Student ID Number: ________

PRELIMINARY EXAMINATION
Department of Physics
University of Florida
Part B, January 3, 2020, 14:00–17:00

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.

   (a) 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.

   (b) 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.

   (c) Your assigned student **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 anywhere on the Exam.

   (d) 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.

   (e) Each problem is worth 10 points.

   (f) 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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B1. A thick spherical shell (inner radius a, outer radius b) is made of dielectric material with a "frozen-in" polarization:

$$\mathbf{P}(\mathbf{r}) = \frac{k}{r}\hat{\mathbf{r}},$$

where k is a constant and r is the distance from the center. There is no *free* charge in the problem. Find the electric field in all three regions ($r < a$, $a < r < b$, and $r > b$) by two different methods:

(a) [**5 points**] Locate all the bound charge, and use Gauss' law to calculate the field that it produces.

(b) [**5 points**] Use

$$\oint \mathbf{D} \cdot d\mathbf{a} = Q_{free,enclosed},$$

to find $\mathbf{D}$, and then get $\mathbf{E}$ from

$$\mathbf{D} = \epsilon_0 \mathbf{E} + \mathbf{P}.$$

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B2. A point charge q is located inside a grounded conducting sphere of radius R, at distance s from its center.

(a) [**4 points**] Find the electrostatic potential inside the sphere.

(b) [**3 points**] Find the density of the induced charge on the surface of the sphere.

(c) [**3 points**] Find the total induced charge on the sphere.

B3. A straight wire with radius a and conductivity σ is aligned with the z-axis. It is surrounded by a cylindrical grounded shell of radius $b\,(b > a)$. A steady current I flows down the wire.

(a) [**2 points**] Calculate the electric field inside the wire as a function of the current, the radii, and the conductivity.

(b) [**2 points**] Find the electrostatic potential inside the wire if the potential at $z = 0$ is set to zero ($V(r = 0, z = 0) = 0$): $V(z, r \leq a) =?$

(c) [**4 points**] Find the electrostatic potential between the wire and the grounded shell for the now known boundary conditions.

Hints:

i. Recall that $\nabla E = \rho/\epsilon_0$ and that $E = -\nabla V$.

ii. Recall that

$$\nabla^2 f(r.\theta, z) = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial f}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 f}{\partial \theta^2} + \frac{\partial^2 f}{\partial z^2}$$

iii. Separation of variables $V(z, r, \theta) = g(z)h(r.\theta)$

(d) [**2 points**] Find the electric field between the wire and the shell. If you could not solve part 3, what do you guess is the r-dependence of the field? (1 point for the correct guess only)