MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Experimental Study Group

Physics 8.022, Spring 2011

Problem Set 7
Magnetic Force, Special Relativity, Review

Due: Monday, March 28 at 10 pm
Review past concepts & problems!!!
Reading on complex numbers: `http://web.mit.edu/sahughes/www/8.022/complex.pdf`

Problem 1:

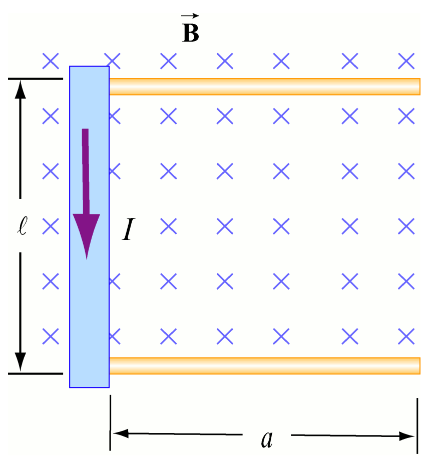
Particle A with charge q and mass m_A and particle B with charge $2q$ and mass m_B, are accelerated from rest by a potential difference ΔV, and subsequently deflected by a uniform magnetic field into semicircular paths. The radii of the trajectories by particle A and B are R and $2R$, respectively. The direction of the magnetic field is perpendicular to the velocity of the particle. What is their mass ratio?

Problem 2:

Let us treat the motion of an electron in a hydrogen atom classically. Suppose that an electron follows a circular orbit of radius r around a proton. What is the angular frequency of the orbit ω? Suppose now that a *small* magnetic field perpendicular to the plane of the orbit is switched on. Assuming that the radius of the orbit does not change, calculate the shift in orbital frequency in terms of the magnitude of B. This is known as the "Zeeman effect".

Problem 3:

A rod with a mass m and a radius R is mounted on two parallel rails of length a separated by a distance ℓ, as shown in the figure below. The rod carries a current I and rolls without slipping along the rails which are placed in a uniform magnetic field $\vec{B}$ directed into the page. If the rod is initially at rest, what is its speed as it leaves the rails?



Problem 4:

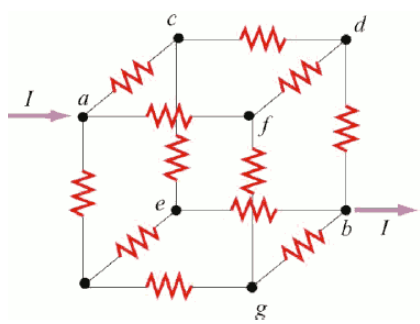
A wire of arbitrary shape which is confined to the $x-y$ plane carries a current I from point A to point B in the plane. Show that if a uniform magnetic field B perpendicular to the $x-y$ plane is present, the force that the wire experiences is the same as that which would be felt by a wire running straight from A to B.

Problem 5:

Calculate the divergence of the magnetic field of a straight wire in Cartesian coordinates.

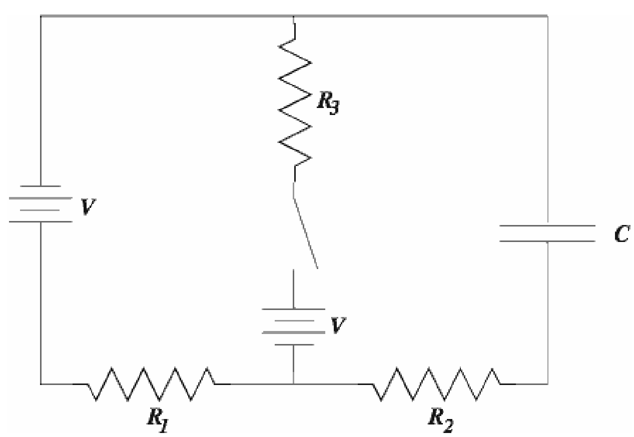
Problem 6:

Consider a cube which has identical resistors with resistance R along each edge, as shown below.



Find the equivalent resistance between points a and b.

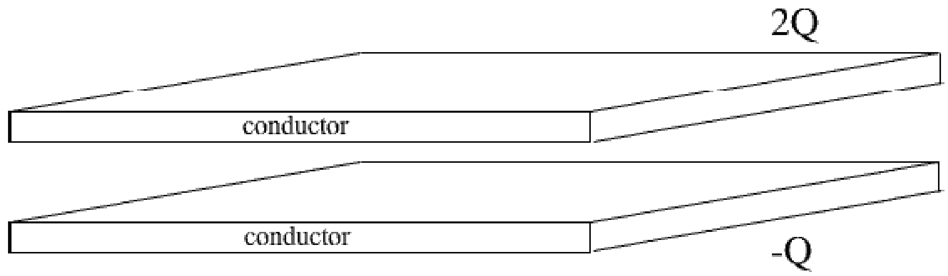
Problem 7:



Suppose that the capacitor is initially charged. The switch is closed at $t=0$. Find the current $I_{R_3}(t)$ through resistor R_3 (i.e., in the middle branch) as a function of time, and the charge in the capacitor $Q(t)$. (Hint: this problem can be simplified greatly using Thévenin. Compute $Q(t)$ first.)

Problem 8:

Consider two parallel plates as shown in the sketch. They each have a surface area A and are separated by a distance s that is small compared to the dimensions of the plate. The top plate has a charge $+2Q$ deposited on it, while the bottom plate has charge $-Q$ deposited on it. The two plates are not connected in any way. For the purposes of this problem, assume that the charge densities are uniform on both surfaces of both plates, and ignore edge effects.



(a) Find $\vec{E}$ between the two plates.

(b) Find the surface charge densities on the top and bottom faces of each of the two plates.

(c) Find $\vec{E}$ just above the top plate and just below the bottom plate.

(d) Show explicitly that the jump in $\vec{E}$ across each of the two plates is equal to $4\pi\sigma\hat{n}$ where σ is the total surface charge density on that plate.