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Midterm #2, Version D
Physics 1B
Prof. David Saltzberg
May 20, 2014

Time: 50 minutes

Closed Notes. Closed Book. Allowed one new 3"x5" index card and one from the last exam. Calculators are allowed. Show your work.

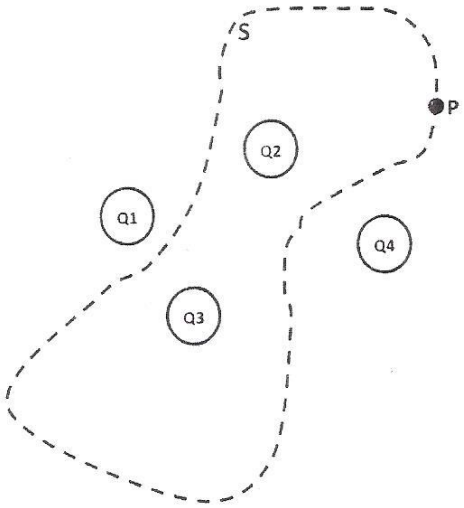
If a problem is confusing or ambiguous, notify the professor

Clarifications will be written on the blackboard. Check the board.

There are 10 pages including this cover sheet. Make sure you have them all. Extra workspace is given and extra paper is at the front of the room.

Problem	Points	Problem	Points
1	10 / 20	5	30 /30
2	20 /20	EC	8 /15
3	10 /10		
4	17 /20	--------	----------
		TOTAL	95/100

1. (20 pts) In the figure below, the dashed line denotes a Gaussian surface, *S*, enclosing part of a distribution of four positive charges. (For simplicity, just the cross-section of the surface with the page is shown.)



a) Which charges contribute to the electric field at point *P*?

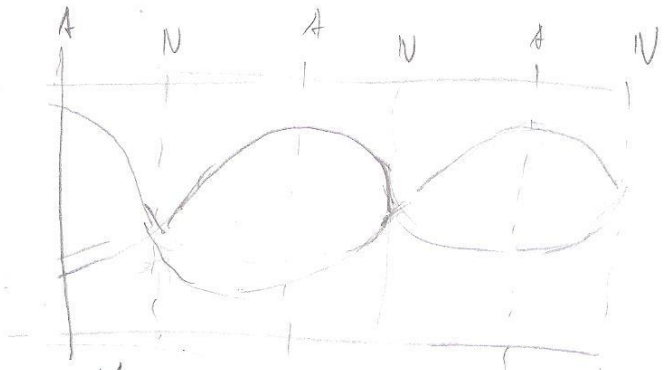
Q_2 Q_3 Q_1 Q_4 ✓

b) Is the contribution to the electric flux through surface *S* from charges *Q1* and *Q2* "greater than", "less than", or "equal to" the contribution to that obtained from all four charges?

greater than ✗

2. (20 pts) An organ pipe of length L in air is closed on one end and open at to atmospheric pressure at the other. It is producing a loud tone at its 3rd harmonic (i.e., 2nd overtone). Sketch the pipe and mark the location of the pressure nodes and antinodes. What is the wavelength, λ, in terms of L?

4 antinodes
4 nodes



$\frac{5}{4}$ in 4 pipe

$\lambda = \frac{4}{5} L$

3. (10 points) What is the ratio of displacement amplitudes of two sound waves that differ in intensity by 3 dB?

$$\bar{I} = \frac{1}{2}\sqrt{\rho B}\,\omega^2 A_1^2$$

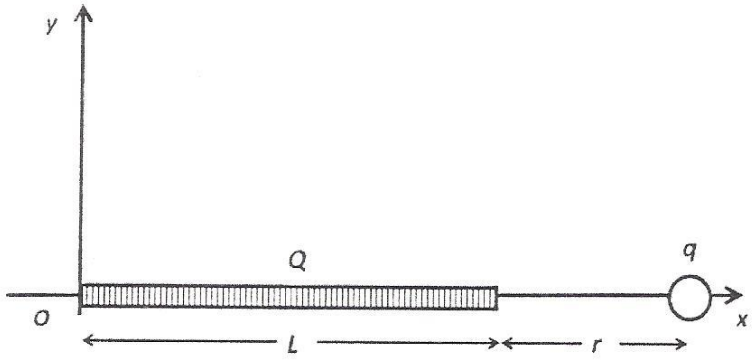
lets say $\sqrt{\rho B} = 1$ (they will be the same for both)

$$\beta = 10 \log \frac{A_1^2}{10^{-12}} \qquad A_1 = 1.585 \times 10^{-6}$$

$$\beta = 10 \log \frac{A_2^2}{10^{-12}} \qquad A_2 = 1.122 \times 10^{-6}$$

$$\frac{A_1}{A_2} = 1.41 \quad \checkmark$$

4. (20 pts) A positive charge Q is distributed uniformly along a rod of length L. For simplicity, the rod is lying on the x-axis with one end on the origin as shown. A positive point charge, q, is placed on the x-axis at a distance r beyond the other end. Calculate the electric force on the point charge.



+17

$\lambda = \frac{dQ}{dx}$

$dE = \frac{1}{4\pi\varepsilon_0}\frac{dQ}{r^2}$

$E = \int_0^L \frac{1}{4\pi\varepsilon_0}\frac{\lambda\, dx}{((L-x)+r)^2}$

$u = (L-x)+r$

$du = -1\,dx$

$= \frac{\lambda}{4\pi\varepsilon_0}\int -u^{-2}\,du$

$= \frac{\lambda}{4\pi\varepsilon_0}\, u^{-1}\Big|$

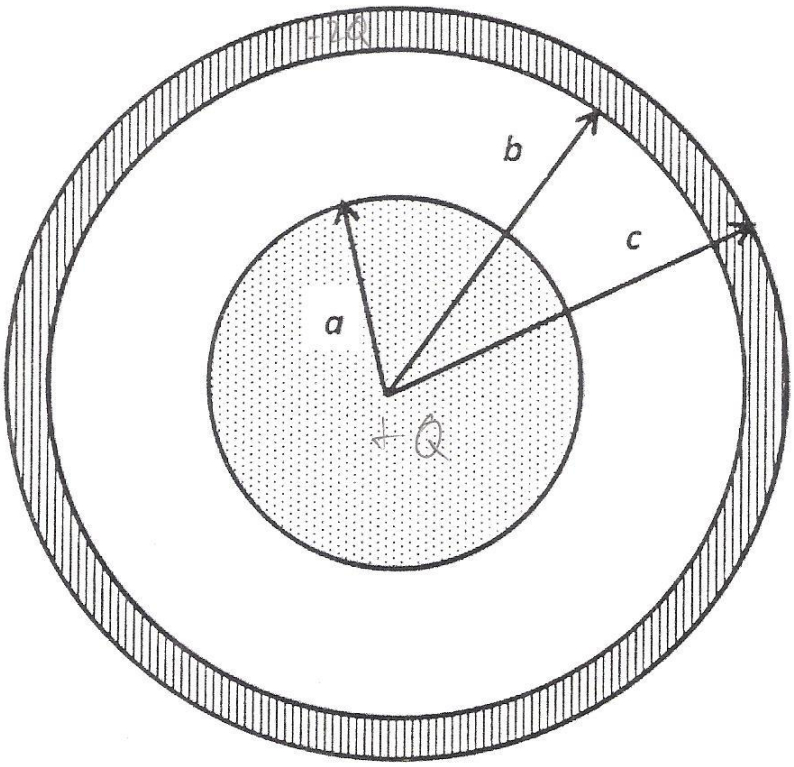
$= \frac{\lambda}{4\pi\varepsilon_0}\left((L-x)+r\right)^{-1}\Big|_0^L$

$\frac{Q}{L}$

$E = \frac{\lambda}{4\pi\varepsilon_0}\left(\frac{1}{r} - \frac{1}{L+r}\right)$

$qE = F = q\left(\frac{Q/L}{4\pi\varepsilon_0}\left(\frac{1}{r} - \frac{1}{L+r}\right)\right)\hat{x}$

5. (30 pts) The figure below shows the cross section of a solid sphere of radius a. It has been placed at the center of a conducting shell with inner radius b and outer radius c. The inner sphere carries a net charge of $+Q$ spread uniformly throughout its volume and the outer shell carries a net charge of $-2Q$.



Answer the questions on the following pages….

a) What is $E(r)$ inside the solid sphere ($r<a$) ?

Surface Area of sphere $= 4\pi r^2$

$$EA = \frac{Q_{enc}}{\varepsilon_0} \qquad \rho = \frac{dQ}{dV}$$

$$E\,4\pi r^2 = \frac{\rho\, dV}{\varepsilon_0} \qquad dV = (4\pi r^2)\,dr$$

$$\rho = \frac{Q}{\frac{4\pi a^3}{3}}$$

$$= \frac{3Q}{4\pi a^3}$$

$$E(4\pi r^2) = \int_0^r \frac{\rho(4\pi r^2)\,dr}{\varepsilon_0} = \rho\,\frac{4\pi r^3}{3\varepsilon_0} = \left(\frac{r}{3\varepsilon_0}\right)\cdot Q\,\frac{3}{4\pi a^3}$$

$$= \frac{Qr}{4\pi a^3 \varepsilon_0}$$

6/6

(continued)
b) What is $E(r)$ between the solid sphere and shell ($a<r<b$) ?

$EA = \frac{Q}{\varepsilon_0}$

$E(4\pi r^2) = \frac{Q}{\varepsilon_0}$

$E = \frac{Q}{\varepsilon_0 4\pi r^2}$

6/6

c) What is $E(r)$ inside the shell ($b<r<c$) ?

0 Conductor!

6/6

(continued)
d) What is $E(r)$ outside the shell ($r>c$) ?

$$EA = \frac{-Q}{\varepsilon_0}$$

$$E = 4\pi r^2 \cdot \frac{-Q}{\varepsilon_0}$$

$$\frac{-Q}{\varepsilon_0 4\pi r^2}$$

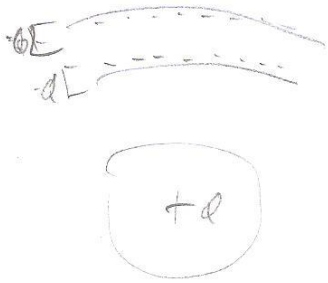
6/6

e) What is the charge per area (if any) on the outside of the conducting spherical shell?

$$\frac{Q}{\text{area}} = \frac{-Q}{4\pi c^2}$$

↑
surface area of sphere

6/6



Extra Credit: (15 pts) The speed of sound at typical aircraft flying altitude is 300 m/s. Suppose that is true at a location where a plane is being chased by another one directly behind it. The plane in front is traveling at 40% of this speed of sound and the second airplane is moving at 60% of this speed. Both speeds are measured relative to the ground. They are flying directly into a steady wind with a speed of 60 m/s relative to the ground. The front plane's engine emits an 8 kHz whine. What pitch does the pilot of the second plane hear? (Hint: this is easier if you do with fractions and not rely on your calculator.)