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EE214000 Electromagnetics, Fall 2020

Your name: ________________ ID: __________________ Oct. 5th, 2020

EE214000 Electromagnetics, Fall, 2020
Quiz #5-1, Open books, notes (31 points), due 11 pm, Wednesday, Oct. 7th, 2020
(email solutions to 劉峰麒 alex851225@gmail.com)

Late submission won't be accepted!

1. What are the two postulates and their physical meaning for electrostatics? Define all the symbols in your answers (8 points)

Ans:

The two postulates are

(1) The Faraday Law of electrostatics: $\nabla \times \vec{E} = 0$, where $\vec{E}$ is the electric field intensity. (2 points) Applying the Stokes theorem to $\nabla \times \vec{E} = 0$ over a close-loop path, one can see immediately that the work done by an electric force on a charge is independent of the path along which the charge moves. (2 points)

(2) Gauss Law: $\nabla \cdot \vec{D} = \rho$, where $\vec{D}$ is the electric flux density and ρ is the volume charge density. (2 points) Applying the divergence theorem to it, one can see immediately that the total electric flux generated by a charge *Q* is equal to the charge itself. (2 points)

2. What happens if you define the electric field intensity as $\vec{E} = +\nabla V$, where *V* is the electric potential ? Is there a way to rescue the definition "work done externally …." for *V*? (3 points)

Ans: There could be several ways to make such a definition consistent with the correct sense of physics. For example, one might re-define the direction of $d\vec{l}$ to be along the moving direction of the charge when one calculate the work. Then, there's no need to modify the "external work" statement given in the lecture. Alternatively, we could take it as that the *kinetic energy* gained by a negative charge is positive when it moves from infinity to somewhere close to a positive charge.

3. Would a lightning rod attract or avoid catastrophic discharge from a high cloud? View the following film to explain it

https://www.youtube.com/watch?v=wGc3q4dVOS0 (5 points)

Ans: The high field on the sharp tip of a lightning rod, connected to ground, ionizes the air molecules to create a conducting path to avoid building up a high potential to cause catastrophic discharge from the cloud.

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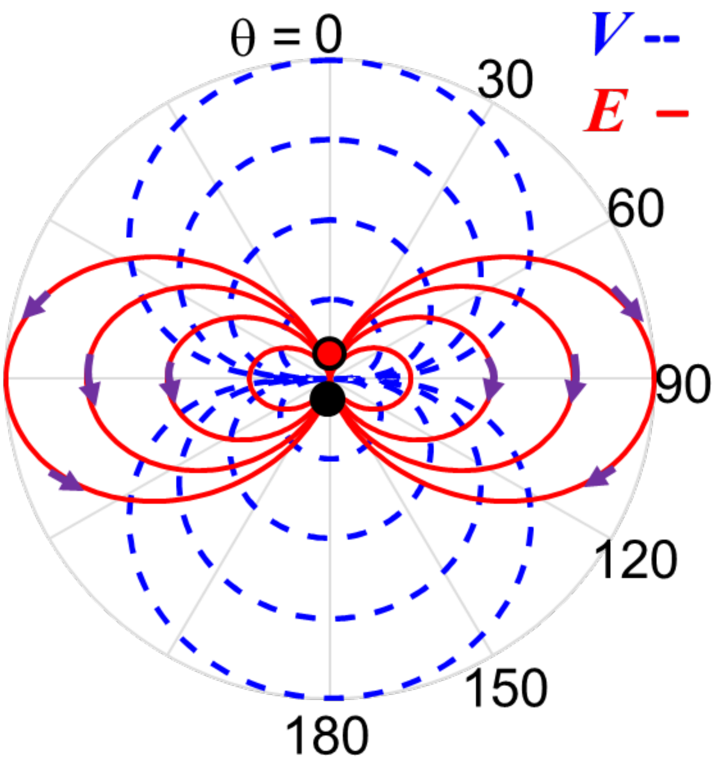
4. What is the *R* dependence of the field and potential of an electric dipole in the far zone? (2 points) Explain why the field and potential have a weak dependence on *R* in comparison with those of a monopole charge? (3 points)

Ans: The field and potential of an electric dipole scales as $1/R^3$ and $1/R^2$, respectively, as compared with $1/R^2$ and $1/R$ for a monopole charge.

An electric dipole consists of a positive and a negative equal charge separated by a small distance. In the far field, the two charges partially cancel each other and therefore the dipole field and potential have a weak dependence on *R*.

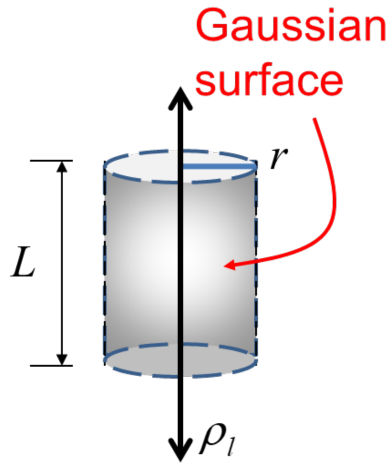
5. Draw the equipotential lines and electric field lines of an electric dipole on the plane of $\phi = 90°$? The two dipole charges are aligned along the z axis. Show the directions of the electric field lines with reference to the polarity of the charges. (5 points)

Ans: The plot is independent of ϕ. Therefore, the plot is simply:



6. What is the Gaussian surface of an infinite straight line charge? (2 points) Use it to derive the electric field (magnitude and direction) intensity at *r*. Assume a line charge density of $-\rho_l$ on the line. (3 points)

Ans: By definition, the Gaussian surface is a constant-radius cylindrical surface centered at the line charge and the two disk surfaces at two constant z intercepting the constant-radius surface, as shown below.



Apply the Gauss law to calculate the radial electrical field on the cylindrical Gaussian surface $\varepsilon_0 \oint_S \vec{E} \cdot d\vec{s} = \varepsilon_0 E_r 2\pi r L = -L\rho_l$ (the two disk surfaces do not contribute to the calculation (why?)). $\Rightarrow \vec{E} = \dfrac{-\rho_l}{2\pi\varepsilon_0 r}\hat{a}_r$