NORGES TEKNISK-
NATURVITENSKAPELIGE UNIVERSITET
INSTITUTT FOR FYSIKK

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EXAM
TFY4155 ELEKTROMAGNETISME
FY1003 ELEKTRISITET OG MAGNETISME

Tuesday May 31 2005, 0900 - 1300
English

Remedies: C

- K. Rottmann: Matematisk formelsamling
- O. Øgrim and B. E. Lian: Størrelser og enheter i fysikk og teknikk, or B. E. Lian and C. Angell: Fysiske størrelser og enheter.
- Approved calculator, with empty memory, according to list composed by NTNU (HP30S or similar.)

Pages 2 - 5: Exercises 1 - 5.
Appendix 1 - 3: Formulas.

The exam consists of 10 partial exercises (1a, 1b, 1c, 2, 3a, 3b, 3c, 4, 5a, 5b). Each of these 10 partial exercises will be given equal weight during the grading. Vectors are given with **bold** letters. Unit vectors are given with a hat above the symbol. If nothing else is stated, you may assume that the surrounding medium is air (vacuum), with permittivity $\varepsilon_0 = 8.85 \cdot 10^{-12}$ F/m and permeability $\mu_0 = 4\pi \cdot 10^{-7}$ H/m. In exercises where numerical values are provided for all necessary parameters, numerical answers are required. In exercises where derivations or proof is *not* explicitly asked for, formulas and results that have been derived in the textbook, the lectures, or in the weekly exercises may be used without deriving them again (provided you remember them). This applies e.g. to exercises 1b, 1c, and 2.

The grades will be available before June 21.

Formulas

$\int d\boldsymbol{A}$ denotes surface integral and $\int d\boldsymbol{l}$ denotes line integral. $\oint$ denotes integral over closed surface or around closed curve. The validity of the formulas and the meaning of the various symbols are assumed to be known.

Electrostatics

- Coulomb's law:
$$\boldsymbol{F} = \frac{qq'}{4\pi\varepsilon_0 r^2}\hat{r}$$
- Electric field and potential:
$$\boldsymbol{E} = -\nabla V$$
$$\Delta V = V_B - V_A = -\int_A^B \boldsymbol{E}\cdot d\boldsymbol{l}$$
- Electric potential from point charge:
$$V = \frac{q}{4\pi\varepsilon_0 r}$$
- Electric flux:
$$\phi_E = \int \boldsymbol{E}\cdot d\boldsymbol{A}$$
- Gauss' law for electric field:
$$\varepsilon_0 \oint \boldsymbol{E}\cdot d\boldsymbol{A} = q$$
$$\oint \boldsymbol{D}\cdot d\boldsymbol{A} = q_{\text{free}}$$
- Electrostatic field is conservative:
$$\oint \boldsymbol{E}\cdot d\boldsymbol{l} = 0$$
- Electric displacement:
$$\boldsymbol{D} = \varepsilon_0\boldsymbol{E} + \boldsymbol{P} = \varepsilon_r\varepsilon_0\boldsymbol{E} = \varepsilon\boldsymbol{E}$$
- Electric dipole moment:
$$\boldsymbol{p} = q\boldsymbol{d}$$

- Electric polarization = electric dipole moment pr unit volume:

$$\boldsymbol{P} = \frac{\Delta \boldsymbol{p}}{\Delta V}$$

- Capacitance:

$$C = \frac{q}{V}$$

- Energy density in electric field:

$$u_E = \frac{1}{2}\varepsilon_0 E^2$$

Magnetostatics

- Magnetic flux:

$$\phi_m = \int \boldsymbol{B} \cdot d\boldsymbol{A}$$

- Gauss' law for the magnetic field:

$$\oint \boldsymbol{B} \cdot d\boldsymbol{A} = 0$$

- Ampère's law:

$$\oint \boldsymbol{B} \cdot d\boldsymbol{l} = \mu_0 I$$

$$\oint \boldsymbol{H} \cdot d\boldsymbol{l} = I_{\text{free}}$$

- Magnetic field from current carrying conductor (Biot–Savart law):

$$\boldsymbol{B} = \frac{\mu_0}{4\pi} I \int \frac{d\boldsymbol{l} \times \hat{r}}{r^2}$$

- The $\boldsymbol{H}$-field:

$$\boldsymbol{H} = \frac{1}{\mu_0}\boldsymbol{B} - \boldsymbol{M} = \frac{1}{\mu_r \mu_0}\boldsymbol{B} = \frac{1}{\mu}\boldsymbol{B}$$

- Magnetic dipole moment:

$$\boldsymbol{m} = I\boldsymbol{A}$$

- Magnetization = magnetic dipole moment pr unit volume:

$$\boldsymbol{M} = \frac{\Delta \boldsymbol{m}}{\Delta V}$$

- Magnetic force on straight current carrying conductor:

$$\boldsymbol{F} = I\boldsymbol{L} \times \boldsymbol{B}$$

- Energy density in magnetic field:

$$u_B = \frac{1}{2\mu_0}B^2$$

Electrodynamics and electromagnetic induction

- Faraday (–Henry)s law:

$$\mathcal{E} = \oint \boldsymbol{E} \cdot d\boldsymbol{l} = -\frac{d\phi_m}{dt}$$

- Ampère–Maxwell's law:

$$\oint \boldsymbol{B} \cdot d\boldsymbol{l} = \mu_0 I + \mu_0 \varepsilon_0 \frac{d\phi_E}{dt}$$

- Selfinductance:

$$L = \frac{\phi_m}{I}$$

- Mutual inductance:

$$M_{12} = \frac{\phi_1}{I_2} \quad , \quad M_{21} = \frac{\phi_2}{I_1} \quad , \quad M_{12} = M_{21} = M$$

- Energy density in electromagnetic field:

$$u = \frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2\mu_0}B^2$$