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Midterm #2, Version A
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.

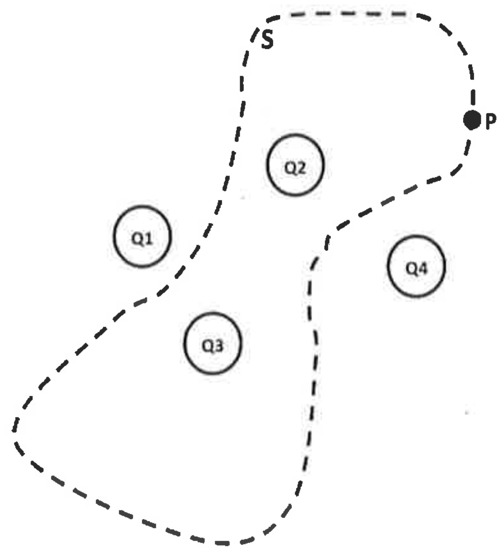
If a problem is confusing or ambiguous, notify the professor

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

There are 11 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	20/ 20	5	30 /30
2	20/20	EC	15 /15
3	10 /10		
4	20/20	--------	------------------------
		TOTAL	115 /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*?

All By Coulomb's law

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?

By Gauss's Law, Q1 & Q4 do not contribute to the electric flux. But Q3 and Q2 do, so the contribution from all exceeds just Q1 & Q2 alone

⇒ "less than"

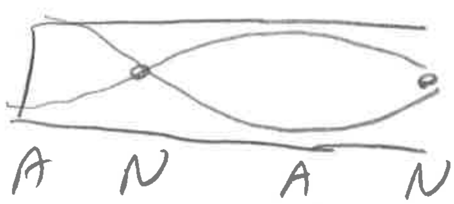
Oops, The 3rd harmonic is not the 2nd overtone in this case, we accept either answer

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?

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

↑ displacement node ⇒ pressure antinode

↑ pressure node



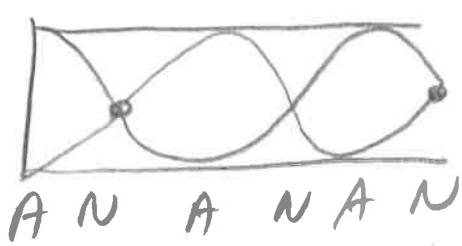
3rd harmonic

1st overtone

$L = \frac{3}{4}\lambda$

$\lambda = \frac{4}{3}L$

either answer accepted



5th harmonic

2nd overtone

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

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

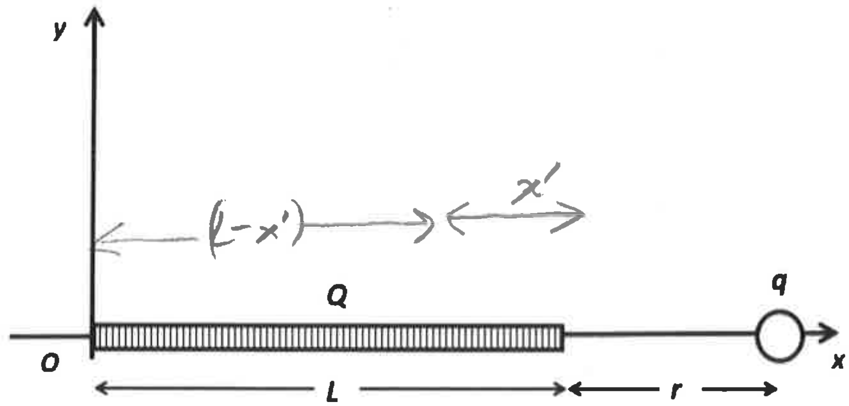
3. (10 points) What is the ratio of displacement amplitudes of two sound waves that differ in intensity by 3 dB?

$$\frac{I_1}{I_2} = 10^{0.3} = 2$$

$$I \propto y_m^2$$

$$\Rightarrow \boxed{\frac{y_m^1}{y_m^2} = \sqrt{2}}$$

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 below. A positive point charge, q, is placed on the x-axis at position r beyond the other end. Calculate the electric force on the point charge.



$\lambda = \frac{Q}{L}$

$E_y = 0,\ E_z = 0 \Rightarrow F_y = F_z = 0$

$$E_x = \int_{rod} \frac{k\,dq}{(x'+r)^2} = k\lambda \int_0^L \frac{dx'}{(x'+r)^2}$$

$$= -k\lambda \left[\frac{1}{(x'+r)}\right]_0^a$$

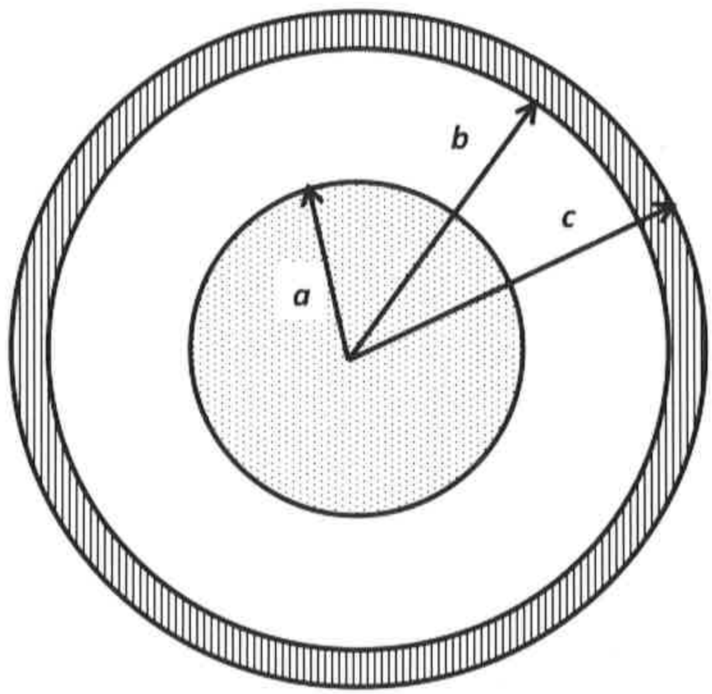
$$= -k\lambda \left[\frac{1}{L+r} - \frac{1}{r}\right]$$

$$= k\lambda \left[\frac{1}{r} - \frac{1}{L+r}\right]$$

$$F_x = kq\lambda \left[\frac{1}{r} - \frac{1}{L+r}\right]$$

$$\vec{F} = \frac{kqQ}{L}\left[\frac{1}{r} - \frac{1}{L+r}\right] \uparrow$$

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 ($r<a$) ?

$$\int_0^r \vec{E}\cdot d\vec{A} = \frac{q_{encl}}{\epsilon_0}$$

$$(E)(4\pi r^2) = \frac{\rho\left(\frac{4}{3}\pi r^3\right)}{\epsilon_0}$$

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

$$(E)(4\pi r^2) = \frac{1}{\epsilon_0}\frac{Q}{\left(\frac{4}{3}\pi a^3\right)}\left(\frac{4}{3}\pi r^3\right)$$

$$\boxed{E = \frac{Q\,r}{4\pi\epsilon_0 a^3}}$$

Note you have to show your work. If you just copied this answer from your card you did not get full credit.

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

Can treat all of Q as if at $r = 0$

$$E = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$$

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

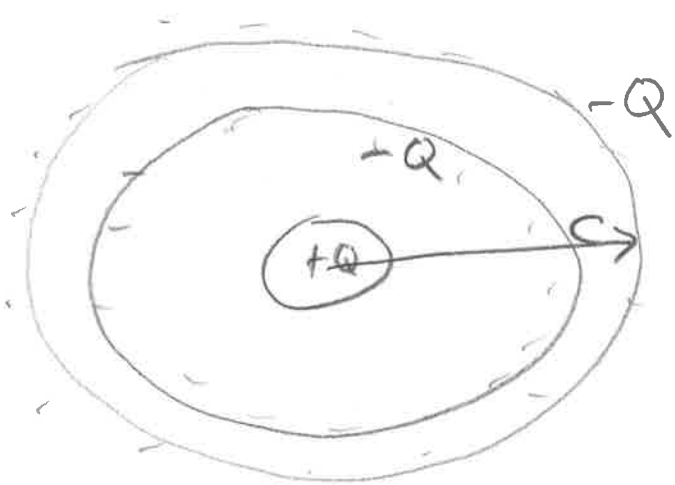
A conductor $\Rightarrow$ $E = 0$

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

Can treat all the charge as if at $r=0$, $+Q + (-2Q) = -Q$

$$E = -\frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$$

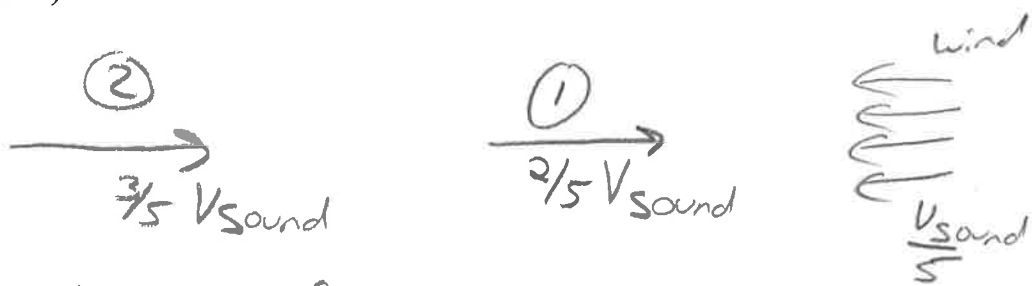
e) What is $\sigma = \frac{\text{charge}}{\text{area}}$ on outer conductor?



outer surface

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

<u>Extra Credit:</u> (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.)



You must do this in a frame where there is no wind.

$$f_L = f_S\left(\frac{V_{sound} \pm V_L}{V_{sound} \mp V_S}\right)$$

$$f_L = (8\,kHz)\left(\frac{V_{sound} + 4/5\,V_{sound}}{V_S + 3/5\,V_{sound}}\right) = 8\,kHz\left(\frac{9/5}{8/5}\right)$$

$$= 8\,kHz\,(9/8)$$

$$= 9\,kHz$$