JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY
SCHOOL OF BIOLOGICAL AND PHYSICAL SCIENCES
UNIVERSITY EXAMINATION FOR THE DEGREE OF BACHELOR OF EDUCATION (SCIENCE)
4TH YEAR 1ST SEMESTER 2018/2019 ACADEMIC YEAR
MAIN
REGULAR

COURSE CODE: SPH 410

COURSE TITLE: ELECTRODYNAMICS

EXAM VENUE: **STREAM: EDUCATION**

DATE: **EXAM SESSION:**

TIME: 2:00 HRS

Instructions:

1. **Answer question 1 (Compulsory) and ANY other 2 questions.**
2. **Candidates are advised not to write on the question paper.**
3. **Candidates must hand in their answer booklets to the invigilator while in the examination room.**

Useful constants

SECTION A

QUESTION 1 (30 MARKS)

a) Let $F_1 = x^2\hat{z}$ and $F_2 = x\hat{x} + y\hat{y} + z\hat{z}$ calculate the divergence and curl of F_1 and F_2 .Which one can be written as the gradient of a scalar? Find a scalar potential that does the job which can be written as the curl of a vector? Find a suitable vector potential. **(6 marks)**

b) Suppose $v = (2xz + 3y^2)\hat{\boldsymbol{y}} + (4yz^2)\hat{\boldsymbol{z}}$**.** Check Stokes' theorem for the square surface shown in the Fig 1.1 below: **(4 marks)**

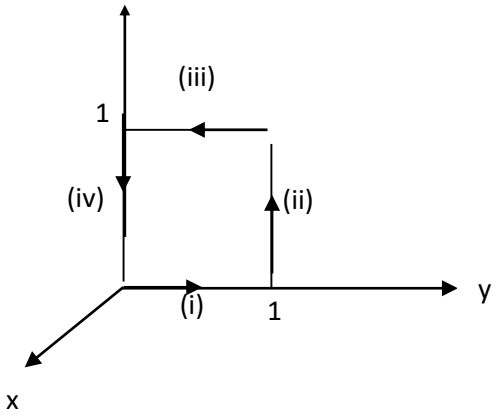

Figure 1.1:

c) A non-conducting rod of length $l$with a uniform charge density λ and a total charge Q is lying along the x -axis, as illustrated in Figure 1.2. Compute the electric field at a point P, located at a distance y from the center of the rod along its perpendicular bisector. **(5 marks)**

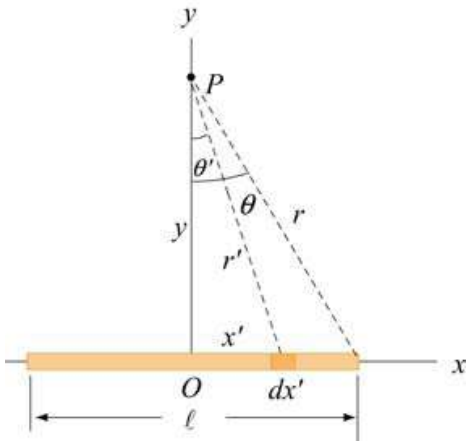

Figure 1.2:

d) i) State the Biot-Savart's law **(2 marks)**

ii) Find the magnetic field a distance s from a long straight wire carrying a steady current I **(3 marks)**

e) An electromagnetic plane wave has an electric field given by

$$\vec{\boldsymbol{E}} = (250\ V/m)cos\left(\frac{2\pi}{3}x - 2\pi \times 10^4 t\right)\hat{\mathbf{k}},$$

Where x and t are in SI units and $\hat{\mathbf{k}}$, is the unit vector in the $+z$-direction. The wave is propagating through ferrite, a ferromagnetic insulator, which has a relative magnetic permeability $k_m = 1000$ and dielectric constant $k_e = 10$.

i) What direction does this wave travel? **(1 mark)**

ii) What is the wavelength of the wave (in metres)? **(3 marks)**

iii) What is the frequency of the wave (in Hz)? **(3 marks)**

iv) What is the speed of the wave (in m/s)? **(3 marks)**

SECTION B

QUESTION 2 (20 MARKS)

a) Find the magnetic field a distance z above the center of a circular loop of radius R, which carries a steady current I. **(6 marks)**

b) Show that the reflection coefficient for radiation at normal incidence **(6 marks)** from free space on to a plane surface of material of refractive index $(n_R - in_x)$ is

$$R = \frac{(n_R-1)^2+n_I^2}{(n_R+1)^2+n_I^2}$$

c) A laser beam, having a power of 100W and a diameter of 1 mm, passes through a glass window of refractive index 1.59. Find the peak values of the electric and magnetic fields of the laser beam in the:

i) air, and **(4 marks)**

ii) glass. **(4 marks)**

QUESTION 3 (20 MARKS)

a) Use a rectangular Cartesian coordinates to show that in a free space where there is no charge the following equation applies: $divE = 0$ **(5 marks)**

b) Electrostatic field is conservative; explain this statement; hence show that

$$curl\ grad\psi = 0$$ **(5 marks)**

c) A dipole consists of two equal but opposite charges, $+q$ and $-q$, separated by a distance $2a$, as shown in Fig. 3.1

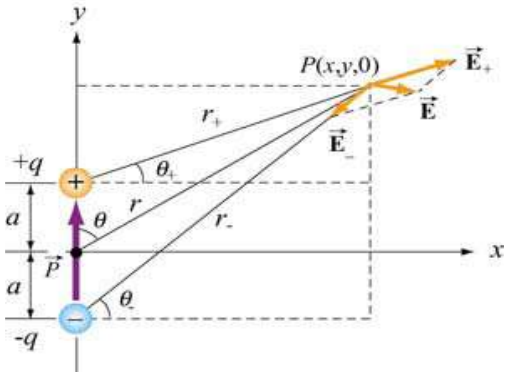

Fig. 3.1: Electric dipole

i) define the dipole moment vector **(1 mark)**

ii) For the point P lying in the y-x plane, give the first order of potential of the dipole. **(3 marks)**

iii) Determine the component of the electric field E_y and E_x in the $x-y$ plane

(5 marks)

iv) What is the potential of the dipole at a point lying along x −axis?

(0.5 mark)

v) On which axis is the maximum potential; calculate the maximum potential if $a = 5.0\ cm$ and $Q = 15\mu C$ **(0.5 mark)**

QUESTION 4 (20 MARKS)

a) Derive Maxwell's equation from Coulomb's, Amperes' and Faradays' laws. Modify the equation to satisfy the conditions of slow varying fields with time. **(6 marks)**

b) A linearly polarized monochromatic EM plane waves in free space (without charges) has electric field given by the following expression $E_y = E_o \cos(\omega t - kx)$

i) Determine the corresponding magnetic field component of the wave

(2 marks)

ii) Show that the electric and magnetic field components bear a constant ratio; give the ratio. **(2 marks)**

iii) The amplitude of the electric field in the plane wave is $0.2Vm^{-1}$. Calculate the amplitude of the magnetic field component. **(2 marks)**

iv) Prove that there is no electric and magnetic field components in the direction of propagation of the wave. **(2 marks)**

c) What is skin effect? Calculate the skin depth for a transmission line made of copper material, with $\mu = 1$ and conductivity $\sigma = 5.9 \times 10^7$ at a frequency of $f = 50MHz$. **(4 marks)**

d) The resistance to direct current of a copper wire of diameter $d = 5.0\ mm$ is $8 \times 10^{-4}\Omega m^{-1}$. Calculate the resistance of the wire at the frequency of, $f = 50MHz$. **(2 marks)**

QUESTION 5 (20 MARKS)

a) Derive Poynting vector for a plane and monochromatic wave in a free space without medium; and give its physical meaning. **(6 marks)**

b) Modify your equation for the Poynting vector to satisfy the conditions for the presence of an isotopic medium with a relative permittivity (ε) and relative permeability (μ) **(4 marks)**

c) Calculate, both magnetic and electric fields amplitude at a point $10\ km$ a way from a $1\ kW$ radio transmitter. **(5 marks)**

d) If the amplitude of electric field in a plane wave is $0.1\ Vm^{-1}$, a few kilometers away from a radio transmitter, calculate the magnitude of the Poynting vector at the place. If the radio waves were transmitted through water with $\varepsilon = 80$ and $\mu = 1$, what would be the difference in magnitude of the Poynting vector. **(5 marks)**