

PHY 114 Spring 09 Final Exam

May 6, 2009

7:15 pm to 10:15 pm

Please write your workshop number and your workshop leader's name at the top of your answer book.

There are six problems with points assigned as indicated.

Derive a formula for the answer before you put in the numbers. This will help you to get partial credit if your final numerical answer is wrong.

Put a box around your final answer for each question.

The permittivity of the vacuum is $\epsilon_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$.

The permeability of the vacuum is $\mu_0 = 4\pi \times 10^{-7} T m A^{-1}$.

The velocity of light is $c = 3.00 \times 10^8 m s^{-1}$.

The magnitude of the charge of an electron is $1.6 \times 10^{-19} C$.

Planck's constant $h = 6.6 \times 10^{-34} J s$.

1. A solid metal sphere of radius 4.00 cm carries a total charge of 5.90 μC .
 - (a) What is the electric field 1 cm from the center (i.e., inside the sphere)? (4 points)
 - (b) If a particle with electric charge 1.2 μC and mass 3.1 mg is placed at a distance 12 cm from the center, what is the magnitude and direction of its acceleration? (5 points)
 - (c) If the particle is released at that point starting from rest, what is its velocity after a long time? (8 points)
2.
 - (a) Copper has resistivity $1.7 \times 10^{-8} \Omega m$ and density $8.95 \times 10^3 kg m^{-3}$. What should be the radius r and the length L of a cylindrical piece of copper conductor if its total mass is to be 1 g and we want the conductor to have a resistance of 0.75 Ω ? (8 points)
 - (b) You are given two 2.5 k Ω resistors and two 3.3 μF capacitors. How would you connect them into an RC circuit to get the largest possible time constant? Draw a circuit diagram representing the answer. Find the value of this time constant. (9 points)

3. (a) Two ions of the same charge but different masses m_1 and m_2 are injected into the same magnetic field \mathbf{B} . The ions have the same initial velocity, which is perpendicular to the magnetic field. The radius of the orbit of the first ion is 20 cm and that of the second is 22 cm . What is the ratio of their masses $\frac{m_2}{m_1}$? What is the ratio $\frac{T_2}{T_1}$ of the periods of their orbits? (8 points)
- (b) A copper wire with a 2.3 mm diameter carries a 40 A current flowing down its length. The current is uniformly distributed over the cross-sectional area of the wire. Determine the magnetic field inside the wire at a distance of 0.50 mm below the surface. (9 points)
4. An LRC series circuit with $R = 200\ \Omega$, $L = 23\text{ mH}$, and $C = 1.0\ \mu\text{F}$ is powered by an ac voltage source of peak voltage $V_0 = 370\text{ V}$.
- (a) At what frequency f of the external voltage will the rms current in the circuit be a maximum? (6 points)
- (b) What is the average power dissipated at this frequency? (6 points)
- (c) If the external voltage is turned off, what is the frequency f' at which the current in the circuit will oscillate? (3 points)
5. (a) A stamp collector uses a converging lens with focal length 28 cm to view a stamp 18 cm in front of the lens. Calculate the magnitude of the distance between the lens and the image. (8 points)
- (b) An outward spreading spherical EM wave comes from a 1300 W source. At a distance of 4.9 m from the source, what is the power per unit area carried by the wave? What is the rms value of the electric field? (9 points)
6. (a) A pi meson is an elementary particle that decays into a pair of photons. What is the frequency f of one of these photons when measured in the rest frame of the meson? The pi meson has a rest mass of $135\text{ MeV}/c^2$. (5 points)
- (b) A pi meson is observed to be moving in the laboratory so that its total relativistic energy (rest mass energy plus kinetic energy) is 260 MeV . What is its lifetime as measured in the laboratory? The lifetime of a pi meson at rest is $8.4 \times 10^{-17}\text{ s}$. (6 points)
- (c) The energy of the hydrogen atom in its ground state is -13.6 eV . What is the wavelength of the photon emitted when a hydrogen atom makes a transition to the ground state from the state with the next highest value of energy? (6 points)