traces of functions from $H^1(\Omega)$? Discuss the trace theorem and the inverse trace theorem (extension theorem) ! Prove Lemma 2.3 !

7. What do you know about traces of functions from $H(div)$? Discuss the trace theorem (Theorem 2.6) and the inverse trace theorem (extension theorem = Theorem 2.5) ! Prove the statement formulated in Exercise 2.6 !

8. What do you know about traces of functions from $H(curl)$? Discuss the trace theorem (Theorem 2.6) ! Prove the statement formulated in Exercise 2.8 !

9. Discuss the solvability of the general curl-curl-equation for the case $\kappa \in R^+$ (Section 2.2.1) !

10. Discuss the solvability of the general curl-curl-equation for the magnetostatic case $\kappa = 0$ (Section 2.2.2) !

11. Discuss the solvability of the general curl-curl-equation for the case $\kappa = \kappa_r + i\kappa_i$ with $\kappa_i \neq 0$ (Section 2.2.3) !

12. Discuss the solvability of the general curl-curl-equation for the case $\kappa \in R^-$ (Section 2.2.4) !

13. What do you know about the regularity (Section 2.2.5) !

14. Define and discuss the lowest-order triangular edge element (Section 3.2.1: Def. 3.4, Properties 3.5, Lemma 3.6, Exercise 3.7, Remark 3.8, Theorem 3.9) !

15. Explain the mapping priciple for the lowest-order triangular edge element (Section 3.2.2: Lemma 3.10) and discuss the implementation aspects (Section 3.2.3) !

16. Define the "nodal" interpolation operator I_h, show that $I_h^2 = I_h$, show the transformation identity for the edge interpolation operator (Lemma 3.12), and the L_2 interpolation error estimate (Theorem 3.13) !

17. Discuss the commuting diagram (Theorems 3.14 and 3.15), and show the $H(curl)$ interpolation error estimate (Theorem 3.16) !

18. Discuss the tetrahedral edge (Nédélec) and Raviart-Thomas finite elements and the corresponding finite element spaces (Section 3.3) !

19. Show the $H(curl)$ discretization error estimate under the assumptions formulated in Theorem 3.21 !