PHYS 301: Electricity and Magnetism

Midterm 1

October 15th 2024

Duration: 1 hr

NAME: _____

Student Number: | | **Signature_____**

Please print your Student Number legibly in this box – we need it for proper scanning and uploading your exam!

- This exam consists of 3 questions, which add up to 30 pts.
- Part marks will be awarded for partially correct solutions. Make sure your work is clear and easy to read; don't skip steps. Include diagrams or brief explanations, if useful.

Please turn off and remove from the desk all cell phones, tablets and other communications devices!

Please note: you are not required to write this exam in series. Consider reading the entire exam first and beginning with what you feel most comfortable

1. Each candidate must be prepared to produce, upon request, a UBC card for identification.
2. Candidates are not permitted to ask questions of the invigilators, except in cases of supposed errors or ambiguities in examination questions.
3. Candidates suspected of any of the following, or similar, dishonest practices shall be immediately dismissed from the examination and shall be liable to disciplinary action:

- having at the place of writing any books, papers or memoranda, calculators, computers, sound or image players/recorders/transmitters (including cell phones), or other memory aid devices, other than those authorized by the examiners;
- speaking or communicating with other candidates; and
- purposely exposing written papers to the view of other candidates or imaging devices. The plea of accident or forgetfulness shall not be received.

5. Candidates must not destroy or mutilate any examination material; must hand in all examination papers; and must not take any examination material from the examination room without permission of the invigilator.
6. Candidates must follow any additional examination rules or directions communicated by the instructor or invigilator.

You can use extra pages at the end of the exam booklet. If you want them to be marked, write "see extra page" in the exam booklet, next to the question that you want us to mark on these extra pages.

Problem 1 [4 pts]. Compute $\int e^{-\frac{2r}{R_0}} \left(\nabla \cdot \frac{\hat{\mathbf{r}}}{r^2}\right) d\tau$, where integration is carried over the whole 3D space.

Problem 2 [13 pts]. An infinite cylinder of radius a is charged with a volume charge density $\rho(s)$; s is radial distance from the axis of the cylinder.

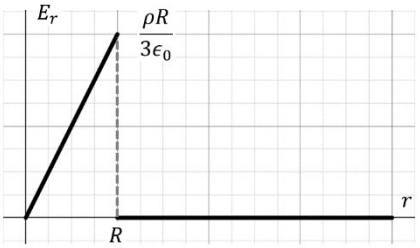
a) [3 pts] Electric field inside the cylinder has functional form $\mathbf{E}_{in}(s) = E_0 \frac{s^2}{a^2} \hat{\mathbf{s}}$**,** where E_0 is a constant. Find $\rho(s)$.

b) [4 pts] Find electric field outside the cylinder. Sketch electric field as a function of s in the whole space.

c) [3 pts] Find electrostatic potential in the whole space, assuming its zero at the surface of the cylinder. Sketch it.

d) [3 pts] Can you come up with a volume charge density, $\rho'(s)$, such that the electric field outside the cylinder does not depend on position? The charge density should not be identically equal to zero, all other possibilities are fine to explore. If yes, state what this volume charge density is. If not, explain why.

Problem 3 [13 pts]. A sphere of radius R carries a uniform volume charge density ρ and a uniform surface charge density $-\sigma$. The radial component of electric field produced by this sphere is shown in this graph.



a) [2 pts] Express σ in terms of ρ.

b) [4 pts] Compute electrostatic potential everywhere in space, if the reference point for the potential is at the surface of the sphere: $V(r = R) = 0$.

c) [3 pts] What is the electrostatic energy stored in this charge distribution?

d) [4 pts] Now a cavity of radius $a = R/4$ centered at $r = R/2$ is cut out of the sphere. Derive electric field in the cavity. (*Hint: empty cavity can be modeled as a superposition of two spheres with opposite charge densities*).

Extra page. If you want your work on it to be marked, indicate this clearly next to the question you are solving.

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