KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS

2020/2021 ACADEMIC YEAR

THIRD YEAR SECOND SEMESTER

SPECIAL/SUPPLEMENTARYEXAMINATIONS

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN PHYSICS.

COURSE CODE: SPH 322

COURSE TITLE: ELECTROMAGNETISM

DATE: 19/1/2022 **TIME: 8-10AM**

INSTRUCTIONS TO CANDIDATES

Answer question ONE and any TWO of the remaining
Symbols used bear the usual meaning.

KIBU observes ZERO tolerance to examination cheating

This Paper Consists of 5 Printed Pages. Please Turn Over.

You may need the following information

Mass of an electron, $m_e = 9.0 \times 10^{-31}$ kg

Mass of proton, $m_p = 1.67 \times 10^{-27} kg$

Charge of an electron, $q = -1.6 \times 10^{-19} C$

Permittivity of free space, $\varepsilon_o = 8.85 \times 10^{-12} C^2/N.m^2$

Permeability of free space, $\mu_0 = 4\pi \times 10^{-7}$ kgm/C^2

Speed of light, $c=3x10^8$ m/s

Electronic charge, $e=-1.6x10^{-19}C$

Divergence Theorem $\oint_s A.dS = \int_\tau \nabla.A\, d\tau$

Stokes Theorem $\oint_c A.dl = \int_s (\nabla \times A).dS$

QUESTION ONE (COMPULSORY) [30 Marks]

(a) A charge of 2.0 μC moves with a speed of $2.0 \times 10^{-6}\, m/s$ along the positive X-axis. A magnetic field $\vec{B}$ of strength $(0.20\vec{j} + 0.40\vec{k})T$ exists in space. Find the magnetic force acting on the charge. [3 marks]

(b) A wire placed along north-south direction carries a current of 10 A from south to north. Find the magnetic field due to a 1 cm piece of wire at a point 200 cm north-east from the piece. [3 marks]

(c) A proton is projected with a speed of $3 \times 10^6\, m/s$ horizontally from east to west. A uniform magnetic field $\vec{B}$ of strength $2.0 \times 10^{-3}\, T$ exists in the vertically upward direction.

i. Find the force on the proton just after it is projected. [2 marks]

ii. What is the acceleration produced? [1 marks]

(d) A current of 10.0 nA is established in a circular loop of radius 5.0 cm. Find the magnetic dipole moment of the current loop. [2 marks]

(e) Figure 1 shows two long, straight wires carrying electric currents in opposite directions. The separation between the wires is 5.0 cm. Find the magnetic field at a point P midway between the wires. [3 marks]

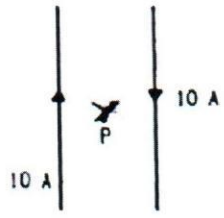

Figure 1.

(f) A current of 2.00 A exists in a square loop of edge 10.0 cm. Find the magnetic field B at the centre of the square loop. [3 marks]

(g) A bar magnet having a magnetic moment of $1.0 \times 10^4 J/T$ is free to rotate in a horizontal plane. A horizontal magnetic field $B = 4 \times 10^{-5} T$ exists in the space. Find the work done in rotating the magnet slowly from a direction parallel to the field to a direction 60° from the field. [3 marks]

(h) Find the magnetic field due to a dipole of a magnetic moment 1.2 A-m^2 at a point 1 m away from it in a direction making an angle of 60° with the dipole axis. [2 marks]

(i) A bar magnet made of steel has a magnetic moment of 2.5 A-m^2 and a mass of 6.6×10^3 kg. If the density of steel is $7.9 \times 10^3 kg/m^3$, find the intensity of magnetization of the magnet.

[3 marks]

(j) An average induced emf of 0.20 V appears in a coil when the current in it is changed from 5.0 A in one direction to 5.0 A in the opposite direction in 0.20 s. Find the self-inductance of the coil.

[3 marks]

(k) The maximum electric field in a plane electromagnetic wave is 600N/C. The wave is going in the x-direction and the electric field is in the y-direction. Find the maximum magnetic field in the wave

and its direction. [2 marks]

QUESTION TWO (20 Marks)

(a) Show that the magnetic field due to current in a straight wire on a perpendicular bisector, is given by: [7 marks]

$$B = \frac{\mu_o i a}{2\pi d\sqrt{a^2 + d^2}}$$

(where $OP=d$, O is the foot of the perpendicular from P to the wire. a is the length of the wire)

(b) Show that

i) The magnetic scalar potential due to a Magnetic Dipole is given by; [6 marks]

$$V(r) = \frac{\mu_o}{4\pi}\frac{M\cos\theta}{r^2}$$

ii) The magnetic field due to a dipole is given by [7 marks]

$$B = \frac{\mu_o}{4\pi}\frac{M}{r^3}\sqrt{1 + 3cos^2\theta}$$

QUESTION THREE (20 Marks)

(a) Two long wires a and b , carrying equal currents of 10.0 A, are placed parallel to each other with a separation of 4.00 cm between them as shown in the figure 2. Find the magnetic field

B at each of the points P, Q and R. [4 marks]

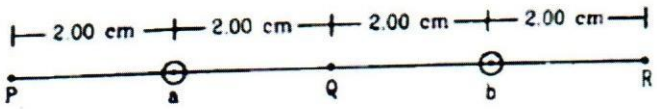

Figure 2.

(b) A solenoid of length 10 cm and radius 1 cm contains 200 turns and carries a current of 10 A. Find the magnetic field at a point on the axis at a distance of 10 cm from the centre.

[5 marks]

(c) An infinite wire is oriented East-West and carries a current of 4.5 A, flowing towards the East. There is a uniform horizontal magnetic field of 0.25 T pointing North. What force (magnitude and direction) acts on unit length of the wire? [3 marks]

(d) Two parallel wires P and Q placed at a separation d = 6 cm carry electric currents i_1 = 5 A and i_2 = 2 A in opposite directions as shown in figure 3. Find the point on the line PQ where the resultant magnetic field is zero. [4 marks]

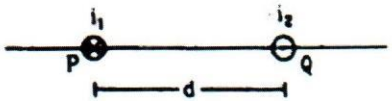

Figure 3.

(l) Find the magnetic intensity H at the centre of a long solenoid having n turns per unit length and carrying a current i;

i. When no material is kept in it [2 marks] ii. When a long copper rod is inserted in the solenoid [2 marks]

QUESTION FOUR (20 Marks)

a) Given Faraday's law of electromagnetic induction, $V = -\frac{d\Phi}{dt}$ derive the equation

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

[5 marks]

b) Differentiate between paramagnetism, ferromagnetism and diamagnetism. [6 marks]

c) A magnetic scalar potential due to a magnetic dipole at a point on its axis situated at a distance of 20 cm from its centre is found to be $1.2 \times 10^{-5}\ T - m$. Find the magnetic moment of

the dipole. [4 marks]

d) Find the per cent increase in the magnetic field B when the space within a current carrying toroid is filled with aluminium. The susceptibility of aluminium is 2.1×10^{-5}. [5 marks

e)

QUESTION FIVE (20 Marks)

a) An inductor (L = 20 mH), a resistor (R = 100 Ω) and a battery (ε = 10 V) are connected in series. Find

i. The time constant [1 marks]

ii. The maximum current [1 marks]

iii. The time elapsed before the current reaches 99% of the maximum value. [2 marks]

b) Show that Ampere's circuital law $\oint \mathbf{B}.d\mathbf{L} = \mu_0 \sum I$, where B is the magnetic field vector, d**L** is the vector specifying an element of a closed path and I is the current, leads to the differential equation $\nabla \times \mathbf{B} = \mu_0 \mathbf{J}$, where J is the current density.

[4 marks]

c) An infinitely long, cylindrical conductor of radius a carries total current I distributed uniformly a cross the conductor. Derive expressions for the magnetic field at a distance r from the centre of the conductor the cases (i) r< a and (ii) r> a. Sketch the variation of the field with r.

[4 marks]

d) State Maxwell's equations in terms of electric (**E**) and magnetic (**B**) fields in a region in which there are charge and current densities (**p** and **J** respectively) which are functions both of space and time. For each equation briefly explain the physical concepts that it encapsulates.

[5 marks]

e) What form do the Maxwell equations reduce to in a vacuum i.e. in the absence of any dielectric or magnetic material? [3 marks]