Homework #6

(29-1) a) \[ F_B = q |\vec{B}| \sin \theta = (3.2 \times 10^{-17} \text{C})(550 \text{ m/s})(0.0457) \sin 52^\circ \]
\[ = 6.24 \times 10^{-18} \text{N} \]

b) \[ a = \frac{F_B}{m} = \frac{6.24 \times 10^{-18} \text{N}}{6.6 \times 10^{-27} \text{kg}} = 9.46 \times 10^8 \text{ m/sec}^2 \]

c) The magnetic force can do no work on a charged particle, so the speed of the particle remains equal to 550 m/s.

For all three cases, the magnetic force on the proton is

\[ \vec{F}_B = q \vec{v} \times \vec{B} \]

\[ \vec{F}_B = (1.6 \times 10^{-19} \text{C})(2000 \text{ m/s})( \hat{j} ) \times (2.5 \times 10^{-3} \text{T}) \]

\[ \vec{F}_B = 8 \times 10^{-17} \text{N} \hat{\mathbf{l}} \]

(29-2) a) \[ \vec{F} = \vec{F}_E + \vec{F}_B = q \vec{E} + \vec{F}_B \]
\[ = (1.6 \times 10^{-19} \text{C})(4 \frac{\text{N}}{\text{C} \cdot \text{m}}} \hat{\mathbf{E}}) + 8 \times 10^{-17} \text{N} \hat{\mathbf{l}} \]
\[ = 1.44 \times 10^{-18} \text{N} \hat{\mathbf{E}} \]

b) \[ \vec{F} = q \vec{E} + \vec{F}_B = (1.6 \times 10^{-19} \text{C})(-4 \frac{\text{N}}{\text{C} \cdot \text{m}}} \hat{\mathbf{E}}) + 8 \times 10^{-17} \text{N} \hat{\mathbf{l}} \]
\[ = 1.6 \times 10^{-19} \text{N} \hat{\mathbf{E}} \]

c) \[ \vec{F} = q \vec{E} + \vec{F}_B = (1.6 \times 10^{-19} \text{C})(4 \frac{\text{N}}{\text{C} \cdot \text{m}}} \hat{\mathbf{E}}) + 8 \times 10^{-17} \text{N} \hat{\mathbf{l}} \]
\[ = 6.4 \times 10^{-19} \text{N} \hat{\mathbf{E}} + 8 \times 10^{-17} \text{N} \hat{\mathbf{l}} \]
The magnitude of the force is

\[ F = \sqrt{(6.4 \times 10^{-19} N)^2 + (8 \times 10^{-19} N)^2} = 1.02 \times 10^{-18} N \]

(29-3)

We want

\[ \vec{F} = \gamma (\vec{E} + \vec{N} \times \vec{B}) = 0 \]

Since \( \vec{N} \perp \vec{B} \), this means that

\[ \vec{E} \perp \vec{N} \perp \vec{B} \] (note that \( \vec{N} \times \vec{B} \) points opposite \( \vec{E} \))

or \[ B = \frac{E}{N} \]

We now must find \( E \) and \( N \), the electron's speed.

Since \( E \) is constant between parallel plates, we use

\[ \Delta V = E \Delta d \lor E = \frac{\Delta V}{\Delta d} = \frac{100 \text{ V}}{20 \times 10^{-3} \text{ m}} = 5000 \text{ V} \]

The electron's kinetic energy is 1 keV, so

\[ \frac{1}{2} m v^2 = 1 \text{ keV} \text{ with } m = 9.11 \times 10^{-31} \text{ kg} \]

\[ \Rightarrow v = \sqrt{\frac{2(10^3 \text{ eV}) \times 1.6 \times 10^{-19} \text{ J}}{9.11 \times 10^{-31} \text{ kg}}} = 1.87 \times 10^7 \text{ m/s} \]

So \[ B = \frac{E}{v} = \frac{5000 \text{ V/m}}{1.87 \times 10^7 \text{ m/s}} = \boxed{2.67 \times 10^{-4} \text{ T}} \]

(29-4) From \( N = \frac{B_i}{(\Delta V)/e} \), \( \Delta V = \frac{B_i}{nle} \) so

\[ \Delta V = \frac{(0.65T \times 23A)}{(8.47 \times 10^{28} \text{ m}^3 \times 150 \times 10^{-6} \text{ m} \times 1.6 \times 10^{-19} \text{ C})} = 7.35 \times 10^{-6} \text{ V} \]
(29-5) a) Using \( K = \frac{1}{2} m \Delta V = \frac{1}{2} \text{ mV}^{-2} \) since the electron starts at rest,

\[
\Delta V = \sqrt{\frac{2K}{m}}
\]

\[
= \sqrt{\frac{2(1.6 \times 10^{-19} \text{C})(350 \text{V})}{9.11 \times 10^{-31} \text{kg}}}
\]

\[
= \sqrt{1.11 \times 10^{-7} \text{ mV sec}}
\]

b) \( r = \frac{m \Delta V}{1 \text{g/m}} = \left(9.11 \times 10^{-31} \text{kg} \times 1.11 \times 10^{-7} \text{ mV sec} \right) \]

\[= \left(1.6 \times 10^{-19} \text{C} \times 200 \times 10^{-3} \text{T} \right) \]

\[= 3.16 \times 10^{-4} \text{ m} \]

(29-6) \( T = \frac{2\pi \text{m}}{1 \text{g/m}} \) so \( m = \frac{1}{2\pi} (T \text{g/m}) \)

\[m = \frac{1}{2\pi} \left[\left(\frac{1.29 \times 10^{-2} \text{sec}}{7} \times 1.6 \times 10^{-19} \text{C} \right) \times (45 \times 10^{-3} \text{T})\right] \]

\[= 2.11 \times 10^{-25} \text{ Kg} \left(\frac{1 \text{ u}}{1.6 \times 10^{-27} \text{kg}}\right) = 127 \text{ u} \]

(29-7) a) \( r = \frac{m \Delta V}{1 \text{g/m}} \) so \( \Delta V = \frac{1 \text{g/m} \times \text{m}}{m} \)

\[\Rightarrow \Delta V = \frac{2(1.6 \times 10^{-19} \text{C})(1.2 \times 0.045 \text{m})}{4 \left(1.6 \times 10^{-27} \text{kg}\right)} = 2.60 \times 10^{-6} \text{ m/V sec} \]

b) \( T = \frac{2\pi r}{\Delta V} = \frac{2\pi (0.045 \text{m})}{2.6 \times 10^{-6} \text{ m/V sec}} = 1.09 \times 10^{-7} \text{ sec} \)

c) \( K = \frac{1}{2} m \Delta V^2 = \frac{1}{2} \left(4 \times 1.6 \times 10^{-27} \text{kg}\right) \left(2.6 \times 10^{-5} \text{m/V sec}\right)^2 \times (1 \text{ eV}) \)

\[= 1.40 \times 10^5 \text{ eV} \]

d) Since the alpha particle has charge of \( q = +2e \), it was accelerated (assumed starting at rest) through

\[\Delta V = \frac{1.40 \times 10^5 \text{ eV}}{2} = 7.0 \times 10^4 \text{ V} \]
(29-8) \[
a) \quad r = \frac{m v}{q B} = \frac{(1.67 \times 10^{-27} \text{ kg})(0.1)(3 \times 10^8 \text{ m/s})}{(1.6 \times 10^{-19} \text{ C})(1.4 \text{ T})} = 0.224 \text{ m} \\
b) \quad f_{osc} = \frac{1}{T} = \frac{N}{2\pi r} = \frac{(0.1)(3 \times 10^8 \text{ m/s})}{2\pi(0.224 \text{ m})} = 2.13 \times 10^7 \text{ Hz}
\]

(29-9)

By the right hand rule for \( \vec{F}_B = i L \times \vec{B} \), the current flows from left to right to create an upward force that balances gravity.

Because \( L \perp B \), we have \( F_B = mg \) (magnitudes)

\[ iLB \sin 90^\circ = mg \]

So \( i = \frac{mg}{LB} = \frac{(13 \times 10^{-3} \text{ kg})(9.8 \text{ m/s}^2)}{(0.62 \text{ m})(0.440 \text{ T})} = 0.467 \text{ A} \]

(29-10)
Recall that torque is $\tau = rF \sin \phi$

There is no torque on side 1 (the pivoted side) because $r=0$.

Using $\vec{F}_B = i \vec{L} \times \vec{B}$ on the top (side 2) and bottom (side 3), we find that the magnetic forces $\vec{F}_2$ and $\vec{F}_3$ are in the plane of the coil. This can’t cause the coil to rotate, so the torques on sides 2 and 3 are zero.

For side 4, the torque is $\tau = r \vec{F}$ Another top view,

The magnitude of the torque on side 4 is

$\tau = rF \sin 60^\circ \times (\# \text{ turns})$

$= r \times LB \sin 60^\circ N$

$= (0.05 \text{ m})(0.1 \text{ A})(0.1 \text{ m})(0.5 \text{ T}) \sin 60^\circ(20)$

$= 4.33 \times 10^{-3} \text{ N} \cdot \text{m}$

The direction of the torque vector is in the direction of $\vec{r} \times \vec{F}_B$, downward ($-y$) direction.
(29-11) a) \( \mu = NiA = Ni\pi r^2 \) for a circular loop

So \( i = \frac{\mu}{Ni\pi r^2} = \frac{2.30 A.m^2}{(160)(\pi)(0.019 m)^2} = \boxed{12.7 A} \)

b) \( z = \mu B \sin \phi \) \( \text{For max } \mu, \text{ set } \phi = 90^\circ \)

\( \Rightarrow z_{max} = \mu B = (2.3 A.m^2 \times 35 \times 10^{-3} T) \)

\( = \boxed{8.05 \times 10^{-2} N.m} \)

(29-12) With \( N = 1 \) turn, \( \mu = iA = i\pi R^2 \) for a circular loop

\( i = \frac{\mu}{\pi r^2} = \frac{8 \times 10^{-2} A.m^2}{\pi (3500 \times 10^3 m)^2} = \boxed{2.08 \times 10^{-7} A} \)

Wow!