Ph213 – Section D Quiz 4

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6.9±4.1

- **You have 15 minutes for this problem.**
- **I will not answer any questions about this problem.**
- **If you fail to specify (again!) a direction for B, you will receive a zero for this quiz, regardless of how much correct work you've done.**

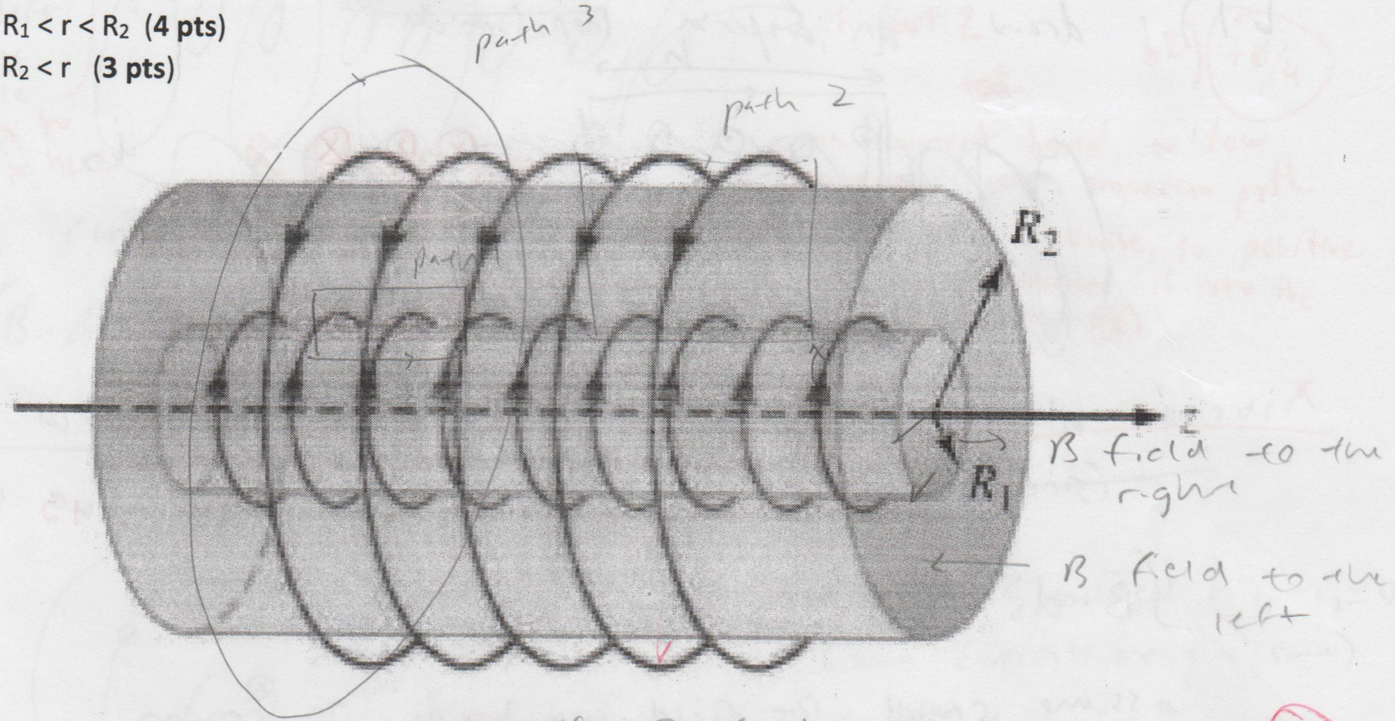
Two long solenoids are nested on the same (z) axis, as in the figure below. The inner solenoid has radius R_1 and n_1 turns per unit length. The outer solenoid has radius R_2 and n_2 turns per unit length. Each solenoid carries the same current I but the currents are flowing in opposite directions as indicated by the arrows.

You will be using Ampere's Law to find the total $\vec{B}$ field in 3 regions.

a) What approximations are **needed** to solve this problem with Ampere's Law? (Just concisely state the approximations. Don't write a book.) **(3 pts)**

b) Use Ampere's Law to find the total $\vec{B}$ field in the following three regions, showing your Amperian path[1] in each case. You can draw the three paths on the single diagram below, labelling them 1, 2, 3, for the three regions.

1) $r < R_1$ **(4 pts)**
2) $R_1 < r < R_2$ **(4 pts)**
3) $R_2 < r$ **(3 pts)**



No B field outside outer solenoid +1

[1] Yes, you can use a single Amperian path to find the field in each region.

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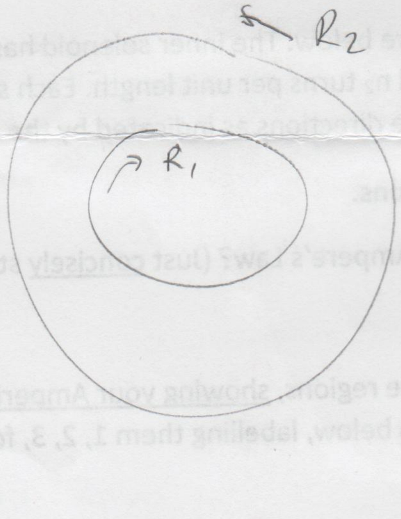
a) - tightly wrapped rings, i.e., turn density is high, approximately uniform field radially

- solenoid is long, i.e., no fringing/end behavior

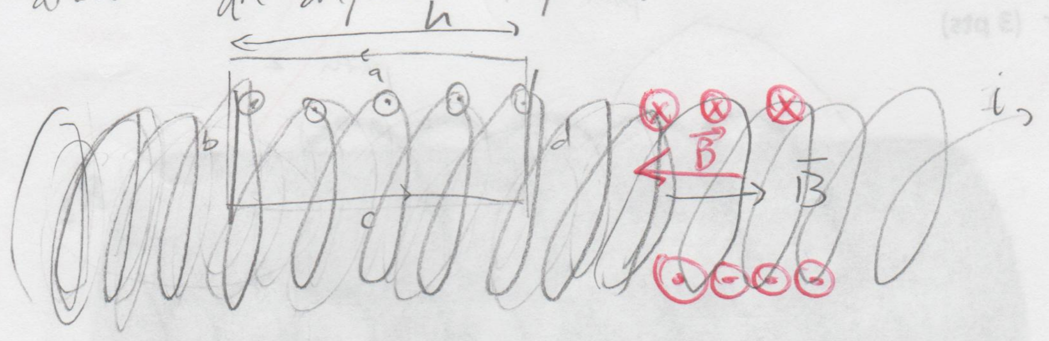
+2

B field = 0 outside solenoid assumptions point given on first page.
total +3/3 for part a)



a) +3/3
b) +3/11

b1) draw an amperian loop inside



along edges b, d, no contribution to b-field (since cosine would equal zero.)

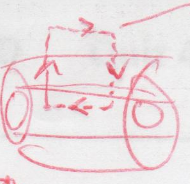
+3

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I$$

assume small B-field contribution to region outside this inner solenoid caused by this solenoid; thus most $\vec{B}$ field is along edge c.

what about B field from the other coil in the region outside the small solenoid.

$$\int \bar{B} \cdot d\bar{s} = \mu_0 I$$



This is the correct path. Or at least easier path to analyze.

all B pointing from the ~~right~~ left. in this diagram, so can sum magnitudes. Also, $\bar{B}$ field is parallel to the edge, so simple multiplication.

There is a B field outside the small solenoid

$$Bh = \mu_0 i n_1 h$$

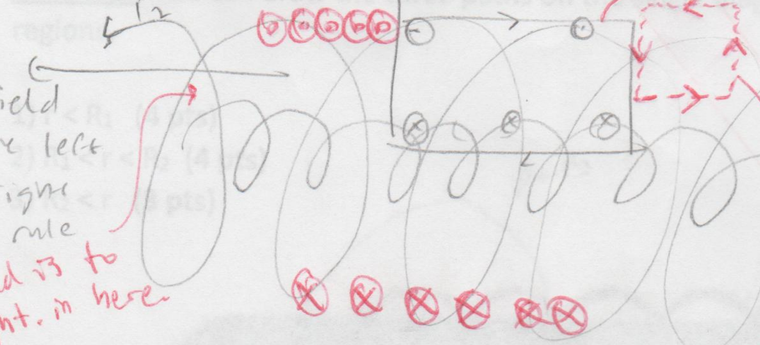
b1) +0/4

$$B = \mu_0 i n_1 \quad \text{✗}$$ where n is the turn density ($n_1 = \frac{\#\text{ turns}}{\text{distance}}$)

This is the B field inside the first solenoid.

I think you might have confused these. ⊗ = into page ⊙ = out of page.

b2) Assume contribution of



i_2

B field to the left by right hand rule

B field is to the right in here.

this is the solution to part 1.

← region in between

this is path for part 2

i_1

b2) +0/4

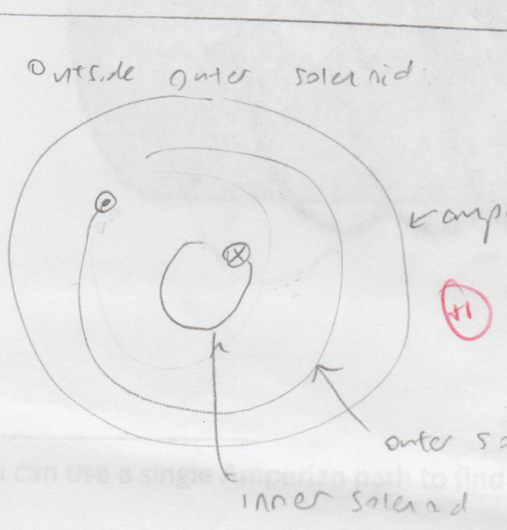
signs incorrect based on how you drew your amperian path. Clockwise, so positive $I_{enclosed}$ is into the page. (⊗)

current enclosed $= i n_2 - i n_1 = i(n_2 - n_1)$

$$\int \bar{B} \cdot d\bar{s} = \mu_0 I = \mu_0 i (n_2 - n_1) h$$

$$\bar{B} = \mu_0 i (n_2 - n_1)$$ to the left between solenoids ✗

b3) outside outer solenoid



+1

b3) +3/3

net current enclosed $= i_1 - i_2 = 0$ (since currents are the same)

Thus $\int B \cdot ds = \mu_0 I = 0$

$$B \cdot 2\pi R = 0$$

+2

$$B = 0 \ \checkmark$$

outside both solenoids.