Physics 202 EXAM I Feb. 13, 2007

Waves

$f_{obs} = f_{source}\frac{c \pm v_{obs}}{c \mp v_{source}}$ $\wp = I\,A$ $I_{ave} = 2\pi^2 A^2 f^2 \rho_0 c$ $I = \frac{\wp}{4\pi R^2}$

$\wp_{ave} = 2\pi^2 A^2 f^2 \mu v$ $v = f\lambda$ $v = \frac{\omega}{k}$ $\beta = 10\,log_{10}\,\frac{I}{I_0}$

$A_{trans} = \frac{2}{1+\frac{k_T}{k_I}}A_{inc}$ $A_{ref} = \frac{1-\frac{k_T}{k_I}}{1+\frac{k_T}{k_I}}A_{inc}$ $k = \frac{2\pi}{\lambda}$ $\omega = 2\pi f$

$y(x,t) = A\sin[\frac{2\pi}{\lambda}(x - vt)]$ $y(x,t) = A\sin[kx - \omega t]$ $v_{str} = \sqrt{\frac{T}{\mu}}$ $v_{sound} = c = \sqrt{\frac{\gamma P_0}{\rho_0}}$

$P = P_0 - P_0\gamma\frac{dy(x,t)}{dx}$ $I_0 = 1.0 \times 10^{-12}\,\frac{W}{m^2}$ $\gamma = 1.4$ $c = 343\,\frac{m}{s}$

$\rho_0 = 1.4\,\frac{kg}{m^3}$ $P_0 = 1.01 \times 10^5\,\frac{N}{m^2}$ $v_{med} = A\omega$ $v_{med} = \frac{dy(x,t)}{dt}$

$\Delta\beta = 20\,\log_{10}\,\frac{r_2}{r_1}$ $\lambda_{cl} = \frac{4\ell}{n}$ $\lambda_{op} = \frac{2\ell}{n}$ $\mu = \frac{m}{\ell}$

$I = \frac{1}{2}\rho v v_{max}^2$ $I = \frac{1}{2}\frac{\Delta P_{max}^2}{\rho v}$ $f_n = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$ $r_1 - r_2 = (n + \frac{1}{2})\lambda$

Electrostatics

$\mathbf{F}_{2,1} = \frac{kq_1q_2(\mathbf{r}_2 - \mathbf{r}_1)}{|\mathbf{r}_2 - \mathbf{r}_1|^3}$ $|\mathbf{F}_{2,1}| = \frac{|kq_1q_2|}{|\mathbf{r}_2 - \mathbf{r}_1|^2}$ $V(r) = \frac{kq}{|\mathbf{r}|}$ $k = \frac{1}{4\pi\epsilon_0} = 9.0 \times 10^9\,\frac{Nm^2}{C^2}$

$\mathbf{E}_1 = \frac{\mathbf{F}_{2,1}}{q_2}$ $|\mathbf{E}_{point}| = \frac{kq}{r^2}$ $|\mathbf{E}_{line}| = \frac{2k\lambda}{r}$ $|\mathbf{E}_{plane}| = 2\pi k\sigma$

$V(r)_{point} = \frac{kq}{r}$ $V(r)_{line} = C - 2k\lambda\,\ln|r|$ $V(x)_{plane} = V_0 - 2\pi k\sigma x$ $\delta W = q\Delta V$

$V(r_f) - V(r_i) = -\int_{r_i}^{r_f}\mathbf{E}\cdot\mathbf{d}r$ $E_x = -\frac{\partial V}{\partial x}$ $\mathbf{E} = -\nabla V$ $\frac{d}{dx}\frac{1}{\sqrt{x^2+y^2}} = -\frac{x}{\sqrt{(x^2+y^2)^3}}$

Arithmetic

$\sin\theta = \frac{opp}{hyp}$ $\cos\theta = \frac{adj}{hyp}$ $hyp^2 = opp^2 + adj^2$ $\tan\theta = \frac{\sin\theta}{\cos\theta}$

$\frac{d}{dx}x^n = nx^{n-1}$ $\frac{d}{dx}\cos(ax) = -a\sin(ax)$ $\frac{d}{dx}\sin(ax) = a\cos(ax)$ $\int x^n\,dx = \frac{1}{n+1}x^{n+1} + c$

$\frac{d}{dx}\tan^{-1}x = \frac{1}{1+x^2}$ $\frac{d}{dx}uv = \frac{du}{dx}v + u\frac{dv}{dx}$ $\frac{d}{dx}\frac{u}{v} = \frac{\frac{du}{dx}v - u\frac{dv}{dx}}{v^2}$ $\int_a^b u\,dv = (uv)|_a^b - \int_a^b v\,du$

$\frac{d}{dx}e^{f(x)} = e^{f(x)}\frac{df(x)}{dx}$ $\frac{d}{dx}\ln|x| = \frac{1}{x}$ $\int_a^b\frac{df(x)}{dx}\,dx = f(b) - f(a)$ $\frac{d}{dx}\sin^{-1}x = \frac{1}{\sqrt{1-x^2}}$

$\tan(a-b) = \frac{\tan a - \tan b}{1 + \tan a\tan b}$ $\cos(a-b) = \cos a\cos b + \sin a\sin b$ $\sin(a-b) = \sin a\cos b - \cos a\sin b$ $\int_a^b\frac{dx}{(x+c)^2} = \frac{1}{a+c} - \frac{1}{b+c}$

Miscellaneous

$\Delta\beta = 10\log_{10}(2(1+\cos\phi))$ $\Delta\beta = 10\log_{10}\frac{R_1^2}{R_2^2}$ $f_n = n\,\frac{c}{2\ell}$ $f_n = (2n+1)\,\frac{c}{4\ell}$

Instructions Your Name;

You must show all work to get full credit, and must give a numerical answer in response to questions in which numerical data is given. Neatness counts in the sense that it helps me to allot partial credit.

Problem 1. 16 points (P-30)

A pipe used as a musical instrument can create resonant sound waves of frequency $1020\,Hz$ and $1700\,Hz$. These are both standing waves within the pipe. In addition there is **one** resonant wave with a frequency between these two values. The speed of sound in air is $340\,\frac{m}{s}$.

A. 5 points Determine the length of the pipe, and whether or not it is closed at one end or open at both.

B. 5 points Determine the lowest frequency resonant standing wave that the pipe can support, and draw a picture of the air displacement within the pipe.

C. 6 points Determine the wavelengths of both the waves.

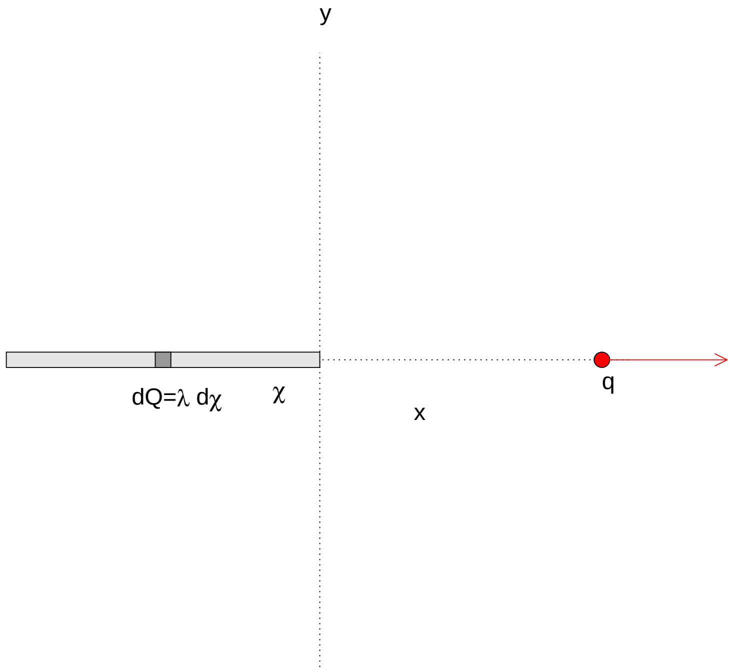
Problem 2. 16 pts

A. 6 points (P-31) A bird flying due north at speed v lets out a chirp of frequency f_0. As the bird approaches you, you hear its chirp at $700\,Hz$. As it passes you and recedes, you hear the chirp shift down to $650\,Hz$. The speed of sound is $340\,\frac{m}{s}$
How fast is the bird traveling? If the bird were at rest, what would be the frequency f_0 of the chirp?

B. 5 points (P-28) A bat flies towards a mosquito hovering motionless in mid-air. The bat emits a $20,000\,Hz$ squeak that echoes from the mosquito and returns to the bat as $20,400\,Hz$. Determine the air-speed of the bat.

C. 5 points (P-39) A car with a siren of frequency $f_0 = 4000\,Hz$ approaches you, accelerating uniformly from rest. When you hear the siren at $4100\,Hz$ you note that its pitch increases at $20\,\frac{Hz}{s}$. Determine its acceleration.

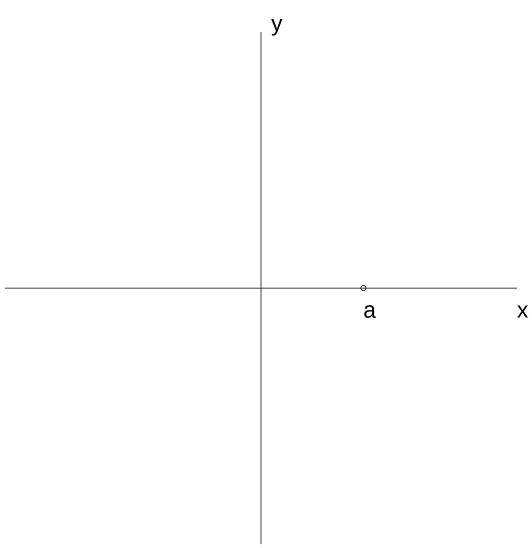
Problem 3.



A. 4+4 points. (E-30)

Find the voltage function of the electric field at point $(x, 0)$ made by a **very long** line charge carrying a charge per unit length λ, and length L.

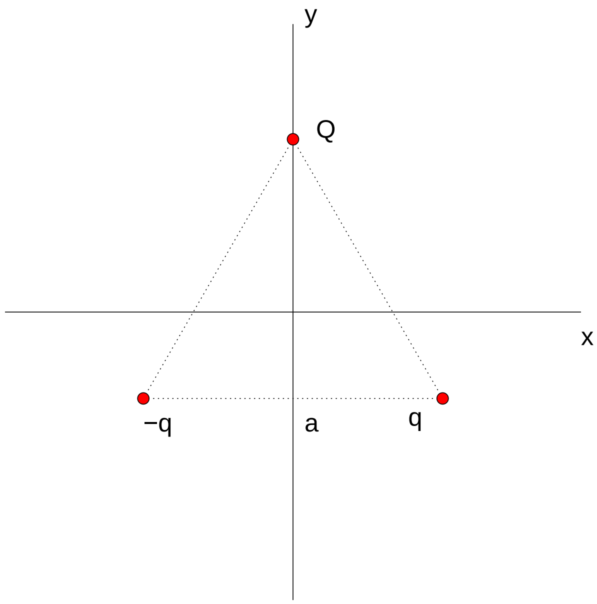
Find the electric field at point $(x, 0)$ made by this line charge carrying a charge per unit length λ. (Do so either starting with your voltage function, or by integration).



B 4+4+4(E-42)

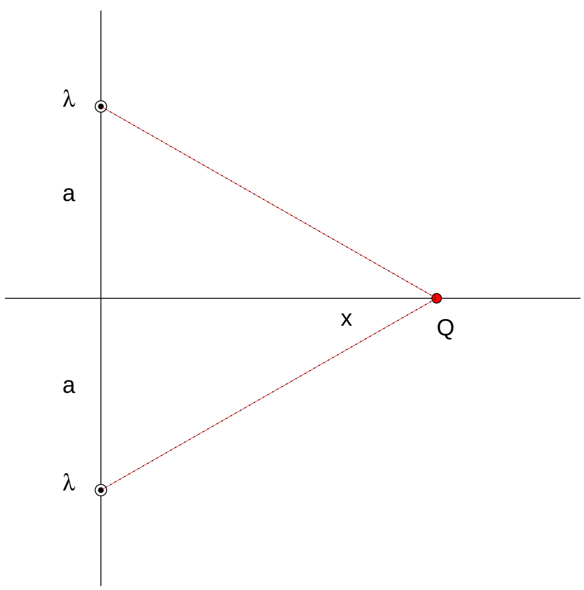
In the region of space $y \geq 0$ there is an electric field with voltage function $V(x, y) = \frac{V_0}{\pi} \tan^{-1} \frac{y}{x-a}$. **Find the equations** of the $V = \frac{V_0}{6}, V = \frac{V_0}{3}, V = \frac{2V_0}{3}$ and $V = \frac{5V_0}{6}$ equipotentials (4 points). **Draw them below**, and draw at least three field lines (4 points). **Find E_x and E_y at** $(x, y) = (2a, a)$**,** $a > 0$ (4 points).

Problem 4. 16 points



A. 4 (P-45)

The charges below form the vertices of an equilateral triangle. Find the force exerted on Q.



B. 4+4 (P-65)

Find the electric field that Q is subjected to (created by λ, a pair of infinite line charges $\perp$ to the paper).

Compute the work done in moving Q from $(0, 0)$ to $(x, 0)$ in the xy-plane.

Problem 5. 16 (E-19,20,21,22,23,24)

Consider a $2000 Hz$ sound wave created by a human voice. You are standing $5\,m$ away, and its loudness is $40\,dB$. The speed of sound is $340\,\frac{m}{s}$, and its density is $1.4\frac{kg}{m^3}$.

A. 2 points. What is the amplitude with which the air molecules move, due to the passage of the wave?

B. 2 points. What is its intensity in Watts per square meter?

C. 2 points. What is the pressure amplitude of the accompanying pressure wave? (compute the largest pressure deviation from atmospheric pressure caused by the wave)

D. 2 points. If a second identical wave of twice the frequency, but of loudness $40\,dB$ is added onto this wave **in phase**, how many decibels will the combined wave be heard at by you?

E. 3 points. If a second wave of the same frequency, but of loudness $40\,dB$ is added onto this wave **in phase**, how many decibels will the combined wave be heard at by you?

F. 3 points. If you **quadruple** your distance from a $40\,dB$ sound source, what will be the new decibel level of the source?

G. 2 points. Find the maximal molecular speed of the air molecules in the original $40\,dB$ wave.

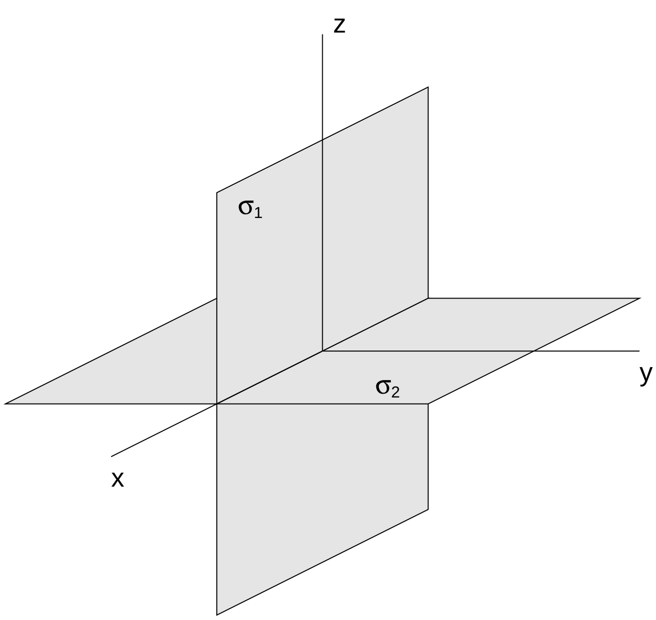
Problem 6. 16 points.

A. 4 (P-68)

An electron of mass $m = 9.11 \times 10^{-31} kg$ is accelerated from rest by an electric field. It starts at a point where $V = 0.0\,V$, compute its speed as it passes through a point where $V = 50,000\,V$.

B. 4 (P-47)

Place a positive point charge q at the origin $x = 0$, and a negative charge $-2q$ such that at $x = d$. Hold both charges in place. There is a point on the x-axis where a third charge Q can be placed such that it experiences no net force. Find x.



C. 4+4 (E-40, 41)

Find the electric field for the two intersecting charged infinite planes ilustrated at the point (a, b, c) in the first quadrant. (Let $\sigma_1 > 0$, $\sigma_2 > 0$).

Find the work done in moving a charge Q from $\mathbf{r}_i = a\mathbf{j}$ to $\mathbf{r}_f = b\mathbf{k}$.