Department of Electrical Engineering
Institutionen för Elektrotekniska system
Electrotechnical design

EXAMINATION in 2C1134 Electrotechnical Design
Thursday December 16 2004 at 1400-1900
Lecture hall Q11-Q12, Osquldas väg 6

The following aids are allowed during the examination

- **Any pocket calculator**
- **Compendium in Electrotechnical modeling and design**
- **Tables in mathematics and physics**

Each task will maximally give 3 credits.

NOTICE! PLEASE WRITE YOUR OWN PERSONAL NUMBER AND NAME ON THE ENVELOPE AND ON EACH SHEET!

Max. one solution per sheet!

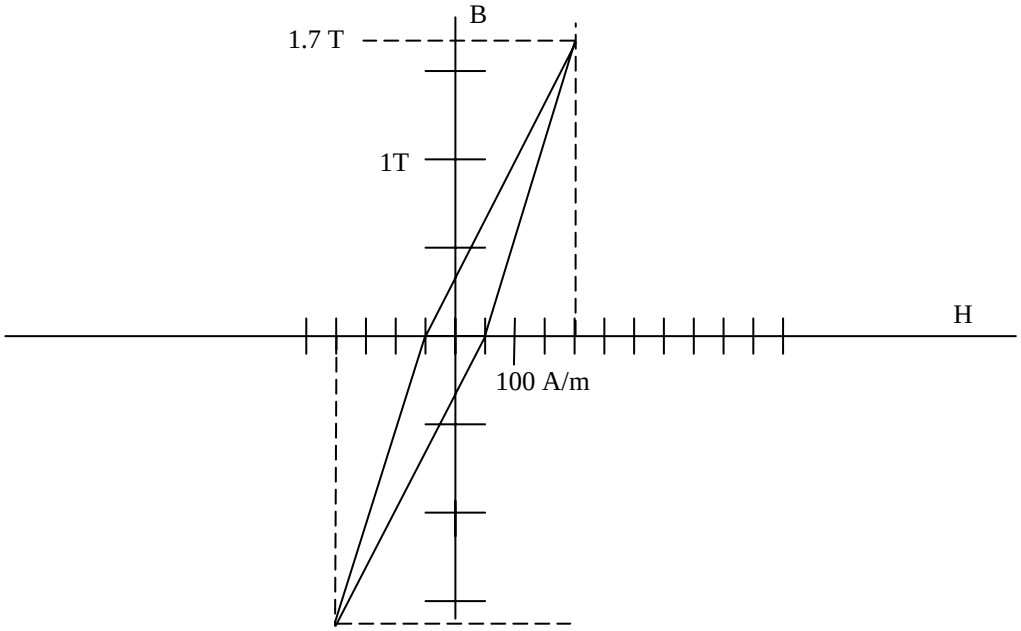
1.
A DC-cable has a conductor of radius 15 mm and its resistance per km at 20° C is 0.0287 Ω. The temperature coefficient of the resistance is 0.00393 per centigrade. The cable insulation is in order from the conductor built up by
0.3 mm conductive paper
7 mm oil-impregnated paper
0.25mm conductive paper
2.5mm lead jacket
4.4mm cover
The heat conductivity of all cable insulation and cover materials is 0.2 W/(mK). The cable is buried 0.8 m in the ground with a heat conductivity of 0.9 W/(mK).
Determine the maximal load current if the ground surface temperature is 20°C and the conductor temperature should not exceed 50°C.

2.

A coaxial cable is terminated by a 50Ω resistor to avoid reflection with respect to incoming transient waves. The cable inner conductor radius is 2mm and and the insulation thickness 8mm. The relative permittivity of the cable insulation is 2. First determine the reflection coefficient β . Then plot the voltage at a point A 30m from the termination as function of time if a voltage ramp of steepness 100 kV/μs arrives and then is is reflected back to point A. Set time equal to zero when the ramp first arrives at A and plot the voltage up to the triple wave propagation time between point A and the cable termination.
Hint: The inductance per meter of a coaxial cable is $\frac{\mu_0}{2\pi}\left(\ln\frac{r_1}{r_0}+\frac{1}{4}\right)$ $[H/m]$

3.

A laminated core for a magnetic device should be designed. The thicknesses of the sheets of magnetic material from one tentative producer are 0.5 mm , 0.3 mm and 0.1 mm. The magnetisation curve looks like that in the figure below. The resistivity of the material is 0.5 μΩm. Determine the corresponding frequencies where the hysteresis and eddy current losses are the same when the peak flux densities are 1.7T.



4.

The electric field strength at the ground surface shall be determined at 10m horizontal distance from the outer phase of a transmission line. The line is a three-phase line with 145kV system voltage. All conductors are located at 12 m height with phase distance 4m. The conductor radius is 12mm. Assume the following capacitance matrix:

$$\begin{bmatrix} 7.83 & -1.67 & -0.79 \\ -1.67 & 8.11 & -1.67 \\ -0.79 & -1.67 & 7.83 \end{bmatrix} \quad (pF/m)$$

5.
Two parallel-plate electrodes in a capacitor will be insulated with oil-impregnated paper ($\varepsilon_r = 3.8$) and mineral oil ($\varepsilon_r = 2.1$). The electrode separation is 1 cm.
The breakdown field-strength (kV/mm) for the oil-impregnated paper as well as for the oil has a thickness (d) dependence according to $E_b(d) = \frac{E_{b0}}{(d/d_0)^{0.3}}$, where E_{b0} is the breakdown field-strength for $d = d_0$.
The insulation consists of 80 % paper (8 mm) and 20 % mineral oil (2mm). The paper insulation is made up of 100 layers.
The breakdown field-strength for 8 mm homogeneous paper insulation is 10 kV/mm and for an oil gap of 2 mm it is 15 kV/mm.

Task: Determine the breakdown voltage of the configuration with all papers together and for a configuration where a lamination of the 100 layers of the paper is formed with oil barriers in-between each layer, still 80% of the insulation is oil-impregnated paper and 20% is mineral oil.

6.
A phase to phase to ground fault occurs in the end of a 70km long, 220kV, 50Hz (phase-to-phase or main voltage) unloaded three-phase transmission line, which is fed from a stiff network. The line has horizontally placed phases with a phase separation of 4m. All conductors have a radius of 15mm. The untransposed conductors are located above a ground with a soil-resistivity of 3000 Ωm.

Determine the short-circuit currents in the two short-circuited conductors and the current to ground if the short circuit occurs between two nearby phases and ground, see picture below.