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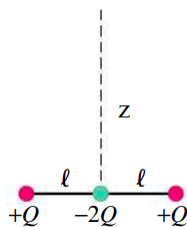
Physics 7B Midterm 2 - Fall 2020
Professor R. Birgeneau

Total Points: 100 + 5 (5 Problems + Bonus)

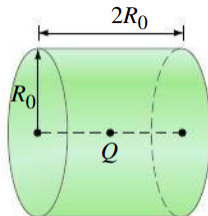
*This exam is out of 100 points with 5 bonus points. Show all your work and take particular care to explain your steps. Partial credit will be given. Use symbols defined in problems and define any new symbols you introduce. **If a problem requires that you obtain a numerical result, first write a symbolic answer and then plug in numbers.** Label any drawings you make. **Good luck!***

Problem 1 (20 pts.) A quadrupole, depicted below, consists of a central charge of $-2Q$ and two positive charges Q .

- (a) (12 pts.) Determine the electric field \vec{E} at points a distance z along the perpendicular bisector (take $z > 0$).
- (b) (4 pts.) What is the long distance behavior of the electric field?
- (c) (4 pts.) Explain qualitatively the difference between your result in part (b) and the long distance behavior of an electric dipole.



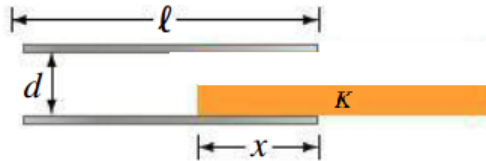
Problem 2 (20 pts.) Depicted below is a short cylinder whose diameter $2R_0$ is equal to its length. A point charge Q is placed on the central axis of the cylinder and at the center of the cylinder. What is the total flux through the curved sides of the cylinder? **Hint:** First calculate the flux through the ends.



Problem 3 (20 pts.)

Consider a square parallel plate capacitor of width d and side length ℓ , as depicted below. A dielectric slab of width $d/2$ and dielectric constant K is inserted a distance x into the space between the plates of the capacitor. As a function of x , find

- (a) (10 pts.) the capacitance of the configuration
- (b) (4 pts.) the energy stored if the potential difference across the capacitor is V_0
- (c) (6 pts.) the magnitude and direction of the force exerted on the slab, assuming that the potential across the capacitor remains at V_0



Problem 4 (20 pts.) Consider two lightbulbs: lightbulb A and lightbulb B. Lightbulb A is rated at 50 W for a voltage of 130 V and lightbulb B is rated at 50 W for a voltage of 11 V.

- (a) (5 pts.) What is the current through each bulb? Assume the maximum voltage is applied.
- (b) (5 pts.) What is the resistance of each bulb?
- (c) (5 pts.) In one hour, how much energy does each bulb use?
- (d) (5 pts.) Which bulb requires larger diameter wires to connect its power source and the bulb? Explain.

Problem 5 (20 pts.)

- (a) (7 pts.) Consider a conducting sphere of radius r_0 that carries a total charge Q . Determine the total electrostatic energy of this sphere. **Hint:** consider starting from 0 charge and charging up a sphere.
- (b) (13 pts.) Now consider a **nonconducting** sphere of radius r_0 and total charge Q that is uniformly distributed. Determine the total electrostatic energy of this sphere.

Bonus (5 pts.) A proton is made up of 2 Up quarks and 1 Down quark.

- (a) (3 pts.) What is the quark composition of the neutron?
- (b) (2 pts.) How are the quarks held together?