Problem 1 (30 points):

A line charge \( \lambda \) is glued onto the rim of a wheel of radius \( R \), which is then suspended horizontally, as in the figure, so that it is free to rotate (the spokes are made of some nonconducting material – wood, maybe). In the central region out to radius \( a \), there is a uniform magnetic field \( B_0 \), pointing up. Now someone turns the field off. What happens? Calculate the total angular momentum imparted to the wheel.

![Diagram of a wheel with a line charge and magnetic field](image)

Problem 2 (30 points):

Suppose a current \( i \) is flowing around a loop, when suddenly someone cuts the wire. The current drops "instantaneously" to zero. That generates a whopping back emf, for although \( i \) may be small, \( di/dt \) is enormous. That's why you often draw a spark when you unplug an iron or a toaster - electromagnetic induction is desperately trying to keep the current going, even if it has to jump the gap in the circuit.

Nothing so dramatic occurs when you plug in a toaster or iron. In this case induction opposes the sudden increase in current, prescribing instead a smooth and continuous buildup. Suppose, for instance, that a battery (which supplies a constant emf \( E_0 \)) is connected to a circuit of resistance \( R \) and inductance \( L \). What current (as a function of time) flows after the circuit is "plugged in" at \( t = 0 \)?

![Diagram of a circuit with a battery, resistor, and inductor](image)
Problem 3 (40 points):

What is the critical angle for total external reflection for high-energy x-rays of wavelength $\lambda$, falling on a metal plate in which all $N$ electrons per unit volume are essentially “free”? 

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