Physics 3034 – Spring 2025
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Homework 03

SPN 3–01 Displacement current vs. conduction current in a wire.
Imagine a copper wire of diameter $d = 1$ mm that is carrying a current as follows $I = I_0 cos(\omega t)$, where $I_0 = 100$ Amperes.

[a] Let $f = 1\ kHz$ and derive an expression for $\vec{E}(t)$ inside the wire.
[b] In this case, compare the maximum displacement current to the conduction current in the wire.
[c] Assuming that nothing changes but the frequency, repeat this calculation for $f = 1\ THz$
[d] Come up with a general ratio of displacement current to conduction current for arbitrary f and $sigma$.
[e] At what frequency is this ratio equal to one (for copper)

SPN 3–02 – Fun with EM units.
In part "d" of problem 3-01 you arrived at an expression for $J_{maxwell}/J_{conduction}$. Show that this ratio is dimensionless.

SPN 3–03 – More fun with EM units.
You probably know that $c = \sqrt{\frac{1}{\epsilon_0 \mu_0}}$. Plug in the values and units for ϵ_0 and μ_0 to show this comes out correctly.

SPN 3–04 – Maxwell's equations in linear media.
Here are the "constitutive relations" for a linear dielectric/paramagnetic medium.

$$\vec{D} = \epsilon_r \epsilon_0 \vec{E} \tag{1}$$

$$\vec{B} = \mu_r \mu_0 \vec{H} \tag{2}$$

[a] Write down all four Maxwell equations in vacuum in differential form in a linear dielectric and para/diamagnetic medium in terms of $\vec{B}$ and $\vec{E}$.(Feel free to just copy these from Table C.2 in Appendix C of the book. I may well ask you to memorize these for the first exam.
[b] Derive the integral form from the differential form for all 4 equations. (In class I derived the differential form from the integral form). Your derivation should show how you explicitly integrate both sides with respect to length, area or volume and should also include stating when you use Stoke's theorem or the divergence theorem.

SPN 3–05 – Electromagnetic Wave Equation in linear media.
Begin with the following two equations.

$$\nabla \times \vec{E} = -d\vec{B}/dt \tag{3}$$

$$\nabla \times \vec{H} = \epsilon \mu d\vec{E}/dt \tag{4}$$

[a] Take the cross product of both sides of equation 1 and use the vector identity for the curl of a curl to arrive at a wave equation for $\vec{B}$. Justify your steps.
[b] Do the same for $\vec{E}$. Justify your steps.
[c] If ϵ_r =3 and $\mu_r = 1.1$, calculate the speed of light in this medium.

SPN 3–06 – Poynting Vector.
Do Griffiths 8.2.

SPN 3–07 – Poynting Vector.
Griffiths 8.1 has two parts. Just do the first part (Poynting vector of currents flowing along an inner cylinder and returning along an outer cylinder).