Peter Dea's Portfolio
EE 311

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Introduction

In this class I learned about many topics regarding electromagnetism. There were 5 main units we covered in this class, Vector Calculus, Electrostatics, Magnetostatics, Electromagnetic Waves, and Transmission Lines. The format of this class was such that I would do games during class time that would allow me to work together with my classmates and gain experience on the topics we were learning. There were also frequent reflections throughout the class where I was tasked with analyzing my performance at that point of the class. As you will see while looking through this portfolio, these reflections proved to be valuable as they played a pivotal role in learning from the mistakes I made along the way and making the path towards my mastery of electromagnetics clearer.

Throughout this portfolio I will include a compilation of the games, assignments, exams, and reflections I participated in for this class. I will also provide a brief reflection following each game in this portfolio that will hopefully provide insight into my progression through the class.

The first assignment for this class was a game in which I introduced myself and provided insight into my knowledge of vector calculus. While most of the games in this class required me to write with a pencil and paper, this game and all of the reflections which you will see in later pages were typed into Microsoft word and submitted as a PDF. As such I will copy and paste the contents of that game onto the next page.

Game 1

EE 311 | Game 1 | Name ______________
Spring 22 1/19/22 | Let us practice

Game 1 about you

9/21/23 Name: **Peter Dea**

Names of the Members of your team: **Caleb, Sam, Scott, Elias, Mina, Denny**

This is our Game 1. Here is for us to practice.
Please use your computer to answer this. If the game is writing about yourself etc, please use your computer. MSWord or equivalent would be good choices it is easier to read, write, and ….

1. Tell us about "you"; who are you? What would you like us to know about you?

I am Peter Dea, I am a junior learning Electrical Engineering. I chose to go into electrical engineering because I enjoy circuitry and I have always had a strong love for math and science. I am excited to learn about fields and waves as it was one of the topics I enjoyed the most in Physics II.

2. How good is your Vector calculus background? Please explain. Please provide a good detailed and patient answer.

   I have a good understanding of vector calculus. I took Calculus 3 last semester and learned concepts such as gradient, curl, directional derivatives, etc. Before that I took Linear Algebra, which had little calculus involved, however it taught me many concepts that helped me learn vector calculus such as dot products and cross products, determinants, and so on. I like to believe I have an intuitive understanding of vector calculus because of these classes.

3. When submitting the games (we would work on them in class, you work with your team and write, submit …) We would like you to use a good scanner write clearly and submit your work in class. This is important. Please note that if the scan is not OK (not clear or not done clearly to be easily read), you will not receive full credit. Would you be OK with this, and will you be mindful of this request?

Yes. I have a very reliable app for scanning things and my previous teachers have told me my scan quality is good.

4. Is there anything you would like to share with us? We are happy to have you in EE311 and look forward to working together and facilitate your learning and your success

Electromagnetism seems like magic and I am looking forward to unlocking a better understanding for it through this class.

Unit 1: Vector Calculus

Vector Introduction

This beginning of this unit was mostly a review of vectors, which are a concept I learned in previous classes that I took such as Calculus III, Physics, Linear Algebra, EE 185, and others. As the unit went on however, I gained much more insight into some of the more advanced topics of vector calculus such as Stoke's Theorem and the Divergence Therorem. Going into it I was fairly confident that my knowledge of vectors was sufficient to give me an easy time going into this unit. You will see from some of the following games, however, that this unit was a necessary review of the topic that is crucial to understand in order to study electromagnetism.

One of the things I struggled with in regards to this topic was using the right vector notation. Throughout my classes that incorporated vectors, I have learned 3 different ways to represent a vector. In linear algebra I used a matrix with one column, in calculus I used a notation using brackets like this: <x,y,z>, and in this class I was expected to use notation in which you scale and add unit vectors represented by symbols such as $\hat{x}$ and $\hat{y}$. There were a couple times I used the wrong vector notation and had to go back and correct myself, but by the end of this unit I was fairly comfortable in using the one expected from me for this class.

Dot and Cross Products

The second game challenged me to resurface my knowledge of vectors. Specifically, I had to recall how to take the dot product and cross product of two vectors. The last portion of this question regarded vector projection, or how much one vector was along another.

Peter Dea

Groupmates: Caleb, Sam, Scott, Alias, mina, Denny

Game 2

$\vec{A} = 3\hat{x} - 2\hat{z}$ $\quad\quad$ $\vec{B} = 4\hat{y} + 5\hat{x}$

1. $\vec{A}\cdot\vec{B} = 3(5) + 0(4) - 2(0) = \boxed{15}$

2. $$\vec{A}\times\vec{B} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ 3 & 0 & -2 \\ 5 & 4 & 0 \end{vmatrix} = (0+8)\hat{x} - (0+10)\hat{y} + (12-0)\hat{z}$$
$$= \boxed{8\hat{x} - 10\hat{y} + 12\hat{z}}$$

3. Area of Parallelogram $= |\vec{A}\times\vec{B}| = |8\hat{x} - 10\hat{y} + 12\hat{z}|$
$$= \sqrt{8^2 + (-10)^2 + 12^2} = \sqrt{64 + 100 + 144} = \boxed{\sqrt{308}}$$

4. You can find this by finding how much of $\vec{B}$ was along $\vec{A}$.

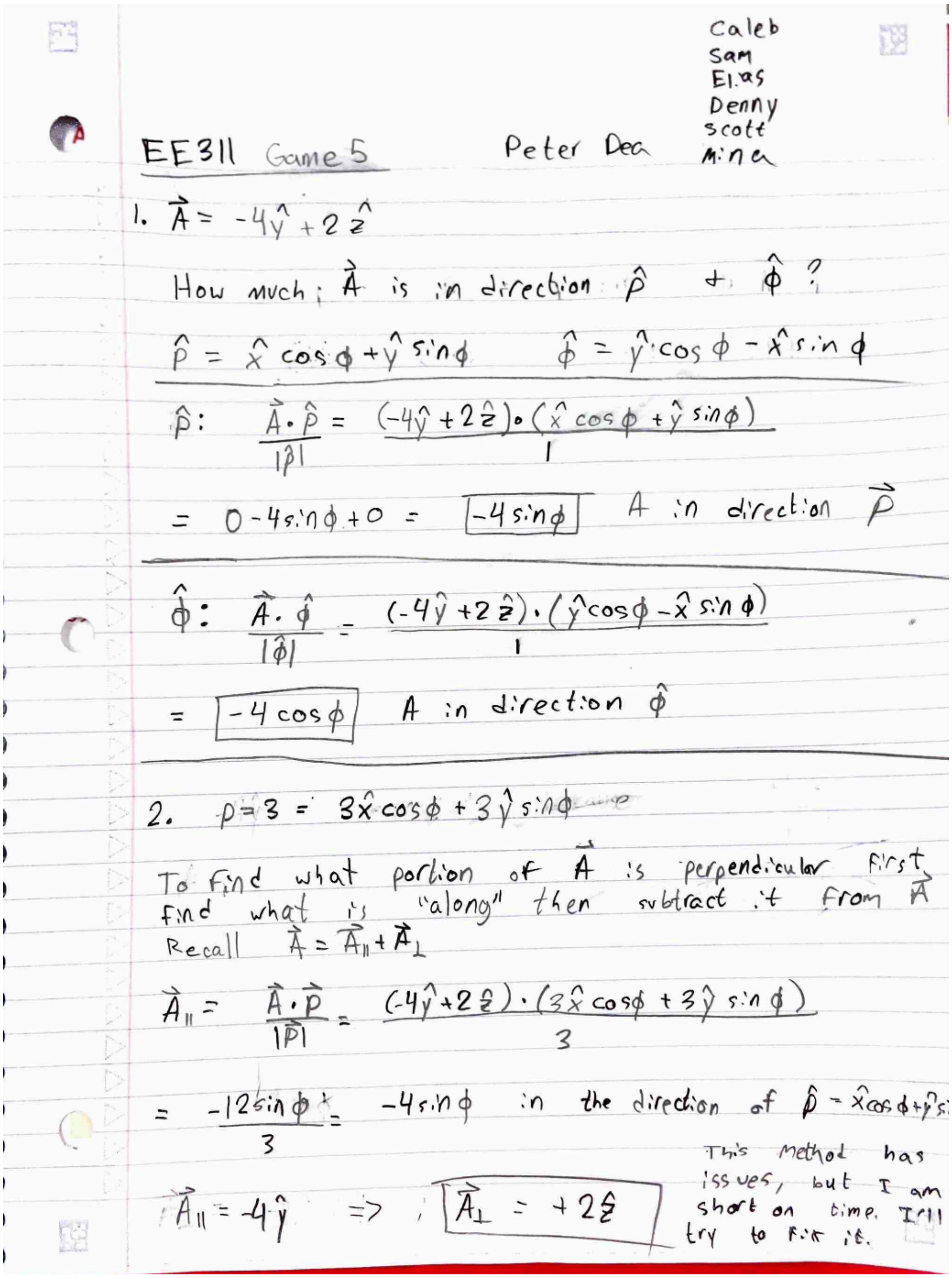
How much of $\vec{B}$ is along $\vec{A} = \dfrac{\vec{A}\cdot\vec{B}}{|\vec{A}|} = \dfrac{15}{|\vec{A}|}$

$|\vec{A}| = \sqrt{3^2 + (-2)^2} = \sqrt{13} \Rightarrow \dfrac{\vec{A}\cdot\vec{B}}{|\vec{A}|} = \boxed{\dfrac{15}{\sqrt{13}}}$

I was off to a good start with vector review as I got all of the answers correct and I got a 5/5 on this game.

Vector Transformations

Another topic I learned in this unit was vector transfotmation, which was a method of converting a vector from one coordinate system to another. Below is a game where I put that into action.



Caleb
Sam
Elias
Denny
Scott
Mina

EE311 Game 5 Peter Dea

1. $\vec{A} = -4\hat{y} + 2\hat{z}$

How much $\vec{A}$ is in direction $\hat{\rho}$ + $\hat{\phi}$?

$\hat{\rho} = \hat{x}\cos\phi + \hat{y}\sin\phi \qquad \hat{\phi} = \hat{y}\cos\phi - \hat{x}\sin\phi$

$\hat{\rho}$: $\dfrac{\vec{A}\cdot\hat{\rho}}{|\hat{\rho}|} = \dfrac{(-4\hat{y} + 2\hat{z})\cdot(\hat{x}\cos\phi + \hat{y}\sin\phi)}{1}$

$= 0 - 4\sin\phi + 0 = \boxed{-4\sin\phi}$ A in direction $\vec{\rho}$

$\hat{\phi}$: $\dfrac{\vec{A}\cdot\hat{\phi}}{|\hat{\phi}|} = \dfrac{(-4\hat{y} + 2\hat{z})\cdot(\hat{y}\cos\phi - \hat{x}\sin\phi)}{1}$

$= \boxed{-4\cos\phi}$ A in direction $\hat{\phi}$

2. $\rho = 3 = 3\hat{x}\cos\phi + 3\hat{y}\sin\phi$

To find what portion of $\vec{A}$ is perpendicular first find what is "along" then subtract it from $\vec{A}$
Recall $\vec{A} = \vec{A}_{\parallel} + \vec{A}_{\perp}$

$\vec{A}_{\parallel} = \dfrac{\vec{A}\cdot\vec{\rho}}{|\vec{\rho}|} = \dfrac{(-4\hat{y} + 2\hat{z})\cdot(3\hat{x}\cos\phi + 3\hat{y}\sin\phi)}{3}$

$= \dfrac{-12\sin\phi}{3} = -4\sin\phi$ in the direction of $\hat{\rho} = \hat{x}\cos\phi + \hat{y}\sin$

$\vec{A}_{\parallel} = -4\hat{y} \Rightarrow \boxed{\vec{A}_{\perp} = +2\hat{z}}$

This method has issues, but I am short on time. I'll try to fix it.

I found this topic a little bit difficult at first and as such I took a lot of time to finish this game. After I submitted it, I was told my work was difficult to follow, however I would get another chance at a game regarding vector transformation, shown on the next page.

Mina
Scott
Denny
Elias
Sam
Caleb

Game 6 Peter Dea

1. $\vec{A} = -2\hat{\phi} = 0\hat{\rho} - 2\hat{\phi} + 0\hat{z}$

$$\begin{bmatrix} \cos\phi & -\sin\phi & 0 \\ \sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ -2 \\ 0 \end{bmatrix} = \begin{bmatrix} 2\sin\phi \\ -2\cos\phi \\ 0 \end{bmatrix}$$

$\Rightarrow \vec{A} = 2\sin\phi\,\hat{x} - 2\cos\phi\,\hat{y}$

$\vec{A}$ along $\hat{x} = \boxed{2\sin\phi}$

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2. $$\begin{bmatrix} \cos\phi & -\sin\phi & 0 \\ \sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 3\cos\phi \\ 3\sin\phi \\ 0 \end{bmatrix}$$

$\vec{B} = 3\hat{\rho} = \boxed{3\cos\phi\,\hat{x} + 3\sin\phi\,\hat{y}}$

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3. $\int_{-10\pi}^{10\pi} \vec{A}\, d\phi = \int_{-10\pi}^{10\pi} 2\sin\phi\, d\phi = 2\left[-\cos\phi\right]_{-10\pi}^{10\pi}$

$= -2\left[\cos(10\pi) - \cos(-10\pi)\right] = -2[1-1] = \boxed{0}$

This game went much better for me and my work for it is a lot neater too. In addition to vector transformation, this game also challenged my understanding of integrating a vector.

Divergence Theorem

The next topic I learned was the divergence theorem, which states that the flux of a vector field through a closed surface is equal to the volume integral of the divergence of that same field. Below is the first game I did that pertained to the divergence theorem.

Sam
Elias
Denny
Scott
Mina

Game 8 Peter Dea

1. Plug in given $\vec{G}$ + $\vec{ds}$ into integral

$$\int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi} \frac{4\pi N}{3} r^2 \hat{r} \cdot r^2 \sin\theta \, d\phi \, d\theta \, \hat{r}$$

pull out constants

$$\frac{4\pi N}{3} r^4 \int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi} \hat{r} \cdot \sin\theta \, d\phi \, d\theta \, \hat{r}$$

Note $\hat{r}\cdot\hat{r} = 1$

$$= \frac{4\pi N}{3} r^4 \int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi} \sin\theta \, d\phi \, d\theta$$

$$= \frac{4\pi N}{3} r^4 \int_{\theta=0}^{\pi} \phi \sin\theta \Big|_{0}^{\phi=2\pi} d\theta = \frac{4\pi N}{3} r^4 \int_{\theta=0}^{\pi} 2\pi \sin\theta \, d$$

$$= \frac{8\pi^2 N}{3} r^4 \left(-\cos\theta\right|_{0}^{\theta=\pi} = \frac{16\pi^2 N}{3} r^4 = \boxed{\frac{16\pi^2 N}{3} R^4}$$

2. Note that $\vec{G}$ has no θ or ϕ componen

$$\nabla\cdot\vec{G} = \frac{1}{r^2}\left[\frac{\partial}{\partial r}\left(r^2 \frac{4\pi N}{3} r^2 \hat{r}\right)\right] = \frac{1}{r^2}\left[4r^3 \frac{4\pi N}{3}\right]\hat{r}$$

$$= \boxed{\frac{16\pi N}{3} r}$$

$dv = r^2 \sin\theta \, dr \, d\theta \, d\phi$

3. $$\int_{r=0}^{R}\int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi} \frac{16\pi N}{3} r \left(r^2 \sin\theta \, dr \, d\theta \, d\phi\right)$$

Looking at this game now it is pretty clear that it was incorrect, as the divergence theorem states that I should have had the same answer for the volume integral and flux integral. I corrected these issues on a later game using the divergence theorem, which I will show on the next page.

Caleb
Sam
Elias
Denny
Scott
Mina

Game 11 EE 311 Peter Dea

$\vec{D} = T\rho\hat{\rho} \frac{c}{m^2}$ $0<\rho<N$

a) $\vec{D}$ has units of $\frac{c}{m^2}$ which means T times ρ must have the same units. We know ρ is in meters so T must have units of $\boxed{\frac{c}{m^3}}$ c/m^3

b) $\oiint \vec{D} \cdot \vec{ds} = \int_{\phi=0}^{2\pi} \int_{z=0}^{L} T\rho^2 \, dz \, d\phi \Big|_{\rho=N}$

$= \int_{\phi=0}^{2\pi} TN^2 z\Big|_{z=0}^{L} d\phi = \int_{\phi=0}^{2\pi} TN^2 L \, d\phi = TN^2 L \phi \Big|_{0}^{\phi=2\pi}$

$= \boxed{TN^2 L 2\pi}$

no $\hat{\phi}$ or $\hat{z}$ terms in $\vec{D}$

c) $\nabla \cdot \vec{D} = \frac{1}{\rho}\frac{\partial}{\partial\rho} \rho T\rho = \frac{1}{\rho} 2\rho T = \boxed{2T}$

d) $\iiint \nabla \cdot \vec{D} \, dv = \int_{\phi=0}^{2\pi} \int_{\rho=0}^{N} \int_{z=0}^{z=L} 2T \, \rho \, dz \, d\rho \, d\phi$

$= \int_{\phi=0}^{2\pi} \int_{\rho=0}^{N} 2T\rho z \Big|_{0}^{z=L} d\rho \, d\phi = \int_{\phi=0}^{2\pi} \int_{\rho=0}^{N} 2T\rho L \, d\rho \, d\phi$

$= \int_{\phi=0}^{2\pi} L \frac{\cancel{2}T\rho^2}{\cancel{2}} \Big|_{\rho=0}^{\rho=N} d\phi = \int_{\phi=0}^{2\pi} LTN^2 \, d\phi = LTN^2 \phi \Big|_{0}^{\phi=2\pi}$

$= \boxed{TN^2 L 2\pi}$ This is equal to the answer from part B as expected.

As you can see from the fact that my solutions to b and c in this game are identical, this game was much more successful for me as they displayed the properties of the divergence theorem.

Stoke's Theorem

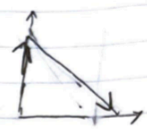
The next topic we learned one is another theorem called Stoke's Theorem. Stoke's Theorem states that the circulation of a vector around a closed path is equal to the curl of that vector over the surface enclosed by that closed path. Below is the first game I did using Stoke's theorem.

Sam
Denny
Scott
Mina

Game 14 - EE 311 - Peter Dea

$\vec{A} = -2y\hat{x} + 3x\hat{y}$ $\quad d\ell = \hat{x}\,dx + \hat{y}\,dy + \hat{z}\,dz$

a) $\oint \vec{A}\cdot\vec{d\ell} = \int -2y\,dx + \int 3x\,dy$



Path 1: $x = 0$

$\int 0\,dy = 0$

Path 2: $\int_0^4 -2y\,dx + \int_0^4 3x\,dy$ $\quad$ note: $y = 4-x$, $x = 4-y$

$\cancel{\int_0^4 2x\,dx + \int_0^4 -3y\,dy}$

$\int_0^4 -2(4-x)\,dx - \int_0^4 3(4-y)\,dy$

$= \int_0^4 -8+2x\,dx + \int_0^4 12-3y\,dy = \left[-8x+x^2\right]_0^{x=4} + \left[12y - \frac{3}{2}y^2\right]_0^{y=4}$

$-32+16-(48-\frac{3}{2}16) = \boxed{-40}$ total $\quad$ Path 3: $=0$ no y change $y=0$

b) $\iint \nabla\times\vec{A}\cdot ds$

$$\nabla\times\vec{A} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ -2y & 3x & 0 \end{vmatrix} = 0\hat{x} - 0\hat{y} + (3+2)\hat{z} = 5\hat{z}$$

$-\iint_S 5\hat{z}\cdot\vec{ds} = -\iint_S 5\,dx\,dy = -\int_0^4\int_0^{(4-y)} 5\,dx\,dy$

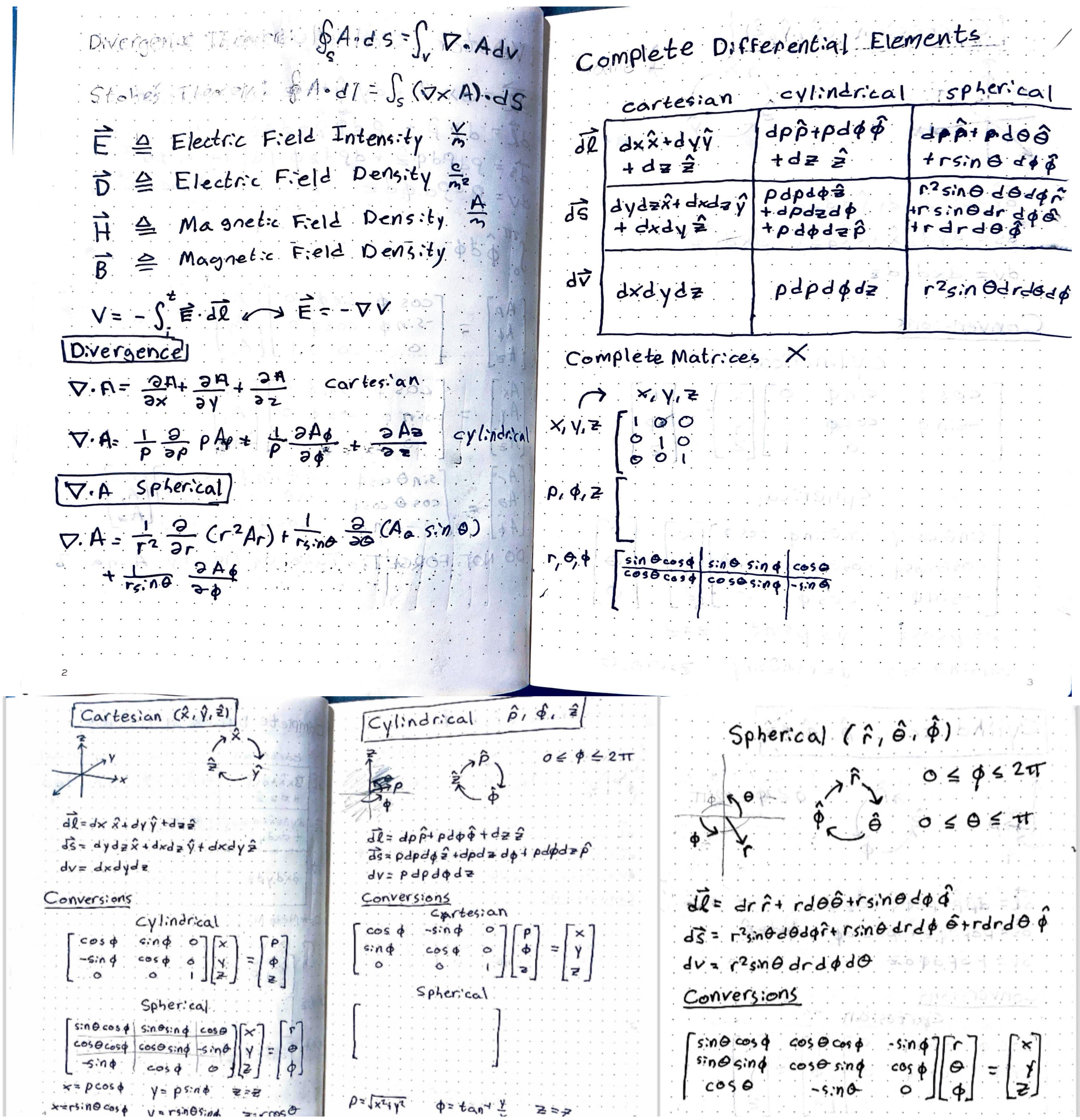
$= -\int_0^4 5(4-y)\,dy = -\int_0^4 20-5y\,dy = -20y + \frac{5}{2}y^2\Big|_0^{y=4}$

$= -80 + \frac{5}{2}16 = \boxed{-40}$

This game went very well for me as you can see that I got the same answers for part a and b, which showcases the theorem. Stoke's theorem came a lot more naturally to me as it was very similar to the divergence theorem, and it was fresh on my mind from learning it in during Calculus III.

Concept Sheets

It was around this point of the semester that we were assigned with a set of homework problems. This set of problems was similar to the games, though it was much more extensive, so it was important to prepare for it. In order to have a good resource that would guide me through the homework problems, I created some concept sheets that I could refer to when I needed help. The concept sheets went through many iterations but below is what I settled on.



Homework 1 & 2

The first and second homework assignments for this class covered the concepts we learned regarding vectors.

EE 311 HW 1 Peter Dea

Problem 1.

$\vec{A} = -2\hat{r} + 3r\hat{\theta} - \hat{\phi}$

a) $\begin{bmatrix} \hat{x} \\ \hat{y} \\ \hat{z} \end{bmatrix} = \begin{bmatrix} \sin\theta\cos\phi & \cos\theta\cos\phi & -\sin\phi \\ \sin\theta\sin\phi & \cos\theta\sin\phi & \cos\phi \\ \cos\theta & -\sin\theta & 0 \end{bmatrix}\begin{bmatrix} -2 \\ 3r \\ -1 \end{bmatrix}$

$\begin{array}{l} \hat{x}: \\ \hat{y}: \\ \hat{z}: \end{array} \begin{bmatrix} -2\sin\theta\cos\phi + 3r\cos\theta\cos\phi + \sin\phi \\ -2\sin\theta\sin\phi + 3r\cos\theta\sin\phi - \cos\phi \\ -2\cos\theta \quad -3r\sin\theta \end{bmatrix}$

$\vec{A}$ along $\hat{x}$: $\boxed{-2\sin\theta\cos\phi + 3r\cos\theta\cos\phi - \sin\phi \text{ cm}}$

b) $\vec{A}$ along $\hat{y}$: $\boxed{-2\sin\theta\sin\phi + 3r\cos\theta\sin\phi - \cos\phi \text{ cm}}$

c) Component of $\vec{A}$ parallel to $\hat{\phi}$ will be $\boxed{-1\hat{\phi} \text{ cm}}$ as seen in the original vector coordinates

d) $\begin{vmatrix} \hat{r} & \hat{\theta} & \hat{\phi} \\ -2 & 3r & -1 \\ 1 & 0 & 0 \end{vmatrix} = 0\hat{r} - \hat{\theta} - 3r\hat{\phi} = \boxed{-\hat{\theta} - 36\hat{\phi} \text{ cm}}$

Plug in $r = 12$cm

$dV = r^2\sin\theta\, dr\, d\theta\, d\phi$

Problem 2

a) $\text{Mass}_{\text{density}} = \frac{M}{r} \quad \frac{kg}{m^3}$

Units of $r = m$, Unit of $M \div$ Units of r

$= \frac{kg}{m^3} \Rightarrow$ Units of $\boxed{M = \frac{kg}{m^2}}$

b) $\int_0^{2\pi}\int_0^{\pi}\int_0^{T} \frac{M}{\cancel{r}} r^{\cancel{2}} \sin\theta\, dr\, d\theta\, d\phi$

$= \int_0^{2\pi}\int_0^{\pi} \frac{M}{2} r^2 \sin\theta \Big|_{r=0}^{T} d\theta\, d\phi = \int_0^{2\pi} -\frac{MT^2}{2}\cos\theta\Big|_{\theta=0}^{\pi} d\phi$

$= \int_0^{2\pi} -\frac{MT^2}{2}(-1-1)\, d\phi = \int_0^{2\pi} MT^2\, d\phi$

$= MT^2\phi\Big|_{\phi=0}^{2\pi} = \boxed{2\pi MT^2 \text{ Kg}}$

Problem 3

$\vec{A} = 3\cos\phi\,\hat{\rho} - 2\rho\hat{\phi} + 5\hat{z}$

$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} \cos\phi & -\sin\phi & 0 \\ \sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 3\cos\phi \\ -2\rho \\ 5 \end{bmatrix}$

$= \begin{bmatrix} 3\cos^2\phi + 2\rho\sin\phi \\ 3\cos\phi\sin\phi - 2\rho\cos\phi \\ 5 \end{bmatrix}$

a) along $\hat{x}$: $\boxed{3\cos^2\phi + 2\rho\sin\phi}$

b) along $\hat{y}$: $\boxed{3\cos\phi\sin\phi - 2\rho\cos\phi}$

c) plug in $\phi = 45°$

$\hat{x}$: $3\cos^2 45° + 2\rho\sin 45°$

$= \left(\frac{3}{2} + \sqrt{2}\rho\right)\hat{x}$

$\hat{y}$: $3\left(\frac{1}{2}\right) - 2\rho\frac{\sqrt{2}}{2} = \frac{3}{2} + \sqrt{2}\rho\,\hat{y}$

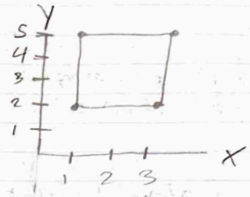
answer $\boxed{\left(\frac{3}{2} + \sqrt{2}\rho\right)\hat{x} + \left(\frac{3}{2} + \sqrt{2}\rho\right)\hat{y}}$

4: $\begin{vmatrix} \hat{\rho} & \hat{\phi} & \hat{z} \\ 3\cos\phi & -2\rho & 5 \\ 1 & 1 & 0 \end{vmatrix} = -5\hat{\rho} + 5\hat{\phi} + (3\cos\phi - 2\rho)\hat{z}$

$= \boxed{-5\hat{\rho} + 5\hat{\phi} + (3\cos\phi - 24)\hat{z} \text{ cm}}$

Problem 4

$\vec{B} = 3y\hat{x} + 2x\hat{y}$



a) $d\vec{l} = dx\,\hat{x} + dy\,\hat{y} + dz\,\hat{z}$

$\oint \vec{B}\cdot d\vec{l} = \int 3y\,dx + \int 2x\,dy$

Path 1: $y=5,\ 1 \le x \le 3,\ dy = 0$

$\int_1^3 3(5)\,dx = 15x\Big|_1^3 = 30$

Path 2: $x=3,\ 5 \ge y \ge 2,\ dx = 0$

$\int_5^2 2(3)\,dy = 6y\Big|_5^2 = 12-30 = -18$

Path 3: $y=2,\ 3 \ge x \ge 1,\ dy = 0$

$\int_3^1 3(2)\,dx = 6x\Big|_3^1 = -12$

Path 4: $x=1,\ 2 \le y \le 5,\ dx = 0$

$\int_2^5 2(1)\,dy = 2y\Big|_2^5 = 6$

Total: $\oint \vec{B}\cdot d\vec{l} = 30-18-12+6 = \boxed{6}$

b) $\nabla \times \vec{B} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ 3y & 2x & 0 \end{vmatrix} = 0\hat{x} + 0\hat{y} + (2-3)\hat{z}$

$= \boxed{-\hat{z}}$

c) $\iint \nabla\times\vec{B}\cdot d\vec{s}$

$d\vec{s} = dy\,dz\,\hat{x} + dx\,dz\,\hat{y} + dx\,dy\,\hat{z}$

$\nabla\times\vec{B}\cdot d\vec{s} = -\hat{z}\cdot d\vec{s} = -dx\,dy$

$\Rightarrow \iint \nabla\times\vec{B}\cdot d\vec{s} = -\int_2^5\int_1^3 dx\,dy = -\int_2^5 x\Big|_{x=1}^{3} dy = -2y\Big|_{y=2}^{5}$

$= -2(5-2) = \boxed{-6}$

d) The answer to part a is the same as the answer to part c, this is an example of stoke's theorem which states

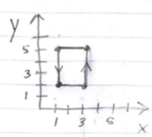
$\oint \vec{B}\,d\vec{l} = \iint \nabla\times B\cdot ds$

EE 311 Homework 2 Peter Dea

Problem 1

$\vec{B} = 8x\hat{y} - 2y\hat{x}$

a) $\oint \vec{B}\cdot d\vec{l}$ path $z=0,\ 3 \ge x \ge 1,\ 5 \ge y \ge 2$



$d\vec{l} = dx\,\hat{x} + dy\,\hat{y} + dz\,\hat{z}$

$\vec{B}\cdot d\vec{l} = -2y\,dx + 8x\,dy$

$\oint \vec{B}\cdot d\vec{l} = \int_c 8x\,dy - \int_c 2y\,dx$

Calculate each path seperate

① $y=5,\ 3 \ge x \ge 1,\ dy=0 \Rightarrow -\int_3^1 2y\,dx = 10\int_1^3 dy = 10(2) = 20$

② $x=1,\ 5 \ge y \ge 2,\ dx=0 \Rightarrow \int_5^2 8x\,dy = -8\int_2^5 dy = -8(3) = -24$

③ $y=2,\ 1 \le x \le 3,\ dy=0 \Rightarrow -\int_1^3 2y\,dx = -4\int_1^3 dx = -4(2) = -8$

④ $x=3,\ 2 \le y \le 5,\ dx=0 \Rightarrow \int_2^5 8x\,dy = 24\int_2^5 dy = 24(3) = 72$

Add paths together

$20-24-8+72 = \boxed{60}$

b) Find curl of $\vec{B}$, $\vec{B} = 8x\hat{y} - 2y\hat{x}$

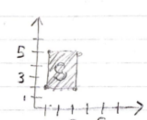
curl of $\vec{B} = \vec{\nabla}\times\vec{B}$

$= \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ -2y & 8x & 0 \end{vmatrix} = 0\hat{x} - 0\hat{y} + (8 - -2)\hat{z} = \boxed{10\hat{z}}$

c) $\iint \nabla\times\vec{B}\cdot d\vec{s}$ $\quad d\vec{s} = dy\,dz\,\hat{x} + dx\,dz\,\hat{y} + dx\,dy\,\hat{z}$

$= \int_{x=1}^{3}\int_{y=2}^{5} 10\,dy\,dx$

$= \int_1^3 10y\Big|_{y=2}^{5} dx$



$= 10(3)x\Big|_{x=1}^{3} = 30(2) = \boxed{60}$

d) Both part a and part c have the same answer as is stated by stoke's theorem. The integral of flux on a path around a closed surface is equal to the integral of the curl of the flux within said surface. In mathematical terms it is written below.

$\oint \vec{B}\cdot d\vec{l} = \iint \nabla\times\vec{B}\cdot d\vec{s}$

Problem 2

$$\vec{A} = \frac{kr}{10}\hat{r} \quad \frac{C}{m^2}$$

a) K units can be found by noting that when k is multiplied by r, which has units of meters, you get units of C/m². That means:

$$K_{units} \cdot m = \frac{C}{m^2} \Rightarrow \boxed{K_{units} = \frac{C}{m^3}}$$

b) $\oiint \vec{A}\cdot d\vec{s} = \int \nabla\cdot\vec{A}\, dv$ Divergence Theorem

$$d\vec{s} = r^2 \sin\theta\, d\theta\, d\phi\, \hat{r} + r\sin\theta\, dr\, d\phi\, \hat{\theta} + r\, dr\, d\theta\, \hat{\phi}$$

$$\vec{A}\cdot d\vec{s} = \frac{kr^3}{10}\sin\theta\, d\theta\, d\phi$$

$$\oiint \vec{A}\cdot d\vec{s} = \int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi} \frac{kr^3}{10}\sin\theta\, d\theta\, d\phi \Big|_{r=2m}$$

$$= \int_{\phi=0}^{2\pi} \frac{kr^3}{10}\left[-\cos\theta\right]_{\theta=0}^{\pi} d\phi = \frac{2kr^3}{10}\,\phi\Big|_{\phi=0}^{2\pi}$$

$$= \frac{2}{5}\pi k r^3\Big|_{r=2m} = \boxed{\frac{16}{5}\pi k \;\; C}$$

c) $\iiint_V \nabla\cdot\vec{A}\, dv$ sphere $r=4$

$\nabla\cdot\vec{A} = \frac{k}{10}$ $dv = r^2\sin\theta\, dr\, d\theta\, d\phi$

$$\Rightarrow \int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi}\int_{r=0}^{4} \frac{k}{10} r^2 \sin\theta\, dr\, d\theta\, d\phi$$

$$= 2\pi \int_{\theta=0}^{\pi} \frac{k}{10}\frac{r^3}{3}\sin\theta\Big|_{r=0}^{4} d\theta = \frac{k}{10}2\pi\frac{64}{3}\left[-\cos\theta\right]_{\theta=0}^{\pi}$$

$$\frac{64}{15}k\pi\cdot 2 = \boxed{\frac{128k\pi}{15} \; C}$$

These homeworks challenged my knowledge on Stoke's theorem, divergence theorem, vector coordinate systems, and vector transformations. I made a few mistakes during the vector transformation portion of the first homework, so I made sure to brush up on that in preparation for the first exam.

Pre-Exam 1 Reflection

Prior to exam 1 as a part of one of the games I wrote a reflection in which I mentioned my preparation strategies and how I was feeling about going into exam 1. Here is what I had to say:

___

How are you preparing?
"I am preparing by reviewing the textbook, previous games, and homework. I am also looking into the files on canvas as I believe they will be very helpful for me when the exam comes around. My purpose for reviewing all of this content is not only for me to gain a better and more intuitive understanding for the content, but also so I can make sure I have the best concept sheet I can for the exam. I think during exam time it will be really important that I am quickly able to find any information that I might need that I do not already have memorized (eg. dl, ds, dv in the different coordinate systems and the matrices to convert between them.)"

2. How do you feel about your preparation, do you think you are in a good place? What else do you need to do?
"I believe I am doing the best I can to prepare for the upcoming exam, though I cannot be sure until I take it. I will certainly learn from any mistakes I make from my preparation this time and make sure to work on them while preparing for the next exams. I think I still need to set aside a lot more time to prepare for this exam, however I think my current preparation strategy will prove to be very helpful if I put in the work for it."

3. What are your worries? And how are you working to get over them?
I am worried that I will see something on the exam that I have not seen in the games or homework and did not prepare for. I hope that by gaining an intuitive understanding of all of the topics we are learning in this class I will be more prepared for unfamiliar questions.

4. What are the points that you need to focus on? These are what you consider are your "weakness", or what you need to practice?
"There were problems on the first homework that I did very poorly on, and I think could use more of my attention. Specifically, the one that asked what portion of a vector was perpendicular to phi hat at a certain angle at a certain point of the vector field. I believe that I am not fully ready to take on another one of these problems, so this is a type of problem that I should practice and focus on."

5. Any other items on your mind please share
"As nervous as I am for the first exam, I am excited to learn the new concepts that this course has to offer. So far it has felt like review of calculus 3 and I look forward to seeing what electromagnetic fields and waves is all about. Hopefully my understanding of coordinates, vectors, the divergence theorem, and stoke's theorem are a good enough foundation for me to do well with what we will be learning in this class in the future."

Exam 1

On exam day I was given the regular class period to solve 3 problems similar to the homework and games we had solved in class.

EE 311
Fall 2023

Test 1

Name Peter Dea

16

Problem 1 (25 points) Show your detailed work
In cylindrical coordinate system you are given the following vector
$\vec{A} = 5\hat{\phi} - 2\hat{\rho} - \rho\hat{z}$ at a point in space.

a) (10 points) How much of this vector is along x direction?
b) (5 points) How much of this vector is tangential to z=5?
c) (10 points) Do the following integral $\int_{-3\pi}^{9\pi}(5\hat{\phi} + \hat{y})\, d\phi$

a) convert to cartesian w/ matrix

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} \cos\phi & -\sin\phi & 0 \\ \sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} -2 \\ 5 \\ -\rho \end{bmatrix} = \begin{bmatrix} -2\cos\phi - 5\cos\phi \\ -2\sin\phi + 5\cos\phi \\ -\rho \end{bmatrix}$$

along x: $\boxed{(-2\cos\phi - 5\cos\phi)\hat{x}}$

X

b)

tangential to $z = 5$
tangential → parallel, $z = 5 \Rightarrow \rho = 5$

tangential $= \boxed{-5\hat{z}}$

X

c) $\int_{-3\pi}^{9\pi} 5(\hat{\phi} + \hat{y})\, d\phi = \int_{-3\pi}^{9\pi} 5\hat{\phi}\, d\phi + \int_{-3\pi}^{9\pi} \hat{y}\, d\phi$

$= 5\hat{\phi}\,\phi\Big|_{-3\pi}^{\phi=9\pi} + \hat{y}\,\phi\Big|_{\phi=-3\pi}^{9\pi} = 5\cdot 12\pi\,\hat{\phi} + 12\pi\hat{y} = \boxed{60\pi\hat{\phi} + 12\pi\hat{y}}$

Do not write on the back of the paper!

EE 311
Fall 2023

Test 1

Name Peter Dea

22

Problem 2 (25 points) Show your detailed work
$\vec{D}$ is given for this problem, please note that you need to

$$\vec{D} = (z^2)\hat{x} - (x - y)\hat{y} - 2xy\hat{z}$$

a) (10 points) Find the surface integral of $\vec{D}$ through the surface of a cube that is defined by $-5 \le x \le 0 \quad -5 \le y \le 0 \quad -5 \le z \le 0$
b) (5 point) Find the divergence of $\vec{D}$
c) (10 points) Find the volume integral of $\nabla.\vec{D}$ for the cube given in part a

a) $\oint \vec{D}\cdot\vec{ds}$: $\quad \vec{ds} = dy\,dz\,\hat{x} + dx\,dz\,\hat{y} + dx\,dy\,\hat{z}$

$\vec{D}\cdot\vec{ds} = z^2\,dy\,dz + (x-y)\,dx\,dz + 2xy\,dx\,dy$

6 surfaces (cube)

① $x = 0 \quad -5 \le y \le 0 \quad = \int_{z=-5}^{0}\int_{y=-5}^{0} z^2\,dy\,dz = \int_{z=-5}^{0} z^2\, y\Big|_{y=-5}^{0} dz = \int_{-5}^{0} 5z^2\,dz$
$dx = 0 \quad -5 \le z \le 0$
$= 5\frac{z^3}{3}\Big|_{z=-5}^{0} = 5\left(0 + \frac{125}{3}\right) = \frac{625}{3}$

Opposite surfaces should have opposite directions

② $x = -5 \quad -5 \le y \le 0 \quad -\int_{-5}^{0}\int_{-5}^{0} z^2\,dy\,dz = \frac{625}{3}$
$dx = 0 \quad -5 \le z \le 0$

③ $y = 0 \quad -5 \le x \le 0 \quad -\int_{-5}^{0}\int_{-5}^{0} x\,dx\,dz = -\frac{x^2}{2}\Big|_{x=-5}^{0} z\Big|_{z=-5}^{0} = -5\left(\frac{25}{2}\right) = -\frac{125}{2}$
$dy = 0 \quad -5 \le z \le 0$

④ $y = -5$

. . .

This will take too long to finish, my method would be to add together the integrals from each surface, but I am running low on time. The answer should equal 125, because the divergence theorem says it will equal $\int \nabla.D\,dv$, which I solve in 2c.

Do not write on the back of the paper!

As long as you set it up correctly I can accept that

EE 311
Fall 2023

Test 1

Name Peter Dea

2 cont.

b) divergence of $\vec{D} = \nabla\cdot\vec{D}$

$= \frac{\partial}{\partial x}z^2 + \frac{\partial}{\partial y}-(x-y) + \frac{\partial}{\partial z}(-2xy) = 0 + 1 + 0 = \boxed{1}$

$\frac{\partial}{\partial y}(x+y)$

c) $\int_{-5}^{0}\int_{-5}^{0}\int_{-5}^{0} 1\,dx\,dy\,dz = \quad xyz\Big|_{x=-5}^{0}\Big|_{y=-5}^{0}\Big|_{z=-5}^{0} = (0--5)(0--5)(0--5)$

$= 5\times 5\times 5 = \boxed{125}$

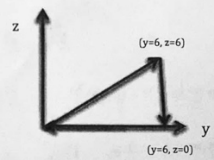
EE 311 Test 1 Name Peter Dea
Fall 2023

22

Problem 3 (25 points) Show your detailed work
The vector field is defined on yz plane.

$$\vec{E} = (xy^2)\hat{z} + (xz)\hat{y}$$

a) (10 points) What is the $\oint \vec{E}.\vec{dl}$ around the given path
b) (5 Point) Find the curl of $\vec{E}$
c) (10 points) Find $\iint \nabla \times \vec{E} \cdot \vec{ds}$ over the surface of the figure (stay on the x=0 plane)



a) $d\vec{l} = dx\hat{x} + dy\hat{y} + dz\hat{z}$

$E \cdot d\vec{l} = xy^2dz + xzdy$

Find $\oint xy^2dz + xz\,dy$ for each part of path

① $y=6$, $dy=0$, $6 \ge z \ge 0$: $\int_{z=6}^{0} xy^2dz = 36xz\Big|_{z=6}^{0} = -216x$

② $z=0$, $dz=0$, $6 \ge y \ge 0$: $\int_{y=6}^{0} xz\,dy = 0 \cdot \int_{y=6}^{0} x\,dy = 0$

③ $y=z$: $\int_0^6 xz^2dz + \int_0^6 xy\,dy = x\frac{z^3}{3}\Big|_{z=0}^{6} + x\frac{y^2}{2}\Big|_{y=0}^{6}$

$= 72x + 18x = 90x$

Add all paths: $\oint \vec{E} \cdot d\vec{l} = -216x + 90x = \boxed{-126x}$

Do not write on the back of the paper! If $x=0$, this equals 0.

EE 311 Test 1 Name Peter Dea
Fall 2023

3 cont.

b) curl of $\vec{E} = \nabla \times \vec{E}$

$$= \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ 0 & xz & xy^2 \end{vmatrix} = \boxed{(2xy - x)\hat{x} - y^2\hat{y} + z\hat{z}}$$

c) $\iint \nabla \times \vec{E} \cdot d\vec{s}$ $\quad d\vec{s} = dydz\,\hat{x} + dxdz\,\hat{y} + dxdy\,\hat{z}$

$(\nabla \times \vec{E}) \cdot d\vec{s} = (2xy - x)dydz - y^2dxdz + zdxdy$

If $x=0$, all of these terms equal 0, so the answer must be 0.

The first problem of this exam was a lot harder than I expected it to be, which I go into detail in my post-exam reflection, which is shown on the next page.

Post-Exam 1 Reflection

1. What do you think about the results of the test?
"While taking the test I thought that the test was more difficult than I expected. Some of the questions felt like they were slightly different than the questions I have encountered in the games so I really
had to think about how to get the right answer. I left feeling unsure about how well I did on it and not super confident in my answers. When I got my results back I had a better score than I had expected given how difficult the test felt at the time of taking it."

2. What did you learn by taking this test? Was the test helpful for your learning and growth? How?
"Regarding the content of this course, the results of this test taught me to be more careful into account the direction of dS when doing a surface integral. I had several integrals end up with the wrong sign because I did not take this into account, but I think during the game today I did it to correct way meaning that this test taught me how to do this the right way."

3. What should you/could you have done differently to get more out of the test?
"I should have studied how to find which portions of a vector are parallel, perpendicular, and tangential to a certain other vector. These questions on the exam were definitely the hardest for me and where the source of most of my errors were. I wish I were to have a more intuitive understanding for how to find the answers to this type of problem."

4. Does the grade represent your knowledge of the material?
"I would say yes. I got much worse scores on the problems that involved topics I do not have a good understanding for while I got better grades for the problems in areas I understand well. For example, I have always felt like stoke's theorem is much easier and more intuitive to me than Divergence theorem and on this exam I did much better on the stoke's theorem question than the divergence theorem one."

5. If the grade does not represent your knowledge, what happened in the test that you could not show what you know?
"As said above I do think the grade represents my knowledge well. There is no area in this exam where I feel like my grade was unfair and there is no part where I felt like I got points I didn't deserve."

6. What would you do differently for the next test?
"I think I should spend more time reviewing the textbook. I think this would better prepare me for questions I have not already seen in the games we've been doing. Given that the format of the questions in the exam was slightly different than the ones in the games and assignments, reviewing the games proved to be slightly less helpful than reviewing the textbook. I think the games led me to expect a certain format of question which left me confused when it was different on the exam."

7. Any other items reflection that you would like to share.
"I think this exam served as a good checkpoint for my understanding of the concepts from Calculus 3 that will be important for this class. While it was slightly more difficult than I was expecting, I think this exam overall made me more confident with my ability to do well in this class and brought attention to the areas I need to focus on more."

And that concluded the unit on Vector Analysis. We then moved onto the next unit: Electrostatics.

Unit 2: Electrostatics

Electrostatics Introduction

This unit pertained to concepts regarding electrostatics. We started with Coulomb's law and then moved onto Gauss' law, which was the first Maxwell equation we learned. This is something I was familiar with from Physics II, though it took a little while for me to get used to it again as Physics II was a class I took 2 years ago. Gauss' law states that the charge enclosed in a volume is equal to the divergence of the electric flux density. In addition to Gauss' law, in this portion of the class there was also a lot of emphasis in this unit on checking boundary conditions for electric fields and electric flux density.

The first game I did as a part of this unit was focused on making sure we understood the units that we are working with in regards to electrostatics and making sure we can solve basic integrals that we might see in these sorts of problems in the future. The game is shown on the next page.

Electrostatic Basics

Caleb
Sam
Elias
Denny
Scott
Mina

EE311
Game 16 - Peter Dea

$$\vec{E} = \frac{Q}{4\pi\epsilon_0 r^2}\hat{r} = k\frac{Q}{r^2}\hat{r}\ \frac{V}{m}$$

1. This field has spherical symmetry because the field is perpendicular to $\hat{r}$ at every point.

2. Units of K times units of Q divided by units of r squared equals V/m

$$\Rightarrow K \text{ units} \cdot \frac{\text{Coulomb}}{\text{meters}^2} = \frac{V}{m}$$

$$K \text{ units} = \frac{Vm^2}{Cm} = \boxed{\frac{Vm}{C}} \qquad \frac{\text{Volt} \times \text{meter}}{\text{coulomb}}$$

3. $$-\int_{\infty}^{a} kQ\frac{T}{r^2}\,dr = +\frac{QkT}{r}\Big|_{\infty}^{r=a} = +\frac{kTQ}{a} + \frac{kTQ}{\infty} = \frac{QkT}{a}\,\frac{VmC^2}{Cm}$$

$$= \boxed{\frac{kT}{a}\ J}$$

4. $$\oiint \frac{kQ}{r^2}\hat{r}\cdot d\vec{s} = \int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi}\frac{kQ}{\cancel{R^2}}\cancel{R^2}\sin\theta\,d\phi\,d\theta$$

$$= \int_0^{\pi} \phi kQ\sin\theta\Big|_{\phi=0}^{2\pi} d\theta = 2\pi kQ\left[-\cos\theta\right]_{\theta=0}^{\pi} =$$

$$2\pi kQ[--1+1] = \boxed{4\pi kQ\ \ Vm}$$

I received feedback that I should have gone into a bit more depth regarding my answer to problem 1, but other than that I was told I was solving the questions correctly, which made me feel confident moving forward with this topic. It was important for me to have a good understanding of this now before going into the next game, which would be our first game on Gauss' law.

Gauss' Law

Caleb
Sam
Elias
Penny
Scott
Mina

Game 18 - EE 311 - Peter Dea

1. $\rho_v = \begin{cases} \rho_0 r^2 \ C/m^3 & r < a \\ 0 & a < r \end{cases}$

ρ_v units $= C/m^3 = \rho_0$ units $\times$ r^2 units

$C/m^3 = \rho_0$ units $\times$ meters^2 $\Rightarrow \rho_0$ units $= \frac{C}{m^3 m^2}$

ρ_0 units $= \boxed{\frac{C}{m^5}}$

2. Yes, because the value of ρ_v depends only on r and the constant ρ_0, so it will be the same value for any radius r.

3. $\oiint \vec{D} \cdot d\vec{S} = \oiint D(r)\,\hat{r} \cdot r^2 \sin\theta \, d\theta \, d\phi \, \hat{r}$

$= \boxed{\int_0^{2\pi}\int_0^{\pi} D(r) r^2 \sin\theta \, d\theta \, d\phi}$

$dv = r^2 \sin\theta \, dr \, d\theta \, d\phi$

4. $\iiint \rho_v \, dv = \int_0^R \int_0^{2\pi} \int_0^{\pi} \rho_0 r^2 r^2 \sin\theta \, d\theta \, d\phi \, dr$

Assume $R < a$

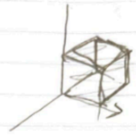
$\int_0^R \int_0^{2\pi} \rho_0 r^4 \left(-\cos\theta \Big|_{\theta=0}^{\pi}\right) d\phi \, dr = \int_0^R 2\rho_0 r^4 \phi \Big|_{\phi=0}^{2\pi} dr$

$= 4\pi \rho_0 \int_0^R r^4 dr = \boxed{\frac{4\pi \rho_0 R^5}{5} \ C}$

In this first game working with Gauss' law, the first portion was focusing on units to make sure I had a good understanding of the topics that I am working with. I then used Gauss' Law, by first setting up the surface integral of the electric flux density field, and then finding the volume integral of the given charge density. I made a mistake in this game by not evaluating my first integral, which meant I was not able to confirm they were equal using Gauss' law. This is something I fixed in later games.

Caleb
San
Elias
Denny
Scott

Game 19 - EE 311, Peter Dea



cube

$\vec{E} = (y-x)\hat{x} + (-y)\hat{y} + xy\hat{z}$

b first

b) $\nabla\cdot\vec{E} = \frac{\partial}{\partial x}(y-x) + \frac{\partial}{\partial y}(-y) + \frac{\partial}{\partial z}(xy) = -1-1+0 = \boxed{-2}$

c) $\iiint_V \nabla\cdot\vec{E} = \int_0^4\int_0^4\int_0^4 -2\,dx\,dy\,dz = 4(4)(4)(-2) = \boxed{-128}$

a) $\oint \vec{E}\cdot\vec{ds}$ $\qquad ds = dy\,dz\,\hat{x} + dz\,dx\,\hat{y} \pm dx\,dy\,\hat{z}$

keep in mind direction of flux

6 integrals, one for each surface of cube

$\vec{E}\cdot\vec{ds} = (y-x)\,dy\,dz - y\,dz\,dx + xy\,dx\,dy$

① $x=0$ $\quad -\int_0^4\int_0^4 y\,dy\,dz = \int_0^4 \frac{y^2}{2}\Big|_{y=0}^{4} dz = 8z\Big|_{z=0}^{4} = -3$

② $x=4$ $\quad +\int_0^4\int_0^4 y-4\,dy\,dz = -32$

③ $y=0$ $\quad -\int_0^4\int_0^4 0\,dz\,dx = 0$

④ $y=4$ $\quad +\int_0^4\int_0^4 -4\,dz\,dx = -64$

⑤ $z=0$ $\quad -\int_0^4\int_0^4 xy\,dx\,dy = -\int_0^4 \frac{x^2y}{2}\Big|_{x=0}^{4} = -8\frac{y^2}{2}\Big|_{y=0}^{4} = -6$

⑥ $z=4$ $\quad +\int_0^4\int_0^4 xy\,dx\,dy = 64$

add integrals from all 6 surfaces

$\oint \vec{E}\cdot\vec{ds} = -32+32+0+64-64+64 = -128$

In the next game regarding Gauss' law, we were using a different coordinate system. Whereas in the last one we were using cylindrical coordinates, in this one we were to use cartesian coordinates. In this game I fixed my problem from last time and calculated both integrals. I was confident in my answers for this game because I ended up with the same answer for both integrals, which is what is expected because of Gauss' law.

In the next game I was again using Gauss' law but this time I was to use spherical coordinates.

Caleb
Sam
Elias
Denny
Scott
Mina

Game 22 - EE 311 - Peter Dea

$0<a<b$ Charge Dist. $= \begin{cases} Q\ C & r=0 \\ kr^2\ \frac{C}{m^3} & a<r<b \\ \text{no charge} & b<r \end{cases}$

i) $Kr^2_{units} = \frac{C}{m^3}$, $r_{units} = m \Rightarrow Km^2 = \frac{C}{m^3}$

$K_{units} = \boxed{\frac{C}{m^5}}$

ii) $\boxed{\text{Region 1:}}$ $0<r<a$

$Q = \int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi} D(r) r^2 \sin\theta \, d\phi \, d\theta = \int_{\theta=0}^{\pi} \phi \Big|_{\phi=0}^{2\pi} D(r) r^2 \sin\theta \, d\phi = Q$

$= 2\pi D(r) r^2 \left[-\cos\theta\right]_{\theta=0}^{\pi} = 4\pi D(r) r^2 = Q \Rightarrow D(r) = \boxed{\frac{Q_{en}}{4\pi r^2}\hat{r}\ \frac{C}{m^2}}$

$\boxed{\text{Region 2}}$ $a<r<b$

$Q_{en} = Q + \iiint kr^4 \sin\theta \, d\theta \, d\phi \, dr = Q + \int_{r=a}^{r}\int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi} kr^4 \sin\theta \, d\theta \, d\phi \, d$

$= Q + \int_{r=a}^{r}\int_{\theta=0}^{\pi} \phi\Big|_{\phi=0}^{2\pi} kr^4 \sin\theta \, d\theta \, dr = Q + \int_{r=a}^{r} 2\pi k r^4 \left[-\cos\theta\right]_{\theta=0}^{\pi} dr$

$= Q + 4\pi K \int_{r=a}^{r} r^4 dr = \boxed{Q + \frac{4\pi K (r^5 - a^5)}{5}\ \frac{C}{m^2}}$

$D(r) = \frac{Q_{en}}{4\pi r^2} = \boxed{\frac{Q}{4\pi r^2}\hat{r} + \frac{K(r^5-a^5)}{5r^2}\hat{r}\ \frac{C}{m^2}}$

Region 3: Next Page

$\boxed{\text{Region 3}}$ $b < r$

$$Q_{en} = \int_{r=a}^{b}\int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi} kr^4 \sin\theta \, d\theta \, d\phi \, dr$$

$$= \boxed{\frac{Q}{4\pi b^2}\hat{r} + \frac{k(b^2-a^2)}{5b^2}\hat{r} \quad \frac{C}{m^2}}$$

iii) $\vec{D}(a-) = \frac{Q}{4\pi a^2}\hat{r} \frac{C}{m^2}$

$\vec{D}(a+) = \frac{Q}{4\pi a^2}\hat{r} + \frac{k(a^2-a^2)}{5a^2} = \frac{Q}{4\pi a^2}\hat{r} \frac{C}{m^2}$

$\Rightarrow \boxed{\vec{D}(a-) = \vec{D}(a+)}$

$\vec{D}(b-) = \frac{Q}{4\pi b^2}\hat{r} + k\left(\frac{b^2-b^2}{5b^2}\right)\hat{r} \frac{C}{m^2} = \frac{Q}{4\pi b^2}\hat{r} \frac{C}{m^2}$

$\vec{D}(b+) = \frac{Q}{4\pi b^2}\hat{r} + k\left(\frac{b^2-b^2}{5b^2}\right)\hat{r} \frac{C}{m^2} = \frac{Q}{4\pi b^2}\hat{r} \frac{C}{m^2}$

$\boxed{\vec{D}(b-) = \vec{D}(b+)}$

iv) $\nabla \cdot \vec{D} : r < a \Rightarrow \frac{1}{r^2}\frac{\partial}{\partial r} r^2 \frac{Q}{4\pi r^2} = \boxed{0}$

$\nabla \cdot \vec{D} : a < r < b \Rightarrow \frac{1}{r^2}\frac{\partial}{\partial r} r^2 \left(\frac{Q}{4\pi r^2} + \frac{k(r^2-a^2)}{5r^2}\right)$

$= \frac{1}{r^2}\frac{\partial}{\partial r}\frac{(kr^2 - ka^2)}{5} = \frac{2rk}{5r^2} = \boxed{\frac{2k}{5r}}$

I had some troubles with the divergence in this game, though it was a good example of using Gauss' law in spherical coordinates.

Finding Charge Distribution

In the next game we had we started working with games where instead of being given the charge distribution and being asked to confirm Gauss' law, we were given electric flux density (D fields) and were asked to use those to find the charge density.

Caleb
Sam
Elias
Denny
Scott
Mina

Game 26 Peter Dea

i) S: $\frac{-3S}{4\pi r^2}\hat{r} + \frac{G}{r}\hat{r} \quad \frac{C}{m^2}$ $\quad 0<r<a$

$-\frac{3S}{4\pi r^2}$ units $= \frac{C}{m^2}$ $\quad -\frac{3S}{4\pi m^2}$ units $= \frac{C}{m^2} \Rightarrow$ $\boxed{\text{S has units of Coulombs}}$

G: $\frac{G}{r}$ units $= \frac{C}{m^2} \Rightarrow$ G units $= \frac{Cm}{m^2} =$ $\boxed{\frac{C}{m} = \text{G units}}$

K: $\frac{Ka^2}{r^2}$ units $= \frac{C}{m^2} = \frac{Km^2}{\cancel{m^2}} \Rightarrow$ $\boxed{\text{K has units of } \frac{C}{m^2}}$

N: $-\frac{Nb^2}{r^2} = \frac{C}{m^2} \Rightarrow$ $\boxed{\text{N has units of } \frac{C}{m^2}}$

ii) $\nabla \cdot \vec{D} = \frac{1}{r^2}\frac{\partial}{\partial r} r^2(\hat{r}\text{ term})$

$0<r<a$: $\frac{1}{r^2}\frac{\partial}{\partial r} r^2\left(-\frac{3S}{4\pi r^2} + \frac{G}{r}\right) = \frac{1}{r^2}\frac{\partial}{\partial r}\left(-\frac{3S}{4\pi} + Gr\right)$

$= \frac{1}{r^2}\frac{\partial}{\partial r}Gr = \boxed{\frac{G}{r^2} \quad \frac{C}{m^3}}$ Region I

r terms cancel

$a<r<b$: $\frac{1}{r^2}\frac{\partial}{\partial r}\cancel{r^2}\left(\frac{-3S}{4\pi \cancel{r^2}} + \frac{Ga}{\cancel{r^2}} + \frac{Ka^2}{\cancel{r^2}}\right) = \boxed{0}$

Region II

$b<r$: $\frac{1}{r^2}\frac{\partial}{\partial r} r^2\left(\frac{-3r}{4\pi r^2} + \frac{Ga}{\cancel{r^2}} + \frac{ka^2}{r^2} - \frac{Nb^2}{\cancel{r^2}}\right) = \boxed{0}$

all r^2 terms cancel again

Region III

iii) $\vec{D}(a-) = -\frac{3S}{4\pi a^2} + \frac{G}{a} \quad \frac{C}{m^2}$

$\vec{D}(a+) = -\frac{3S}{4\pi a^2} + \frac{Ga}{a^2} + \frac{Ka^2}{a^2} = -\frac{3S}{4\pi a^2} + \frac{G}{a} + K$

$\boxed{\vec{D}(a-) \text{ is equal to } \vec{D}(a+) + K}$

$\vec{D}(b-) = \frac{-3S}{4\pi b^2} + \frac{Ga}{b^2} + \frac{Ka^2}{b^2} \quad \frac{C}{m^2}$

$\vec{D}(b+) = -\frac{3S}{4\pi b^2} + \frac{Ga}{b^2} + \frac{Ka^2}{b^2} - \frac{Nb^2}{b^2}$

$\Rightarrow \boxed{\vec{D}(b-) = \vec{D}(b+) - N}$

So $\vec{D}(a+)$ includes the charge $+K$ and $\vec{D}(b+)$ includes $-N$

---

iv) Given answers from part 3 we can tell there are surface charges at $r=a$ and $r=b$. We can tell they are surface charges becaus of our units of C/m^2 we found in part 1.

$$\boxed{\text{Charge distribution} = \begin{cases} -3S \ C & \text{at } r=0 \\ G/r^2 \ C/m^3 & \text{at } r<a \\ K \ C/m^2 & r=a \\ -N \ C/m^2 & r=b \end{cases}}$$

I caught onto this style of problem very quickly and was successfully able to find the charge distribution given the D field.

Concept Sheets

After completing the first few games, we were assigned with another set of homework problems. Like the last set, these problems ere similar to the games, but went into more depth and took more time. Again to prepare for the homework I created more concept sheets which included the new topic we had covered. Below are images of these concept sheets.

Coulomb's Law (Forces)

$\vec{F} = \frac{Q_1 Q_2}{4\pi\epsilon_0 R^2}\hat{R}$ N

$\vec{E} = \frac{Q}{4\pi\epsilon_0 R^2}\hat{R}$ $\frac{V}{m}$ or $\frac{N}{C}$

• Electric Field ^^

Line, Surface, and Volume Charges

$Q = \int_L \rho_L \, d\ell$ line charge, $\rho_L = \frac{C}{m}$

$Q = \int_S \rho_S \, dS$ surface charge, $\rho_S = \frac{C}{m^2}$

$Q = \int_V \rho_V \, dV$ volume charge, $\rho_S = \frac{C}{m^3}$

Infinite Line Charge: $\boxed{\vec{E} = \frac{\rho_L}{2\pi\epsilon_0\rho}\hat{\rho}}$

Infinite Sheet of Charge: $\boxed{\vec{E} = \frac{\rho_S}{2\epsilon_0}\hat{n}}$

Constants: $\epsilon_0 = 8.854 \times 10^{-12} \frac{F}{m}$
$k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{m}{F}$

Gauss' Law (Electric Flux)

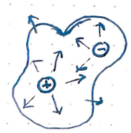
Electric Flux Density
$\boxed{\vec{D} = \epsilon_0 \vec{E}}$

$\Psi = \int_S \vec{D} \cdot d\vec{S}$ Electric Flux

Gauss' Law

$\Psi = \oint_S \vec{D} \cdot d\vec{S} = Q_{en} = \int_V \rho_V \, dV$

$\rho_V = \nabla \cdot \vec{D}$
Maxwell Equation I



Flux = Charge Enclosed

Work done moving a charge from A to B

$W = -Q \int_A^B E \cdot d\ell$

Electric Potential

$V(r) = \frac{Q}{4\pi\epsilon_0 |r - r'|} + C$

$V = -\int_A^B \vec{E} \cdot d\ell + C$, $V_{AB} = V_B - V_A = \frac{W}{Q}$

$\oint_L E \cdot d\ell = 0 = \boxed{\nabla \times E = 0}$
Maxwell Eqn II

$\vec{E} = -\nabla V$

Capacitance

$C = \frac{Q}{V}$ Farads

Q/V

Boundary Conditions

$E_{1t} = E_{2t}$, $D_{1n} - D_{2n} = \rho_S$

Poisson's Equation: $\boxed{\nabla^2 V = -\frac{\rho_V}{\epsilon}}$

Charge free region: $\nabla^2 V = 0$

Homework 3

The third homework assignment for this class covered the concepts we learned regarding electrostatics.

EE 311 - Peter Dea - Homework 3

Problem 1

Charge distribution =
$$\begin{cases} 0 & r<a \\ \rho_s \ \ C/m^2 & r=a \\ \rho_v \ \ C/m^3 & a<r<b \\ 0 & b<r \end{cases}$$

a) Region I $\quad r<a$

$$\oint\!\!\oint \vec{D}\cdot d\vec{s} = Q \Rightarrow \int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi} D(r)\hat{r}\cdot r^2\sin\theta \, d\phi \, d\theta \, \hat{r}$$

$$Q = D(r)r^2\int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi}\sin\theta\,d\phi\,d\theta = D(r)r^2 2\pi\left[-\cos\theta\right]_0^{\pi}$$

$$\Rightarrow Q = 4\pi r^2 D(r)\hat{r} \Rightarrow \boxed{\vec{D}(r) = \frac{Q}{4\pi r^2}\hat{r} \ \ \frac{C}{m^2}}$$

$$\vec{E}(r) = \frac{\vec{D}(r)}{\epsilon} \Rightarrow \boxed{\vec{E}(r) = \frac{Q}{4\pi\epsilon r^2}\hat{r} \ \ \frac{V}{m}}$$

Region II: $\quad r=a$

$$Q_{enc} = Q + \int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi}\rho_s a^2\sin\theta\,d\phi\,d\theta = \rho_s a^2 2\pi\int_{\theta=0}^{\pi}\sin\theta\,d\theta$$

$$\Rightarrow Q_{enc} = Q + \rho_s a^2 4\pi \Rightarrow \boxed{\vec{D}(r) = \frac{Q}{4\pi a^2}\hat{r} + \rho_s\hat{r} \ \ \frac{C}{m^2} \quad r=a}$$

$$\vec{E}(r) = \frac{\vec{D}(r)}{\epsilon} \Rightarrow \boxed{\vec{E}(r) = \frac{Q}{4\pi a^2\epsilon}\hat{r} + \frac{\rho_s}{\epsilon}\hat{r} \ \ \frac{V}{m}}$$

Region III: $\quad a<r<b$

$$Q_{enc} = Q + \rho_s a^2 4\pi + \int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi}\int_a^r \rho_v r^2\sin\theta\,dr\,d\phi\,d\theta$$

$$\frac{\rho_v(r^3-a^3)}{3}2\pi\cdot 2 \Rightarrow Q_{enc} = Q + \rho_s a^2 4\pi + \frac{\rho_v(r^3-a^3)}{3}4\pi$$

$$Q_{enc} = \frac{4}{3}\pi\rho_v(r^3-a^3) + \rho_s a^2 4\pi + Q$$

$$\boxed{\begin{aligned} &\Rightarrow \vec{D}(r) = \frac{Q}{4\pi r^2}\hat{r} + \frac{\rho_s a^2}{r^2}\hat{r} + \frac{\rho_v(r^3-a^3)}{3r^2}\hat{r} \ \ \frac{C}{m^2} \\ &\Rightarrow \vec{E}(r) = \frac{Q}{4\pi r^2\epsilon}\hat{r} + \frac{\rho_s a^2}{\epsilon r^2}\hat{r} + \frac{\rho_v(r^3-a^3)}{3r^2\epsilon}\hat{r} \ \ \frac{V}{m} \end{aligned}}$$

Region IV: $\quad b<r$

$$Q_{enc} = Q + 4\pi a^2\rho_s + \frac{4}{3}\pi\rho_v(b^3-a^3)$$

$$\boxed{\begin{aligned} &\vec{D}(r) = \frac{Q}{4\pi r^2}\hat{r} + \frac{\rho_s a^2}{r^2}\hat{r} + \frac{\rho_v(b^3-a^3)}{3r^2} \ \ \frac{C}{m^2} \\ &\vec{E}(r) = \frac{Q}{4\pi r^2\epsilon}\hat{r} + \frac{\rho_s a^2}{r^2\epsilon}\hat{r} + \frac{\rho_v(b^3-a^3)}{3r^2\epsilon} \ \ \frac{V}{m} \end{aligned}}$$

b) $\boxed{D(a^-) = \frac{Q}{4\pi a^2}\hat{r} \ \frac{C}{m^2} \ \Big| \ D(a^+) = \frac{Q}{4\pi a^2}\hat{r} + \rho_s\hat{r} \ \ \frac{C}{m^2}}$

when $r \geq a$, the surface charge at $r=a$ is included

$$\boxed{D(b^-) = \frac{Q}{4\pi b^2}\hat{r} + \frac{\rho_s a^2}{b^2}\hat{r} + \frac{\rho_v(b^3-a^3)}{3b^2}\hat{r} \ \frac{C}{m^2} \ \Big| \ D(b^+) = \frac{Q}{4\pi b^2}\hat{r} + \frac{\rho_s a^2}{b^2}\hat{r} + \frac{\rho_v(b^3-a^3)}{3b^2}\hat{r} \ \frac{C}{m^2}}$$

There is no difference between $D(b^-)$ and $D(b^+)$ because there is no surface charge at $r=b$.

Problem 2

a)
$$D(r) = \begin{cases} 0 & \frac{C}{m^2} \quad r<a \\ \frac{a^2x}{r^2}\hat{r} & \frac{C}{m^2} \quad a<r<b \\ ? & \frac{C}{m^2} \quad b<r<c \\ \frac{a^2x}{r^2}\hat{r} + \frac{Y(r-c)}{r^2}\hat{r} & \frac{C}{m^2} \quad c<r<d \\ \frac{a^2x}{r^2}\hat{r} + \frac{Y(d-c)}{r^2}\hat{r} + \frac{3gd^2}{r^2}\hat{r} & \frac{C}{m^2} \quad d<r \end{cases}$$

$a<r<c$

It makes most sense for $D(r)$ to be the same at $b<r<c$ and $a<r<b$

$\boxed{a: \ D(a^-) = 0, \ D(a^+) = x\hat{r} \ \frac{C}{m^2}}$

$\boxed{b: \ D(b^-) = \frac{a^2x}{b^2}\hat{r} \ \frac{C}{m^2} = D(b^+)}$

$\boxed{c: \ D(c^-) = \frac{a^2x}{c^2}\hat{r} \ \frac{C}{m^2}, \quad D(c^+) = \frac{a^2x}{c^2}\hat{r} \ \frac{C}{m^2}}$

d: $D(d^-) = \frac{a^2x}{d^2}\hat{r} + \frac{Y(d-c)}{d^2}\hat{r} \ \frac{C}{m^2}$

$D(d^+) = \frac{a^2x}{d^2}\hat{r} + \frac{Y(d-c)}{d^2}\hat{r} + 3g\hat{r}$

b) $\nabla\cdot D = \frac{1}{r^2}\frac{\partial}{\partial r}r^2 D_r$

Region I: $\nabla\cdot D = \boxed{0}$ $\quad$ 0 Flux density

Region II: $\nabla\cdot D = \frac{1}{r^2}\frac{\partial}{\partial r}r^2\frac{a^2x}{r^2} = \boxed{0}$ derivative of constant

Region III: $\nabla\cdot D = \frac{1}{r^2}\frac{\partial}{\partial r}r^2\left(\frac{a^2x}{r^2} + \frac{Yr-Yc}{r^2}\right)$

$= \frac{1}{r^2}\frac{\partial}{\partial r}Yr = \boxed{\frac{Y}{r^2} \ \ \frac{C}{m^2}}$

Region IV: $\nabla\cdot D = \frac{1}{r^2}\frac{\partial}{\partial r}r^2\left(\frac{a^2x}{r^2} + \frac{Y(d-c)}{r^2} + \frac{3gd^2}{r^2}\right)$

$= \frac{1}{r^2}\frac{\partial}{\partial r}\left(a^2x + Y(d-c) + 3gd^2\right) = \boxed{0}$

c. $\boxed{\text{charge dist} = \begin{cases} x \ \frac{C}{m^2} & r=a \\ Y/r^2 \ \frac{C}{m^2} & r=c \\ 3g \ \frac{C}{m^2} & r=d \end{cases}}$

$\boxed{\text{Problem 3}}$

We need to find. First find the gradient of the surface.

$$\nabla(-2x+4y-2z) = -2\hat{x}+4\hat{y}-2\hat{z},$$

a_n must be a unit vector

$$|\nabla(-2x+4y-2z)| = \sqrt{(-2)^2+4^2+(-2)^2} = \sqrt{24} = 2\sqrt{6}$$

$$a_n = \frac{-2\hat{x}+4\hat{y}-2\hat{z}}{2\sqrt{6}} \Rightarrow a_n = \frac{-\hat{x}+2\hat{y}-\hat{z}}{\sqrt{6}} \text{ for } -2x+4y-2z > 3$$

$$a_n = \frac{\hat{x}-2\hat{y}+\hat{z}}{\sqrt{6}} \text{ for } -2x+4y-2z < 3$$

$$\vec{E} = \frac{\rho_s}{2\epsilon} a_n = \boxed{\frac{\rho_s}{2\epsilon\sqrt{6}}(-\hat{x}+2\hat{y}-\hat{z})\frac{V}{m} \text{ for } -2x+4y-2z > 3}$$

$$\vec{E} = \frac{\rho_s}{2\epsilon} a_n = \boxed{\frac{\rho_s}{2\epsilon\sqrt{6}}(\hat{x}-2\hat{y}+\hat{z})\frac{V}{m} \text{ for } -2x+4y-2z > 3}$$

---

b)

E tangential $= 0$ at the border, no portion goes through the plane.

$$\vec{D}_1 - \vec{D}_2 = \rho_s a_n \qquad D_1 = \frac{\rho_s(-\hat{x}+2\hat{y}-\hat{z})}{2\sqrt{6}}$$

$$D_2 = \frac{-\rho_s(-\hat{x}+2\hat{y}-\hat{z})}{2\sqrt{6}}$$

This homework went really well for me, showing I had a good understanding of the unit on electrostatics.

Pre-Exam 2 Reflection

Again, prior to exam 2, one of the games had me reflect on how I was feeling going into the next exam. Here is what I had to say this time:

What did you learn from test 1, and how have you changed your approach since test 1?

In test 1 I learned that I should not simply rely on my experience from the games we did in class. Instead, I should nstead try to make sure I have an intuitive understanding of the material, so I am able to face any problem that is given to me. Test 1 was a lot harder than I expected it to be because I was not prepared to solve a problem that deviated too far from the problems in the games. I have changed my approach studying the textbook and its problems more carefully because I think they encourage me to think about the problems more generally and have a less streamlined approach to solving them so that I am better prepared for anything that can come my way on the next test.

How are you planning to prepare for the second test? What have you done? How are you getting ready based on your previous experiences with the test and games?

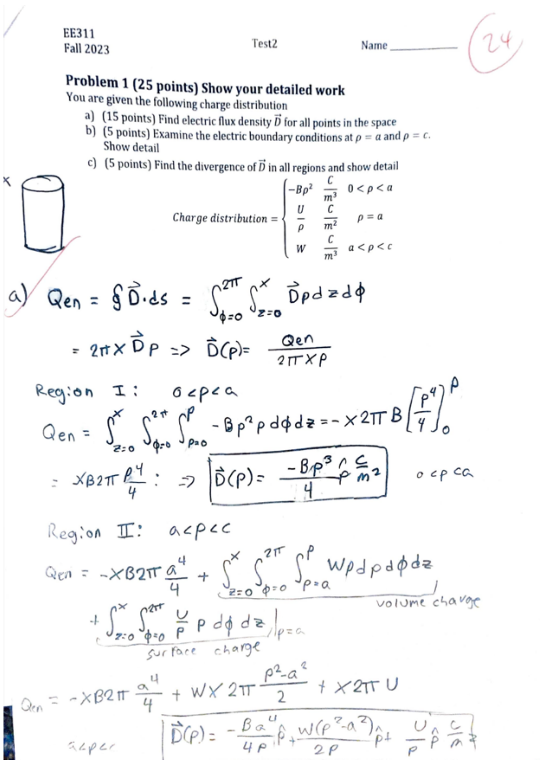
I am planning to spend a lot of time heavily reviewing the textbook before the next test. From the information I gather from the textbook, I plan to update my concept sheets to be quickly accessible during the test, so I do not have to waste time looking through old games and homework. However, I do want to have some sample problems easily accessible to me in case I get stuck and need something to guide me through the problem-solving process. I want to carefully review the solutions to the homework and games so I can learn from all of the mistakes I made in them and practice the areas I am rusty in so I can avoid making the same mistakes on the test.

What are you focusing on, what are your fears, and what are your concerns?

Right now, I am focusing on maximizing my understanding of the concepts that will be in this test. Specifically, I need to practice problems that involve charge distributions and boundary conditions. I have had a hard time with these problems in the games and I need to brush up on my understanding of these topics before the test. My biggest fear going into the exam is that the questions will deviate too far from what I am familiar with and I will be unsure what to do. I think I can prevent this by making sure to broaden my understanding of the topics that will be on this exam.

Exam 2

Exam 2 followed the same format as exam 1, so I had my normal class time to solve 3 problems pertaining to the content we had been learning in the current unit.



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Problem 1 (25 points) Show your detailed work

You are given the following charge distribution

a) (15 points) Find electric flux density $\vec{D}$ for all points in the space

b) (5 points) Examine the electric boundary conditions at $\rho = a$ and $\rho = c$. Show detail

c) (5 points) Find the divergence of $\vec{D}$ in all regions and show detail

$$Charge\ distribution = \begin{cases} -B\rho^2 & \frac{C}{m^3} & 0<\rho<a \\ \frac{U}{\rho} & \frac{C}{m^2} & \rho = a \\ W & \frac{C}{m^3} & a<\rho<c \end{cases}$$

a) $Q_{en} = \oint \vec{D}\cdot ds = \int_{\phi=0}^{2\pi}\int_{z=0}^{x} \vec{D}\rho\, dz\, d\phi$

$= 2\pi x \vec{D}\rho \Rightarrow \vec{D}(\rho) = \frac{Q_{en}}{2\pi x \rho}$

Region I: $0<\rho<a$

$Q_{en} = \int_{z=0}^{x}\int_{\phi=0}^{2\pi}\int_{\rho=0}^{\rho} -B\rho^2 \rho\, d\rho\, d\phi\, dz = -x 2\pi B\left[\frac{\rho^4}{4}\right]_0^{\rho}$

$= xB2\pi\frac{\rho^4}{4} \Rightarrow \boxed{\vec{D}(\rho) = \frac{-B\rho^3}{4}\hat{\rho}\frac{C}{m^2}}$ $0<\rho<a$

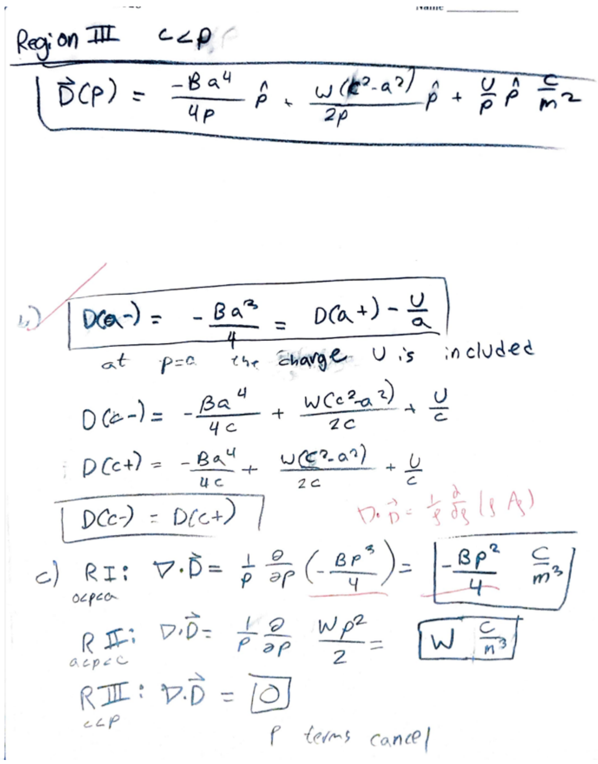
Region II: $a<\rho<c$

$Q_{en} = -xB2\pi\frac{a^4}{4} + \underbrace{\int_{z=0}^{x}\int_{\phi=0}^{2\pi}\int_{\rho=a}^{\rho} W\rho\, d\rho\, d\phi\, dz}_{\text{volume charge}}$

$+ \underbrace{\int_{z=0}^{x}\int_{\phi=0}^{2\pi}\frac{U}{\rho}\rho\, d\phi\, dz\Big|_{\rho=a}}_{\text{surface charge}}$

$Q_{en} = -xB2\pi\frac{a^4}{4} + Wx2\pi\frac{\rho^2-a^2}{2} + x2\pi U$

$a<\rho<c$ $\boxed{\vec{D}(\rho) = -\frac{Ba^4}{4\rho}\hat{\rho} + \frac{W(\rho^2-a^2)}{2\rho}\hat{\rho} + \frac{U}{\rho}\hat{\rho}\frac{C}{m^2}}$



Region III $c<\rho$

$\boxed{\vec{D}(\rho) = \frac{-Ba^4}{4\rho}\hat{\rho} + \frac{W(c^2-a^2)}{2\rho}\hat{\rho} + \frac{U}{\rho}\hat{\rho}\frac{C}{m^2}}$

b) $\boxed{D(a-) = -\frac{Ba^3}{4} = D(a+) - \frac{U}{a}}$

at $\rho=a$ the charge U is included

$D(c-) = -\frac{Ba^4}{4c} + \frac{W(c^2-a^2)}{2c} + \frac{U}{c}$

$D(c+) = -\frac{Ba^4}{4c} + \frac{W(c^2-a^2)}{2c} + \frac{U}{c}$

$\boxed{D(c-) = D(c+)}$

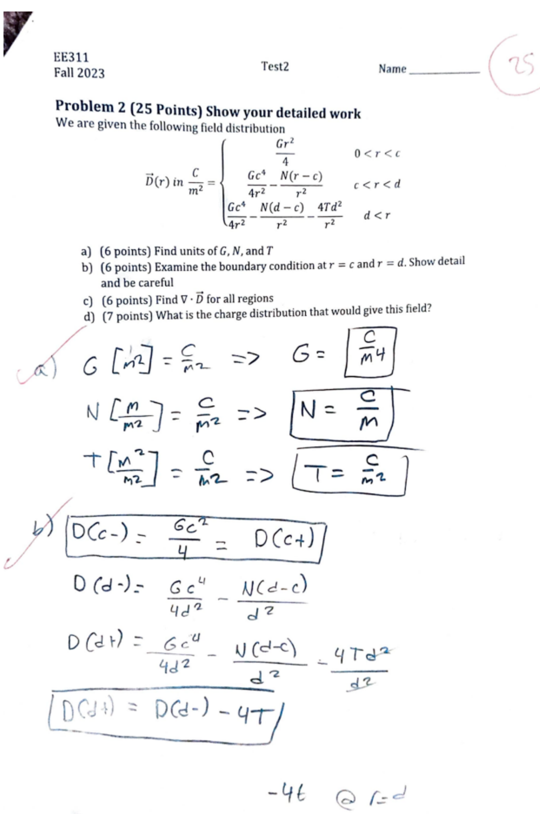
$\nabla\cdot\vec{D} = \frac{1}{\rho}\frac{\partial}{\partial\rho}(\rho A)$

c) R I: $0<\rho<a$ $\nabla\cdot\vec{D} = \frac{1}{\rho}\frac{\partial}{\partial\rho}\left(-\frac{B\rho^3}{4}\right) = \boxed{-\frac{B\rho^2}{4}\ \frac{C}{m^3}}$

R II: $a<\rho<c$ $\nabla\cdot\vec{D} = \frac{1}{\rho}\frac{\partial}{\partial\rho}\frac{W\rho^2}{2} = \boxed{W\ \frac{C}{m^3}}$

R III: $c<\rho$ $\nabla\cdot\vec{D} = \boxed{0}$

ρ terms cancel



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Problem 2 (25 Points) Show your detailed work

We are given the following field distribution

$$\vec{D}(r)\ in\ \frac{C}{m^2} = \begin{cases} \frac{Gr^2}{4} & 0<r<c \\ \frac{Gc^4}{4r^2} - \frac{N(r-c)}{r^2} & c<r<d \\ \frac{Gc^4}{4r^2} - \frac{N(d-c)}{r^2} - \frac{4Td^2}{r^2} & d<r \end{cases}$$

a) (6 points) Find units of G, N, and T

b) (6 points) Examine the boundary condition at $r=c$ and $r=d$. Show detail and be careful

c) (6 points) Find $\nabla\cdot\vec{D}$ for all regions

d) (7 points) What is the charge distribution that would give this field?

a) $G\left[m^2\right] = \frac{C}{m^2} \Rightarrow G = \boxed{\frac{C}{m^4}}$

$N\left[\frac{m}{m^2}\right] = \frac{C}{m^2} \Rightarrow \boxed{N = \frac{C}{m}}$

$T\left[\frac{m^2}{m^2}\right] = \frac{C}{m^2} \Rightarrow \boxed{T = \frac{C}{m^2}}$

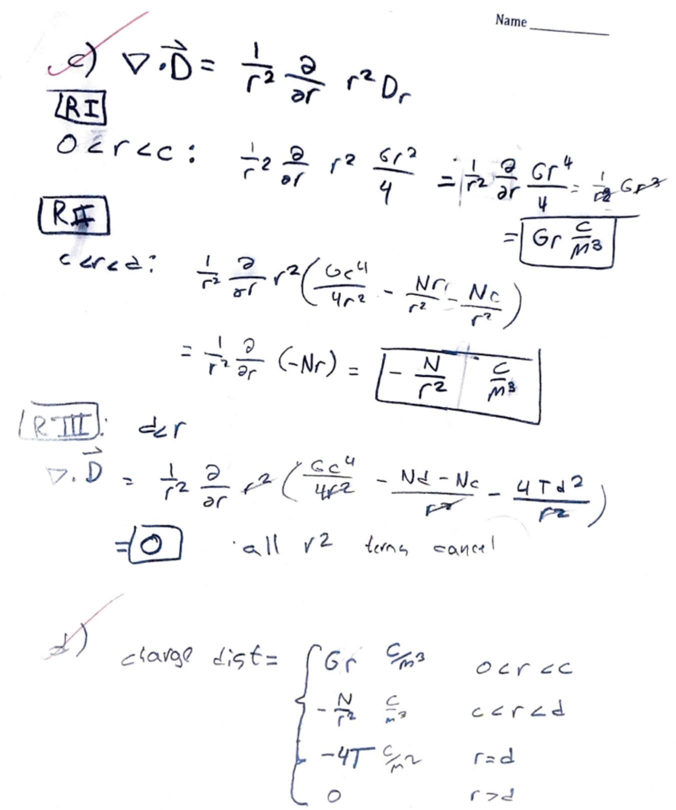
b) $\boxed{D(c-) = \frac{Gc^2}{4} = D(c+)}$

$D(d-) = \frac{Gc^4}{4d^2} - \frac{N(d-c)}{d^2}$

$D(d+) = \frac{Gc^4}{4d^2} - \frac{N(d-c)}{d^2} - \frac{4Td^2}{d^2}$

$\boxed{D(d+) = D(d-) - 4T}$

$-4t$ @ $r=d$



Name ________

c) $\nabla\cdot\vec{D} = \frac{1}{r^2}\frac{\partial}{\partial r}r^2 D_r$

RI

$0<r<c$: $\frac{1}{r^2}\frac{\partial}{\partial r}r^2\frac{Gr^2}{4} = \frac{1}{r^2}\frac{\partial}{\partial r}\frac{Gr^4}{4} = \frac{1}{r^2}Gr^3$

RII $= \boxed{Gr\ \frac{C}{m^3}}$

$c<r<d$: $\frac{1}{r^2}\frac{\partial}{\partial r}r^2\left(\frac{Gc^4}{4r^2} - \frac{Nr}{r^2} - \frac{Nc}{r^2}\right)$

$= \frac{1}{r^2}\frac{\partial}{\partial r}(-Nr) = \boxed{-\frac{N}{r^2}\ \frac{C}{m^3}}$

RIII: $d<r$

$\nabla\cdot\vec{D} = \frac{1}{r^2}\frac{\partial}{\partial r}r^2\left(\frac{Gc^4}{4r^2} - \frac{Nd-Nc}{r^2} - \frac{4Td^2}{r^2}\right)$

$= \boxed{0}$ all r^2 terms cancel

d) charge dist $= \begin{cases} Gr & C/m^3 & 0<r<c \\ -\frac{N}{r^2} & \frac{C}{m^3} & c<r<d \\ -4T & C/m^2 & r=d \\ 0 & & r>d \end{cases}$

Problem 3 (25 points) Show your detailed work

The plane $4x - 4y + 7z = 9$ is covered with a surface charge density of $G\ \frac{C}{m^2}$

The space around the plane is filled with air

For this problem you need to clearly show your work

a) (12 points) Find the electric field intensity E everywhere in the space. You have to clearly identify the sides of the plane and the field on each side.
b) (13 points) You have two different E's and D's, examine the boundary condition for E ad D using your answers in part a

Find normal $\nabla(4x - 4y + 7z) = 4\hat{x} - 4\hat{y} + 7\hat{z}$

normalize $|4\hat{x} - 4\hat{y} + 7\hat{z}| = \sqrt{32 + 49} = 9$

$$\hat{n}_{>9} = \frac{4\hat{x} - 4\hat{y} + 7\hat{z}}{9}$$

$$\hat{n}_{<9} = \frac{-4\hat{x} + 4\hat{y} - 7\hat{z}}{9}$$

Infinite sheet charge $\vec{E} = \frac{\rho_s}{2\epsilon_0}\hat{n}$ $\qquad \rho_s = G$

$$\boxed{\begin{aligned} \vec{E} &= \frac{G}{2\epsilon_0}\left(\frac{4\hat{x} - 4\hat{y} + 7\hat{z}}{9}\right)\frac{V}{m} \quad \text{for } 4x - 4y + 7z > 9 \\ \vec{E} &= \frac{G}{2\epsilon_0}\left(\frac{-4\hat{x} + 4\hat{y} - 7\hat{z}}{9}\right)\frac{V}{m} \quad \text{for } 4x - 4y + 7z < 9 \end{aligned}}$$

Name __________

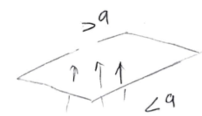
3b $\boxed{E_{t1} = E_{t2} = 0}$

$D_{\perp 1} = |\vec{D}_1| = \frac{G}{2}$

$D_{\perp 2} = |\vec{D}_2| = -\frac{G}{2}$

$\oint \vec{D} \cdot d\vec{s} = Q_{en} = \rho_s\,\text{Area} = (D_{\perp 1} - D_{\perp 2})\,\text{Area}$

$\Rightarrow \boxed{D_{\perp 1} - D_{\perp 2} = G\ \frac{C}{m^2}}$



This exam went really well for me, especially compared to the first one. I go into more detail about this in my exam 2 reflection, which is shown on the next page.

Post-Exam 2 Reflection

How was your performance? How did you do, and what did you think? Did you learn anything about the material and yourself?

During this test I felt a lot more confident about the material than I did during the first test. By this point I was very familiar with Gauss' law so the problems within this test felt very natural for me to complete. I was a little nervous during the first problem because I felt like it took a very long time for me to complete and I was scared I was going to run out of time during the next two problems, but thankfully that didn't happen. I left the test a little nervous, but I didn't think I would have done anything differently if given any more time. As it turns out I did very well on this test, and I was very pleased with how I performed.

What would you do differently in preparing for the next test?

My preparation for this test was significantly better than my preparation for the last test, so for the next test I believe I should try to use a similar method to what I did this time. What I did to prepare for this test was set aside the evening before the test and that evening I went back and did every game and homework that was applicable to the test. I also had the textbook with me so that I could review it and fill out a better note sheet. This guaranteed that the content was fresh on my mind went test day came so it prepared me very well. I do not think there is too much I have to change about my study method other than doing it earlier as I believe this method could help me with the homeworks and even the games too.

What would you do differently while taking the test?

Something that was tricky about this test is that the first problem was the longest and hardest one, so I think it could have been beneficial for me to have completed the other problems first. I spent so much time on the first problem that it was possible for me to have run out of time during the test if the other problems took just as long. Thankfully it did not happen, but I think it is important for me moving forward to make sure to do the quicker problems first so that I can get as many points as possible if I do end up running out of time. I should also practice completing the problems quicker so that the likelihood of this happening is lower.

Please feel free to share any other thoughts, ideas, or suggestions?

This module went very well for me, and I think the homework and games did a great job at preparing me for the test. I am a little bit nervous that the next test will be in Kildee because that room is very small, and it would be difficult navigating through my notes and resources during that game. I hear our lecture hall on Thursdays is significantly better, so I hope that is the room we get to take our tests in.

Thus ended unit 2 on electrostatics. We then jumped right into unit 3, which was on magnetostatics.

Unit 3: Magnetostatics

Magnetostatics Introduction

The topics we covered in unit 3 regarding magnetostatics were very similar to those we covered in unit 2. In fact, a lot of the games and assignments given to us during this unit were solved using a very similar method to the games in the last unit. When making my concept sheets for this section, I found it helpful for me to write down not only the new magnetostatic concepts I was learning, but also next to it write down the equivalent concept for electrostatics.

Specifically, the topics we covered in this unit were magnetic forces, Ampere's law, magnetic flux, and magnetic boundary conditions. Ampere's law is similar to Gauss' law but instead pertains to the magnetic field and the current enclosed within. This is the third Maxwell equation we learned, so at this point in the semester we were getting close to being familiar with all 4.

We started by jumping straight into using Ampere's law, the style of this game is very similar to the style of the games that challenged us on Gauss' law. The first one is shown on the next page.

Ampere's Law

Caleb
Sam
Elias
Denny
Scott
Mina

Game 31 - EE 311 - Peter Dea

a) $\left(\frac{M}{2\pi\rho}\hat{\phi} + \frac{A\rho^2}{3}\hat{\phi}\right)_{units} = \frac{A}{m}$

$\Rightarrow A_{units} \cdot meters^2 = \frac{A}{m} \Rightarrow \boxed{A\ units = \frac{A}{m^3}}$

$\frac{M_{units}}{meters} = \frac{A}{m} \Rightarrow \boxed{M_{units} = A}$

$\left(\frac{M}{2\pi\rho}\hat{\phi} + \frac{Ab^3}{3\rho}\hat{\phi} + \frac{Sb}{\rho}\right)_{units} = \frac{A}{m}$

$\frac{Sb}{\rho}\ units = \frac{A}{m} \Rightarrow \boxed{S_{units} = \frac{A}{m}}$

$\frac{Gc}{\rho}\ units = \frac{A}{m} \Rightarrow \boxed{G_{units} = \frac{A}{m}}$

b) $\nabla \times \vec{H}$ for all regions $= \frac{1}{\rho}\frac{d}{d\rho}(\rho H_\phi)\hat{z}$

$0 < \rho < b$: Region 1.

$\nabla \times \vec{H} = \frac{1}{\rho}\left(\frac{d}{d\rho}\rho\left(\frac{M}{2\pi\rho} + \frac{A\rho^2}{3}\right)\right)\hat{z} = \frac{1}{\rho}\frac{\partial}{\partial\rho}\frac{A\rho^3}{3} = \frac{1}{\rho}A\rho^2\hat{z}$

$= \boxed{A\rho\,\hat{z}\ \frac{A}{m^2}}$

$b < \rho < c$: Region 2.

$\nabla \times \vec{H} = \frac{1}{\rho}\left(\frac{\partial}{\partial\rho}\rho\left(\frac{M}{2\pi\rho} + \frac{Ab^3}{3\rho} + \frac{Sb}{\rho}\right)\hat{z}\right) \Rightarrow \rho$ terms cancel

$\boxed{\nabla \times \vec{H} = 0\ \frac{A}{m^2}}$

$c < \rho$: Region 3

$$\nabla \times \vec{H} = \frac{1}{\rho}\frac{\partial}{\partial \rho}\rho\left(\frac{M}{2\pi\cancel{\rho}} + \frac{Ab^3}{3\cancel{\rho}} + \frac{Sb}{\cancel{\rho}} - \frac{Gc}{\cancel{\rho}}\right)\hat{z}$$

All ρ terms cancel again

$$\nabla \times \vec{H} = \boxed{0 \ \frac{A}{m^2}}$$

c) $(\vec{H}_1 - \vec{H}_2) \times \hat{n}_{12} = \vec{k}$

Evaluate $H(b^-)$ and $H(b+)$

$$H(b^-) = \frac{M}{2\pi b}\hat{\phi} + \frac{Ab^2}{3}\hat{\phi} \qquad = \vec{H}_1$$

$$H(b^+) = \left(\frac{M}{2\pi b} + \frac{Ab^2}{3} + S\right)\hat{\phi}\ \frac{A}{m} \quad = H_2$$

$$\hat{n}_{12} = \hat{\rho}$$

$$(\vec{H}_1 - \vec{H}_2) \times \hat{\rho} = -S\hat{\phi} \times \hat{\rho} = \boxed{S\hat{z} \ \frac{A}{m} = \vec{k}}$$

Boundary 2: $\rho = c$

$$H(c^-) = \left(\frac{M}{2\pi c} + \frac{Ab^3}{3c} + \frac{Sb}{c}\right)\hat{\phi} \quad \frac{A}{m}$$

$$H(c^+) = \left(\frac{M}{2\pi c} + \frac{Ab^3}{3c} + \frac{Sb}{c} - \frac{G\cancel{c}}{\cancel{c}}\right)\hat{\phi}\ \frac{A}{m}$$

$$(H_2 - H_3) \times \hat{\rho} = \vec{k} = G\hat{\phi} \times \hat{\rho} = \boxed{-G\hat{z} \ \frac{A}{m}}$$

d) Yes, the line current is equal to M in this question and has units of A

e) current distribution =
$$\begin{cases} M \quad A & \rho=0 \text{ along } z \\ S\hat{z} \quad A/m & \rho=b \\ -G\hat{z} \quad A/m & \rho=c \\ A\rho\hat{z} \quad A/m^2 & 0<\rho<b \end{cases}$$

Despite this being the first game of the unit, I caught onto the topics behind magnetostatics quickly and made no major mistakes in my first game. Many topics were covered in this game, Ampere’s law, current distributions, boundary conditions, and so on. The next few games were very similar in structure, I will include a few more in the following pages.

Caleb
Elias
Sam
Denny
Scott

Game 32 - EE 311 - Peter Dea

a.) $\oint_L \vec{H} \cdot d\vec{\ell} = I_{enc}$ $\quad \vec{H}(\rho) = \frac{I_{enc}}{2\pi\rho} \hat{\phi} \ \frac{A}{m}$

Region I: $\rho < b$

$$\int_{\phi=0}^{2\pi} H(\rho) \hat{\phi} \cdot \rho d\phi \hat{\phi} = H(\rho) \rho \, 2\pi \Rightarrow H(\rho) = \boxed{\frac{I_{enc}}{2\pi\rho} \hat{\phi} \ \frac{A}{m}}$$

$\rho < b$

Region II: $b < \rho < c$

$$\int_{\phi=0}^{2\pi}\int_{\rho=b}^{\rho} -k\hat{z} \cdot \rho d\rho d\phi \hat{z} = -k 2\pi \int_{\rho=b}^{\rho} \rho d\rho = -k\pi(\rho^2 - b^2)$$

$$I_{enc} = I - k\pi(\rho^2 - b^2) \Rightarrow \boxed{\vec{H}(\rho) = \frac{I}{2\pi\rho}\hat{\phi} - \frac{k(\rho^2 - b^2)}{2\rho}\hat{\phi} \ \frac{A}{m}}$$

$b < \rho < c$

Region III: $c < \rho$

$$\int_{\phi=0}^{2\pi}\int_{\rho=b}^{c} -k\hat{z} \cdot \rho d\rho d\phi \hat{z} = -k\pi(c^2 - b^2)$$

$$I_{enc} = I - k\pi(c^2 - b^2) \Rightarrow \boxed{\vec{H}(\rho) = \frac{I}{2\pi\rho}\hat{\phi} - \frac{k(c^2 - b^2)}{2\rho}\hat{\phi} \ \frac{A}{m}}$$

$c < \rho$

Sam
Elias
Scott
Denny
Mind

Game 33 - EE 311 - Peter Dea

Current Distribution = $\begin{cases} S\hat{z} & A \text{ along } \hat{z} \text{ axis} \\ -W\hat{z} & A/m \quad \rho = a \\ U & A/m^2 \quad a<\rho<b \\ G\hat{z} & A/m \quad \rho = b \end{cases}$

a) $I_{en} = \oint \vec{H} \cdot d\ell = \int_{\phi=0}^{2\pi} H(\rho)\,\hat{\phi} \cdot \rho\, d\phi\, \hat{\phi} = H(\rho)\,\rho\, 2\pi$

$\Rightarrow H(\rho) = \frac{I_{enc}}{2\pi\rho}\,\hat{\phi}\ A/m$

$\boxed{\text{Region I: } \frac{S}{2\pi\rho}\,\hat{\phi}\ \frac{A}{m}}$ $\quad \rho<a$

$\rho = a$ $\quad I_{en} = S\,\hat{\phi} + \int_0^{2\pi} -W\hat{z} \cdot a\, d\phi\, \hat{z}$

$\Rightarrow \vec{H}(a) = \frac{S}{2\pi a}\,\hat{\phi} - W\hat{\phi}\ \frac{A}{m}$

$\rho = a$

Region II:

$2\pi\rho\,\vec{H}(\rho)\,\hat{\phi} = S + \int_0^{2\pi}\int_a^{\rho} U\, d\rho\, d\phi - 2\pi a W$

$\boxed{\vec{H}(\rho) = \frac{S}{2\pi\rho}\,\hat{\phi} - \frac{Wa}{\rho}\,\hat{\phi} + \frac{U(\rho^2-a^2)}{2\rho}\,\hat{\phi}\ \frac{A}{m}}$ $\quad a<\rho<b$

Region III

$\boxed{H(\rho) = \frac{S}{2\pi\rho}\,\hat{\phi} - \frac{Wa}{\rho}\,\hat{\phi} + \frac{U(\rho^2-a^2)}{2\rho} + \frac{Gb}{\rho}\,\hat{\phi}\ \frac{A}{m} \quad b<\rho}$

b) $\vec{H}(a-) = \frac{S}{2\pi a}\hat{\phi} \quad \frac{A}{m}$

$\vec{H}(a+) = \frac{S}{2\pi a}\phi - W\hat{\phi} \quad \frac{A}{m}$

W is added at $\rho = a$

c) $\vec{H}(b-) = \frac{S}{2\pi b}\hat{\phi} - \frac{Wa}{b}\hat{\phi} + \frac{U(b^2-a^2)}{2b}\hat{\phi} \quad \frac{A}{m}$

$H(b+) = \frac{S}{2\pi b}\hat{\phi} - \frac{Wa}{\rho}\hat{\phi} + \frac{U(b^2-a^2)}{2b}\hat{\phi} + G\hat{\phi} \quad \frac{A}{m}$

G is added at $\rho = b$

d) at boundary $\rho = a$

$\vec{H}_1 - \vec{H}_2 = W\hat{\phi} \qquad \vec{n}_{12} = \hat{\rho}$

$(\vec{H}_1 - \vec{H}_2) \times \hat{\rho} = W\hat{\phi} \times \hat{\rho} = \boxed{-W\hat{z} \quad \frac{A}{m}}$

at boundary $\rho = b$

$\vec{H}_1 - \vec{H}_2 = G\hat{\phi} \Rightarrow (\vec{H}_1 - \vec{H}_2) \times \hat{\rho} = G\hat{\phi} \times \hat{\rho} = \boxed{G\hat{z} \quad \frac{A}{m}}$

$\vec{H}_1$ is the field within the boundary

$\vec{H}_2$ is outside the boundary.

Infinite Sheet of Current

This next game was slightly different and pertained to an infinite sheet of current and the magnetic field that it would create. Magnetic boundary conditions were used to solve it.

Caleb
Sam
Elias
Denny
Scott
Ming

Game 34 - EE 311 - Peter Dea

$2x - 3y = 5$ plane

$\vec{k} = k_0 \hat{z} \ \frac{mA}{m}$

1. First side $\quad 2\hat{x} - 3\hat{y} < 5$

$\nabla(2x-3y) = 2\hat{x} - 3\hat{y}$ normalize

$\hat{n}_{12} = \frac{2\hat{x} - 3\hat{y}}{\sqrt{13}}$

$\vec{H}_1 = \frac{1}{2} k_0 \hat{x} \times (2\hat{x} - 3\hat{y}) = \boxed{-\frac{3}{2\sqrt{13}} k_0 \hat{x} - \frac{k_0}{\sqrt{13}} \hat{y} \ \frac{mA}{m}}$

Second Side: $\quad 2\hat{x} - 3\hat{y} > 5$

$\hat{n}_{21} = \frac{3\hat{y} - 2\hat{x}}{\sqrt{13}} \Rightarrow \vec{H}_2 = \boxed{+\frac{3}{2\sqrt{13}} k_0 \hat{x} + \frac{k_0}{\sqrt{13}} \hat{y} \ \frac{mA}{m}}$

2. $(\vec{H}_1 - \vec{H}_2) \times \hat{n}_{12} = \left(-\frac{3}{2\sqrt{13}} k_0 \hat{x} + 2k_0 \hat{y}\right) \times (2\hat{x} - 3\hat{y})$

$\Rightarrow$ surface current $= \sqrt{13}(-2k_0\hat{y} - 3k_0\hat{x}) \times \left(\frac{-2\hat{x} + 3\hat{y}}{\sqrt{13}}\right)$

$= 4k_0 \hat{z} + 9k_0 \hat{z} = \boxed{13 k_0 \hat{z} \ \frac{mA}{m} \text{ from 1 to 2}}$

second surf current $(\vec{H}_1 - \vec{H}_2) \times \hat{n}_{12}$

$= \boxed{-13 k_0 \hat{z} \ \frac{mA}{m} \text{ from 2 to 1}}$

Concept Sheets

Again, in preparation for the upcoming homeworks and exam, I created concept sheets that covered the topics of magnetostatics. They are shown below.

Magnetostatics

Magnetic Counterparts to Electric Field Equations

$\vec{F} = \frac{Q_1 Q_2}{4\pi\epsilon r^2} a_r \iff d\vec{B} = \frac{\mu_0 I \, d\vec{I} \times \hat{r}}{4\pi R^2}$

$\oint \vec{D} \cdot d\vec{S} = Q_{enc} \iff \oint \vec{H} \cdot d\vec{l} = I_{enc}$

$\vec{D} = \epsilon \vec{E} \iff \vec{B} = \mu \vec{H}$

$E = -\nabla V \iff H = -\nabla V_m \quad (\vec{J} = 0)$

$\nabla^2 V = -\frac{\rho_v}{\epsilon} \iff \nabla^2 \vec{A} = -\mu \vec{J}$

see textbook p 298

- H - Magnetic Field Intensity $\left[\frac{A}{m}\right]$
- B - Magnetic Flux Intensity $\left[\frac{Wb}{m^2}\right]$ or T
- μ_0 - Permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ H/m
- V_m - Magnetic Scalar Potential [A]

Ampere's Law

$\boxed{\oint \vec{H} \cdot d\vec{l} = I_{enc}} = \int_S \nabla \times \vec{H} \cdot d\vec{S}$

Maxwell's Equation 3: $\boxed{\nabla \times H = J} \neq 0$

Infinite Sheet of Current:

$\boxed{\vec{H} = \frac{1}{2} \vec{K} \times \hat{n}}$ K = current density $\left[\frac{A}{m}\right]$

Magnetic Flux

$\Psi = \int_S \vec{B} \cdot d\vec{S}$ Magnetic Flux

$\vec{B} = \mu_0 \vec{H}$

Maxwell's 4th equation: $\boxed{\nabla \cdot B = 0}$

Magnetic Boundary Conditions

$(\vec{H}_1 - \vec{H}_2) \times \hat{n}_{12} = \vec{K}$

Homework 4

I was then assigned with Homework 3, which covered the concepts we learned about magnetostatics in this unit.

EE 311 - Homework 4 - Peter Dea

$$\text{current distribution} = \begin{cases} I\hat{z} \ \ A & \text{along } z \\ K/\rho\,\hat{z} \ \ A/m^2 & a<\rho<b \\ S\hat{z} & b=z \end{cases}$$

a) Region I $\quad \rho < a$

$\oint \vec{H}\cdot d\vec{l} = I_{enc} \qquad \vec{H}(\rho) = \frac{I_{enc}}{2\pi\rho}\hat{\phi} \ \frac{A}{m}$

$\oint_{\phi=0}^{2\pi} H(\rho)\cdot\rho\, d\phi\,\hat{\phi} = H(\rho)\rho 2\pi \Rightarrow H(\rho) = \boxed{\frac{I}{2\pi\rho}\hat{\phi} \ \frac{A}{m}}$

Region II $\quad a<\rho<b$

$I_{enc} = I + \int_{\phi=0}^{2\pi}\int_{\rho=a}^{\rho} \frac{K}{\rho}\cdot\rho\, d\phi\, d\rho = I + 2\pi K(\rho-a)$

$\Rightarrow H(\rho) = \boxed{\frac{I}{2\pi\rho}\hat{\phi} + \frac{K(\rho-a)}{\rho}\hat{\phi} \ \frac{A}{m}}$

Region III $\quad b<\rho$

$I_{enc} = I + 2\pi K(\rho-a) + \int_{\phi=0}^{2\pi} S\rho\, d\phi \Big|_{\rho=b} = I + 2\pi K(b-a) + 2\pi S$

$\boxed{H(\rho) = \frac{I}{2\pi\rho}\hat{\phi} + \frac{K(b-a)}{\rho}\hat{\phi} + \frac{Sb}{\rho}\hat{\phi} \ \frac{A}{m}}$

$$\boxed{H(\rho) = \begin{cases} \frac{I}{2\pi\rho}\hat{\phi} \ \frac{A}{m} & \rho<a \\ \frac{I}{2\pi\rho}\hat{\phi} + \frac{K(\rho-a)}{\rho}\hat{\phi} \ \frac{A}{m} & a<\rho<b \\ \frac{I}{2\pi\rho}\hat{\phi} + \frac{K(b-a)}{\rho}\hat{\phi} + \frac{Sb}{\rho}\hat{\phi} \ \frac{A}{m} & b<\rho \end{cases}}$$

1b) $H(a-) = \frac{I}{2\pi a}\hat{\phi} \ \frac{A}{m}$

$H(a+) = \frac{I}{2\pi a}\hat{\phi} \ \frac{A}{m} \Rightarrow \boxed{H(a-) = H(a+) \ \frac{A}{m}}$ They're equal because there is no surface current

$H(b-) = \frac{I}{2\pi b}\hat{\phi} + \frac{K(b-a)}{b}\hat{\phi} \ \frac{A}{m}$

$H(b+) \ \frac{I}{2\pi b}\hat{\phi} + \frac{K(b-a)}{b}\hat{\phi} + S\hat{\phi} \ \frac{A}{m}$

$\boxed{H(b+) = H(b-) + S}$ H(b+) includes the surface current S

1c) $\nabla\times H = \frac{1}{\rho}\frac{\partial}{\partial\rho}\rho\vec{H}\hat{z}$ (note H only has $\hat{\phi}$)

Region I: $\rho<a$

$\nabla\times\vec{H} = \frac{1}{\rho}\frac{\partial}{\partial\rho}\rho\frac{I}{2\pi\rho}\hat{z} = \boxed{0}$

R II $\quad a<\rho<b$

$\nabla\times\vec{H} = \frac{1}{\rho}\frac{\partial}{\partial\rho}\rho\left(\frac{I}{2\pi\rho} + \frac{K\rho}{\rho} - \frac{Ka}{\rho}\right)\hat{z} = \boxed{\frac{K}{\rho}\hat{z} \ \frac{A}{m}}$

R III: $b<\rho$

$\nabla\times\vec{H} = \frac{1}{\rho}\frac{\partial}{\partial\rho}\rho\left(\frac{I}{2\pi\rho} + \frac{Kb}{\rho} - \frac{Ka}{\rho} + \frac{Sb}{\rho}\right)\hat{z} = \boxed{0}$

$$\boxed{\nabla\times\vec{H} = \begin{cases} \frac{K}{\rho}\hat{z} \ \frac{A}{m} & a<\rho<b \\ 0 & \text{otherwise} \end{cases}}$$

Problem 2

RI: $\rho<a \quad \rho\frac{J_1}{2}\hat{\phi} \ \frac{A}{m}$

RII: $a<\rho<b \quad \frac{a^2J_1}{2\rho}\hat{\phi} \quad \frac{aK}{\rho}\hat{\phi} + \frac{J_2}{\rho}(\rho^3-a^3)\hat{\phi} \ \frac{A}{m}$

RIII: $b<\rho<c \quad \frac{a^2J_1}{2\rho}\hat{\phi} + \frac{aK}{\rho}\hat{\phi} + \frac{J_2}{\rho}(b^3-a^3)\hat{\phi} \ \frac{A}{m}$

RIV: $c<\rho \quad \frac{a^2J_1}{2\rho} + \frac{aK}{\rho} + \frac{J_2}{\rho}(b^3-a^3) + \frac{Ac}{\rho}\hat{\phi} \ \frac{A}{m}$

a) $H(a-) = a\frac{J_1}{2}\hat{\phi} \ \frac{A}{m}$

$H(a+) = a\frac{J_1}{2}\hat{\phi} + K \ \frac{A}{m} \quad \boxed{H(a+) = H(a-) + K \ \frac{A}{m}}$ H(a+) includes K

$H(b-) = \frac{a^2J_1}{2b}\hat{\phi} + \frac{aK}{b}\hat{\phi} + \frac{J_2}{b}(b^3-a^3)\hat{\phi} \ \frac{A}{m}$

$H(b+) = \frac{a^2J_1}{2b}\hat{\phi} + \frac{aK}{b}\hat{\phi} + \frac{J_2}{b}(b^3-a^3)\hat{\phi} \ \frac{A}{m}$

$\boxed{H(b-) = H(b+) \ \frac{A}{m}}$ No change

$H(c-) = \frac{a^2J_1}{2c}\hat{\phi} + \frac{aK}{c}\hat{\phi} + \frac{J_2}{c}(b^3-a^3)\hat{\phi} \ \frac{A}{m}$

$H(c+) = \frac{a^2J_1}{2c}\hat{\phi} + \frac{aK}{c} + \frac{J_2}{c}(b^3-a^3) + A \ \frac{A}{m}$

$\boxed{H(c+) = H(c-) + A \ \frac{A}{m}} \quad H(c+) - H(c-) = A \ \frac{A}{m}$

H(c+) includes A

Note again $\vec{H}$ only has $\hat{\phi}$

2b) $\nabla\times\vec{H} = \frac{1}{\rho}\frac{\partial}{\partial\rho}\rho\vec{H}\hat{z}$

RI $\quad \rho<a$

$\nabla\times\vec{H} = \frac{1}{\rho}\frac{\partial}{\partial\rho}\rho\left(\rho\frac{J_1}{2}\right)\hat{z} = \frac{1}{\rho}\cdot\frac{2\rho}{2} = \boxed{J_1\hat{z} \ \frac{A}{m^2}}$

RII $\quad a<\rho<b$

$\nabla\times\vec{H} = \frac{1}{\rho}\frac{\partial}{\partial\rho}\rho\left(\frac{a^2J_1}{2\rho}\hat{\phi} + \frac{aK}{\rho}\hat{\phi} + \frac{J_2}{\rho}(b^3-a^3)\hat{\phi}\right) = \boxed{0}$

2c)
$$\text{current dist} = \begin{cases} J_1\hat{z} \ \frac{A}{m^2} & a<\rho \\ K\hat{z} \ A/m & \rho=a \\ 3J_2\rho\hat{z} \ A/m^2 & a<\rho<b \\ A\hat{z} \ A/m & \rho=c \end{cases}$$

Problem 3

$\vec{K} = -2\hat{z} + 2\hat{x}\ \frac{A}{m}$

a) $\vec{n}_1 = \hat{y}$ **RI** $y > 0$

$\vec{H} = \frac{1}{2}\vec{K} \times \vec{n} = \frac{1}{2}(-2\hat{z} + 2\hat{x}) \times (\hat{y})$ cancel 2s & $\frac{1}{2}$

$$\vec{H}_1 = (-\hat{z} + \hat{x}) \times (\hat{y}) = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ 1 & 0 & -1 \\ 0 & 1 & 0 \end{vmatrix} = \boxed{\hat{x} + \hat{z}\ \frac{A}{m}}$$

RII $y < 0$, $\vec{n}_2 = -\hat{y}$

$$\vec{H}_1 = (-\hat{z} + \hat{x}) \times (-\hat{y}) = \boxed{-\hat{x} - \hat{z}\ \frac{A}{m}}$$

$$\Rightarrow \boxed{\vec{H} = \begin{cases} \hat{x} + \hat{z}\ A/m & y > 0 \\ -\hat{x} - \hat{z}\ A/m & y < 0 \end{cases}}$$

b) $\vec{H}_1 - \vec{H}_2 = \hat{x} + \hat{z} - (-\hat{x} - \hat{z}) = 2\hat{x} + 2\hat{z}$ $\hat{n}_{21} = -\hat{y}$

$\Rightarrow (\vec{H}_1 - \vec{H}_2) \times \hat{n}_{21} = (2\hat{x} + 2\hat{z}) \times (-\hat{y})$

$$= \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ 2 & 0 & 2 \\ 0 & -1 & 0 \end{vmatrix} = \boxed{2\hat{x} - 2\hat{z}\ A/m = \vec{K}}$$

Consistent with original $\vec{K}$

Homework 4 went fairly well for me. I made a few mistakes on it but reviewing those prepared me very well for the next exam. After this homework, we covered the next chapter, which was on Maxwell's equations.

Maxwell's Equations

This unit also covered the next chapter, which was on all 4 of Maxwell's equations, so we both reviewed the equations we were already familiar with and were introduced to the final one in this chapter. In the following pages are a few games on Maxwell's Equations.

Caleb
Sau
Elias
Scott
Mina

Game 37 - EE 311 - Peter Dea

a) $\nabla \times \vec{E} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 0 & 0 & E_0 \cos(\omega t + \beta y) \end{vmatrix}$

$= -E_0 \beta \sin(\omega t + \beta y)\,\hat{x} = -\mu \frac{\partial \vec{H}}{\partial t}$

integrate w/- respect to t

$-\mu \vec{H} = -E_0 \beta \int \sin(\omega t + \beta y)\,\hat{x}\,dt$

$= -\frac{E_0 \beta}{\omega} \cos(\omega t + \beta y) + C = \mu \vec{H}$

$\boxed{\vec{H} = -\frac{E_0 \beta}{\omega \mu} \cos(\omega t + \beta y)\,\hat{x} + C\,\hat{x}\ \frac{A}{m}}$

b) $\nabla \times \vec{H} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ \frac{-E_0\beta}{\omega\mu}\cos(\omega t + \beta y) + C & 0 & 0 \end{vmatrix}$

$= \frac{+E_0 \beta}{\beta \mu} \sin(\omega t + \beta y)\,\omega \hat{x} = \frac{E_0 \omega}{\mu} \sin(\omega t + \beta y)\,\hat{x}$

$= \frac{\epsilon \partial \vec{E}}{\partial t}$

$\epsilon \frac{\partial E}{\partial t} = \frac{E_0 \omega}{\mu} \sin(\omega t + \beta y)\,\hat{x}$

$\vec{E} = \frac{E_0 \omega}{\epsilon \mu} \int \sin(\omega t + \beta y)\,dt\ \hat{x}$

$\boxed{\vec{E} = -\frac{E_0}{\epsilon \mu} \cos(\omega t + \beta y)\,\hat{x} + C\,\hat{x}\ \frac{V}{m}}$

This satisfies if $\epsilon = -\frac{1}{\mu}$

Denny
Caleb
Scott
Sam
Elias
Mina

Game 38 - EE 311 - Peter Dea

$\vec{E}(y,t) = E_0 \cos(\omega t + \beta y)\,\hat{z}\ \frac{V}{m}$

$\vec{E}(y) = E_0 e^{j\beta y}\hat{z}\ \frac{V}{m}$ steady

a) $\nabla \times \vec{E} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ 0 & 0 & E_0 e^{j\beta y} \end{vmatrix} = j\beta E_0 e^{j\beta y}\,\hat{x}$

$\nabla \times \vec{E} = -j\omega\mu \vec{H} = j\beta E_0 e^{j\beta y}\,\hat{z}$

$\boxed{\vec{H} = -\frac{\beta E_0}{\mu\omega} e^{j\beta y}\,\hat{x}\ \frac{A}{m}}$

b) $\nabla \times \vec{H} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ -\frac{\beta E_0}{\mu\omega}e^{j\beta y} & 0 & 0 \end{vmatrix} = \frac{\beta E_0}{\mu\omega} j\beta e^{j\beta y}\,\hat{z}$

$\nabla \times \vec{H} = j\omega\epsilon \vec{E} = \frac{\beta E_0}{\mu\omega} j\beta e^{j\beta y}$

$\Rightarrow \vec{E} = \frac{\beta^2 E_0 j}{\mu\omega} \cdot \frac{1}{j\omega\epsilon} e^{j\beta y} = \boxed{\frac{\beta^2 E_0}{\mu\omega^2\epsilon} e^{j\beta y}\,\hat{z}\ \frac{V}{m}}$

This is the same when $\boxed{\frac{\beta^2}{\mu\omega^2\epsilon} = 1}$

In the first game, I made many mistakes in my integration, however this was fixed when I tried again in the next game, where I got the correct answer. My understanding of Maxwell's equations now would be critical in the next unit on electromagnetic wave propagation.

Pre-Exam 3 Reflection

We were now approaching on exam 3, so it was time for me to reflect on my progress from the last few weeks and explain how I was preparing for the upcoming exam. Below is what I had to say.

What did you learn from test 1,2 that can help you, and how have you changed your approach since test 1?

Based on my performance on the last two exams, I believe that I did a better job studying for exam 2 than I did studying for exam 1. I learned better study strategies for exam 2 that I will try to incorporate into my studying for exam 3. Since test 1, I have also spent a lot more time reviewing the textbook and creating good concept sheets that will help me through the problems that show up during games, homeworks, and exams. I think that this has been what has helped me most over the past few weeks in this class and it has ensured that I am better prepared for the challenges presented to me in class when they are assigned. I also think this will help me significantly during exam 3 because instead of having to look back at previous games to find a similar solution to the problem, I can instead review my concept sheet to find the right steps I need to use in order to solve the problem.

How are you planning to prepare for the third test? What have you done? How are you getting ready based on your previous experiences with the test and games?

In my studying for test 2, I found that reviewing the concepts on the homework assigned to us was the most beneficial because it seemed to be designed to directly prepare us for the concepts and types of problems that will be on the test. I plan to incorporate this strategy into my studying for exam 3. I am also going into this exam prepared much more ahead of time because I have had my concept sheet for the topics on this exam finished for a long time. I think this will help me not have to spend so much time leading up to the exam making sure that I have all of the notes I need available to me easily.

What are your focuses, what are your fears, and what are your concerns?

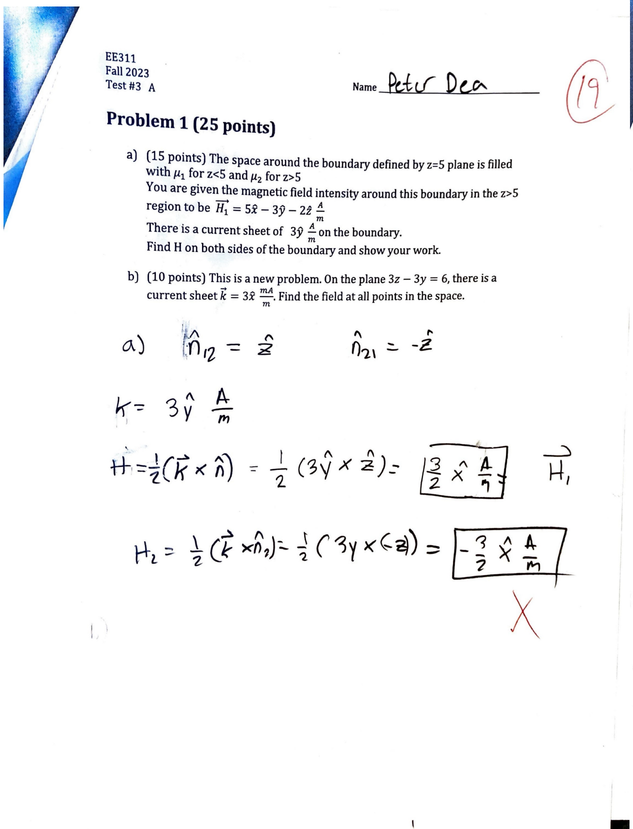
I am concerned about having the test in a new location. The location we had in Marston Hall was great because we had so much room on the tables to lay out all of our resources for easy access while we try to solve the problems. I feel like it the room we have does not give us enough space it could make it more difficult to access these resources as it can be hard to fit a calculator, notes, and my laptop on a desk while being able to keep the sheets up paper with the exam on them in order. If we aren't given enough space I am nervous that things will get messy and I will have a harder time keeping everything in order and focusing on the exam problems.

I am also nervous about how long it has been since we received a game on the topic that will be in this exam. For the past couple weeks we have solely been focusing on wave propagation and I haven't put too much thought into the chapters this exam is covering other than for working on the homework. I believe that by reviewing the material closely it will make it more fresh in my mind and it will not matter that it has been a while, but I will have to study a lot for it.

Following the reflection, it was time for the next exam.

Exam 3

Like the previous 2 exams, exam 3 had 3 problems regarding the topics I learned during the unit. Below are images of my work for the exam.



EE311
Fall 2023
Test #3 A

Name Peter Dea

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Problem 1 (25 points)

a) (15 points) The space around the boundary defined by z=5 plane is filled with μ_1 for z<5 and μ_2 for z>5
You are given the magnetic field intensity around this boundary in the z>5 region to be $\vec{H_1} = 5\hat{x} - 3\hat{y} - 2\hat{z}\ \frac{A}{m}$
There is a current sheet of $3\hat{y}\ \frac{A}{m}$ on the boundary.
Find H on both sides of the boundary and show your work.

b) (10 points) This is a new problem. On the plane $3z - 3y = 6$, there is a current sheet $\vec{k} = 3\hat{x}\ \frac{mA}{m}$. Find the field at all points in the space.

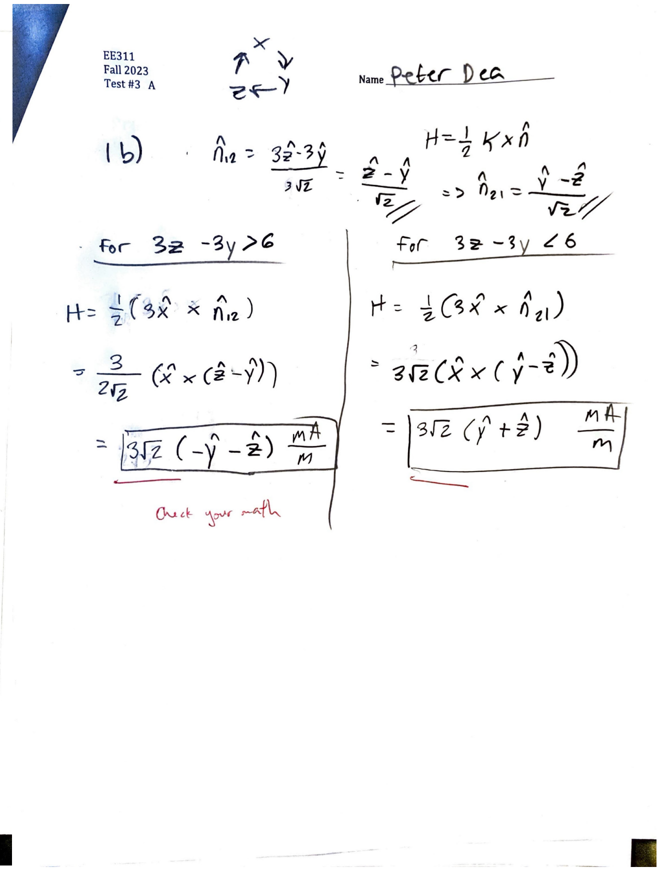
a) $\hat{n}_{12} = \hat{z}$ $\quad \hat{n}_{21} = -\hat{z}$

$K = 3\hat{y}\ \frac{A}{m}$

$H = \frac{1}{2}(\vec{K} \times \hat{n}) = \frac{1}{2}(3\hat{y} \times \hat{z}) = \boxed{\frac{3}{2}\hat{x}\ \frac{A}{m}}$ $\quad \vec{H_1}$

$H_2 = \frac{1}{2}(\vec{k} \times \hat{n}_2) = \frac{1}{2}(3y \times (-\hat{z})) = \boxed{-\frac{3}{2}\hat{x}\ \frac{A}{m}}$

X



EE311
Fall 2023
Test #3 A

Name Peter Dea

1b) $\hat{n}_{12} = \frac{3\hat{z} - 3\hat{y}}{3\sqrt{2}} = \frac{\hat{z} - \hat{y}}{\sqrt{2}}$ $\Rightarrow \hat{n}_{21} = \frac{\hat{y} - \hat{z}}{\sqrt{2}}$

$H = \frac{1}{2} K \times \hat{n}$

For $3z - 3y > 6$

$H = \frac{1}{2}(3\hat{x} \times \hat{n}_{12})$

$= \frac{3}{2\sqrt{2}}(\hat{x} \times (\hat{z} - \hat{y}))$

$= \boxed{3\sqrt{2}(-\hat{y} - \hat{z})\ \frac{mA}{m}}$

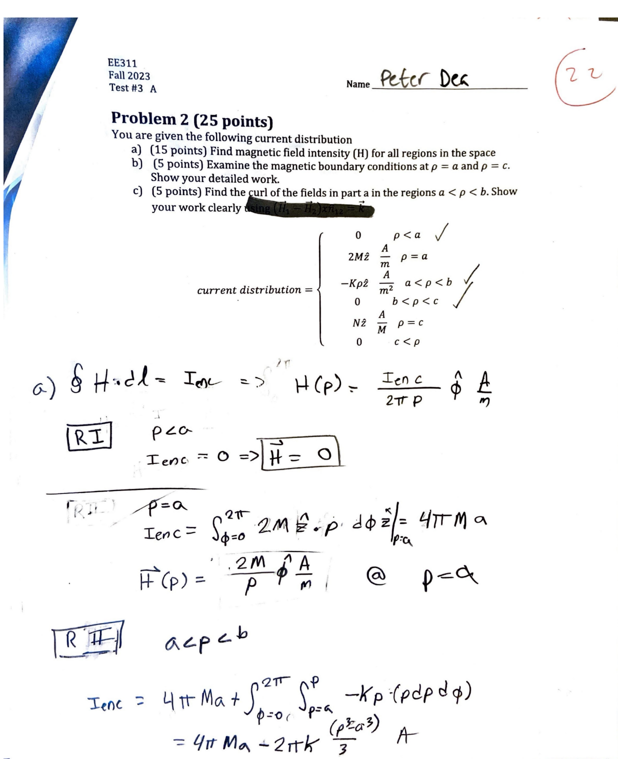
Check your math

For $3z - 3y < 6$

$H = \frac{1}{2}(3\hat{x} \times \hat{n}_{21})$

$= 3\sqrt{2}(\hat{x} \times (\hat{y} - \hat{z}))$

$= \boxed{3\sqrt{2}(\hat{y} + \hat{z})\ \frac{mA}{m}}$



EE311
Fall 2023
Test #3 A

Name Peter Dea

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Problem 2 (25 points)

You are given the following current distribution

a) (15 points) Find magnetic field intensity (H) for all regions in the space
b) (5 points) Examine the magnetic boundary conditions at $\rho = a$ and $\rho = c$. Show your detailed work.
c) (5 points) Find the curl of the fields in part a in the regions $a < \rho < b$. Show your work clearly [redacted]

$$\text{current distribution} = \begin{cases} 0 & \rho < a \\ 2M\hat{z}\ \frac{A}{m} & \rho = a \\ -K\rho\hat{z}\ \frac{A}{m^2} & a < \rho < b \\ 0 & b < \rho < c \\ N\hat{z}\ \frac{A}{M} & \rho = c \\ 0 & c < \rho \end{cases}$$

a) $\oint H \cdot dl = I_{enc} \Rightarrow H(\rho) = \frac{I_{enc}}{2\pi\rho}\hat{\phi}\ \frac{A}{m}$

RI $\quad \rho < a$

$I_{enc} = 0 \Rightarrow \boxed{\vec{H} = 0}$

$\rho = a$

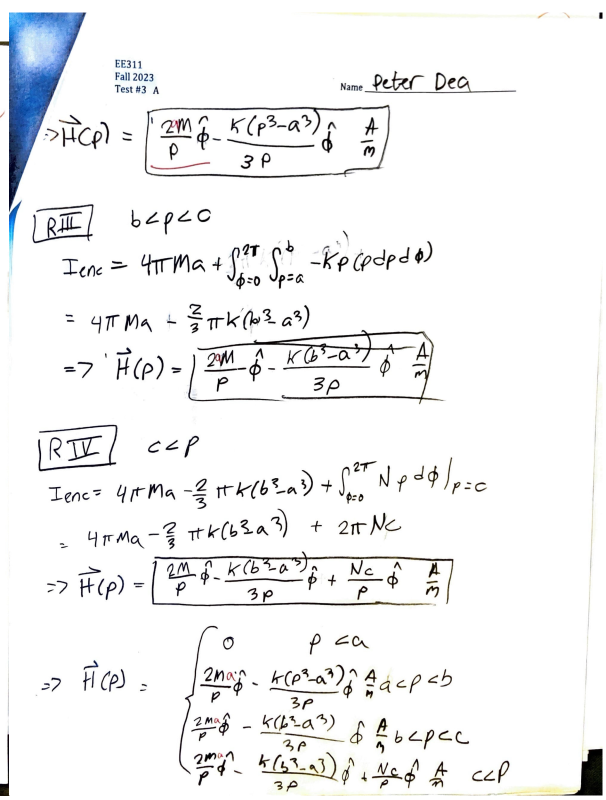
$I_{enc} = \int_{\phi=0}^{2\pi} 2M\hat{z} \cdot \rho\, d\phi\, \hat{z} \Big|_{\rho=a} = 4\pi M a$

$\vec{H}(\rho) = \frac{2M}{\rho}\hat{\phi}\ \frac{A}{m}$ @ $\rho = a$

RII $\quad a < \rho < b$

$I_{enc} = 4\pi Ma + \int_{\phi=0}^{2\pi}\int_{\rho=a}^{\rho} -K\rho\,(\rho\, d\rho\, d\phi)$

$= 4\pi Ma - 2\pi k\frac{(\rho^3 - a^3)}{3}$ A



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Name Peter Dea

$\Rightarrow \vec{H}(\rho) = \boxed{\frac{2aM}{\rho}\hat{\phi} - \frac{K(\rho^3 - a^3)}{3\rho}\hat{\phi}\ \frac{A}{m}}$

RIII $\quad b < \rho < c$

$I_{enc} = 4\pi Ma + \int_{\phi=0}^{2\pi}\int_{\rho=a}^{b} -K\rho\,(\rho\, d\rho\, d\phi)$

$= 4\pi Ma - \frac{2}{3}\pi k(b^3 - a^3)$

$\Rightarrow \vec{H}(\rho) = \boxed{\frac{2aM}{\rho}\hat{\phi} - \frac{K(b^3 - a^3)}{3\rho}\hat{\phi}\ \frac{A}{m}}$

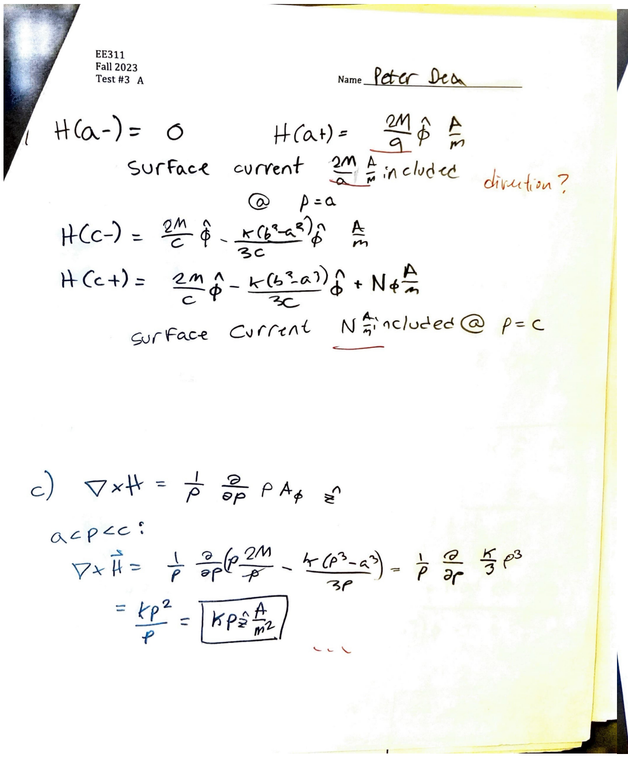
RIV $\quad c < \rho$

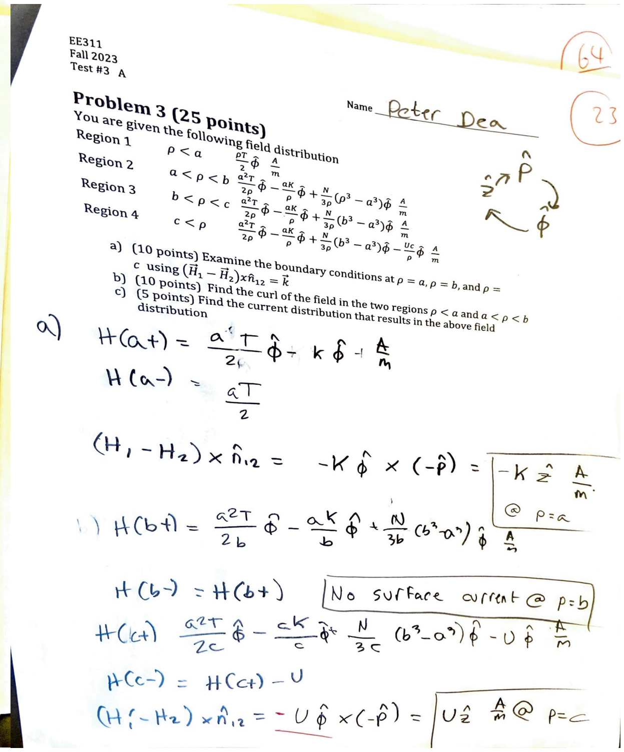
$I_{enc} = 4\pi Ma - \frac{2}{3}\pi k(b^3 - a^3) + \int_{\phi=0}^{2\pi} N\rho\, d\phi \Big|_{\rho=c}$

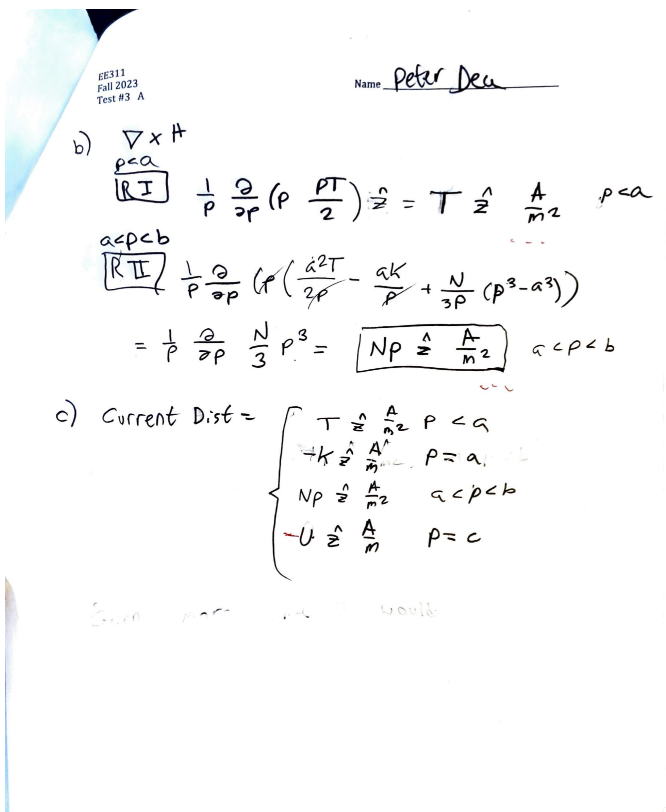
$= 4\pi Ma - \frac{2}{3}\pi k(b^3 - a^3) + 2\pi Nc$

$\Rightarrow \vec{H}(\rho) = \boxed{\frac{2M}{\rho}\hat{\phi} - \frac{K(b^3 - a^3)}{3\rho}\hat{\phi} + \frac{Nc}{\rho}\hat{\phi}\ \frac{A}{m}}$

$$\Rightarrow \vec{H}(\rho) = \begin{cases} 0 & \rho < a \\ \frac{2Ma}{\rho}\hat{\phi} - \frac{k(\rho^3 - a^3)}{3\rho}\hat{\phi}\ \frac{A}{m} & a < \rho < b \\ \frac{2Ma}{\rho}\hat{\phi} - \frac{k(b^3 - a^3)}{3\rho}\hat{\phi}\ \frac{A}{m} & b < \rho < c \\ \frac{2Ma}{\rho}\hat{\phi} - \frac{k(b^3 - a^3)}{3\rho}\hat{\phi} + \frac{Nc}{\rho}\hat{\phi}\ \frac{A}{m} & c < \rho \end{cases}$$







According to the professor, this exam was a lot harder than the previous ones and a lot of students struggled with it. While it wasn't my best exam, this one went alright for me. I struggled with the first question, as did a bunch of other students, so before ending this unit we had one more game in which we tried to correct our mistakes in the first problem on the current sheet. I will show that game, but first I will show my reflection following the exam.

Post-Exam 3 Reflection

How was your performance? How did you do, and what did you think about the test and about your experience? Did you learn anything about the material and yourself?

The test was harder than I expected. I did not perform my best on it, and I believe that I solved the problems slower than normal, which led me to run out of time and not be able to figure out the correct solution to the first problem which I saved for last. I believe had I been a little quicker in question 2 I could have been able to come up with a better solution for problem 1a. I think I spent too much time making sure my presentation for the latter problems made sense. The room we took the test in was much better than the room we normally are in on Mondays, but I still had a difficult time keeping all of my exam sheets in order. I did not have enough space on my desk for all of my resources and I spent a fair bit of time fumbling around with sheets of paper. I also think I did not get quite enough sleep the night before which probably contributed to me solving the problems slower than normal. This is something I am certainly going to learn from going into the next exam and I will try to prepare myself better in more areas than just studying the material.

2. What would you do differently in preparing for the next test (test 4 EM propagation)?

I am going to try to study more during the day than at night so that the information sticks with me better. I have been learning this semester that the time of day I study at affects how well I retain information. Additionally, there weren't really any games or homework problems that prepared me for the first problem on this exam so I think it could be helpful for me to review more practice problems within the book to make sure I will be prepared better for the less predictable exam questions. I also want to carefully review the equations I believe I will be using on the exam and make sure that I understand all of the different types of questions that can be solved using these equations. I had the equation for the first problem written down in my note sheet but because I was not familiar with the way the exam was asking the question, I was unaware that it was the equation that I was supposed to use in the given situation.

3. What would you do differently this is regarding while taking the test?

During this exam I basically wrote down the answers to all of my questions twice. This was not only to keep all of my answers organized for whoever will be grading it, but it also helped me refer back to my previous answers in case the next question required me to use it. While this is normally very helpful and good practice during the games and homework, I believe this took too much of my time which I could have spent trying to find better solutions to the first problem which I did not understand well. I think what I should have done was come back to these questions at the end if I believed I had time to format my answers better. I think if I did not get the time to do this I still would have gotten credit for the answers I did right so really by doing it I was just taking time away from myself.

4. Please feel free to share any other thoughts, ideas, or suggestions.

Overall, this exam was not my best work, and it has definitely highlighted areas that I need to work on. I hope that I will be able to learn from these things and perform better on the next exam. I am still unsure exactly how I was supposed to go about solving the first problem on the exam and even after the game we did in class today it is not clear to me what the right method was for finding the solutions. The classmates that I have talked to were also confused about how to do it so I look forward to reviewing the solution to the game and getting our test results back so I can learn from the mistakes that I made.

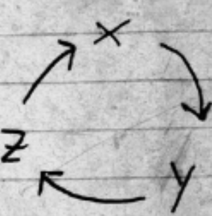
Magnetic Boundary Conditions Revisited

Before ending this unit, we had one more game in which we corrected our mistakes on problem 1 of the exam. Here is what I came up with.

Elias
Sam
Scott
Caleb

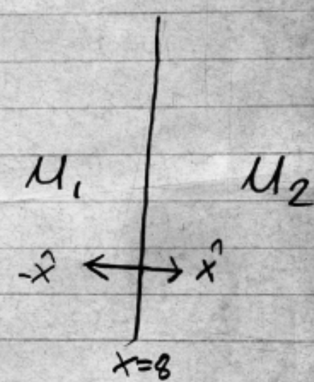
Game 46 - EE 311 - Peter Dea Denny

$\hat{n}_{12} = \hat{x} \qquad \hat{n}_{21} = -\hat{x}$



$(\vec{H}_1 - \vec{H}_2) \times \hat{n}_{12} = \hat{k} = -2\hat{z} \ \frac{A}{m}$

$\vec{H}_2 = 3\hat{x} + \hat{y} - 4\hat{z} \ \frac{A}{m}$



$(\vec{H}_1 - \vec{H}_2) \times \hat{x} = -2\hat{z}$

$\Rightarrow (\vec{H}_1 - \vec{H}_2) = 2\hat{y}$

$\vec{H}_1 - (3\hat{x} + \hat{y} - 4\hat{z}) = 2\hat{y}$

$\Rightarrow H_1 = -3\hat{x} + 3\hat{y} - 4\hat{z}$

However the portion of $\vec{H}$ in the $\hat{x}$ direction can be anything, because crossing it with $\hat{x}$ results in 0 anyway.

$\Rightarrow \boxed{\vec{H}_1 = 3\hat{y} - 4\hat{z} \ \frac{A}{m}} \quad x < 8$

$\boxed{\vec{H}_2 = 3\hat{x} + \hat{y} - 4\hat{z} \ \frac{A}{m}} \quad x > 8$

I did a lot better on this game than I did when I received this question on the exam, and with the magnetic unit being complete, it was now time to move on to the next unit of Electromagnetic Wave Propagation.

Unit 4: Electromagnetic Wave Propagation

Electrostatics Introduction

The fourth unit was where everything we had learned in the previous one came together. The topic was on electromatic wave propagation, so it was time to learn about how electric fields and magnetic fields interact to create travelling waves. We learned about many of the properties behind electromagnetic waves such as how their speeds, frequency, and wavelengths relate, how they are reflected, how to calculate their power, and much more. This unit was very different from the last couple, but it is definitely where I began to understand the significance of the things we had been learning up until this point.

Phasor Review

It was critical for this unit that we understood how to use phasors and how to go to them from the time domain, in this game we had a brief review on how to do this.

Caleb
Scott
Elias
Sam
Mina

Game 39 - EE 311 - Peter Dea (Feat Yash)

a) A steady state condition is the condition a system is in after the transient response dies down. It is typically a constant or periodic function.

b)

i) $A = 3\cos(\omega t - 5z)$ Euler's Formula

$$= \frac{3}{2}\left(e^{j(\omega t - 5z)} + e^{-j(\omega t - 5z)}\right)$$

$$= \boxed{\frac{3}{2}\left(e^{j\omega t} e^{-j5z} + e^{-j\omega t} e^{j5z}\right)}$$

ii) $B = 5\sin(\omega t + \beta x)$

$$= \boxed{\frac{5}{2j}\left(e^{\omega t} e^{\beta x} - e^{-\omega t} e^{-\beta x}\right)}$$

c) $\frac{1}{2}$ comes from the magnitudes of V & I being $\sqrt{2}$

conjugate comes from the need to negate the phase angle

Poynting Vectors

Pointing vectors are used a lot during this unit and they pertain to the complex power of an electromagnetic wave. In this game we began working with these pointing vectors.

Elias
Sam
caleb
Scott
Danny Dang

Game 40 - EE 311 - Peter Dea

1) $\frac{1}{2}\vec{E}_i \times \vec{H}_i^* = \frac{1}{2}\left(240\pi e^{-j\beta x}\left(2e^{j\beta_1 x}\right)\right)\hat{x}$

$$\vec{S}_i = \boxed{240\pi\,\hat{x}\ \frac{\mu W}{m}}$$

$$\frac{1}{2}\vec{E}_r \times \vec{H}_r^* = \frac{1}{2}\left(48\pi e^{j\beta_1 x}\left(\frac{2}{5}e^{-j\beta_1 x}\right)\right)(-\hat{y}\times\hat{z})$$

$\hat{x}$

$$\vec{S}_r = \boxed{\frac{48\pi}{5}(-\hat{x})\ \frac{\mu W}{m}}$$

-9.6π

$$\frac{1}{2}\vec{E}_t \times \vec{H}_t^* = \frac{1}{2}\left(192\pi e^{-j\beta_2 x}\left(2.4e^{j\beta_2 x}\right)\right)(\hat{y}\times\hat{z})$$

$$\vec{S}_t = \boxed{230.4\pi\,\hat{x}\ \frac{\mu W}{m}}$$

2) Original Power: $240\pi\,\hat{x}$

Add powers following reflections

$$\frac{48\pi}{5} + 230.4\pi = 240\pi$$

As you can see, $|\vec{S}_i| = |\vec{S}_r| + |\vec{S}_t|$ which makes sense because power is conserved.

Boundary Between Dielectrics

Most of the problems in the games from this point had to do with the properties of waves at the boundary between two dielectrics. Below is the first game we had regarding this.

Elias
Sam
Scott
Caleb
Mina

Game 41 - EE 311 - Peter Dea

$$\boxed{\Gamma_n = \frac{40-120}{40+120} = \frac{-80}{160} = -\frac{1}{2}}$$

$$\vec{E}_r = \Gamma \vec{E}_i = -120\pi e^{-j\beta_1 x}\,\hat{y}\ \frac{mV}{m} \qquad \vec{E}_r$$

$$\vec{E}_t = \vec{E}_r + \vec{E}_i = 240\pi e^{-j\beta x} - 120\pi e^{-j\beta x} = \boxed{120\pi e^{-j\beta_2 x}\,\hat{y}\ \frac{mV}{m}} \qquad \vec{E}_t$$

$$\vec{H}_r = \frac{\vec{E}_r}{\eta_1} = \frac{-120\pi e^{-j\beta_1 x}}{120\pi} = \boxed{-e^{-j\beta_1 x}\,\hat{z}\ \frac{mA}{m}}$$

$$\vec{H}_t = \frac{\vec{E}_t}{\eta_2} = \frac{120\pi e^{-j\beta x}}{40\pi} = \boxed{3e^{-j\beta_2 x}\,\hat{z}\ \frac{mA}{m}}$$

1) $$\vec{S}_i = \frac{1}{2}\left(240\pi e^{-j\beta_1 x}\,\hat{y} \times 2e^{j\beta_1 x}\,\hat{z}\right)$$
$$= \boxed{240\pi\,\hat{x}\ \frac{\mu W}{m^2}}$$

$$\vec{S}_r = \frac{1}{2}\left(-120\pi e^{-j\beta_1 x}\,\hat{y} \times -e^{j\beta_1 x}\,\hat{z}\right) = \boxed{-60\pi\,\hat{x}\ \frac{\mu W}{m^2}}$$

$$\vec{S}_t = \frac{1}{2}\left(120\pi e^{-j\beta_2 x}\,\hat{y} \times 3e^{+j\beta_2 x}\,\hat{z}\right) = \boxed{180\pi\,\hat{x}\ \frac{\mu W}{m^2}}$$

2) Check that $\vec{S}_t = \vec{S}_r + \vec{S}_i$

$180\pi = -60\pi + 240\pi$ True

Power Balances at Boundary

I was off to a good start for this type of problem, over the next few games we would do something similar. On the next page I will show a similar game.

Uniform Plane Waves

San
Scott
Caleb
Mina

Game 42 - EE 311 - Peter Dea

$z < 0$ | $z > 0$

$\leftarrow$

$\eta = 60\pi = \eta_2$ | $\eta = 120\pi$

RII | RI

a) $T = \frac{2 \cdot 60\pi}{180\pi} = \frac{2}{3}$

$\Gamma = \frac{60\pi - 120\pi}{180\pi} = -\frac{1}{3}$

$\boxed{\vec{E}_i = \frac{3}{2} e^{j\beta_2 z} \hat{y} \ \frac{mV}{m}}$

$\vec{H}_i = \frac{\vec{E}_i}{120\pi} = \boxed{\frac{1}{80\pi} e^{j\beta_2 z} \hat{x} \ \frac{mA}{m} = \vec{H}_i}$

$\boxed{\vec{E}_r = \Gamma \vec{E}_i = -\frac{1}{2} e^{j\beta_2 z} \hat{y} \ \frac{mV}{m}}$

$\boxed{\vec{H}_r = \Gamma \vec{H}_i = -\frac{1}{240\pi} e^{j\beta_2 z} \hat{x} \ \frac{mA}{m}}$

b) $\vec{E}_i(z=0) = \frac{3}{2} \hat{y} \ \frac{mV}{m}$ $\quad \vec{E}_r(z=0) = -\frac{1}{2} \hat{y} \ \frac{mV}{m}$ $\quad \vec{E}_t(z=0) = 1 \hat{y} \ \frac{mV}{m}$

$\vec{H}_t = \frac{1}{60\pi} \vec{E}_t = \frac{1}{60\pi} e^{j\beta_2 z} \hat{y} \ \frac{mA}{m}$

$\vec{H}_t(z=0) = \frac{1}{60\pi} \hat{x} \ \frac{mA}{m}$

$\vec{H}_i(z=0) = \frac{1}{80\pi} \hat{x} \ \frac{mA}{m}$ $\qquad$ Note $\vec{H}_t \neq \vec{H}_i + \vec{H}_r$

$\vec{H}_r(z=0) = -\frac{1}{240\pi}$

c)

$$\vec{S}_t = \vec{E}_t \times \vec{H}_t^* = e^{j\beta_2 z}\,\hat{y} \times \frac{1}{60\pi}\hat{x} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ 0 & e^{j\beta_2 z} & 0 \\ \frac{e^{j\beta_2 z}}{60\pi} & 0 & 0 \end{vmatrix}$$

$$\Rightarrow \boxed{\vec{S}_t = -\frac{1}{60\pi}\,\hat{z}\ \frac{\mu W}{m^2}}$$

$$\vec{S}_i = \vec{E}_i \times \vec{H}_i^* = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ 0 & \frac{3}{2}E_t & 0 \\ \frac{1}{60\pi}E_t^* & 0 & 0 \end{vmatrix}$$

$$\boxed{\vec{S}_i = -\frac{3}{160\pi}e^{-j\beta_2 z}\,\hat{z}\ \frac{\mu W}{m^2}}$$

$$\vec{S}_r = E_r \times H_r^* = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ -\frac{1}{2}\vec{E}_t & 0 & 0 \\ 0 & -\frac{1}{120\pi}\vec{E}_t^* & 0 \end{vmatrix}$$

$$\boxed{\vec{S}_r = \frac{1}{240\pi}e^{-j2\beta_2 z}\,\hat{z}\ \frac{\mu W}{m^2}}$$

These powers do not balance so there must have been a calculation error

This is an example of a game I had a harder time on, as my powers did not end up balancing at the boundary, so I determined I must have made a calculation error along the way. I got better at doing these as we progressed through the unit.

Sam
Elias
Scott
Caleb
Denny
Mina

Game 43 - EE 311 - Peter Dea

$\eta_1 = 80\pi$ $\qquad$ $\eta_2 = 120\pi$

$\beta_1 = 6$ $\qquad$ $\beta_2 = W$

$\vec{E}_i = e^{j6y}\,\hat{z}\ \frac{mV}{m}$

$$\Gamma = \frac{80\pi - 120\pi}{200\pi} = -\frac{1}{5}$$

$$T = \frac{2 \cdot 120\pi}{200\pi} = \frac{6}{5}$$

a) $\boxed{\vec{E}_i = e^{j6y}\,\hat{z}\ \frac{mV}{m}} = \vec{E}_i$

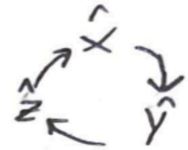
$\boxed{\vec{E}_r = \Gamma \vec{E}_i = -\frac{1}{5} e^{j6y}\,\hat{z}\ \frac{mV}{m}} = \vec{E}_r$

$\vec{E}_t = T e^{j6y}\hat{z} = \boxed{\frac{6}{5} e^{jWy}\,\hat{z}\ \frac{mV}{m}} = \vec{E}_t$

$\vec{H}_i = \frac{\vec{E}_i}{\eta_1} = \boxed{\frac{1}{80\pi} e^{j6y}\,\hat{x}\ \frac{mA}{m}} = \vec{H}_i$

$\vec{H}_r = \Gamma \vec{H}_i = \boxed{-\frac{1}{400\pi} e^{j6y}\,\hat{x}\ \frac{mA}{m}} = \vec{H}_r$

$\vec{H}_t = T \vec{H}_i = \boxed{\frac{3}{200\pi} e^{jWy}\,\hat{x}\ \frac{mA}{m}} = \vec{H}_t$



b) $\vec{E}_i(y=0) = 1\ \hat{z}\ \frac{mV}{m}$

$\vec{E}_r(y=0) = -\frac{1}{5}\hat{z}\ \frac{mV}{m}$

$\vec{E}_t(y=0) = \frac{6}{5}\hat{z}\ \frac{mV}{m}$

$\boxed{\vec{E}_i = \vec{E}_r + \vec{E}_t}$ $\quad 1 = -\frac{1}{5} + \frac{6}{5}$

$\vec{H}_i(y=0) = \frac{1}{80\pi}\hat{x}\ \frac{mA}{m}$

$\vec{H}_r(y=0) = -\frac{1}{400\pi}\hat{x}\ \frac{mA}{m}$

$\vec{H}_t(y=0) = \frac{3}{200\pi}\hat{x}\ \frac{mA}{m}$

$\frac{1}{80\pi} = -\frac{1}{400\pi} + \frac{3}{200\pi} \Rightarrow \boxed{\vec{H}_i = \vec{H}_r + \vec{H}_t}$

c) $\vec{S}_i = \frac{1}{2}\vec{E}_i \times \vec{H}_i^* = \frac{1}{2}\left(e^{j6y}\hat{z} \times \frac{1}{80\pi}e^{-j6y}\hat{x}\right)$

$\boxed{\vec{S}_i = \frac{1}{160\pi}\hat{y}\ \frac{\mu W}{m^2}}$

$\vec{S}_t = \frac{1}{2}(\vec{E}_t \times H_t^*) = \frac{1}{2}\left(\frac{6}{5}e^{j\omega t}\hat{z} \times \frac{3}{200\pi}e^{-j\omega t}\hat{x}\right)$

$= \boxed{\frac{3}{1000\pi}\hat{y}\ \frac{\mu W}{m^2}}$

$\vec{S}_r = \frac{1}{2}(\vec{E}_r \times \vec{H}_r) = \frac{1}{2}\left(-\frac{1}{5}e^{-j6y} \times -\frac{1}{400\pi}e^{j6y}\right)$

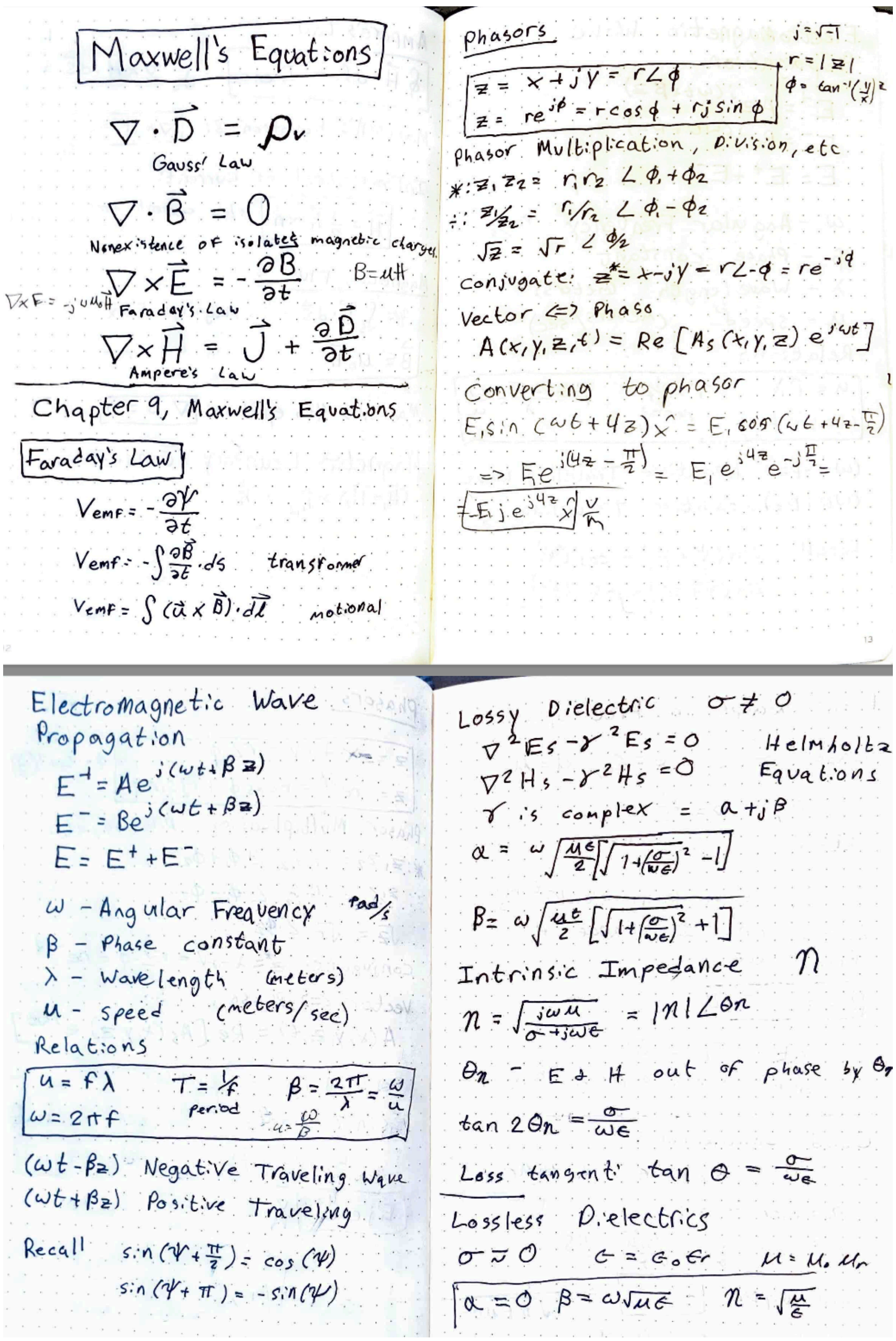
$\boxed{\frac{1}{4000\pi}\hat{y}\ \frac{\mu W}{m^2}}$

S_i should $= S_t + S_r$

After doing several of these games I got pretty good at doing this style of problem with uniform plane waves.

Concept Sheets

We were again getting to the point of the unit where we had a homework assignment and exam coming up, so it was important for me to have all of my concepts organized for easy access during the homeworks and exams. Here are the images of my concept sheets for this unit on electromagnetic wave propagation.



Plane Waves in Free Space

Case: $\sigma = 0, \quad \epsilon = \epsilon_0, \quad \mu = \mu_0$

$\alpha = 0, \quad \beta = \frac{\omega}{c}$

$u = c \qquad \lambda = \frac{2\pi}{\beta}$

c = speed of light = 3×10^8 m/s

η_0 = Intrinsic Impedance of Free space

$$\boxed{\eta_0 = 377\,\Omega}$$

$$\underset{\text{direction of } E}{\vec{a_E}} \times \underset{\text{of } H}{\vec{a_H}} = \underset{\text{of propagation}}{\vec{a_k}}$$

Good Conductors

case: $\sigma \simeq \infty, \quad \epsilon = \epsilon_0, \quad \mu = \mu_0 \mu_r$

$\alpha = \sqrt{\pi f \mu \sigma} = \beta$

$\eta = (1+j)\frac{\alpha}{\sigma} = \sqrt{\frac{\omega\mu}{\sigma}} \angle 45^\circ$

Skin Depth: $\boxed{\delta = \frac{1}{\alpha}} = \frac{1}{\sqrt{\pi f \mu \sigma}}$

depth when amplitude of EM waves decreases by $1/e$

$R_s = \frac{1}{\sigma \delta} = \sqrt{\frac{\pi f \mu}{\sigma}}$

$R_{dc} = \frac{l}{\sigma S} \qquad R_{ac} = \frac{l}{\sigma \delta w} = \frac{R_s l}{w}$

Power

$\mathcal{P} = \vec{E} \times \vec{H}$ = Poynting vector

Instantaneous Power Density

$\mathcal{P}_{avg} = \frac{1}{2} \mathrm{Re}(\vec{E_s} \times \vec{H}_s^*) = \frac{E_0^2}{2|\eta|} e^{-2\alpha z} \cos\theta_\eta$

$P_{avg} = \int_S \mathcal{P}_{avg} \cdot dS$

Reflection Coefficient

$$\boxed{\Gamma = \frac{E_r}{E_i} = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}} \qquad \vec{E_r} = \Gamma \vec{E_i}, \quad \vec{E_t} = \vec{E_i} + \vec{E_r}$$

$$\boxed{\tau = \frac{E_t}{E_i} = \frac{2\eta_2}{\eta_2 + \eta_1}}$$

Transmission coefficient

Standing Wave Case

$\vec{E}_1 = 2E_{i0} \sin\beta_1 z \sin\omega t \, \hat{x}$

$H_1 = \frac{2E_{i0}}{\eta_1} \cos\beta_1 z \cos\omega t \, \hat{y}$

Homework 5

The fifth and final homework covered all of the topics within the unit of electromagnetic wave propagation. Below is my work for the homework.

EE 311 - HW5 - Peter Dea - Fall 2023

1. $\vec{E}(z,t) = E_1 \sin(\omega t + 4z)\hat{x}$ V/m

a) Direction of propagation $= \boxed{-\hat{z}}$

b) Direction of oscillation $= \boxed{\hat{x}}$

c) Yes, because $\hat{x}$ and $\hat{z}$ (the direction of propagation and oscillation) are perpendicular

d) Yes, this is a uniform plane wave because the amplitude of the wave is constant

e) Faraday's Law: $\nabla \times \vec{E} = -\frac{\partial B}{\partial t} = -\mu \frac{\partial \vec{H}}{\partial t}$

$$\nabla \times \vec{E} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ E_1 \sin(\omega t + 4z) & 0 & 0 \end{vmatrix} = 4E_1 \cos(\omega t + 4z)\hat{y}$$

$\Rightarrow -\omega\mu\vec{H} = 4E_1 \cos(\omega t + 4z)\hat{y}$

$\Rightarrow \boxed{\vec{H} = -\frac{4E_1}{\omega\mu}\cos(\omega t + 4z)\hat{y} \quad \text{A/m}}$

f) $Im(re^{j\phi}) = r\sin(\omega t + \phi)$

$\Rightarrow$ Phasor form: $\boxed{E_1 e^{j4z}\hat{x} \ \text{V/m}}$

g) $\nabla \times \vec{E} = -\mu\frac{\partial \vec{H}}{\partial t} = -j\omega\mu\vec{H}$

$$\nabla \times \vec{E} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ E_1 e^{j4z}\hat{x} & 0 & 0 \end{vmatrix} = E_1 j4 e^{j4z}\hat{y} = -j\omega\mu\vec{H}$$

$\Rightarrow \vec{H} = \frac{4E_1 j e^{j4z}}{-j\omega\mu}\hat{y} \Rightarrow \boxed{\vec{H} = -\frac{4E_1}{\omega\mu}e^{j4z}\hat{y} \ \frac{A}{m}}$

h) Form: $r\cos(\omega t + \phi) = Re(re^{j\phi})$

$\boxed{\vec{H} = -\frac{4E_1}{\omega\mu}\cos(\omega t + j4z)\hat{y}\frac{A}{m}}$

2. $E_i = 160e^{-j4\pi z}\hat{x}$ | $E_{ref} = 40e^{j\frac{\pi}{4}}e^{j4\pi z}\hat{x}$ mV/m

RI	RII
$z<0$	$0<z$
Air	
$\eta = 120\pi\Omega$	

$z=0$

a) $u = \frac{\omega}{\beta} = c = 3\times10^8$ m/s

$\Rightarrow f = \frac{\beta c}{2\pi} = \frac{4\pi \times 3\times10^8}{2\pi}$

$\Rightarrow \boxed{f = 6\times10^8 \ \text{Hz}}$

b) $\Gamma = \frac{E_r}{E_i} = \frac{40}{160} = \frac{1}{4}$

$\Gamma = \frac{1}{4} = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} = \frac{\eta_2 - 120\pi}{\eta_2 + 120\pi}$

$\Rightarrow \eta_2 + 120\pi = 4\eta_2 - 4(120\pi)$

$\Rightarrow 3\eta_2 = 5\cdot120\pi \Rightarrow \eta_2 = \frac{5}{3}\cdot120\pi \Rightarrow \boxed{\eta_2 = 200\pi\Omega}$

b) Find $\vec{H_i}, \vec{H_r}, \vec{E_t} + \vec{H_t}$ First

Recall $\vec{E_i} = 160e^{-j4\pi z}\hat{x}$ mV/m

$\vec{E_r} = 40e^{-j\frac{\pi}{4}}e^{j4\pi z}\hat{x}$ mV/m

$\vec{H_i} = \frac{160}{120\pi}e^{-j4\pi z}\hat{y} = \frac{4}{3\pi}e^{-j4\pi z}\hat{y}$ mA/m

$\vec{H_r} = \Gamma\vec{H_i} = -\frac{1}{4}\cdot\frac{4}{3\pi}e^{-j4\pi z}\hat{y} = \frac{1}{3\pi}e^{-j4\pi z}(-\hat{y})$ mA/m

$\vec{E_t} = \vec{E_i} + \vec{E_r} = 200e^{-j4\pi z}\hat{x}$ mV/m

$\vec{H_t} = \frac{E_{to}}{200\pi} = \frac{1}{\pi}e^{-j4\pi z}\hat{y}$ mA/m

Find Poynting Vectors

$\vec{S_i} = \frac{1}{2}(\vec{E_i}\times\vec{H_i}^*) = \frac{1}{2}(160e^{-j4\pi z}\hat{x}\times\frac{4}{3\pi}e^{j4\pi z}\hat{y})$

$\Rightarrow \boxed{\vec{S_i} = \frac{320}{3\pi}\hat{z} \ \frac{\mu W}{m^2}}$

$\vec{S_r} = \frac{1}{2}(\vec{E_r}\times\vec{H_r}^*) = \frac{1}{2}(40e^{-j\frac{\pi}{4}}e^{j4\pi z}\hat{x}\times\frac{1}{3\pi}e^{j4\pi z}(-\hat{y}))$

phase doesn't matter

$\Rightarrow \boxed{\vec{S_r} = \frac{20}{3\pi}(-\hat{z}) \ \frac{\mu W}{m^2}}$

$\Rightarrow \eta_2 + 120\pi = 4\eta_2 - 4(120\pi)$

$\Rightarrow 3\eta_2 = 5\cdot120\pi \Rightarrow \eta_2 = \frac{5}{3}\cdot120\pi \Rightarrow \boxed{\eta_2 = 200\pi\Omega}$

b) Find $\vec{H_i}, \vec{H_r}, \vec{E_t} + \vec{H_t}$ First

Recall $\vec{E_i} = 160e^{-j4\pi z}\hat{x}$ mV/m

$\vec{E_r} = 40e^{-j\frac{\pi}{4}}e^{j4\pi z}\hat{x}$ mV/m

$\vec{H_i} = \frac{160}{120\pi}e^{-j4\pi z}\hat{y} = \frac{4}{3\pi}e^{-j4\pi z}\hat{y}$ mA/m

$\vec{H_r} = \Gamma\vec{H_i} = -\frac{1}{4}\cdot\frac{4}{3\pi}e^{-j4\pi z}\hat{y} = \frac{1}{3\pi}e^{-j4\pi z}(-\hat{y})$ mA/m

$\vec{E_t} = \vec{E_i} + \vec{E_r} = 200e^{-j4\pi z}\hat{x}$ mV/m

$\vec{H_t} = \frac{E_{to}}{200\pi} = \frac{1}{\pi}e^{-j4\pi z}\hat{y}$ mA/m

Find Poynting Vectors

$\vec{S_i} = \frac{1}{2}(\vec{E_i}\times\vec{H_i}^*) = \frac{1}{2}(160e^{-j4\pi z}\hat{x}\times\frac{4}{3\pi}e^{j4\pi z}\hat{y})$

$\Rightarrow \boxed{\vec{S_i} = \frac{320}{3\pi}\hat{z} \ \frac{\mu W}{m^2}}$

$\vec{S_r} = \frac{1}{2}(\vec{E_r}\times\vec{H_r}^*) = \frac{1}{2}(40e^{-j\frac{\pi}{4}}e^{j4\pi z}\hat{x}\times\frac{1}{3\pi}e^{j4\pi z}(-\hat{y}))$

phase doesn't matter

$\Rightarrow \boxed{\vec{S_r} = \frac{20}{3\pi}(-\hat{z}) \ \frac{\mu W}{m^2}}$

c) $\vec{S} = \frac{1}{2}\left(10(-\hat{x} - j\hat{y})e^{j25z} \times (-\hat{x} - j\hat{y})\, e^{-j25z} \cdot \frac{10}{120\pi}\right)$

$= \frac{1}{2}\left(\frac{100}{120\pi}(-\hat{z}) + \frac{100}{120\pi}\right)(-\hat{z})\Big)$

$\Rightarrow \vec{S} = \boxed{\frac{100}{120\pi}(-\hat{z})\,\frac{uW}{m^2}}$

4. a) $\lambda = \frac{u}{f}$ $\quad u = 1.4\times10^{8}$, $f = 0.5\times10^{7}$

$\Rightarrow \lambda = \frac{1.4\times10^{8}}{0.5\times10^{7}} = 2\times1.4\times10 = \boxed{28\ m}$

b) $\eta = \frac{E_0}{H_0} = \frac{-1800}{3.8}$

$\Rightarrow \boxed{\eta = 473.68\ \Omega}$

c) $\vec{S} = \frac{1}{2}(E\times H^{*}) = \frac{1}{2}\left(1400e^{\beta z}(-\hat{x}) \times 3.8\, e^{-\beta z}\hat{y}\right)$

$\vec{S} = \boxed{3420\,(-\hat{z})\ W}$

With the last homework behind me, it was time to begin preparing for the test. Unlike the last tests, this test did not have a pre-exam reflection, but I recall going into it pretty confident in my understanding of electromagnetic wave propagation.

Exam 4

Below is my work for the final midterm exam.

EE 311
Fall 2023
Test 4 B

Name Peter Dea

(21)

Please do not write on the back of the pages

Problem 1 (25 points)
You are given the incident and reflected electric fields in region 1. The electric field gets reflected and transmitted at the boundary.

$$\vec{E}_{inc} = 16\, e^{j6\pi x}\hat{y}\ \frac{V}{m} \quad and \quad \vec{E}_{ref} = -4\, e^{-j6\pi x}\hat{y}\ \frac{V}{m}$$

a) (5 points) What is the intrinsic impedance η_1 of the material in region 1. Can you find it? If you can show your work and find it (in terms of π), and if you cannot explain.
b) (5 points) If the angular frequency of this wave is $\omega = 6\pi \times 10^8\ rad/s$, find the speed of the wave in region 1
c) (10 points) Find incident, reflected and transmitted E and H
d) (5 points) Find the incident, reflected and transmitted average Poynting vectors

Region 2 (Air) $x<0$ | Region 1 $0<x$

$x=0$

a) $\Gamma = \dfrac{-4e^{-j6\pi x}}{16 e^{j6\pi x}} = -\dfrac{1}{4} e^{j12\pi x}$ // $\quad x=0 \Rightarrow -\dfrac{1}{4}$

$\Gamma(x=0) = \dfrac{\eta_2 - \eta_1}{\eta_2 + \eta_1} = -\dfrac{1}{4} \Rightarrow -\dfrac{\eta_2 + \eta_1}{4} = \eta_2 - \eta_1$

$\Rightarrow \frac{5}{4}\eta_1 = \eta_2 - \frac{1}{4}\eta_2 \Rightarrow \eta_1 = \frac{3}{4}\eta_2 \cdot \frac{4}{5} = \frac{3}{5}\eta_2$ //

Check your math

$\Rightarrow \eta_1 = 120\pi \cdot \frac{3}{5} = \boxed{72\pi}$

b) $u = f\lambda = 3\times 10^8$ X

EE 311
Fall 2023
Test 4 B

Name Peter Dea

Please do not write on the back of the pages

c. $E_i = \boxed{16 e^{j6\pi x}\ \hat{y}\ \frac{V}{m}}$ given

$E_r\ \boxed{4 e^{-j6\pi x}(-\hat{y})\ \frac{V}{m}}$ given

$T = \dfrac{240\pi}{120\pi + 72\pi} = \dfrac{240}{192}$ //

$E_t = T E_i = \boxed{\dfrac{240 * 16}{192} e^{j\beta x}\ \hat{y}\ \frac{V}{m}}$

$\vec{H}_i = \dfrac{\vec{E}_i}{\eta_1} = \boxed{\dfrac{16}{72\pi} e^{j6\pi x}\ (-\hat{z})\ \frac{A}{m}}$

$\vec{H}_r = \dfrac{\vec{E}_r}{\eta_1} = \boxed{\dfrac{4}{72\pi} e^{-j6\pi x}\ (-\hat{z})\ \frac{A}{m}}$

$\vec{H}_t = \dfrac{\vec{E}_t}{\eta_2} = \dfrac{240(16)}{192(120\pi)} \cdots = \boxed{\dfrac{32}{192\pi} e^{j\beta x}\ (-\hat{z})\ \frac{A}{m}}$

d) $\vec{S}_i = \frac{1}{2} E_i \times H_i^* = \frac{1}{2}\left(16 e^{j6\pi x}\hat{y} \times \frac{16}{72\pi} e^{-j6\pi x}(-\hat{z})\right)$

$\boxed{\dfrac{128}{72\pi}(-\hat{x})\dfrac{W}{m^2}}$

$\vec{S}_r = \frac{1}{2}\left(4e^{-j6\pi x}(-\hat{y}) \times \frac{4}{72\pi} e^{j6\pi x}(-\hat{z})\right)$

$= \boxed{\dfrac{8}{72\pi}\ \hat{x}\ \dfrac{W}{m^2}}$

EE 311
Fall 2023
Test 4 B

Name Peter Dea

(24)

Please do not write on the back of the pages

Problem 2 (25 points)
The electric field of a uniform plane wave in free space is given by

$$\vec{E}_{inc} = 6e^{j15\pi z}(-\hat{x})\ \frac{mV}{m}$$

a) (5 points) Can you find the wavelength of this field? Explain and if you can show how.
b) (5 points) Find the frequency of operation and show your work.
c) (5 points) Find the magnetic field using Maxwell's equation and show it in frequency domain.
d) (5 points) from part c, show the magnetic field in time domain.
e) (5 points) Find the average Poynting vector and show your work.

a) $\beta = 15\pi$

$\lambda = \dfrac{2\pi}{\beta} = \dfrac{2\pi}{15\pi} = \boxed{\dfrac{2}{15}\ m}$

b) $u = f\lambda \Rightarrow f = \dfrac{u}{\lambda} = \dfrac{15}{2}\times 3\times 10^8 = \boxed{\dfrac{45}{2}\times 10^8\ \frac{m}{s}}$

c) $\nabla \times E = -j\mu\omega H$ $\quad \begin{vmatrix} x & y & z \\ \partial x & \partial y & \partial z \\ -6e^{\cdots} & 0 & 0 \end{vmatrix}$

$\nabla \times E = 6j15\pi\, e^{j15\pi z}\ \hat{y}$

$\Rightarrow H = \dfrac{6j15\pi\, e^{j15\pi z}}{-j\mu\omega} = \boxed{-\dfrac{6(15)\pi}{\mu\omega} e^{j15\pi z}\ \hat{y}\ \frac{mA}{m}}$

d) $\boxed{-\dfrac{6(15)\pi}{\mu\omega}\cos(\omega t + 15\pi z)\ \hat{y}\ \frac{mA}{m}}$

e) $\frac{1}{2} E \times H^* = \boxed{\dfrac{18(15\pi)}{\mu\omega}\ (-z)\ \frac{\mu W}{m^2}}$

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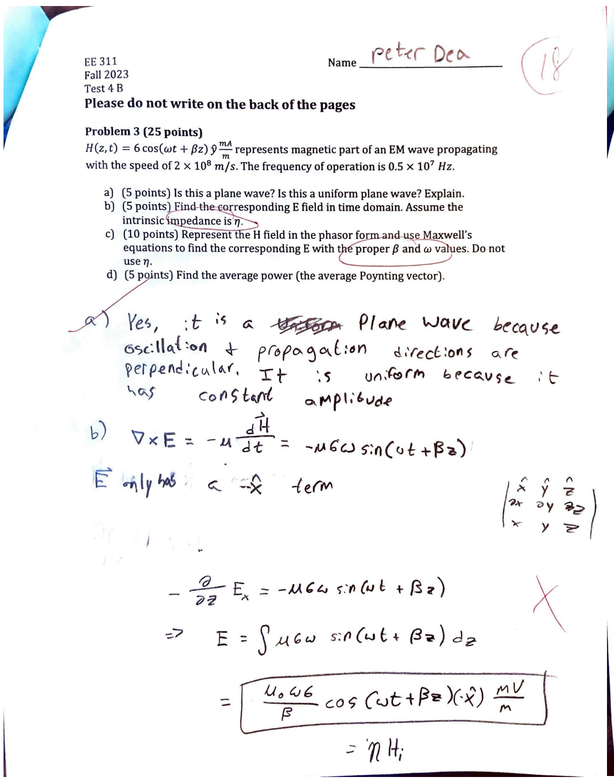
$S_t = \frac{1}{2}\left(\frac{240(16)}{192} e^{j\beta x}\hat{y} \times \frac{32}{192\pi} e^{-j\beta x}(-\hat{z})\right)$

$\boxed{\dfrac{240(16)(32)}{2(192)^2\pi}(-\hat{x})\dfrac{W}{m}}$



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Problem 3 (25 points)

$H(z,t) = 6\cos(\omega t + \beta z)\,\hat{y}\,\frac{mA}{m}$ represents magnetic part of an EM wave propagating with the speed of $2 \times 10^8\ m/s$. The frequency of operation is $0.5 \times 10^7\ Hz$.

a) (5 points) Is this a plane wave? Is this a uniform plane wave? Explain.
b) (5 points) Find the corresponding E field in time domain. Assume the intrinsic impedance is η.
c) (10 points) Represent the H field in the phasor form and use Maxwell's equations to find the corresponding E with the proper β and ω values. Do not use η.
d) (5 points) Find the average power (the average Poynting vector).

a) Yes, it is a ~~uniform~~ plane wave because oscillation + propagation directions are perpendicular. It is uniform because it has constant amplitude

b) $\nabla \times E = -\mu \frac{d\vec{H}}{dt} = -\mu 6\omega \sin(\omega t + \beta z)$

$\vec{E}$ only has a $-\hat{x}$ term

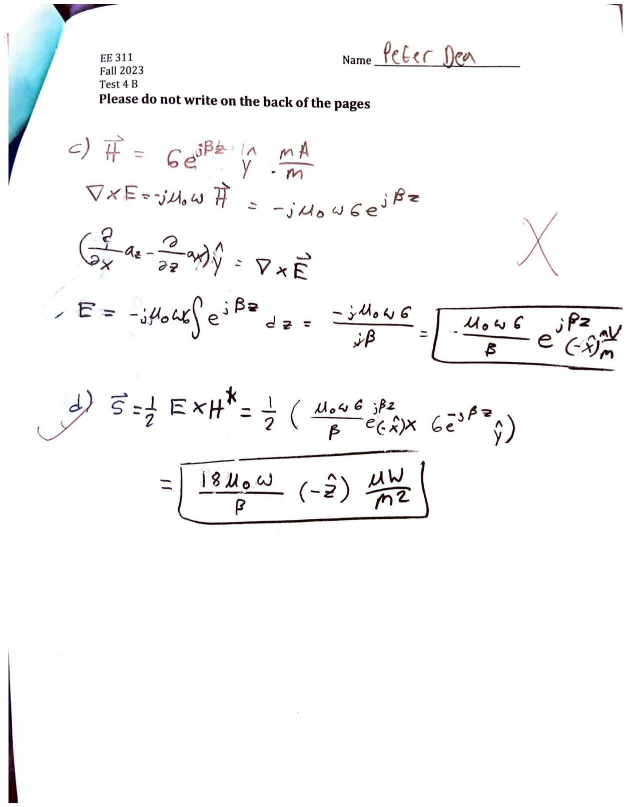
$$\begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \partial x & \partial y & \partial z \\ x & y & z \end{vmatrix}$$

$-\frac{\partial}{\partial z} E_x = -\mu 6\omega \sin(\omega t + \beta z)$

$\Rightarrow E = \int \mu 6\omega \sin(\omega t + \beta z)\, dz$

$= \boxed{\frac{\mu_0 \omega 6}{\beta} \cos(\omega t + \beta z)(-\hat{x})\ \frac{mV}{m}}$

$= \eta H_i$



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c) $\vec{H} = 6e^{j\beta z}\,\hat{y}\ \frac{mA}{m}$

$\nabla \times E = -j\mu_0\omega \vec{H} = -j\mu_0 \omega 6 e^{j\beta z}$

$\left(\frac{\partial}{\partial x} a_z - \frac{\partial}{\partial z} a_x\right)\hat{y} = \nabla \times \vec{E}$

$E = -j\mu_0\omega 6 \int e^{j\beta z}\, dz = \frac{-j\mu_0 \omega 6}{j\beta} = \boxed{-\frac{\mu_0 \omega 6}{\beta} e^{j\beta z} (-\hat{x})\frac{mV}{m}}$

d) $\vec{S} = \frac{1}{2} E \times H^* = \frac{1}{2}\left(\frac{\mu_0 \omega 6}{\beta} e^{j\beta z}(-\hat{x}) \times 6e^{-j\beta z}\hat{y}\right)$

$= \boxed{\frac{18\mu_0 \omega}{\beta}(-\hat{z})\ \frac{\mu W}{m^2}}$

And thus, the midterm exams were behind me. Before moving onto our final unit, it was time to reflect on my experience with the last midterm exam.

Post-Exam 4 Reflection

1. How was your performance? How did you do, and what did you think about the test and about your experience? Did you learn anything about the material and yourself?

This test was a bit different than I expected. Prior to doing the test I was feeling fairly confident because the games we had on this topic were relatively intuitive to me. I did a lot of studying on how the wave propagation questions work for different kind of conductors and I experimented a lot with the past games. During the test, however, I had a harder time with the problems regarding the relationships between wavelength, frequency, and speed, and I spent a lot of time flipping through my notes to find the correct equations to use. I also had trouble on the last problem of this exam because it asked to use Maxwell's equation to find the E field give the H field, which is not the type of question I was prepared for and it was much harder to solve using the equation I wrote down for easy access. I ended up trying to take a reverse cross product which was very difficult, and I made mistakes in the process which lost me points. I believe had I studied the homework a little bit more than I studied the games I would have been better off.

2. What would you do differently in preparing for the next test the final?

Before the final I am going to have to review all of the topics I have learned throughout the semester, so it will be important for me to incorporate all of the strategies I have shown work through my experiences with the exams. Something that I think could prove to be especially helpful is to carefully review the past 3 exams and correct all of the mistakes I have made. I should make sure that I feel confident in my ability to get every question on those tests right if I were to be asked them again. I also think it would be beneficial for me to review all of the past homeworks because they will provide me with a lot more material and tend to ask questions that check your broader understanding of the topics. I will of course also look at the past games through each of the topics we have covered so far during class in order to be the best prepared for the upcoming final that I can be.

3. What would you do differently this is regarding while taking the test?

When I am taking a test and I come upon a problem I do not feel confident on or that I believe will take longer than normal for me to solve, I like to skip to a later question in order to best use my time and get all of the points I can with the time I am given. However during this test, I skipped both the first and second problem after thinking of them for a while, then I committed to doing the last one without really fully understanding how to do it. In hindsight I think the first two problems were much easier and probably would have better prepared me for the third problem, so what I should have done is gone back to one of the other two and did one of them first. Instead, I was stuck solving the easier problems when time was running out, which means I lost points which I almost certainly could have gotten otherwise. I think this is a problem I need to work on going forward. I need to find a way to be more efficient with my time and be able to more quickly decide which problem I am best prepared for at any given moment.

4. Thinking about the Kolbian cycle, did you feel that you did a reasonable experiment based on your learning and practice for this material? If you remember at the beginning we all had difficulties with detail, …….

I believe so, and the structure of this class certainly encourages playing around with the concepts we are learning in order to gain a full understanding of the material. I think the games exposed me to the concepts well and were enough of a challenge that it inspired me to work hard and learn the topics in this unit. I also think the homework was a good challenge that made sure I understood the concepts more broadly and not exclusive to the structure of the in-class games.

5. Please feel free to share any other thoughts, ideas, or suggestions.

Personally, I felt like there were some topics in the exam and on the homework 5 that were not really covered in the in class games and I believe it could have helped with my understanding a bit better. I don’t think we worked much with wavelengths and wave speeds during the games and I think that could have been helpful to prepare me for the homework and exams. Overall though, I think the games did a good job at preparing me and hopefully I am doing a good job preparing myself for the final.

Unit 5: Transmission Lines

Transmission Lines Introduction

The final unit of this class was different from the previous ones. This unit did not have any homeworks or exam, in fact the content from this unit was not even going to be on the final exam. Instead, we simply did a few games regarding the content we learned in this unit before moving onto the final.

The content in question was on transmission lines, which is a topic I was already fairly familiar with after taking EE 303, Energy Systems and Power Electronics. It had a lot to do with impedances throughout a power line and the different types of waves travelling through them. This type of game was quite different than what I was used to in this class and it reminded me a lot of my circuits classes as a lot of the problems seemed like circuit analysis.

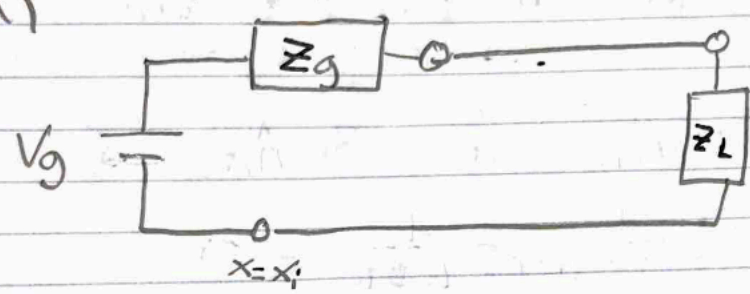
There were about three games with this content that I did and I will show them on the following pages.

Working with Transmission Lines

Caleb
Elias
Sam
Scott

Game 49 - EE 311 - Peter Dea...

a)



$$\Gamma_0 = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{100-50}{150} = \frac{1}{3}$$

$$\Gamma_{x in} = \Gamma_0 e^{2j\left(\frac{2\pi}{\lambda}\left(-\frac{17\lambda}{2}\right)\right)} = \frac{1}{3} e^{-34\pi j} \Rightarrow \Gamma_{in} = \frac{1}{3}$$

$$\Gamma_{in} = \frac{V^-}{V^+} \Rightarrow \frac{1}{3} = \frac{10}{V^+} \Rightarrow \boxed{V^+ = 30\ V}$$

$$I_t = \frac{V_{in}}{Z_{in}} = \frac{30+10}{100} = \boxed{400\ mA}$$

b) $I^- = \frac{V_{in}^-}{Z_0} = -\frac{10}{50} = \boxed{-200\ mA}$

$I^-_{Load} = I^-\left(t = -\frac{17\lambda}{2}\right) e^{j\beta \frac{17\lambda}{2}} = -\frac{1}{3} = \boxed{200\ mA}$

c) $Z_g = \frac{V_g - V_{in}}{I_{in}} = \frac{10-40}{0.4} = \boxed{75\Omega}$

d) IF line rength $= \frac{616}{4}\lambda$ ...

$$\Gamma_{xin} = \Gamma_0 e^{2j\frac{2\pi}{\lambda}\left(-\frac{616\lambda}{4}\right)} = \Gamma_0 e^{-616\pi} = \frac{1}{3}$$

$$V^+ = \frac{V_{in}}{\Gamma_{in}} = 3(10) = \boxed{30V}$$

$$I_t = \frac{V_{in}}{Z_{in}} = \frac{30+10}{100} = \boxed{400mA}$$

$$I^- = \frac{V_{in}^-}{Z_0} = -\frac{10}{50} = \boxed{-200\ mA}$$

$$I^-_{Load} = I^-\left(x = -\frac{616\lambda}{4}\right) e^{j\beta\frac{616\lambda}{4}} = 1$$

$$\Rightarrow \boxed{I^-_{Load} = -200mA}$$

c: $Z_g = \frac{V_g - V_{in}}{I_{in}} = \frac{10-40}{0.4} = \boxed{75\Omega}$

In this game specifically I had an error with my value of Zg, but I got the hand of this content fairly quickly as I have always enjoyed analyzing circuits. The next 2 games were some of my best performances yet in this class, so I will display them both on the following pages.

Peter Dea
Team: Scott, Sam, Elias, Caleb, Denny, Mina

EE311
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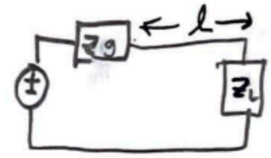
Game T-line voltage, current

For the following T-line system, you know Z_L=200 ohms Z_0=50 ohms Z_g =100 ohms and the length of the line is $\frac{3\lambda}{4}$

You know that the V_g =400 V

All of the answers need to have no exponential nor sin cos, they need to be in either exponential or a+jb form.

a) Find $Z_{in}(x = -\frac{3\lambda}{4})$ and $\Gamma_{in}\left(x = -\frac{3\lambda}{4}\right)$, show your work
b) Using part a, find $V_{in} = V_{in}\left(x = -\frac{3\lambda}{4}\right)$ and show your work
c) Find $V_{at\ the\ load}(x = 0)$ and show your work



a) $\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{150}{250} = \frac{3}{5}$

$\Gamma_{in}(x = -\frac{3\lambda}{4}) = \frac{3}{5} e^{2j\frac{2\pi}{\lambda}(-\frac{3\lambda}{4})} = \frac{3}{5} e^{-3\pi j} = \boxed{-\frac{3}{5}}$

$Z_{in}(x = -\frac{3\lambda}{4}) = Z_{in} = 50 \frac{1 + \frac{3}{5} e^{j\frac{4\pi}{\lambda}(-\frac{3\lambda}{4})}}{1 + \frac{3}{5} e^{-j\frac{4\pi}{\lambda}(-\frac{3\lambda}{4})}}$

$Z_{in} = 50 \frac{1 + (-\frac{3}{5})}{1 - (-\frac{3}{5})} = 50 \frac{2/5}{8/5} = \frac{50}{4} = \boxed{12.5\Omega}$

b)

$V_{in} = V(x = -\frac{3\lambda}{4}) = \frac{V_g Z_{in}}{Z_g + Z_{in}} = \frac{12.5(400)}{112.5} = \boxed{44.4 V} = \boxed{\frac{400}{9} V}$

c) $V_{in} = V_{in}^+ + V_{in}^-$ $\quad V_{in}^+ = \frac{V_{in}}{1 + \Gamma_{in}} = \frac{400}{9(1 - 3/5)} = \frac{400(5)}{18} = \frac{1000}{9} V$

$V_{in}^+(x) = V_L^+ e^{-j\beta x}$ $\quad V_{in}^- = -j\frac{600}{9}$

$\Rightarrow V_{(x=0)} = V^+(x=0) + V^-(x=0) = j\frac{1000}{9} - j\frac{600}{9} = \boxed{j\frac{400}{9} V}$

Elias
Sam
Scott
Caleb

Game 52 - Peter Dea -

Given I or V at the load, how many ways can you find Z_{in}.

1. $$\boxed{Z_{in} = \frac{V_{in}}{I_{in}}}$$

2. $$\Gamma_{in} = \frac{V_{in}^-}{V_{in}^+} = \frac{Z_{in} - Z_0}{Z_{in} + Z_0}$$

$$V_{in}^- Z_{in} + Z_0 V_{in}^- = V_{in}^+ Z_{in} - V_{in}^+ Z_0$$

$$Z_{in}(V_{in}^- - V_{in}^+) = -Z_0 V_{in}^- - Z_0 V_{in}^+$$

$$\Rightarrow \boxed{Z_{in} = \frac{-Z_0 (V_{in}^- + V_{in}^+)}{V_{in}^- - V_{in}^+}}$$

3. $$\boxed{Z_{in} = Z_0 \frac{1 + \Gamma_{in}}{1 - \Gamma_{in}}}$$

This was the last game we had on Transmission Lines. At this point in the semester we were getting very close to the final week, and after transmission lines we learned no new content. As such this is the last game that I will include in the Portfolio. The remaining pages in it will be dedicated to reflection and advice to future EE 311 students.

Advice to Future EE 311 Students

There are several pieces of advice that I would give to incoming EE 311 students. By far the biggest piece of advice I think I could give them is to try to stay caught up with **reading the textbook**. Sometimes it can be difficult to know exactly what to expect when coming into class the next day, but if you pay attention, you should know what is coming and which section of the textbook you should read. It can be easy to forget to read it or assume that it will be easy when you get to class to catch up, but I found that when I came to class well prepared, I performed much better on the games and often finished them much quicker than I would have if I had not read the textbook. I think the textbook also does a great job at making sure you have a full understanding of the concepts you are covering in class. Sometimes it seems like you can just get by with remembering what formulas to use for a certain type of question, but this does not help you gain the deep understanding of the material you need. Sometimes on the exam, questions can be brought about in a way that is similar to the games but uses a different presentation that you would only understand if you also read the textbook. The practice problems and the review problems within the textbook are very wide ranging and if you read them, you will certainly get a deep understanding of all of the topics you are learning.

Another piece of advice that I would give to future students enrolling into EE 311 is to **stay organized,** make sure you have quick access to your note sheets in a way that finding exactly the information you need when you need it can be done extremely quickly. This especially helps during exams when you have a limited amount of time to complete your problems. Sometimes I found myself flipping through multiple different notebooks, past games, homeworks and exams, and this really slows you down. Make sure you have quick and convenient access to all of the information you need. This will not only help you in the exams though, but it will also help you complete the games and homeworks quicker. I personally had a small notebook that I would write the most important formulas and concepts in that I would refer to all the time. I wish I had put a bit more in it, and maybe a few sample games that I often struggled with so that when they came up I knew exactly what to do.

My final piece of advice that I would give to future EE 311 students would be to **have fun** with the games. The games are a great opportunity to learn with your classmates. Getting the hands-on experience with practice problems covering the new concepts is extremely beneficial to your learning. This is personally the method of learning that I have found most effective to me. I have often heard that there are several different types of learners: people who learn best from reading, those who need visual cues, and those who perform best by actively solving problems regarding a concept. I think if you fall into that last category then you will especially find this class to be effective. If that is not your preferred learning style, there are still plenty of opportunities to learn the topics covered in this class such as the textbook and different resources online.

I hope that everyone joining this class next year has a lot of fun with it and learn a lot about the topics in electromagnetic fields and waves.

Final Reflection

Before taking this class, electromagnetism was quite a mystery to me. I did not understand the interaction between electric and magnetic fields or how the physics behind them enabled the propagation of light and other electromagnetic waves. Initially, I was confused by the focus on vector calculus, assuming it belonged in a math class like Calculus, not here in 311 where I expected to learn about the physics of waves. As the class progressed, however, I began to better understand the importance of these topics and why they were so integral to fields and waves. Take for example the cross product. I never had a good understanding of why we needed to use it until getting to the propagation section of this class. I was able to crunch the numbers in my Calculus 3 class to a Stoke's Theorem problem, but I had no idea why what I was learning about was important. Now, I can explain exactly why I am learning these topics. I understand why these concepts are so deeply important. That is something that I enjoyed a lot about this class; the fact that it made me have a deeper understanding of all of the topics I have been learning while pursuing Electrical Engineering.

The way this class was structured I personally found to be extremely effective in helping me learn and retain new concepts. Repetitively working with my peers to master the topics is a learning style that I find to be the most effective for me, and it was very helpful that this approach was ingrained into this class. It was very rewarding being able to feel myself improving as I learned the new concepts. While making this portfolio over the past few weeks, it has been especially obvious to me how much I've learned during this course. It appears that almost every time a new concept was introduced, I struggled with it at first but after working with it two or three more times I learned immensely from my mistakes and slowly became more and more prepared to tackle similar problems when I am dealt them in the future.

As of the time of writing this I have just finished the final exam for this class. I do not know my results yet, but I am very impressed by how well I have retained the information I have learned in this class. Usually, I struggle around finals because I feel like I have already forgotten everything and that I have to re-teach myself. This time, however, I believe that due to all of the repetitive practice I have had in this class, I have done a much better job at retaining my knowledge. Especially given how fundamental the concepts of electromagnetism are to this branch of engineering, I believe that this will prove to be invaluable to me moving forward while I continue working on my studies.

I think during this reflection it is also important for me to acknowledge the areas I could have done better in or that I would do differently in the future if given the chance. I wish that I would have spent more time outside of class doing supplemental learning. The game structure definitely benefitted me a lot, but due to the fact that we are doing them as groups in class together it meant there was less time for learning new material during class time. I think if I had read the resources of canvas ahead of time more often, I would have been better prepared for whatever would be thrown my way during class. This was not a major issue, but it is definitely something I can improve on moving forward.

Overall, I have really enjoyed learning the concepts behind electromagnetism. During our last class of the semester, I was reminded why I chose to be an electrical engineer. I often forget that this field isn't just about plugging numbers into a calculator or finding the optimal solution to a problem, but the last class reminded me about how cool what I am doing is. It's fascinating learning ways to manipulate these fundamental forces of the universe to do what we want. This feeling was magnified by the awe-inspiring experience of seeing the arch of electricity from a Tesla coil. The sudden demonstration of the power of electromagnetism never ceases to inspire me. Out of all of my Electrical Engineering classes, this is definitely the one that amplified this feeling the most. It's certainly true that electromagnetism is the most fundamental part of electrical engineering, and I have had a lot of fun learning about it this semester. I look forward to putting my new knowledge to use in the future.