Physics 1B Spring 2010

Quiz 4 version A

Solution

1.(d)

As we know the general form of torque is,

$$\tau = BAI \sin\theta \tag{1}$$

θ is the angle between the magnetic moment and the magnetic field. In this problem, it's 90°. Applying the above formula, we'll get,

$$\begin{aligned} \tau &= BAI \sin 90^\circ \\ &= BAI \\ &= IBL^2 \end{aligned} \tag{2}$$

2.(c)

Please refer to Figure 1.

$$\begin{aligned} F &= qvB \sin\theta \\ &= 1.6 \times 10^{-19} C \times 3.8 \times 10^{6} m/s \times 0.25 \times 10^{-4} T \times \sin 70^\circ \\ &= 1.428 \times 10^{-17} N \end{aligned} \tag{3}$$

3.(b)

Please refer to Figure 2.

The magnetic force should be equal to the gravitational force acted on the conductor.

$$\begin{aligned} F_B &= IBl \\ &= mg \end{aligned} \tag{4}$$

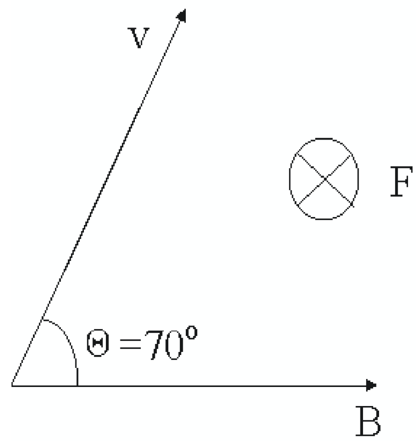

Figure 1:

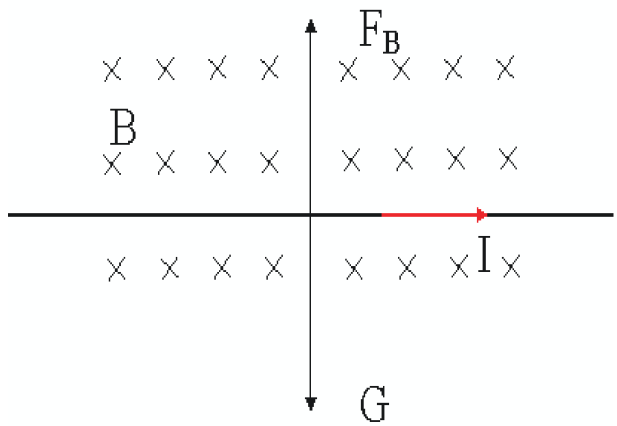

Figure 2:

Then

$$
\begin{aligned}
I &= \frac{mg}{Bl} \\
&= \frac{(\frac{m}{l})g}{B} \\
&= \frac{0.040kg/m \times 10N/kg}{3.6T} \\
&= 0.11A
\end{aligned} \tag{5}
$$

The direction is indicated in the figure.

4.(b)

Please refer to Figure 3. From cyclotron equation, we have

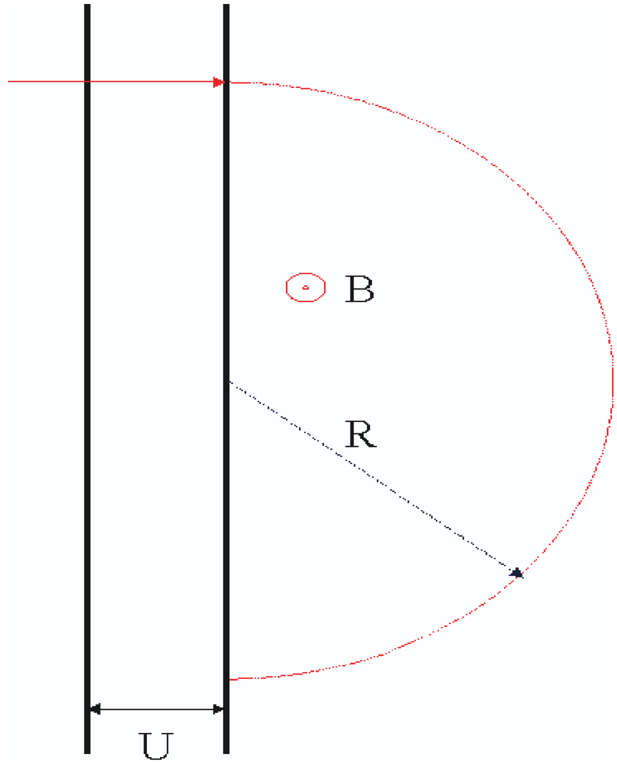

Figure 3:

$$R = \frac{mv}{qB} \tag{6}$$

After the ion passes through the potential U, it gains kinetic energy.

$$qU = \frac{1}{2}mv^2 \tag{7}$$

We get the velocity when the ion begins passing the magnetic field from Eq.7.

$$v = \sqrt{\frac{2qU}{m}} \tag{8}$$

Putting Eq.8 into Eq.6, we get the radius.

$$\begin{aligned} R &= \frac{mv}{qB} \\ &= \frac{m}{qB}\sqrt{\frac{2qU}{m}} \\ &= \sqrt{\frac{2mU}{qB^2}} \\ &= \sqrt{\frac{2 \times 2.5 \times 10^{-26} kg \times 1000V}{1.6 \times 10^{-19} C \times (0.5T)^2}} \\ &= 3.54 \times 10^{-2} m \\ &= 3.54 cm \end{aligned} \tag{9}$$

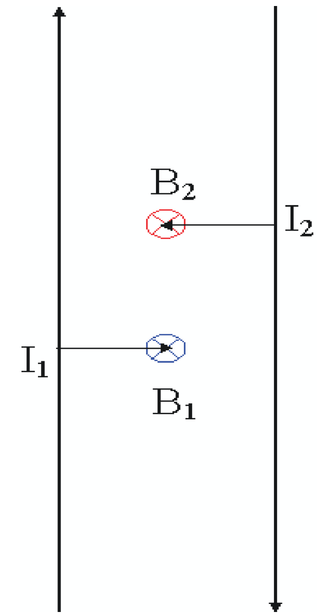

Figure 4:

5.(e)

Please refer to Figure 4. The magnetic fields created by the two wires are denoted in Figure 4. The magnetic field of a single long wire is

$$B = \frac{\mu_0 I}{2\pi r} \tag{10}$$

The two magnetic fields in Figure 4 then are B_1, B_2 respectively.

$$\begin{aligned} B_1 &= \frac{\mu_0 I_1}{2\pi r} \\ &= \frac{4\pi \times 10^{-7} T \cdot m/A \times 8.0A}{2\pi \times 0.2 \times 10^{-2} m} \\ &= 0.8 \times 10^{-3} T \end{aligned} \tag{11}$$

$$\begin{aligned} B_2 &= \frac{\mu_0 I_2}{2\pi r} \\ &= \frac{4\pi \times 10^{-7} T \cdot m/A \times 12.0A}{2\pi \times 0.2 \times 10^{-2} m} \\ &= 1.2 \times 10^{-3} T \end{aligned} \tag{12}$$

The resultant B field is $B_1 + B_2 = 2.0 \times 10^{-3} T$.

6.(e)

Please refer to Figure 5. The discussion is very similar to the last one. Two wires create two B

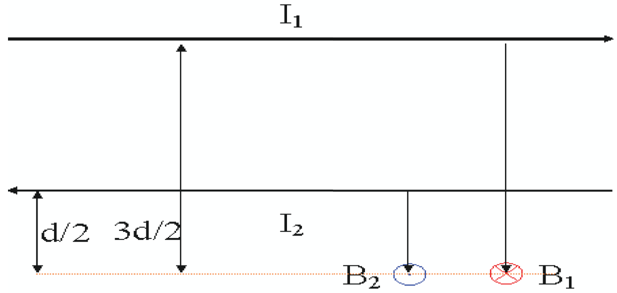

Figure 5:

fields, which are B_1 and B_2. The direction of B_1 is opposite from B_2.

$$\begin{aligned} B &= B_2 - B_1 \\ &= \frac{\mu_0}{2\pi}\left(\frac{I_2}{d/2} - \frac{I_1}{3d/2}\right) \\ &= \frac{4\pi \times 10^{-7} T \cdot m/A}{\pi}\left(5 - \frac{8}{3}\right) \times \frac{1}{18 \times 2 \times 10^{-2} m} \\ &= 2.6 \mu T \end{aligned} \tag{13}$$

B comes out of the page.

7.(c)

The magnetic field inside a solenoid is given by

$$B = \mu_0 n I = \mu_0 \frac{N}{l} I \tag{14}$$

From this, we get the current,

$$\begin{aligned} I &= \frac{Bl}{\mu_0 N} \\ &= \frac{5T \times 10 \times 10^{-2} m}{4\pi \times 10^{-7} T \cdot m/A \times 800} \\ &= 4.97 \times 10^2 A \end{aligned} \tag{15}$$

8.(e)

Please refer to Figure 6. The two currents create two B fields separately, which are B_1 and B_2. The directions of the B fields are shown in the figure. Now we'll calculate the magnitude. Notice

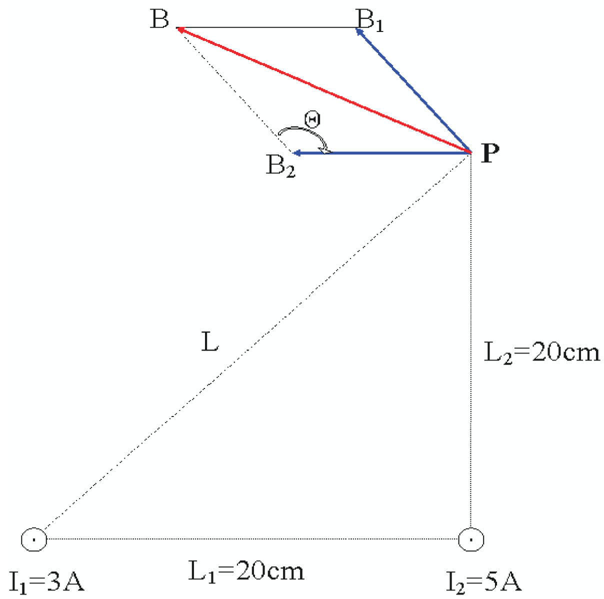

Figure 6:

$L = \sqrt{L_1^2 + L_2^2} = 20\sqrt{2}cm.$

$$\begin{aligned} B_1 &= \frac{\mu_0 I_1}{2\pi L} \\ &= \frac{4\pi \times 10^{-7} T \cdot m/A \times 3A}{2\pi \times 20\sqrt{2} \times 10^{-2} m} \\ &= 2.1213 \times 10^{-6} T \end{aligned} \tag{16}$$

$$\begin{aligned} B_2 &= \frac{\mu_0 I_2}{2\pi L_2} \\ &= \frac{4\pi \times 10^{-7} T \cdot m/A \times 5A}{2\pi \times 20 \times 10^{-2} m} \\ &= 5.0000 \times 10^{-6} T \end{aligned} \tag{17}$$

From the superposition of the vectors, we get the resultant B field. The magnitude of it is, (from the geometry relation, we can see $\theta = 135°$, labeled in the figure.)

$$\begin{aligned} B &= \sqrt{B_1^2 + B_2^2 - 2B_1 B_2 \cos\theta} \\ &= \sqrt{B_1^2 + B_2^2 - 2B_1 B_2 \cos 135°} \\ &= \sqrt{B_1^2 + B_2^2 + \sqrt{2} B_1 B_2} \\ &= \sqrt{2.1213^2 + 5.0000^2 + \sqrt{2} \times 2.1213 \times 5.0000} \times 10^{-6} T \\ &= 6.67 \times 10^{-6} T \\ &\simeq 6.7 \mu T \end{aligned} \tag{18}$$