**33.30. Solve:** **(a)** From Equation 33.19, the cyclotron radius is

$$r_{\text{elec}} = \frac{mv}{qB} = \frac{(9.11\times10^{-31}\ \text{kg})(1.0\times10^{6}\ \text{m/s})}{(1.60\times10^{-19}\ \text{C})(5.0\times10^{-5}\ \text{T})} = 0.114\ \text{m} = 11.4\ \text{cm}$$

**(b)** For the proton,

$$r_{\text{proton}} = \frac{(1.67\times10^{-27}\ \text{kg})(5.0\times10^{4}\ \text{m/s})}{(1.60\times10^{-19}\ \text{C})(5.0\times10^{-5}\ \text{T})} = 10.4\ \text{m}$$

**33.34. Model:** Assume that the field is uniform. The wire will float in the magnetic field if the magnetic force on the wire points upward and has a magnitude *mg*, allowing it to balance the downward gravitational force.

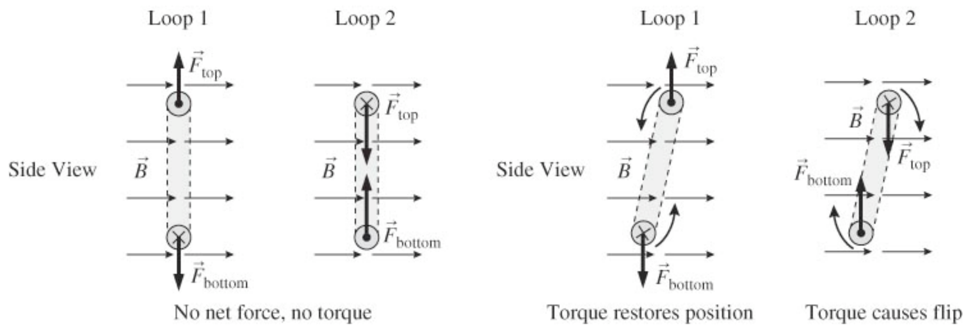
**Visualize:** Please refer to Figure EX33.34.

**Solve:** We can use the right-hand rule to determine which current direction experiences an upward force. The current being from right to left, the force will be *up* if the magnetic field $\vec{B}$ points out of the page. The forces will balance when

$$F = ILB = mg \Rightarrow B = \frac{mg}{IL} = \frac{(2.0 \times 10^{-3}\ \text{kg})(9.8\ \text{m/s}^2)}{(1.5\ \text{A})(0.10\ \text{m})} = 0.131\ \text{T}$$

Thus $\vec{B}$ = (0.131 T, out of page).

**33.38. Model:** The torque on a current loop is due to the magnetic field.
**Visualize:**




(a) (b)

**Solve:** **(a)** We can use the right-hand rule to find the force direction on the currents at the top, bottom, front, and back segments of loop 1 and loop 2 in Figure P26.36. We see that $\vec{F}_{top}$ and $\vec{F}_{bottom}$ are equal and opposite to each other. $\vec{F}_{front}$ and $\vec{F}_{back}$ are not seen in the figure above because they are perpendicular to the page. But, they are also equal and opposite to each other.

Thus, $\vec{F}_{top}+\vec{F}_{bottom}=\vec{0}$ and $\vec{F}_{front}+\vec{F}_{back}=\vec{0}$. Since the top-bottom or front-back forces act along the same line, they cause no torque. Thus, both the loops are in static equilibrium.

**(b)** Now let us rotate each loop slightly and re-examine the forces. The two forces on loop 1 still give $\vec{F}_{net}=\vec{0}$, but now there is a torque that tends to rotate the left loop *back* to its upright position. This is a restoring torque, so this loop position is stable. But for loop 2, the torque causes the loop to rotate even further. Any small angular displacement gets magnified into a large displacement until the loop gets flipped over. So, the position of loop 2 is unstable.

**33.58. Visualize:** Please refer to Figure P33.58.

**Solve:** The electric field is

$$\vec{E} = \left(\frac{200\text{ V}}{1\text{ cm}}, \text{down}\right) = (20{,}000\text{ V/m, down})$$

The force this field exerts on the electron is $\vec{F}_{\text{elec}} = q\vec{E} = -e\vec{E} = (3.2\times10^{-15}\text{ N, up})$. The electron will pass through without deflection *if* the magnetic field also exerts a force on the electron such that $\vec{F}_{\text{net}} = \vec{F}_{\text{elec}} + \vec{F}_{\text{mag}} = 0\text{ N}$. That is, $\vec{F}_{\text{mag}} =$ $(3.2\times10^{-15}\text{ N}, 3.2\times10^{-15}\text{ N, down})$. In this case, the electric and magnetic forces cancel each other. For a *negative* charge with $\vec{v}$ to the right to have $\vec{F}_{\text{mag}}$ down requires, from the right-hand rule, that $\vec{B}$ point *into* the page. The magnitude of the magnetic force on a moving charge is $F_{\text{mag}} = qvB$, so the needed field strength is

$$B = \frac{F_{\text{mag}}}{ev} = \frac{3.2\times10^{-15}\text{ N}}{(1.60\times10^{-19}\text{ C})(1.0\times10^{7}\text{ m/s})} = 2.0\times10^{-3}\text{ T} = 2.0\text{ mT}$$

Thus, the required magnetic field is $\vec{B}$ = (2.0 mT, into page).

**33.64. Model:** Charged particles moving perpendicular to a uniform magnetic field undergo circular motion at constant speed.
**Visualize:** Please refer to Figure P33.64.
**Solve:** The potential difference causes an ion of mass $m$ to accelerate from rest to a speed $v$. Upon entering the magnetic field, the ion follows a circular trajectory with cyclotron radius $r = mv/eB$. To be detected, an ion's trajectory must have radius $d = 2r = 8$ cm. This means the ion needs the speed

$$v = \frac{eBr}{m} = \frac{eBd}{2m}$$

This speed was acquired by accelerating from potential $V$ to potential 0. We can use the conservation of energy equation to find the voltage that will accelerate the ion:

$$K_1 + U_1 = K_2 + U_2 \Rightarrow 0\text{ J} + e\Delta V = \tfrac{1}{2}mv^2 + 0\text{ J} \;\Rightarrow \Delta V = \frac{mv^2}{2e}$$

Using the above expression for $v$, the voltage that causes an ion to be detected is

$$\Delta V = \frac{mv^2}{2e} = \frac{m}{2e}\left(\frac{eBd}{2m}\right)^2 = \frac{eB^2d^2}{8m}$$

An ion's mass is the sum of the masses of the two atoms *minus* the mass of the missing electron. For example, the mass of $N_2^+$ is

$$m = m_N + m_N - m_{elec} = 2(14.0031\text{ u})(1.661 \times 10^{-27}\text{ kg/u}) - 9.11 \times 10^{-31}\text{ kg} = 4.65174 \times 10^{-26}\text{ kg}$$

Note that we're given the atomic masses very accurately in Exercise 28. We need to retain this accuracy to tell the difference between $N_2^+$ and $CO^+$. The voltage for $N_2^+$ is

$$\Delta V = \frac{\left(1.6\times10^{-19}\text{ C}\right)\left(0.200\text{ T}\right)^2\left(0.08\text{ m}\right)^2}{8\left(4.65174\times10^{-26}\text{ kg}\right)} = 110.07\text{ V}$$

| Ion | Mass (kg) | Accelerating voltage (V) |
|---|---|---|
| $N_2^+$ | $4.65174 \times 10^{-26}$ | 110.07 |
| $O_2^+$ | $5.31341 \times 10^{-26}$ | 96.36 |
| $CO^+$ | $4.64986 \times 10^{-26}$ | 110.11 |

**Assess:** The difference between $N_2^+$ and $CO^+$ is not large but is easily detectable.