Physics 172
Winter Quarter 1987
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George Williams

$N = 301$

$\langle X \rangle = 22.1$

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FOURTH MIDTERM

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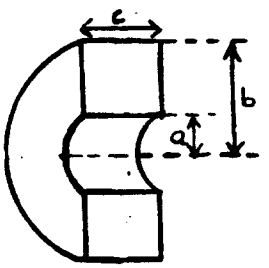
SHOW ALL WORK!!!!!
REPORT ALL NUMBERS TO THREE SIGNIFICANT FIGURES!
Use the conversion constants and data given on the front page.

Consider a toroid with a rectangular cross section and dimensions shown. The toroid has 975 turns of wire and carries a current of 2.75 A.

(a) Calculate the magnetic field within the toroid at any value of r between r = a and r = b. (This requires a numerical answer, except for r.)
(b) Calculate the flux crossing a section of the toroid of width c, between r = a and r = b/2. (This requires a numerical answer.)

a = 2.50 cm
b = 12.50 cm
c = 4.00 cm

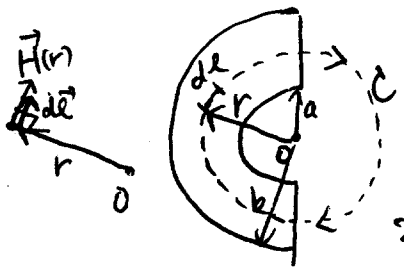


(15 points)

(a) By Ampère's law

[redacted] $= \oint_C \vec{B} \cdot d\vec{l} = \mu_0 \int \vec{J} \cdot d\vec{A} = \mu_0 I$

Now we take contour like this



$\vec{B} \cdot d\vec{l} = |\vec{B}|\,|d\vec{l}| \cos\theta$

$= 2\pi B(r)\, dr$ (B(r): constant)

$2\pi \int_0^r B(r)\, dr = B \cdot 2\pi r$

$= \mu_0 N I$ (N: number of current inside the contour)

$\therefore \boxed{B = \dfrac{\mu_0 N I}{2\pi r}}$

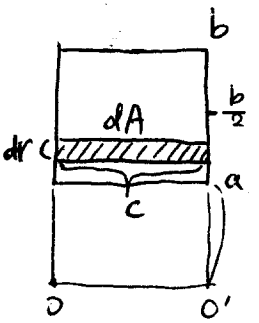
$B = \dfrac{4\pi \times 10^{-7}\, T\frac{m}{A} \times 2.75A \times 975}{2\pi \times r\, m} = \boxed{\dfrac{5.36 \times 10^{-4}}{r}\, T}$

(10 points)

(b)

The flux is given by

$\Phi = \int \vec{B} \cdot d\vec{A}$



Now we can define area dA like

$dA = c\, dr$

Therefore

$\Phi = \int_a^{b/2} B\, c\, dr = \dfrac{\mu_0 N I}{2\pi} c \int_a^{b/2} \dfrac{1}{r} dr$

$= \boxed{\dfrac{\mu_0 N I}{2\pi} c \ln\left(\dfrac{b}{2a}\right)}$

$\therefore \Phi = \dfrac{4\pi \times 10^{-7} \frac{T_m}{A} \times 2.75A \times 975 \times 4.00 \times 10^{-2} m}{2\pi} \times \ln\left(\dfrac{12.5}{2 \times 2.50}\right) \approx 1.965 \times 10^{-5}\, Wb$

$= \boxed{1.97 \times 10^{-5}\, Wb}$