Minor-2: ELL212/EEL207 Engineering Electromagnetics, 2015-16 Semester 2

Instructions: NO mobile phones on person; one sided A4 cheat sheet allowed; read the questions very carefully, and show all intermediate steps. Total points : [**21**]. Code: A7L
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IMPORTANT: Write your question paper code on your answer sheet.

Basics [No more than one/two line answers; anything more will not be evaluated. *Tip: Budget 10-15 minutes for this section.*]

1. In a lossless, homogeneous medium with refractive index 4, what will the ratio of electric (E) to magnetic (B) field be for a monochromatic plane wave that is travelling through it? [**1**]

2. What was Maxwell's key contribution in the formulation of the equations of electromagnetics? [**1**]

3. A radar overflies two plots of land. One has a sandy top, and the other has a top layer rich in metallic/mineral content. Over which plot (first/second?) will the radar have better success in looking for buried treasures? Give a one line explanation. [**1**]

4. If the seconds hand of a wall-clock correspond to the electric field vector of a plane wave travelling normally into the wall, describe the type of wave polarization. [**1**]

5. The word *current* usually implies a change of charge w.r.t. time. Is displacement current a current in that sense? (Yes/No?) How would you state it more precisely? [**1**]

Beyond basics [Be sure to reason out all intermediate steps; correct answers without reasoning will not get credit. Do NOT rewrite the question. *Tip: Budget 5-12 minutes per question.*]

6. A solid perfect conductor of arbitrary shape is placed in front of a radiating antenna. Prove that there can be no electric field in the interior. Will the Earth's magnetic field be measurable in the interior of the conductor? [**3**]

7. In an alternate universe, which has different physical laws than ours, there exist two kinds of fields: a $V-$field and a $W-$field, which seem to follow these relations, as inferred by experiment:

$$\nabla \times \vec{V}(\vec{r},t) = \partial \vec{W}(\vec{r},t)/\partial t \tag{1}$$

$$\nabla \cdot \vec{V}(\vec{r},t) = \tau(\vec{r},t) \tag{2}$$

$$\nabla \times \vec{W}(\vec{r},t) = -\partial \vec{S}(\vec{r},t)/\partial t \tag{3}$$

$$\nabla \cdot \vec{W} = 0 \tag{4}$$

where $\tau, \vec{S}$ are scalar and vector quantities, respectively (physical parameters of some type).

(a) Can these laws form a meaningful description of this universe? (Yes/No?) Why? *Tip: Ask whether they are mathematically consistent.* **[2]**

(b) Imagine that Dumbledore gave you a magical power by which you could change one and only one symbol (i.e. alphabet) on the RHS of any one of the above equations! What change would you make, so that one of the forces propagates as a wave? Can you show how the resulting change leads to wave like behaviour? Remember: show, not solve. **[2]**

(c) Using equation (1) and this alone, can you derive a boundary condition for the normal component of $\vec{V}$ across an interface? (Yes/No?) Why/how? **[2]**

8. A monochromatic forward travelling wave whose complex phasor form is $\vec{E}_i = \hat{z}E_o \exp(-jkx)$ impinges on a flat interface and produces a reflected field of the form $\vec{E}_r = \hat{z}\frac{E_o}{2}\exp(j(kx-\phi))$. What is the net (a) E-field, and (b) H-field that you would measure in the lab (as a function of space and time), and (c) what is the time-averaged Poynting vector in space? Is this zero? Give a physical interpretation to it. **[4]**

9. You are part of an underwater expedition which involves a parent ship and a submarine. In order to communicate wirelessly with the submarine, you have a choice of a couple of frequencies: 1 KHz and 10 KHz. The receiving antenna needs to have a minimum electric field magnitude of $1\mu V/m$ in order to reliably get data. Given that the maximum depth expected in this expedition is 100m, which is the most efficient choice of frequency? Why? Assume field magnitude just below the water surface to be $1V/m$, and sea water to have relative permittivity and conductivity $\epsilon_r = 80$, $\sigma = 4\mho/m$. *Tip: Make reasonable assumptions about whether sea water is a good or a bad conductor and simplify your calculations accordingly.* Complex wavevector in a lossy medium, $\tilde{\epsilon} = \epsilon - j\frac{\sigma}{\omega}$ is $\tilde{k} = \omega\sqrt{\frac{\mu\epsilon}{2}}\left[\sqrt{a+1} - j\sqrt{a-1}\right]$ where $a = \sqrt{1+(\frac{\sigma}{\epsilon\omega})^2}$ and $\epsilon_0 = 8.85 \times 10^{-12}\, C^2/Nm^2, \mu_0 = 4\pi \times 10^{-7}\, Tm/A$ **[3]**

$a = \frac{\sigma}{\epsilon\omega}$

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