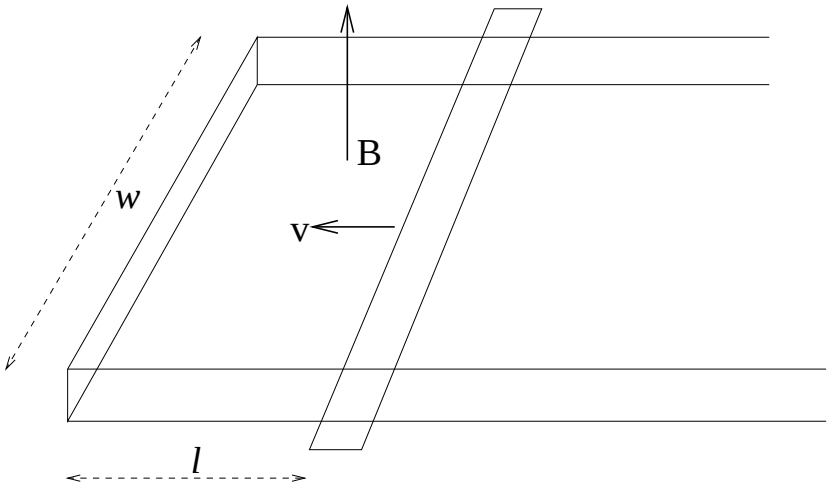
PHY6938 E & M Fall '97 July 10, 2000

Note: hand in questions 1 and 3 as homework; we will work 2 and 4 in class on Friday.

1. A bar slides along two parallel rails separated by a distance w, with no friction and with velocity v. The parallel bars, connector, and sliding bar are all made of a conductor with resistance r per unit length. The bars are in a uniform magnetic field B which is perpendicular to the plane of the bars and directed upward. Assume the bar starts at a distance l from the end.



a) Show the direction of the current and the force on the bar due to the field.

b) Find the current in the bar as a function of time.

c) Find the electrical power dissipated in the loop as a function of time.

d) Find the mechanical power which must be provided to move the bar with velocity v.

2. A superconducting (SC) solenoid is to be wound from superconducting wire having a critical current density $J_c = 10^5$ A/cm^2 at 15 T (J_c is the current above which the resistance of the wire suddenly becomes very large compared to the resistance of the copper) and a diameter of 2 mm. The wire is clad with a copper sheath of thickness 0.5 mm. The magnet has a field of 15 T, a bore (inner diameter) of 1 m, and is 2 m long. Remember that the resistance of a superconductor in the superconducting state is exactly zero.

Use the long solenoid approximation to determine the requested characteristics including the approximation that the flux is confined to the innermost winding. You may also assume the layer thickness is very small compared with the inner diameter of the solenoid, obviously a good approximation. (Note this magnet is approximately the size of the SC outsert of the new hybrid under construction at the NHMFL. These are to be only "back of the envelope" calculations to give some idea of the parameters.)

$m_0 = 4\pi \times 10^{-7}$ T·m/A; the resistivity of Cu is 1.7×10^{-8} Ω·m.

a) What is the maximum current the SC wire can carry and remain superconducting at 15 T?

b) How many layers of wire are needed to produce the 15 T field, and how many total turns?

c) What is the resistance of the Cu sheath?

d) What is the inductance of the solenoid?

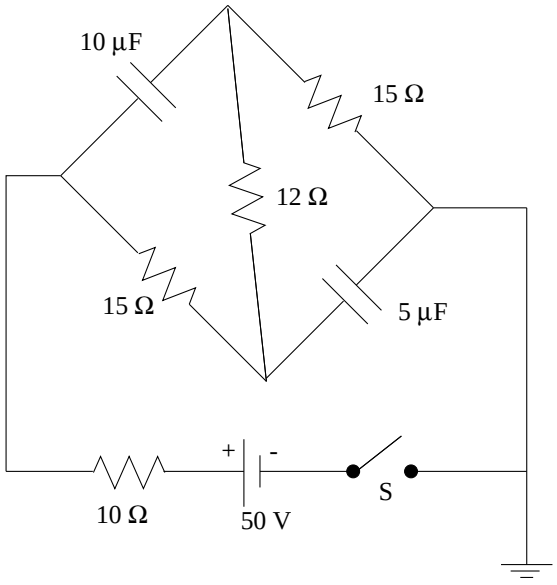
e) How much energy is stored in the solenoid when it is at full field and superconducting?

For the parts below assume the Cu part of the coil is shorted so the circuit is a resistance and inductance in series.

f) If the magnet quenches, that is if the resistance of the SC suddenly becomes very large, what will be the maximum voltage across the solenoid (and thus the Cu sheath)?

g) Find the current in the Cu sheath as a function of time after the quench. Assume the equivalent circuit is just the Cu sheath of the solenoid shorted with a conductor of negligible resistance.

3. The capacitors in the circuit shown in the figure are initially uncharged.



a) What is the initial value of the current drawn from the battery when the switch S is closed?

b) What is the current drawn from the battery a long time after the switch is closed?

c) What are the final charges on the capacitors?

4) A large slab of dielectric material with a plane surface is inserted into an electric field **E**,

such that $\mathbf{E}$ is at an angle θ with the normal to the surface of the dielectric. The dielectric constant of the dielectric is $\epsilon = \kappa\epsilon_0$.

a) Find the magnitude of $\mathbf{E}$ and the magnitude of the displacement vector $\mathbf{D}$ inside the dielectric.

b) Find a relationship between the dielectric constant and the angle $\mathbf{E}$ and $\mathbf{D}$ make with the normal inside the dielectric. Sketch $\mathbf{E}$ and $\mathbf{D}$ inside the dielectric assuming $\epsilon = 3\epsilon_0$ and $\theta = 30°$.