



Strathmore
UNIVERSITY

**SCHOOL OF COMPUTING AND ENGINEERING SCIENCES
BACHELOR OF SCIENCE IN ELECTRONICS AND ELECTRICAL ENGINEERING
END OF SEMESTER EXAMINATION
BEE 3102 – ELECTROMAGNETIC FIELDS**

DATE: 24th July 2023

Time: 3 Hours

BEE3102, Electromagnetic Fields

- You have 3 hours for completing the examination.
- The first question is mandatory, and has to be completed before the others.
- Answer the questions in your provided booklet, not in these pages.
- Provide clear schematics, drawn with pencil and usual material.
- Programmable calculators are accepted, as long as these are NOT SMART-PHONES
- Do not include any document inside of your copy. NO COMMUNICATION is allowed during the exam
- In case a constant is not part of the given you will estimate it by using known relations among other constants

Question I: Fields and Waves [30 Marks]

A- Skin Effect

1. (5 points) We want to recall the expression of the damping of the EM wave at the surface of a conductor, this phenomenon is called the 'skin effect'. The skin depth δ is defined as a the inverse of the attenuation factor α . For a lossy dielectric we have derived that:

$$\alpha = \omega \sqrt{\frac{\mu_0 \epsilon}{2} \left[\sqrt{1 + \left[\frac{\sigma}{\omega \epsilon} \right]^2} - 1 \right]}$$

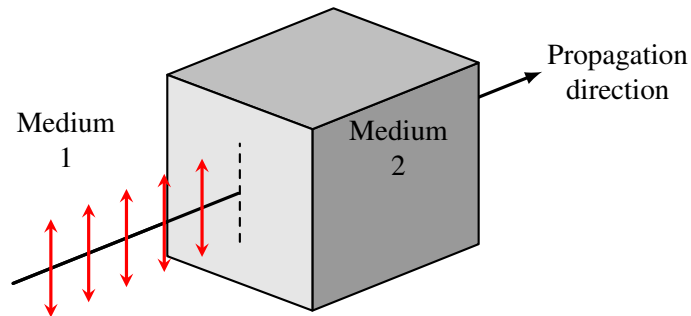
From this expression derive the relation between δ and frequency, permeability of vacuum, and conductivity considered to be very high. Using the appropriate approximations give the expression of the skin depth.

B- Find corresponding E waveform from an H wave

The magnetic component, of a plane wave is traveling along \vec{e}_x , the expression is given for a incident medium '1', that is again nonmagnetic ($\mu_r = 1$) and pointing towards a transmitted medium 2' has a mathematical expression given by:

$$\vec{H}_i = 30 \cos(3.10^8 t - \beta_1 z) \vec{e}_x \text{ mA/m}$$

Considering the incident propagating medium is characterised by $\epsilon_r = 1$, $\mu_r = 1$, and $\sigma = 81 S/m$. In free space ($z \leq 0$), a plane wave with a magnetic component:



2. (5 points) With the data given above, find α the attenuation coefficient in this specific
The plane wave is incident normally on to a lossless medium ($\epsilon = 2\epsilon_o, \mu = 8\mu_o$) in material region $z \geq 0$.
3. (5 points) Determine the propagation constants β_1, β_2 of incident and transmitted medium, and the corresponding impedances η_1, η_2 .
4. (3 points) From the preceding calculated impedance, deduce the mathematical expression of the incident electric field \vec{E}_i

C- Scattering

5. (5 points) The reflexion coefficient at an interface between two materials can be determined thanks to the reflexion coefficient, n_i (incident medium) and n_t (transmitted medium). We define the expression seen during the course for the "reflection coefficient" Γ , starting from the one of R expressed in the following ratio:

$$R = \frac{n_i - n_t}{n_i + n_t}$$

obtained from Snell-Descartes laws. Give a more general expression for Γ .

6. (7 points) Does the standing wave ratio given by the 'dummy-load' in the document below (fig.1) warranties you against a failure in the 300W, High Power amplifier ? Supposing that the power amplifier will be damaged if more that 5W or reflected power comes back its output give an expert statements on why to use this dummy load.

Constants

$$\mu_o \approx 4\pi 10^{-7} H/m$$

$$c \approx 3 10^8 m/s$$

2W SMA Male Dummy Load,
DC-6GHz, SWR<1.2, 50 Ohm



Figure 1: A ‘dummy load’ is a termination for a HF transmission line, normally connected between the inner conductor and the shielding of this transmission line

Question II: Induction [10 Marks]

A metallic bar of mass m glides without friction over two conductive rails that are parallel, horizontal and separated by a distance l . One resistance of value R connects, on the same side, the two rails. The intrinsic resistance of those rails, of the bar and contact is taken to be negligible. The ensemble is surrounded by a magnetic field \vec{B} directed perpendicular to the plane containing the bars and oriented upwards.

At a moment $t = 0$ the moving bar is thrown at a speed \vec{v}_o towards the right side of the plane.

- (2 points) Draw a clear schematic describing the rails, including a frame of coordinates, the projection of the Magnetic field, and the drag force associated to magnetic induction.
- (2 points) Using the experimental setup described in the previous picture, determinate the mathematical expression of the speed, as a function of time $V(t)$, we will introduce a constant T dependant of m, B, R and l the distance between the two rails.
- (3 points) Give the **literal expression** for the total distance completed during the movement.
- (1 point) Numerical application, $B = 1.425 T$, $V_o = 10 m/s$, $l = 0.750 m$, $m = 5 g$, $R = 100 \Omega$, what is the maximal length that has been recorded ?
- (2 points) Using a proper energy description, validate the result found in the preceding question.

III- Antenna [10 Marks]

- (5 points) Using the expression of Maxwell equations including conductive currents in the Ampere’s equation, and the classical distribution equation:

$$\vec{\nabla} \cdot (\vec{A} \times \vec{B}) = \vec{B} \cdot (\vec{\nabla} \times \vec{A}) - \vec{A} \cdot (\vec{\nabla} \times \vec{B})$$

Justify that the sum of the power stored in electric and magnetic fields and the ohmic power dissipated equals the flux of the Pointing vector $\vec{\mathcal{P}} = \vec{E} \times \vec{H}$.

2. (5 points) An antenna is located at the origin of a spherical coordinate system. The fields produced by the antenna in free space are

$$\begin{aligned}\vec{E} &= \frac{E_o}{r} \sin \theta \sin \omega(t - r/c) \vec{e}_\theta \\ \vec{H} &= \frac{E_o}{\eta r} \sin \theta \sin \omega(t - r/c) \vec{e}_\phi\end{aligned}$$

(9)

Determine the time-average power radiated by the antenna

IV- Standing wave ratio [10 Marks]

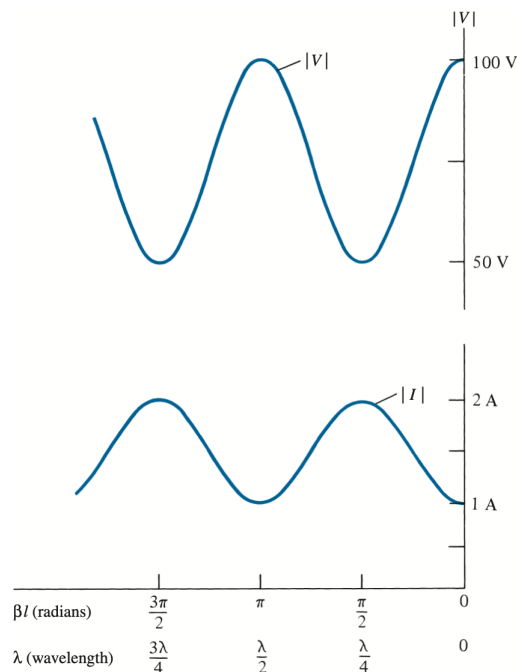


Figure 2: Standing wave, producing a distribution of voltages and currents along the transmission line

1. (5 points) From the schematic presented in the figure 2, explain what type of load is terminating the transmission line (open, load, closed) ?

2. (5 points) What is a $\lambda/4$ transmission line and why is it so important ? Justify using the figure 2.
3. (5 points) From the figure 2, show that in this case Γ can be taken to be such that $|\Gamma| = 0.5$, the quality of your answer will depends on judicious assumptions on the value of the characteristic impedance of the cable in order to justify your choice.

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