Electromagnetic Fields Wangsness Solution

Electricity and Magnetisme Homework V Solution
Roald K. Wangsness, Electromagnetic Fields 2nd Edition, Chapter 19
by *Chalis Setyadi*

1. **Exercise 19-15** : A point dipole **m** is located at the origin, but it has no special orientation with respect to the coordinate axes. (For example,**m** is not parallel to any of the axes.) Express its potential **A** at a point **r** in rectangular coordinates, and find the rectangular components of **B**. Show that **B** can be written in the form

$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi r^3}\left[3\left(\mathbf{m}\cdot\hat{\mathbf{r}}\right)\hat{\mathbf{r}} - \mathbf{m}\right] \quad (19-55)$$

and compare with (8-84).

Solution : In rectangular coordinate, we can write :

$$\begin{aligned} \mathbf{m} &= m_x\hat{\mathbf{x}} + m_y\hat{\mathbf{y}} + m_z\hat{\mathbf{z}} \\ \mathbf{r} &= x\hat{\mathbf{x}} + y\hat{\mathbf{y}} + z\hat{\mathbf{z}} \\ r &= |\mathbf{r}| = \left(x^2+y^2+z^2\right)^{1/2} \end{aligned} \tag{1}$$

Then inserting equation (1) to equation (19-55) we get

$$\begin{aligned} \mathbf{B}(\mathbf{r}) &= \frac{\mu_0}{4\pi r^3}\left[3\left(\mathbf{m}\cdot\hat{\mathbf{r}}\right)\hat{\mathbf{r}} - \mathbf{m}\right] \\ &= \frac{\mu_0}{4\pi}\left[\frac{3\left(\mathbf{m}\cdot\mathbf{r}\right)\mathbf{r}}{r^5} - \frac{\mathbf{m}}{r^3}\right] \\ \mathbf{B}(x,y,z) &= \frac{\mu_0}{4\pi}\left[\frac{3\left(m_x x + m_y y + m_z z\right)\left(x\hat{\mathbf{x}} + y\hat{\mathbf{y}} + z\hat{\mathbf{z}}\right)}{\left(x^2+y^2+z^2\right)^{5/2}} - \frac{\left(m_x\hat{\mathbf{x}} + m_y\hat{\mathbf{y}} + m_z\hat{\mathbf{z}}\right)}{\left(x^2+y^2+z^2\right)^{3/2}}\right] \end{aligned} \tag{2}$$

And we can write

$$\begin{aligned} B_x &= \frac{\mu_0}{4\pi}\left[\frac{3\left(m_x x + m_y y + m_z z\right)x}{\left(x^2+y^2+z^2\right)^{5/2}} - \frac{m_x}{\left(x^2+y^2+z^2\right)^{3/2}}\right] \\ B_y &= \frac{\mu_0}{4\pi}\left[\frac{3\left(m_x x + m_y y + m_z z\right)y}{\left(x^2+y^2+z^2\right)^{5/2}} - \frac{m_y}{\left(x^2+y^2+z^2\right)^{3/2}}\right] \\ B_z &= \frac{\mu_0}{4\pi}\left[\frac{3\left(m_x x + m_y y + m_z z\right)z}{\left(x^2+y^2+z^2\right)^{5/2}} - \frac{m_z}{\left(x^2+y^2+z^2\right)^{3/2}}\right] \end{aligned} \tag{3}$$

Then we will show that we can get expressions in equation (3) from $\mathbf{B} = \nabla\times\mathbf{A}$ in rectangular coordinat.

The first problem in this exercise is expressing potential vector **A** in rect-

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