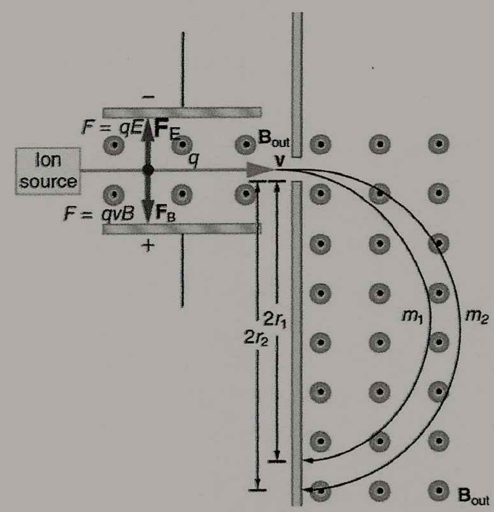

Figure 2: A basic diagram of a *toroid*, which is a solenoid wrapped into a circular tube.

2. Consider Fig. 2. **Mass spectrometer**. Suppose that the velocity of the charged particles moving to the right is $v = E/B$. (a) Show that if $v = E/B$, $F_{net} = 0$ in the region in the top left[1]. (b) Recall that the centripetal force on a particle of mass m is mv^2/r. Set this equal to the magnitude of the Lorentz force to prove that

a) Electrical $= qE$ $\quad qE + qvB = 0$
Fmag $= qv \cdot B$ (downwards) $\quad \frac{qE}{B} = \frac{qvB}{B} \quad \frac{E}{B} = v$

$$r = \frac{mE}{qB^2} \tag{2}$$

The mass of an oxygen nucleus is 16 times that of a proton (mass of proton: 1.67×10^{-27} kg). Suppose oxygen ions with the charge of 1 proton are sent through the mass-sepctrometer. The E-field is 10 V/m, and the B-field is 0.01 T. What is the distance r?

b) centripital force $= mv^2/r$
$qvB = \frac{mv^2}{r}$ $\quad r = \frac{mv}{qB}$ $\quad v = E/B$ $\quad r = \frac{m\,E/B}{qB}$ $\quad r = \frac{mE}{qB^2}$

$r = \frac{(1.67 \cdot 10^{-27})(10 V/m)}{(1.6 \cdot 10^{-19} C)(.01)^2}$

$r = .0167 m$

4 Chapter 13: Electromagnetic Induction

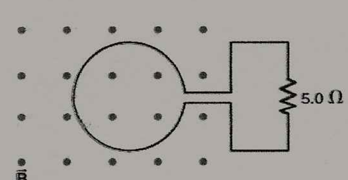

Figure 3: A voltage is induced on a loop by a changing B-field.

1. The magnetic field in Fig. 3 flows out of the page through a single ($N = 1$) loop, and changes in magnitude according to

$$\frac{\Delta B}{\Delta t} = \frac{B_0}{T_0}\left(\sin(2\pi f t)\right) \tag{3}$$

The loop has a radius r. (a) In terms of the given variables, what is the induced voltage in the circuit? (b) If $B_0 = 0.1$ T, $r = 0.1$ m, $f = 10^3$ Hz, and $T = 1$ ms, what is the induced emf at $t = 0$? (c) What about $t_1 = 0.16$ ms? (d) What is the current through the resistor at t_1?

a) Induced voltage $V \cdot s/A = \Omega s$
$\mathcal{E} = -\frac{mdI}{dt}$, $\mathcal{E}$ Blv $\quad \frac{\Delta B}{\Delta t} = \frac{T}{s}$ $\quad Hz\,s \quad \frac{Vs}{m^2} \quad \frac{1}{s}\left(\frac{1}{1}\right)s$
$\mathcal{E} = N\frac{\Delta\Phi}{\Delta t} = NBA = NB(\pi r^2)$
$N\left(\frac{\Delta B}{\Delta t}\right)(\pi r^2) = N\left(\frac{B}{T}\sin(2\pi f t)\right)(\pi r^2)$

b) $\mathcal{E} = 1\left(\frac{.1T}{1 \cdot 10^{-3}s}\right)\sin(2\pi(10^3 Hz)(0))\pi(.1m)^2$
$\mathcal{E} = 1\left(\frac{.1T}{1 \cdot 10^{-3}s}\right)\sin 0 \quad \mathcal{E} = 0V$ b)
c) $\mathcal{E} = 1\left(\frac{.1T}{10^{-3}s}\right)\sin(2\pi(10^3 Hz)(.16 \cdot 10^{-3}))\pi(.1m)^2$
$100\,T/s\ \sin(1.0053\,Hz\,s)\ .03$ $\quad \mathcal{E} = .052V$ c)
d) $I = V/R$, $V = .052V$, $R = 5\Omega$ $\quad .052V/5\Omega$ $\quad .0105A$ d)

[1]Molecules that do not have this velocity will hit the sides of this portion of the instrument.