Prelim ID Number: ______

**PRELIMINARY EXAMINATION**

Department of Physics

University of Florida

Part C, 09:00–12:00, Jan 4, 2011

**Instructions**

1. You may use a calculator and CRC Math tables or equivalent. No other tables or aids are allowed or required. You may **NOT** use programmable calculators to store formulae.
2. All of the problems will be graded and will be tabulated to generate a final score. Therefore, you should submit work for all of the problems.
3. For convenience in grading please write legibly, use only one side of each sheet of paper, and work **different problems on separate sheets of paper**. The sheets for each problem will be stapled together but separately from the other two problems.
4. You will be assigned a **Prelim ID Number**, *different from your UF ID Number*. The **Prelim ID Number**, the **Problem Number**, and the **Page Number** should appear in the upper right hand corner of **each sheet**. Do **NOT** use your name or UF ID Number anywhere on the Exam.
5. All work must be shown to receive full credit. Work must be clear and unambiguous. Be sure that you hand your completed work to the Proctor.
6. Each problem is worth 10 points.
7. Following the UF Honor Code, your work on this examination must reflect your own independent effort, and you must not have given, nor received, any unauthorized help or assistance. If you have any questions, ask the Proctor.

   **University of Florida Honor Code:** We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honesty and integrity. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: *"On my honor, I have neither given nor received unauthorized aid in doing this assignment."*

**DO NOT OPEN EXAM UNTIL INSTRUCTED**

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C1. A neutral infinite cylinder of radius $R$ carries a uniform current, $I(t)$

(a) (*3 points*) Calculate $\boldsymbol{E}$ and $\boldsymbol{B}$ for a steady current, $I(t) = I_0$.

(b) (*7 points*) Now consider that the current is a function of time

$$I(t) = 0 \quad \text{for} \quad t < 0 \quad \text{and} \quad I(t) = I_0 \quad \text{for} \quad t \geq 0$$

and recall that the speed of electromagnetic waves is $c$. The potentials are functions of retarded time $t_r$

$$V(\boldsymbol{r}, t) = \frac{1}{4\pi\epsilon_0} \int \frac{\rho(\mathbf{r}', t_r)}{|\mathbf{r} - \mathbf{r}'|} \, d^3r$$

$$\boldsymbol{A}(\boldsymbol{r}, t) = \frac{\mu_0}{4\pi} \int \frac{\boldsymbol{J}(\mathbf{r}', t_r)}{|\mathbf{r} - \mathbf{r}'|} \, d^3r$$

i. (*3 points*) Find the scalar $V$ and vector $\boldsymbol{A}$ potentials , in the region far away from the cylinder, as functions of time.

ii. (*2 points*) Find $\boldsymbol{E}$ and $\boldsymbol{B}$ as functions of time, in the region far away from the cylinder.

iii. (*2 points*) Find $\boldsymbol{E}$ and $\boldsymbol{B}$ in the region far away from the cylinder in the limit $t \to \infty$.

Hint:

$$\int \frac{dx}{\sqrt{a + x^2}} = \ln(\sqrt{a + x^2} + x)$$

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C2. In special relativity, the "proper" force, also known as the **Minkowski force**, is defined by

$$K^\mu = \frac{dp^\mu}{d\tau}. \tag{1}$$

Consider a particle of mass, $m$, which starts from rest at the origin. The Minkowski force is related to the particle's proper 4-acceleration by $K^\mu = mA^\mu$, with $A^\mu$ being the particle's 4-acceleration given by $A^\mu = dV^\mu/d\tau$ and $V^\mu$ being the particle's 4-velocity. Suppose that the particle is subject to a Minkowski force for which the spatial component in the $x$-direction is constant, say $K^x = f$. Let the 4-position of the particle be given by $(ct, x, 0, 0)$ where $c$ is the speed of light.

(a) (*2 points*) Write down expressions for the 4-velocity and 4-acceleration of the particle, in terms of its 3-velocity, $v = dx/dt$. (Hint: you my find it helpful to use the abbreviation $\gamma = 1/\sqrt{1 - v^2/c^2}$.)

(b) (*2 points*) The temporal component of the Minkowski 4-force gives an expression for the power delivered to the particle by the external force: $mA^t = c^{-1}dE/d\tau$. Integrate that expression to find an equation for the particle's energy as a function of its 3-velocity.

(c) (*2 points*) Integrate the spatial component of the relativistic equations of motion Eq. (1) to find the particle's 3-velocity as a function of its $x$-position.

(d) (*3 points*) Find a relation between the time, $t$, and the particle's 3-velocity at each point along the worldline. Do this by an alternative integration of the equation used in part (c). **Hint**: write the equation so you can integrate it with respect to time.

(e) (*1 point*) Use results from parts (c) and (d) to find a relation between $t$ and $x$ on the particle's worldline. How are $t$ and $x$ related asymptotically?

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C3. The total radiant energy flux density at the earth from the sun is called the Solar constant and has a value $1.36\text{kW/m}^2$. To solve the following problems, you will need the following numbers:

Earth-Sun distance $1.5 \times 10^{11}\,\text{m}$
Radius of the Sun $7 \times 10^{8}\,\text{m}$
Radius of Earth $6.37 \times 10^{6}\,\text{m}$
Stefan-Boltzman constant $5.67 \times 10^{-8}\,\text{W/m}^2\text{K}^4$

(a) (*2 points*) Calculate the total rate of energy generation of the Sun.

(b) (*2 points*) Calculate the effective temperature of the surface of the Sun.

(c) (*3 points*) Calculate the Earth's surface temperature on the assumption that a black body in equilibrium re-radiates as much thermal radiation as it receives from the Sun.

(d) (*3 points*) The answer for part (c) above is reasonably close to the Earth's temperature. Show, following the same ideas, that the relationship between the planetary temperature (for any planet in the solar system) $T_p$ and the planetary distance from the Sun $R_p$ is $T_p\sqrt{R_p} = \text{constant}$. Derive that constant.