NATIONAL EXAMS, MAY 2018

04-BS-9, BASIC ELECTROMAGNETICS

3 HOURS DURATION

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. Candidates may use one of two calculators, the Casio or Sharp approved models. This is a closed book exam.

3. Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.

4. All questions are of equal value.

5. Aids: $\varepsilon_0 = 8.85 \times 10^{-12}\, F/m$, $\mu_0 = 4\pi \times 10^{-7}\, H/m$, $e = 1.6 \times 10^{-19}\, C$

1. A point charge +2e is surrounded by a sphere of 10^{-10} m radius of uniform volume charge density of total charge –e. The outer surface of the sphere is an infinitely thin layer of uniform surface charge of total charge –e. The positive point charge +2e is located at the centre of the sphere.

   What is the difference of electric fields at points just inside and just outside of the surface charge layer?

2. A point charge –e is located in each vertex of equilateral triangle of 10^{-10} m sides. A positive point charge +3e is located at the centre of the triangle.

   What is the total electrostatic energy with respect to infinite distance of the charge system?

3. A beam of electrons of circular cross-section of 1mm diameter carries a current of 1 microamperes. The electrons in the beam have been accelerated by potential of 10^4 volts. The beam current flows horizontally north.

   What is the magnitude and direction of the magnetic flux density vector on the top surface of the beam?

4. A 2 amperes current loop consists of two parallel wires 2 cm horizontally apart aligned north-south and 1 km long. At both ends the wires are connected by horizontal semicircular jumpers. Current in the western wire flows north.

   Using appropriate approximations determine magnitudes and directions of magnetic flux densities at

   (i) midpoint of the loop and

(ii) centres of semicircular jumpers.

5. Magnetic field $\hat{H}=(H_x, H_y, H_z) = (0, 0, H)$. H is specified below:

For $|x| > w$, $H=0$,

For $-w < x < 0$, $H=H_0 (1+x/w)$,

For $0 < x < w$, $H=H_0 (1 - x/w)$,

with $H_0 = 5 \times 10^{-3}$ A/m and $w = 10^{-6}$ m.

Determine distribution of current density producing H field specified above.

Aid: curl $\bar{A}$ = grad x $\bar{A}$

6. A horizontal square loop of 1 m sides, with sides aligned in north-south and east-west directions moves horizontally in westerly direction at 30m/s velocity. At one time, it enters a region of vertical magnectic field of 10^{-5} teslas. Dimensions of magnetic field region are: 30 m in east-west direction and infinite in north-south and up-down directions (an infinite vertical plate 30m thick aligned in north-south direction).

Plot EMF induced in the loop as it passes through the region of magnetic field.

7. What is the upper limit of electric energy that can be stored in a parallel plate capacitor described below: Plate areas 50cm^2, plate separation 1 mm. A layer ¾ mm thick of dielectric of relative permittivity 2.5 is glued to one of the plates. Maximum permitted electric field in air is 10^6 V/m, that in the dielectric is 10^7 V/m.

8. Eye of a fish is 50 cm below surface of water. It sees an insect flying 20 cm above the surface of the water at 30° angle away from vertical. Assuming that the fish is aware that insects fly 20 cm above the surface of the water and also that the fish is not familiar with Snell's law, what is the horizontal distance between apparent and real positions of the insect?

Assistance: index of refraction of water is 1.33.