Electrical & Computer Engineering Department
National University of Singapore

EE2011 Engineering Electromagnetics
Tutorial 5: Magnetic Fields

The tutorial discussion will focus on Questions 2 and 3 (which are marked by asterisks *).

1. **BASICS**

(a) A charged particle is initially travelling with velocity $\vec{v} = v_1 \hat{u}_x + v_2 \hat{u}_z$ (where v_1 and v_2 are constants). What do you expect to observe after it enters a region with uniform magnetic field $\vec{B} = B_0 \hat{u}_z$ (where B_0 is a constant)?

(b) Figure 1(b) depicts a current-carrying wire (formed by circular segments and radial lengths). Derive an expression for the magnetic flux density vector at P (which is the common center of the circular segments with radii *a* and *b*).

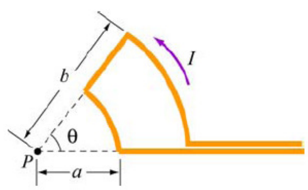

Figure 1(b)

(c) A thin circular disk of radius r_0 rotates with angular speed ω. Show that the magnetic field strength at the center of the disk (with uniform surface charge density σ) is given by $B = \frac{1}{2}\mu_0 \sigma \omega r_0$.

2. * Figure 2 depicts a rectangular wire loop (of length *l* and width *w*) which is placed in the vicinity of a long straight wire. Determine the mutual impedance between these two (with separation *s*).

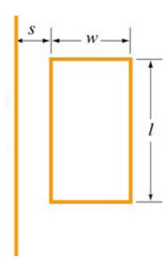

Figure 2

3. * Figure 3(a) depicts a circular wire loop (with radius r = 50 cm) which is connected to a resistor (with resistance R = 100 Ω). The uniform magnetic field $\vec{B}$ in the vicinity varies with time t in accordance with the plot reproduced in Figure 3(b). Sketch the variation of the current flowing in R as a function of time t, given that $\vec{B}$ is in the +z direction (as denoted by the circles with enclosed dots) and the corresponding positive convention for the circular loop is given by the faint arrow.

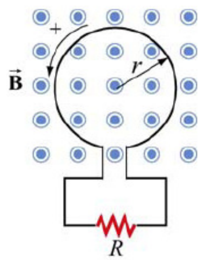

Figure 3(a)

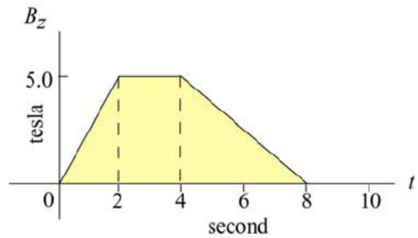

Figure 3(b)

4. Engineers often employ Helmholz coils to provide a region with sufficiently uniform magnetic field. As shown in Figure 4, the basic set-up comprises two identical coils that are symmetrically equidistant from the origin of the Cartesian coordinate system. Both coils have N turns of wire, radius R, current I and +z orientation.

Derive an expression for the magnetic field at any point on the z-axis and show that its first-order derivative is zero (*i.e.* $\frac{\partial B}{\partial z} = 0$) at the coordinate-system origin.

Derive the design condition for its second-order derivative to be zero (*i.e.* $\frac{\partial^2 B}{\partial z^2} = 0$) as well at the coordinate-system origin.

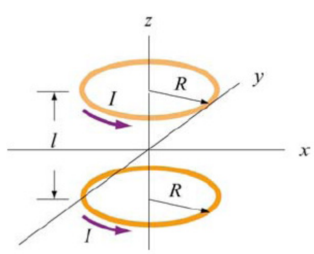

Figure 4

<u>Answers</u>:

1(b) $\frac{\mu_o I\theta}{4\pi}\left(\frac{1}{a} - \frac{1}{b}\right)$

2 $\frac{\mu_0 l}{2\pi}\ln\left(1 + \frac{w}{s}\right)$