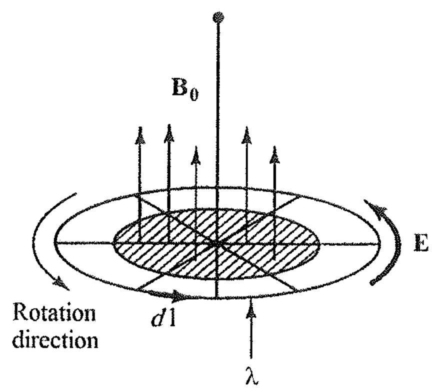
FO-3
August 2010 QE

Problem 1 (30 points):

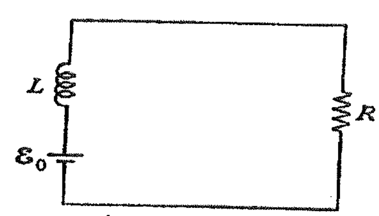
A line charge λ is glued onto the rim of a wheel of radius R, which is then suspended horizontally, as in the figure, so that it is free to rotate (the spokes are made of some nonconducting material – wood, maybe). In the central region out to radius a, there is a uniform magnetic field $\mathbf{B}_0$, pointing up. Now someone turns the field off. What happens? Calculate the total angular momentum imparted to the wheel.



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 ε_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 $t = 0$?



Write in Exam Book Only

Problem 3 (40 points):

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

Write in Exam Book Only