Physics 31B 2nd Midterm (200 pts Max.)
Spring 2004

Show your works with diagrams, explanations, and clear writings. No credit will be given for answers without diagrams, explanations, and clear writings.

1. (a) Find the values of R, V, and all the unknown branch currents in the network of Fig. 1. Given that $I_3 = 1.0$ A.

   (b) The R-C circuit in Fig. 2, which depicts a capacitor being charged, and derive an expression for *I(t)*. What is the initial value of the current, I_i, at t = 0?

2. (a) Determine the *B*-field inside a very long straight inhomogeneous rod of radius *R*, carrying a current that increases out from the center according to the expression $J = C/r$. Given your answer in terms of *I*. Neglect any end effects.

   (b) Use the Biot-Savart Law to determine the magnetic field at a point *P* anywhere on the central axis of a circular loop of wire of radius *R* carrying a counterclockwise current *I*.

3. (a) The Bohr model depicts the hydrogen atom as an electron circulating around a proton in an orbit with a radius of 0.052 9nm at a speed of 2.2×10^6 m/s. Compute the orbital magnetic moment of the electron μ_B, also called the *Bohr magneton*.

   (b) What is the force per unit length experienced by each of two extremely long parallel wires carrying equal 1.0-A currents in opposite directions while separated by a distance of 1 m in vacuum?

4. (a) Considering the induced emf in a circuit bounding an area *A* in a magnetic field $\vec{B}$, show that in general $\xi = -(A\cos\theta)\frac{dB}{dt} - (B\cos\theta)\frac{dA}{dt} + BA\omega\sin\theta$

   (b) A narrow flat coil of area *A* having *N* turns rests on a horizontal surface which is placed between the pole pieces of a very large electromagnet. A uniform downward *B*-field fills and surrounds the coil. If the field is made to decrease such that $B(t) = B_0 e^{-Ct}$, find the expression for the induced emf in the coil.

5. (a) A simple single-coil dc generator rotates at a constant frequency of 60 Hz in a 0.40-T magnetic field. Given that the coil has 10 turns and encompasses an area of 1200 cm^2, what will be its maximum emf?

   (b) The current in a 50-μH coil (for which *R* is negligible) goes from 0 to 2.0 A in 0.10 s. Determine the average self-induced emf measured across its terminals.

6. (a) A voltage signal (shown in Fig. 4) consists of a series of parabolic humps given by the expression $v(t) = V_0[1 - 4(t/T)^2]$. Determine its rms value.

   (b) Use the calculus to show directly that if $i(t) = I_m \cos \omega t$, it follows that $I\text{eff} = I_m/\sqrt{2}$.

7. (a) In 1982, workers at Bell Labs produced optical pulses lasting 30.0 femtoseconds. How many wavelengths of the 620-nm red light correspond to one of these little wavetrains?

   (b) A laser that emits pulses of UV lasting 2.00 ns has a beam diameter of 2.5 mm. If each burst contains an energy of 3.0 J, (a) what is the length in space of each pulse? (b) what is the average energy per unit volume (J/m^3), the energy density, in one of these pulses?