EMBU UNIVERSITY COLLEGE

(A CONSTITUENT COLLEGE OF THE UNIVERSITY OF NAIROBI)

FIRST SEMESTER EXAMINATIONS 2013/2014

THIRD YEAR EXAMINATION FOR THE DEGREE OF BACHELOR SCIENCE

SPH 304: ELECTRODYNAMICS

DATE: DECEMBER 17, 2014 **TIME: 08:00 -10:00AM**

INSTRUCTIONS:

ANSWER QUESTION ONE AND ANY OTHER TWO QUESTIONS

QUESTION ONE

a) i) Write the integral mathematical statement of Gauss law explaining all the terms used. (2 marks)

ii) Derive Gauss law in differential form from the expression in b (i). (3 marks)

b) Apply Gauss' law to

i) Find the electric field $\vec{E}$ due to a very long line charge of charge density λ per unit length. (3 marks)

(ii) Find the electric field $\vec{E}$ at a point **P** anywhere outside the surface of the sphere filled with a uniform distribution of charge (3 marks)

c) Derive the relation $\vec{E} = -\vec{\nabla}\phi$ where $\vec{E}$ is the electric field and ϕ is the electrostatic potential. (4 marks)

d) Show that the electrostatic field is conservative and hence define the electrostatic potential. (5 marks)

e) A charge **q** is placed at a distance **a** away from a plane infinite conductor held at zero potential. Apply the method of images to find the force between the charge and the conductor. (5 marks)

f) With the help of a parallel-plate capacitor, show that the potential at a point x inside its plates is given by $\Phi\ (x) = \frac{V_0}{d} x$ (5 marks)

QUESTION TWO

a) i) Derive the relation $\nabla^2 \phi = -\frac{\rho_f}{\varepsilon \varepsilon_0}$ between the electrostatic potential ϕ and the free charge density ρ_f in a medium whose relative permittivity is ε. (3 marks)

ii) Use the above relation to show that electrostatic potential inside a co-axial cable filled with a uniform dielectric having no free charge is given by

$$\phi(r) = -\frac{V}{In(b/a)}\left[In(r) - In(b)\right]$$

Where $\phi(r)$ is the electrostatic potential at a perpendicular distance r from the inner conductor, V is the potential maintained across the cable, a is the radius of the inner conductor and b is the radius of the outer conductor. (8 marks)

b) Derive the Poisson's equation and hence the Laplace's equation (4 marks)

c) Derive the relation between the polarization charge density ρ_p and the polarization vector $\vec{P}$ (5 marks)

QUESTION THREE

a) State the differential form of Amperes law and hence derive its integral form. (4 marks)

b) Derive the differential form of Faraday's law and use it to deduce the general expression for an electric field in terms of the vector and scalar potentials. (6 marks)

c) i) Write down the general set of Maxwell's equations in differential form for time varying fields. (4 marks)

ii) From the Maxwell's equations, derive the electromagnetic vector wave equations;

$\nabla^2 \vec{B} = \varepsilon_0 \mu_0 \frac{\partial^2 \vec{B}}{\partial t^2}$ and $\nabla^2 \vec{E} = \varepsilon_0 \mu_0 \frac{\partial^2 \vec{B}}{\partial t^2}$ in linear, isotropic and charge free medium.

(6 marks)

QUESTION FOUR

a) Explain how the presence of dielectric material increases capacitance in a parallel plate capacitor. (2 marks)

b) Distinguish between 'Electric displacement density' (D) and 'Electric field intensity' (E). (2 marks)

c) Two dielectric media of permittivity ε_1 and ε_2 are separated by a plane boundary. With aid of sketches, explain the boundary conditions of the tangential component of electric field $\vec{E}$ and normal component of flux density $\vec{D}$. (6 marks)

d) Distinguish between a linear polarization and random polarization of a wave. (1 mark)

e) Distinguish between a 'conductor' and 'dielectric'. (2 marks)

f) A plane electromagnetic wave through vacuum is incident normally on a dielectric. Find the ratio of the amplitudes of the reflected and incident waves in terms of the refractive index of the dielectric. Explain the negative value of this ratio for medium whose refractive index is greater than unity. (7 marks)

QUESTION FIVE

a) State the Uniqueness theorem, and by prove it by contradiction method. (8 marks)

b) Show that the relation $div\vec{E} = \frac{\rho}{\varepsilon_0}$, which is true for electrostatic case, is also true for the sum of induced and electrostatic fields. (ρ is charge density) (4 marks)

c) Give the physical meaning of the poynting vector and show that is equal to $\boldsymbol{E}$ x $\boldsymbol{H}$. $\boldsymbol{E}$ and $\boldsymbol{H}$ are electric and magnetic fields respectively of the electromagnetic wave. (Consider plane wave in free space.) (8 marks)

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