Week 14, Session 1 Problems

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1 Faraday's Law

1.1 Alternating Current through Rotations

Alternating current generator. A rectangular loop of N turns with length a and width b is rotated at an angular frequency ω in a uniform field of induction $\vec{B}$. Show that there is an induced EMF $\epsilon = \omega NbaB\sin\omega t = \epsilon_0 \sin\omega t$.

(Source: Halliday and Resnick, Problem 35.9)

1.2 Falling Rails

A rod with length l, mass m, and resistance R slides without friction down parallel conducting rails of negligible resistance, as shown below. The plane of the rails makes an angle θ with the horizontal, and a uniform vertical magnetic field $\vec{B}$ exists throughout the region.

(a) Find the steady-state terminal velocity of the sliding rod.

(b) Show that the rate at which the internal energy of the rod is increasing is equal to the rate at which the rod is losing gravitational potential energy.

(c) Discuss the situation if $\vec{B}$ were directed down instead of up.

(Source: Halliday, Resnick, Krane 34.9)

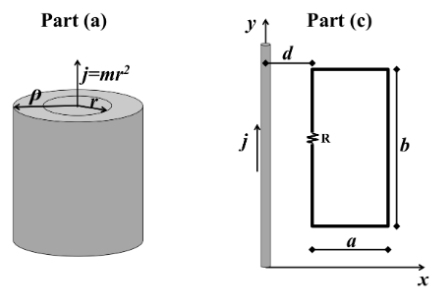
2 Previous Exam Problems

A long straight wire of radius ρ carries a current along its axis with a non-uniform current density $j(r) = mr^2$ (m=constant), r being the radial distance measured from the symmetry axis of the wire, as shown below.

(a) Calculate the magnitude of the magnetic field produced inside and outside the wire.

(b) Draw some field lines to show qualitatively how the magnitude and direction of the magnetic field vary. Specify the direction of the current in your drawing.

(c) A rectangular loop of sides a and b and resistance R is placed a distance d ($d > \rho$) from the center of the current-carrying wire, as shown below. What is the induced current in the lop if it is (i) translated along the y-axis at constant speed v? (ii) translated along the x-axis at speed v?



(Source: Birgeneau, Fall 2015 Final Exam, Problem 4)

2.1 Loops and Forces

The figure shows a wire loop, which has a length, l, and width, w, inside a magnetic field, B. The loop is made of a wire with resistivity, ρ, and cross-sectional area, A. A crossbar made of a conducting metal with negligible resistance is in contact with the loop, and at the instant shown in the figure, it has velocity, v, and there are currents on both sides of the bar. What force, F, (magnitude and direction) must be placed on the rod when it is at the position shown so that the velocity of the rod is constant?

(Source: Speliotopoulos, Fall 2012 Final Exam, Problem 3)