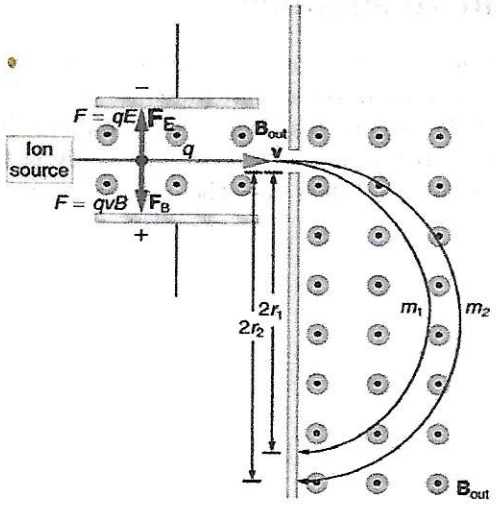

Figure 2: A basic diagram of a *toroid*, which is a solenoid wrapped into a circular tube.

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

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

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?

a) $F_{T,1} = F_e + F_M = 0$ $E = vB \Rightarrow v = \frac{E}{B}$ for $F_{net} = 0$ b) $r = \frac{mv}{qB} = \frac{m\frac{E}{B}}{qB} = \frac{mE}{qB^2} \Rightarrow$

$q[E + v \times B] = 0$ $F_{T,1} = q(E - v \times B) = 0$

radius $= \frac{16(1.67 \times 10^{-27})(10)}{(1.602 \times 10^{-19})(0.01)^2}$

(radius $= 1.67 < m$

4 Chapter 13: Electromagnetic Induction

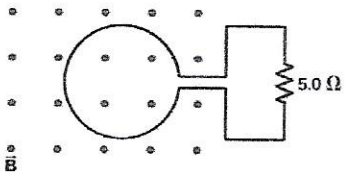

Figure 3: A voltage is induced on a loop by a changing B-field.

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

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

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) $\frac{d\Phi}{dt} = \frac{d(BA)}{dt} = \frac{d(B)}{dt}$ b) induced emf @ $t = 0$ is 0

$\mathcal{E} = \pi r^2 \cdot \frac{B_0}{T_0} \sin(2\pi f t)$ d) $I = \frac{\mathcal{E}}{R} =$

$I = 0.011$ A

c) $\mathcal{E} = \pi(0.1)^2 \cdot \frac{0.1}{1\text{ms}} \times \sin\left(2\pi \times 10^3 \frac{1}{\text{ms}} \times 0.16 \times 10^{-3}\text{ms}\right)$

$\mathcal{E} = 3.14 \times (0.1)^2 \times 0.16 \times 10^{-3} \times 0.175$

$\mathcal{E} = 0.0558$ V

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