S11 PHY114 Problem Set 7

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March 22, 2011

Due Monday 28 Mar 2011

1. An iron atom has a magnetic dipole moment of about $1.8 \times 10^{-23} Am^2$. Determine the dipole moment of an iron bar 9.5cm long 1.6 cm wide and 2.0 cm thick, assuming that all the atomic dipole moments are pointing along its length (i..e, it is saturated.) What torque would be exerted on this bar if is placed in a magnetic field of $0.8T$, acting at right angles to the bar?

2. A simple generator has a square coil of side a with Nloops. How many times must it turn in a magnetic field B second to produce a peak output emf of V volts?

3. The primary windings of a transformer which has an 88% efficiency are connected to a 120V ac. The secondary windings are connected across a 3Ω, $75W$ light bulb. Calculate the current through the primary coil of the transformer.Calculate the ratio of the number of primary windings of the transformer to the number of secondary windings of the transformer.

4. Suppose we apply an external voltage $V(t) = V_0 \sin \omega t$ to a circuit with resistance $R$and capacitance C. Then the equation relating the charge, its time derivative and the external voltage, is

$$R\frac{dQ}{dt} + \frac{Q}{C} = V_0 \sin \omega t$$

- Determine constants A and ϕ in terms of V_0, R, C, ω so that the following is a solution:
$$Q(t) = A \sin[\omega t + \phi]$$
- What is the current as a function of time?
- Determine the peak current I_0 as a function of V_0, R, C and ω.
- Show that the peak current grows as a function of ω. This is an example of a "high-pass" filter which reduces low frequency inputs.

Hint You will find the following identities useful

$$\sin[\theta + \phi] = \sin\theta\cos\phi + \sin\phi\cos\theta, \quad \cos[\theta + \phi] = \cos\theta\cos\phi - \sin\theta\sin\phi$$

$$\cos\phi = \frac{1}{\sqrt{1+\tan^2\phi}}$$

5. Recall that the energy of a coil (solenoid) carrying a current I and with inductance L is $\frac{1}{2}LI^2$. Find a formula for the energy density of a magnetic field by considering a coil of cross-sectional area A and length $l >> r$ with N turns. Compare with the energy density of an electric field. Typical large electric and magnetic fields that can be produced in the laboratory are about $10^4 V/m$ and $1T$ respectively. Which of these fields carries the greater energy density?