NAME .....

PHY-841: CLASSICAL ELECTRODYNAMICS - I

Final Subject Exam: Total = 100 points

May 4, 2015; room 1420 BPS; 7:45 a.m. - 10:45 a.m.

1. /20/ An infinitely long straight wire carrying a steady current I lies in the same plane as a square circuit of linear dimension a, but outside it, and is parallel to two of the sides of the square. (*The picture will be given on the board.*)

   (a). The magnetic flux through the area of the square is measured to be equal to Φ. What is the distance from the current to the closest side of the square?

   (b). In the same geometry, let there be in addition a steady current I' in the square circuit. What is the force (magnitude and direction) acting on the square?

2. /20/ Find the electrostatic potential at large distance from the following system of charges:
   Three point particles are located along the z-axis at the points $z_1 = -2a$, $z_2 = -a$ and $z_3 = 0$. Their charges are $q_1 = q_3 = q$ and $q_2 = -2q$.

3. /20/ a. A particle with mass m, charge $e > 0$ and initial velocity $u_0 \ll c$ crosses the space between the plates of a capacitor where a constant voltage V is applied. The distance between the plates is equal to l, the initial angle between $\mathbf{u}_0$ and the electric field in the capacitor is $\alpha < \pi/2$. Find the energy loss by dipole radiation during the time of flight inside the capacitor. /Neglect the influence of radiation on the trajectory./

   b. For a positron with initial kinetic energy 4 eV, $V = 10$ kV, $l = 1$ cm, and $\alpha = 0$, determine if approximations of non-relativistic kinematics and trajectory unperturbed by radiation are justified.

4. /20/ A spaceship is launched from the surface of the Earth with constant speed $v = (3/5)c$ (relative to Earth). An astronaut on board has her birthday 10 days after the launch by the Earth calendar. Her friends decided to send the congratulation using a laser (assume that this signal propagates in space with speed of light). When should they send this message in order for the astronaut to get it exactly when she will celebrate (of course, by her calendar)?

5. /5 × 4 = 20/ **QUICK QUESTIONS**. Explain your answers in detail.

(a) Assume that a point charge and a small magnetic moment are placed at rest at the origin. Then it is easy to see that the Poynting vector of the resulting field is not zero. Does this mean that there is an energy flux leaving the system?

(b) Can field lines of the electrostatic field form closed loops?

(c) In the laboratory frame we have the electric, $\mathcal{E} = \mathcal{E}_y$, and magnetic, $\mathcal{B} = \mathcal{B}_z$, static fields; we know that $\mathcal{E} < \mathcal{B}$. Is it possible to find the frame where the electric field is absent? If so, what is the magnitude of the magnetic field in that frame?

(d) Estimate the magnitude of the applied magnetic field $\mathcal{B}_0$, for which its interaction energy with an electron spin reaches $1\text{Ry}=me^4/2\hbar^2$.

(e) Assume that there exist magnetic monopoles with density ρ_m and currents $\mathbf{j}_m$ and the total magnetic charge is conserved. What should be changed in the system of Maxwell equations?