Exercise 1. Electric Field Lines

Draw the electric field lines for (a) an isolated silver ion Ag^+, (b) a water molecule, (c) an argon atom at rest, (d) an argon atom moving.

Exercise 2. Magnetic Field Lines

Draw the magnetic field lines for (a) an isolated silver atom with one net spin up $Ag^{\uparrow}$, (b) a calcium ion Ca^{2+} moving, (c) a chlorine molecule Cl_2 at rest, (d) a chlorine molecule Cl_2 moving.

Exercise 3. Magnetic Flux I

The magnetic flux through a square of sidelength 1 [cm], if the field is perpendicular to the surface of the square and the strength of the magnetic field is 1 [T]:

(a) 10^0 [Wb]
(b) 10^{-2} [Wb]
(c) 10^{-4} [Wb]*
(d) 10^{-6} [Wb]

Exercise 4. Magnetic Flux II

The magnetic flux through a ring of diameter 1.596 [cm], if the field is at a 30° to the hole in the ring with strength 4 [T]:

(a) 1×10^{-4} [Wb]
(b) 2×10^{-4} [Wb]
(c) 4×10^{-4} [Wb]*
(d) 8×10^{-4} [Wb]

Exercise 5. "Magnetic Fields do no Work"

Consider the statement: "magnetic fields do work." (a) Is this statement true or false? (b) Given your answer to (a) explain cyclotron motion where charged particles in a perpendicular magnetic field orbit in circles at a uniform velocity.

Exercise 6. Cyclotron Motion with a Twist

Suppose that an electron is moving in the plane with an initial velocity v, and at $t = 0$ a uniform magnetic field is turned on at an angle of 80° to the plane. Describe the subsequent motion:

(a) circular orbits in the plane
(b) helical orbits along the z axis
(c) circular orbits around the $\hat{B}$ direction
(d) it depends on the initial velocity
(e) elliptical orbits in the plane
(f) helical orbits along the $\hat{B}$ direction*
(g) elliptical orbits around the $\hat{B}$ direction
(h) none of the above

Exercise 7. Cyclotron Motion I

What is the cyclotron radius of an electron in copper for which the Fermi velocity is 1.57×10^6 [m/s] where $m_e = 9.11 \times 10^{-31}$ [kg], and $m_{\text{effective}} = 1.01 m_e$, and $q = 1.60 \times 10^{-19}$ [C] in a perpendicular magnetic field of strength 10 [T]. Give your answer in lattice constants $a = 3.61 \times 10^{-10}$ [m]. Hint: $R = mv/qB$.

(a) $2.5a$

(b) $25a$

(c) $250a$

(d) $2500a$*

(e) $25000a$

(f) $250000a$

Exercise 8. Cyclotron Motion II

Suppose that we are told that in a field of 1 [T] the cyclotron orbits in a zinc sample have radius $R = 8.86 \times 10^{-6}$ [m] and we know that the Fermi velocity in zinc is 1.83×10^{-6} [m/s]. What is the effective mass of the electron in zinc?

(a) $0.85 m_e$*

(b) $0.99 m_e$

(c) $1.12 m_e$

(d) $1.28 m_e$

Exercise 9. Mass Spectrometer

Suppose that a beam of ions each with charge $+e = 1.602 \times 10^{-19}$ [C] enter a mass spectrometer at velocity 3×10^4 [m/s]. In the mass spectrometer, there is a narrow slit a distance 1 [cm] along and 1 [cm] across from where the beam enters. If the strength of the magnetic field in the mass spectrometer is 2 [T], what mass ions pass through the slit? Answer in atomic mass units 1 [amu] $= 1.66 \times 10^{-27}$ [kg].

(a) 32 [amu]

(b) 64 [amu]*

(c) 128 [amu]

(d) 192 [amu]

Exercise 10. Lorentz Force for Currents

From $F = qv \times B$ it follows that $dF = dqv \times B$. With a current $q = I\ell/v$. Show that $dF = Id\ell \times B$.