

National Exams December 2002

98-Elec-A7

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: $\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$, $\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$.

1. Three negative point charges $-e$ are symmetrically located on the circumference of a circle of 0.5×10^{-10} m radius. A positive charge $+3e$ is located at the centre of the circle.

What energy is required to move two of the negative charges to infinity?

$$e = 1.6 \times 10^{-19} \text{ C.}$$

2. A 30 MHz magnetic field of 10^{-13} Tesla RMS points in the horizontal northwest-southeast direction.

Calculate the peak value of EMF induced in a circular loop of 50 cm diameter lying in the north-south vertical plane.

3. The shape of a horizontal current loop is a square of 20 cm side. The magnetic field 40 cm above the centre of the square is 10^{-6} Tesla, pointing up.

What is the magnitude and sense of circulation of the current in the loop?

$$\text{Aid: } \int \frac{du}{(1+u^2)^{3/2}} = \frac{u}{(1+u^2)^{1/2}}.$$

4. Internal impedance of a 1000 MHz generator is 377 Ohm resistive. The generator drives an infinite transmission line the characteristic impedance and phase velocity of which are 377 Ohm and 3×10^8 m/s respectively. A 4.2 pF capacitor is connected across the line some unknown distance away from the generator. At time $t = 0$ the generator launches a $1 \mu\text{s}$ long pulse of 1000 MHz signal on the line. The EMF of the carrier is 2 Volt RMS. The time interval between the pulse leaving the generator terminals and the reflected pulse returning is $67 \mu\text{s}$.

i. How far is the capacitor from the generator and,

ii. what is the total energy in the returning pulse?

iii. Describe in not more than twenty words a real world system simulated by this transmission line problem.

5. A 10 MHz plane wave propagates 30° east of north in horizontal direction. The electric field is polarized in vertical direction and the time averaged power density of the wave is 6.6×10^{-16} W/m².

- i. What is the RMS value of the magnetic field of the wave, expressed in Tesla?
 - ii. At a point in space designated A and instant of time t_0 the value of electric field is maximum and points up. What is the direction of the magnetic field at the same point and instant of time?
 - iii. What is the value of magnetic field at a point 8.66 m due north of A and instant of time quarter of period later than t_0 ?
6. A 5 MHz and a 15 MHz transmitters operate into the same 1 m long vertical antenna located on a perfectly conducting ground plane. The 5 MHz signal is received by a station 10 km away horizontally while the 15 MHz signal is received by an aircraft 3.4 km away horizontally and 2 km high.

What should be the ratio of the 5 MHz and 15 MHz antenna currents if the vertical components of the received electric fields are to be of the same amplitude?

7. A wide band receiver is connected to an antenna receiving 100 MHz and 200 MHz signals. What length short-circuited stub of a 50 Ohm, 3×10^8 m/s transmission line connected across the receiver terminals will pass the 100 MHz signal and stop the 200 MHz signal from reaching the receiver?
8. A TE mode propagating in a rectangular waveguide can be considered to be a superposition of a plane wave and its reflection bouncing between two opposite walls in the guide. Consider the case of X-band guide of 2.25 cm \times 1 cm internal dimensions. A propagating signal consists of a wave impinging on the short wall of the guide at 60° angle of incidence and its reflection. The electric field of the wave is polarized parallel to the short wall.

What are the two lowest frequencies for which this can happen?