

Mid Semester Examination

Physics III,
B. Math., 3rd year,
September - December 2022.
Instructor: Prabuddha Chakraborty (prabuddha@isibang.ac.in)

September 19th, 2022, Morning Session.

Duration: 90 minutes.

Total points: 50.

Please give arguments where necessary. If it is unclear from your answer why a particular step is being taken, full credit will not be awarded. Grades will be awarded not only based on what final answer you get, but also on the intermediate steps.

1. Suppose that, instead of the Coulomb's force law, experimentally it was found that the electrostatic force between two point charges q_1 and q_2 , at a distance r_{12} apart is given by

$$\vec{F}_{12} = \frac{q_1 q_2}{4\pi\epsilon_0} \cdot \frac{(1 - \sqrt{\alpha r_{12}})}{r_{12}^2} \hat{e}_{\vec{r}_{12}}$$

where α is a constant with dimension $[L]^{-1}$.

- (a) Find the electric field everywhere for a point charge of strength q . [**2 points**]
 - (b) Show that a electric potential can be defined for this force law. [**8 points**]
2. Imagine a cube without any charge in the interior in which five faces are grounded while the sixth face, insulated from the other five, is held at a potential ϕ_0 . Find the potential at the center of the cube. You must justify your answer. You may assume that the potential at the center is given by a linear combination of the potential on the six faces. [**10 points**]
 3. Consider a hollow spherical metal (conducting) shell with an inner radius R_1 and an outer radius R_2 . The interior of the shell is non-conducting and filled with a uniform charge density ρ . The shell is now grounded.
 - (a) Find the potential at $r = 0$. [**5 points**]
 - (b) Find the total electrostatic energy of the system. [**5 points**]

4. A capacitor is made up of three concentric spherical conducting shells of radii a , b and c , in increasing order. The inner and the outer shells are connected by a thin wire through a hole in the middle shell (ignore the effects of the hole in electrostatics).
- (a) Find the capacitance of the system. [**6 points**]
 - (b) Suppose a net charge Q is added to the middle shell. How will this charge distribute itself on the inner and outer surfaces of the middle shell (even though we are speaking of the inner and outer surfaces of the middle shell, you can assume the thickness of the middle shell is tiny compared to the other length scales in the system)? [**4 points**]
5. Imagine an infinite wire, of radius a , is located at a distance b ($b \gg a$) from a grounded infinite plane. The wire carries a charge density λ per unit length. The potential due to the wire alone at a distance r ($r \gg a$) is given by

$$\phi(r) = \frac{\lambda}{2\pi} \ln\left(\frac{1}{r}\right) + \text{const.}$$

In the presence of the plane:

- (a) Find the force on the wire, if any. [**4 points**]
- (b) Find the capacitance of the system. [**6 points**]