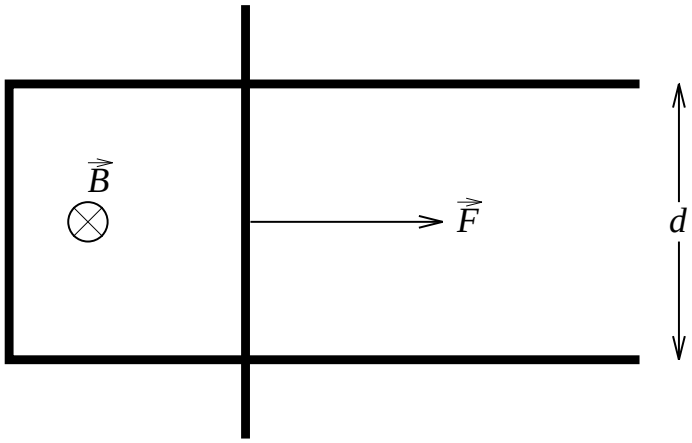

E & M Proficiency Exam, Spring 2001

Useful constants:

$$\begin{aligned} e &= 1.60 \times 10^{-19}\ \text{C} \\ hc &= 1240\ \text{eV} \cdot \text{nm} \\ c &= 3.00 \times 10^{8}\ \frac{\text{m}}{\text{s}} \\ m_e &= 0.511\ \frac{\text{MeV}}{\text{c}^2} \\ k &= \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^{9}\ \frac{\text{Nm}^2}{\text{C}^2} \\ \epsilon_0 &= 8.85 \times 10^{-12}\ \frac{\text{C}^2}{\text{Nm}^2} \end{aligned}$$

1. The two rails of a superconducting track are separated by a distance d. A conductor can slide along the track. The conductor, initially at rest, is pulled to the right by a constant force F. The friction force between the conductor and the track is directly proportional to its velocity with a proportionality constant α. The portion of the conductor between the rails has a resistance of R. The entire setup is in a uniform magnetic field $\vec{B}$ as shown in the figure. The field $\vec{B}$ points *into* the page.

   (a) What is the direction of the induced current in the conductor?

   (b) Determine the magnitude of the velocity of the conductor as a function of time.

   (c) Determine the magnitude of the induced current as a function of time.

   (d) Determine the terminal velocity of the conductor.

2. Consider a circuit consisting of a resistance $R = 6\ \Omega$, an inductance $L = 0.5$ H and a capacitance $C = 0.02$ F, all connected in series. A sinusoidal voltage $V(t) = V_0 \sin(\omega t)$ is applied to this LCR circuit.

   (a) What is the impedance of the circuit as a function of ω?

   (b) Find the resonance frequency.

   (c) Assume now that $V_0 = 240$ V and $\omega = 10$ rad/s. Assume that both the current and the charge vanish at $t = 0$. Obtain the charge on the capacitor, $Q(t)$, for these initial conditions.

3. A parallel plate capacitor with capacitance C is charged to a potential difference V and is then disconnected from the charging source. The capacitor has an area A and a plate separation z.

   (a) What is the force acting on the upper capacitor plate as a function of z?

   (b) Assume now that a glass plate of the same area A completely fills the space between the plates. The glass has a dielectric constant κ. How much work is required to pull the glass plate out of the capacitor?