Assiut University
Faculty of Engineering
Electrical Engineering Department
Final Exam

2^{nd} Semester 2014/2015
1^{st} year, Bylaw 2004
Time Allowed: 3 hours
Total marks: 100 marks

Theory of Electric Fields (1-B)

Answer the following questions:

Question No. 1 **(25 Marks)**

(a) Discuss in detail the analogy between current density in conducting media filling a two-electrode arrangement and electric flux density in dielectric media filling the same arrangement. How is this analogy used to assess the capacitance and resistance of the arrangement? **[10 marks]**

(b) Construct a curvilinear-square map of the potential field about two parallel circular cylinders in air, each of 3.5 cm radius, separated a center-to-center distance 21 cm. Calculate from the sketch and from the exact formula:
(i) Capacitance per meter.
(ii) Maximum electric field provided that the two cylinders are stressed by ±1 Volt. **[15 marks]**

Question No. 2 **(25 Marks)**

(a) Starting from the principle of charge conservation, derive the current continuity equation in its differential form. **[6 marks]**

(b) Explain in detail how the conductivity of metallic conductors and intrinsic semiconductors change with the increase of temperature. **[4 marks]**

(c) The cross section of an infinitely-long cylinder of 5 m radius at a potential of 100 V in free space. Its axis is 13 m away from a plane at zero potential. Find:
(i) the location of the equivalent line charge, a.
(ii) the value of the potential parameter, K_1.
(iii) the strength of the equivalent line charge, ρ_L.
(iv) the capacitance between cylinder and plane, C.
(v) new values for the potential parameter, K_1, the cylinder radius, b, and the distance between the cylinder axis and the plane, h, to identify the cylinder representing the 50 V equipotential surface.
(vi) the ratio between the maximum and minimum values of conductor surface-charge density.
[15 marks]

Question No. 3 **(25 Marks)**

(a) With the aid of neat sketches, compare briefly between the polar and nonpolar dielectric molecules. **[6 marks]**

(b) A point charge Q of 10 nC is located at point (2, 0, 3) between two semi-infinite conducting planes (z=0 and x=0) intersecting at right angles. Determine the potential at point (4, 5, 6) and the force acting on the charge Q. **[10 marks]**

(c) A copper sphere of radius 4 cm carries a uniformly distributed total charge of 5 μC in free space. Calculate:

(i) the total energy stored in the electrostatic field.

(ii) the capacitance of the isolated sphere. **[9 marks]**

Question No. 4 **(25 Marks)**

(a) In a p-n junction extending in the z-direction, the region for $z < 0$ is the p-type material and the region for $z > 0$ is the n-type material, where z=0 is at the p-n interface. The degree of doping is identical on each side of the junction. The volume charge density at the junction is expressed as:

$$\rho_v = 2\rho_{v0} \operatorname{sech}\left(\frac{z}{a}\right) \tanh\left(\frac{z}{a}\right)$$

where ρ_{v0} and a are constants related to the junction.

Solve Poisson's equation to determine the potential and electric field for the junction as a function of distance z from the center of the junction. Derive an expression of the junction capacitance. **[15 marks]**

(b) Solve Laplace's equation for the potential field in the homogeneous region between two concentric conducting spheres with radii 0.2 m and 0.3 m, if V = 200 V at r = 0.2 m and E_r = 6000 V/m at r = 0.3 m. **[10 marks]**

-- *Best wishes* --

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$$\nabla^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 0 \qquad \text{(cartesian)}$$

$$\nabla^2 V = \frac{1}{\rho}\frac{\partial}{\partial \rho}\left(\rho \frac{\partial V}{\partial \rho}\right) + \frac{1}{\rho^2}\left(\frac{\partial^2 V}{\partial \phi^2}\right) + \frac{\partial^2 V}{\partial z^2} \qquad \text{(cylindrical)}$$

$$\nabla^2 V = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \frac{\partial V}{\partial r}\right) + \frac{1}{r^2 \sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta \frac{\partial V}{\partial \theta}\right) + \frac{1}{r^2 \sin^2\theta}\frac{\partial^2 V}{\partial \phi^2} \qquad \text{(spherical)}$$