Problem 1. Short Answer Conceptual Physics Problems (40 pts)

The following questions are short answer questions. Please answer these questions with minimal exposition

a) (3 pts) If a positively charged particle travelling in the $\hat{i}$ direction, enters a region with a constant $\vec{B}$ in the $\hat{k}$ direction, does the kinetic energy of the particle increase, decrease or stay the same?

b) (3 pts) Can you accelerate a resting electron with a steady magnetic field? With a fluctuating magnetic field?

c) (4 pts) A charged particle moves in a straight line at constant velocity through a particular region of space which may or may not have an external $\vec{E}$ field or $\vec{B}$ field. What are the 2 non-trivial $\vec{E}$ and $\vec{B}$ field configurations which could match this scenario (the 3rd field configuration is the trivial one ... both the $\vec{B}$ and $\vec{E}$=0)?

d) (5 pts) 2 insulated long wires carrying equal currents, I, cross at right angles to each other Fig. 1 left. Describe the magnetic forces and torques induced on one of the wires by the other.

e) (5 pts) 2 loops of wire are moving in the vicinity of a very long straight wire carrying a steady current as shown in Figs. 1 center and 1 right. Find the direction of the induced current in each loop. Is there a net force on either of the loops?.

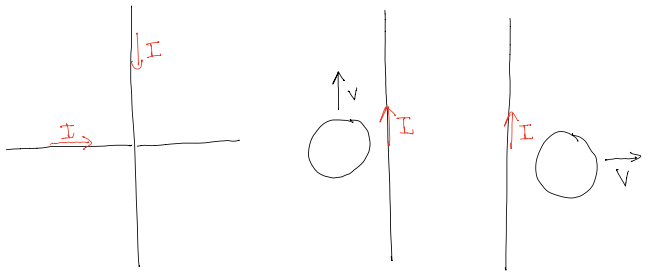

Figure 1: *left*: 2 wires crossing *center*: loop traveling parallel to wire *right*: loop traveling perpindicular to wire

f) (5 pts) A transformer designed for 120 V_{rms} AC 60 Hz source will often "burn out" if connected to a 120V DC source. Explain.

g) (5 pts) Which solenoid configuration shown in Fig. 2 has the largest mutual inductance?

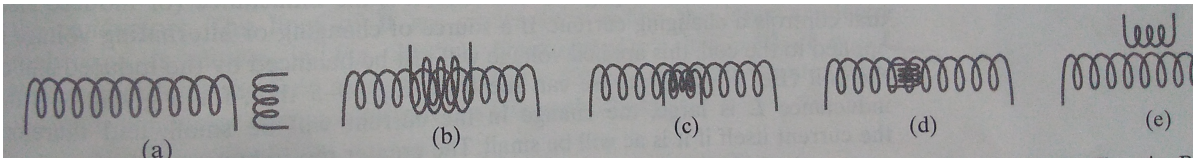

Figure 2: 2 inductors in various configurations

h) (5 pts) What is the impedance of the circuit shown in Fig. 3 left (2 pts)? At high frequencies, is the voltage amplitude across the resistor, V_{out}, larger or smaller than at low frequencies (the amplitude of the AC power source is constant for all frequencies)? (2 pts) Does this circuit have a resonance? (1 pt)

i) (5 pts) At what frequency is the current flow in the circuit (Fig. 3 right) minimum (for a fixed amplitude AC power source)?

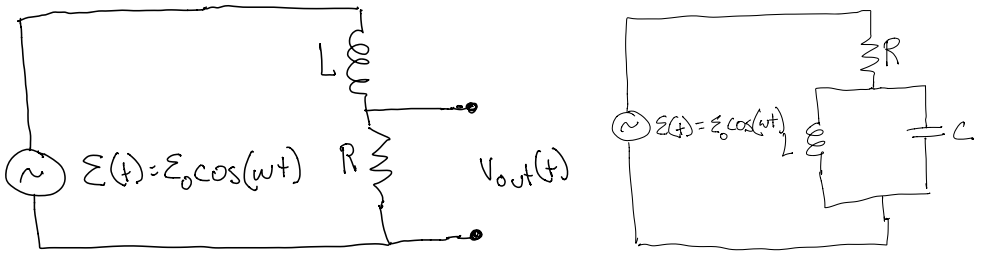

Figure 3: *left:* Electrical circuit for 1h. *right:* Electrical circuit for 1i

Problem 2. B-Fields from finite wires (15 pts) A steady current I flows down a long cylindrical wire of radius a. The current is distributed such that the current density, J, is proportional to 1/r. Find the magnetic field, inside and outside the wire.

Problem 3. AC generator (15 pts) A square loop (with length a) is mounted on a vertical shaft and rotated at angular velocity,ω (Fig. 4 left). A uniform magnetic field $\vec{B}$ points to the right as shown in the figure. Find the $\epsilon(t)$ for this AC generator.

Problem 4. Falling Loop (25 pts) A square loop with length a is made from wire with cross sectional area A_{cs}, mass density, ρ_m, and resistivity, ρ_Ω (Fig. 4 right). The top part of the wire loop is in a constant $\vec{B}$ that is out of the page, while the bottom half is outside the B-field region. At t=0, it's let go.

a) 2 pts: What is the loop's total mass ?

b) 3 pts: What is the loop's total resistance?

c) 10 pts: What is the magnetic force on the loop as a function of the loops velocity?

d) 5 pts: What is the terminal velocity of the loop? Assume that the loop reaches terminal velocity before it completely leaves the B field region?

e) 5 pts: If the loop is superconducting what is it's terminal velocity ?

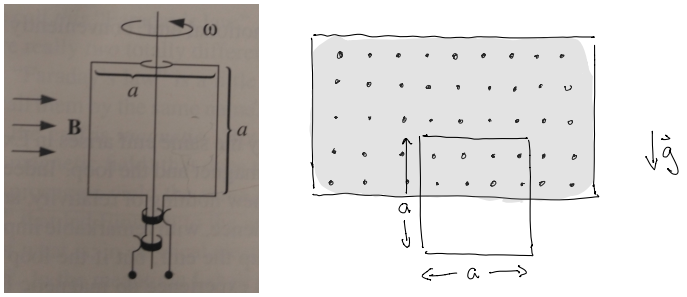

Figure 4: *left:* Simple AC Generator *right:* Falling Loop