Electromagnetic Fields

ECSE 351 Sec. 342

April 25 2008 14:00 – 17:00

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Student Name:		**McGill ID:**									

INSTRUCTIONS: (Examples)

- This is a CLOSED BOOK examination.
- Only two hand-written double-sided CRIB SHEETS permitted.
- STANDARD CALCULATOR permitted ONLY.
- This examination is PRINTED ON BOTH SIDES of the paper
- This examination paper and crib sheets MUST BE RETURNED

Question1 (10 Marks) Your employer is planning on making a deepwater automated probe. Part of the design will require a custom hard-drive. Your team is required to design the magnetic write-head. The head is a silicon-steel toroid core (B-H data found in table 1) with mean radius 3 cm. The core has a 0.02 cm^2 circular cross-section. The write head has a 0.1 mm air gap (where the magnetic flux will write to the storage material). The fringe factor for the air-gap is 1.2. The 100 turn coil is wrapped about the core. Your team leader assigns you the task of analyzing the write-head. *Show all work; include all numerical values and relevant constants. Put a box around your final answer.*

a) Write the equivalent magnetic circuit for the write-head. Include all relevant information (including orientation of the source and direction of magnetic flux).(**3 Marks**)
b) In order to write the information to the storage material, the magnetic flux density in the gap must be 0.8 (T). Compute the current required to produce this flux. (**5 Marks**)
c) If the magnetic circuit is active for 1 nano-second, how much power did the circuit consume? (**2 Marks**)

Table 1

Magnetization properties of silicon steel at room temperature, with an applied magnetic field (Ampere-turns per meter) producing a magnetic flux density (Webers per square meter or Tesla) within the material

H (A t /m)	B (Wb/m^2)
0	0
100	0.6
200	1.0
300	1.1
400	1.2
500	1.22
600	1.26
700	1.28

Question 2 (10 Marks) The automated system introduced in question 1 uses a co-axial cable to communicate with the controller. The inner conductor of the co-axial cable has a radius of 0.6 mm. The outer conductor of the cable has an inner radius of 4.2 mm and an outer radius of 5 mm. Due to the pressure and cold the material between the two conductors is not uniform. The conductivity of the material between the two conductors is a function of distance from the center axis of the cable and is given by $\sigma(\rho) = \frac{9}{10^5 \rho}$ (S/m). In addition, the relative permittivity of the material is also a function of distance from the center axis and is given by $\varepsilon(\rho) = \frac{2.4\varepsilon_o}{\rho}$ (F/m). Your team leader assigns you the task of characterizing the cable. *Show all work; include all numerical values and relevant constants. Put a box around your final answer.*

a) Compute the capacitance per meter for this cable. (**3 Marks**)
b) Compute the resistance per meter for this cable. (**3 marks**)

c) Write the equivalent circuit for the impedance between the inner and outer conductors. (**2 Marks**)
d) Compute the steady state conduction current and displacement current that flows between the inner and outer conductors when 1 (V) is applied. (**2 Marks**)

Question 3 (10 Marks) The controller system for the motor for the deepwater probe seems to be having some problems. *The control system will malfunction if the power of the noise from outside sources is greater than 50% of the power of the control signal*. Your team is assigned to determine if there is interference from the 60 Hz motor circuit. Another member of the team has determined that the flux density emitted from the motor is $B = 0.4\cos(120\pi t)$ (T). The control circuit, shown in figure 1, consists of a signal source that is modeled as a 10 V source with internal resistance of 50 ohm, a motor modeled as a load (Z1) and a loop of loss-less wire connecting the two components. The rectangular loop is 20 cm long a 7 cm wide. The flux from the motor crosses the surface of the loop uniformly. Your task is to determine if the flux from the motor is causing the malfunction. *Show all work; include all numerical values and relevant constants. Put a box around your final answer.*

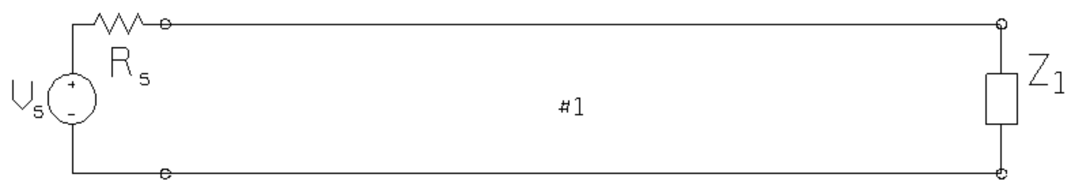

Figure 1 Motor control circuit. Signal source is 10 V (DC) with internal resistance of 50 ohm. The motor system (Z1) is a 50 ohm load.

a) Compute the power from the signal source seen by the motor (Z1). (**4 Marks**)
b) Compute induced power from the magnetic flux seen by the motor (Z1). (**4 Marks**)
c) Determine if the malfunction is due to the magnetic flux (i.e. Power of induced flux greater than or equal to 50% of signal power). (**2 marks**)

Question 4 (10 Marks) The probe uses magnetic field sensors to detect mineral deposits. *The field emitter of the sensor is a current carrying disk with inner radius 2 mm and outer radius 8 mm*. The sensor will detect minerals when the magnetic field directly in front of the disk is 15 micro-amperes per meter. Your team leader has tasked you with the job of determining what power supply the field emitter will require. *Show all work; include all numerical values and relevant constants. Put a box around your final answer.*

a) Assuming a uniform current density on the emitter, write an expression for the magnetic field a distance of "*d*" meters in front of the emitter (i.e. the distance measured from the plane of the ring along the center axis). (**6 Marks**)
b) What current would the sensor require if the detection distance is required to be *d*=4 meters in front of the emitter? (**4 Marks**)

Question 5 (10 Marks) The probe will also use electric field sensors to detect changes in the water. The electric field sensor consists of two rectangular (50 cm^2 area) plates kept at different potentials. The ground (V=0) plate lies on the $\phi = 0$ plane. The other plate is kept at a voltage $V_o = 10$ (V) and lies on the $\phi = \frac{\pi}{6}$ plane. The amount of charge that forms on the plates is a function of the permittivity of the sea water. *Show all work; include all numerical values and relevant constants. Put a box around your final answer.*

a) Write an expression for the electric field between the plates (you may neglect fringing *i.e. voltage not a function of* ρ or z). (**5 Marks**)

b) Compute the total charge on the upper plate if the sea water has a relative permittivity of 72. (**5 marks**)

Question 6 (10 Marks) Your team leader asked you to review an interview question. Given an electric field $\overline{E} = (10\hat{a}_x - 10\hat{a}_y)[\cos(10^9 \pi t - 0.3\pi z)]$(V/m); *Show all work; include all numerical values and relevant constants. Put a box around your final answer.*

a) Show that this field satisfies all of Maxwell's Equations in free space $(\mu_o, \varepsilon_o, \sigma = 0)$ (**10 Marks**).