Department of Electrical Engineering
Institutionen för Elektrotekniska system
Electrotechnical design

EXAMINATION in 2C1134 Electrotechnical Design
Tuesday December 16 2003 at 1400-1900
Lecture hall Q24-25, 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.

Three single cables should be placed in a flat ground. The heat conductivity of the ground is 1 W/(mK) . The cable jacket radius of the cables are 35 mm. Buried in ground the cables should be located at the same depth 0.5 m. What is the minimal allowed horizontal cable separation if the highest temperature rise of any cable should not exceed 20 K and the power dissipation of the cables are 20 W/m .

2.

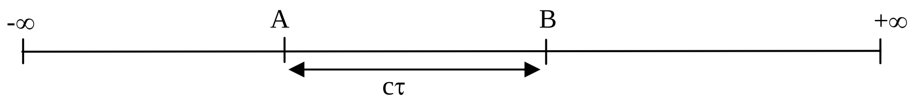
A dielectric material has a complex permittivity that can be described by a Debye-response:

$\tilde{\varepsilon}_r(\omega) = \varepsilon_r'(\omega) - j\varepsilon_r''(\omega) = \varepsilon_\infty + \dfrac{\Delta\varepsilon}{1 + j(\omega/\omega_p)}$ where $\varepsilon_\infty = 2$ and $\Delta\varepsilon = \varepsilon_s - \varepsilon_\infty = 6$.

$\omega_p = 2\pi f_p$ where $f_p = 1\,kHz$. Determine the frequency where the loss tangent tan $\delta(\omega)$ is at maximum and determine the maximum value.

3.
The individual phases of a 420 kV three-phase transmission line over flat ground are equipped with three 10mm diameter conductors arranged in triangle that can be circumscribed by a circle of radius 20cm.
The phases are located in the points (-4,19) , (0,24) and (4,19) [m,m] and the resistivity of the ground is 2000 [Ωm].
Calculate all inductances (inner+ outer inductance) per length (H/m) for all phases and use these to calculate the resulting current amplitude if one outer phase is shorted against the middle phase 200 km from the feeding of the line.

4.
The characteristic impedance of a transmission line changes in A and B such that the transmission coefficient from -∞A to AB is 0.5 and the transmission coefficient from AB to B+∞ is 0.5. The travelling time of an electromagnetic wave between point A and B is τ. Illustrate the voltage variation at B up to time $t=5\tau$ if an incoming voltage step of amplitude U_0 arrives at A at time t=0. Also calculate the value of the voltage at B after an infinite number of reflections. c is the the speed of light. Hint: Use the expression of the sum of a geometric series



5.
The individual phases of a three-phase transmission line over a flat conductive ground are equipped with three 10mm diameter conductors arranged in triangle that can be circumscribed by a circle of radius 20cm.
The phases are located in the points (-4,19) , (0,24) and (4,19) [m,m].

Calculate all capacitive coupling coefficients and then describe how these can be used to calculate the capacitances per length (F/m) between all phases and each phase to ground.

6.

A Thomson coil is shaped like a flat clock spring and is initially placed on a flat plane of a good electrical conductor. By injection of a fast current pulse eddy currents are induced in the conductive material. The original current in the coil and the induced current in the conductive material cause a huge repulsive force that declines when the coil separates from the conducting surface. The Thomson coil wire radius is r_1.

Calculate an expression of the initial force F of a single turn of radius R_0. Assume that the current is located in the centres of the coil turn and its mirror image. Use the principle of virtual motion i. e. $F = -\left.\frac{\partial W_m}{\partial z}\right|_{\phi}$ where ϕ is the flux generated by the Thomson coil turn and its mirror image representing the eddy current in the flat plane of electrical conductive material. Then insert a current of 5kA in the derived expression to get the corresponding initial force when R_0=5mm and r_1=0.25mm.

Hint: Straighten out the wire and make the calculations on a straight line over a conducting ground. Neglect end effects. Calculate the inductance by integration of the generated flux to get the magnetic energy of the system.