C Code: 1

PHSX 212 — Exam 1 — September 13, 2006

Student Name [redacted] **KUID** [redacted]

Important—read before you start

This exam consists of 12 problems with total of 100 points. In addition, there is one extra credit problem of 10 points. Since the exam will hand graded, please do all work on this paper and show all intermediate steps and derivations that lead to your answer. Your objective should be to show us what you know about each problem.

Please write your name and KUID at the top of each page.

For grading use:

Problem	Score
1	5
2	5
3	5
4	5
5	10
6	4
7	9
8	10
9	10
10	10
11	10
12	10
Extra credit	5
Total (110 possible)	98

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1. **(5 points)** You generate traveling waves on a stretched string by wiggling one end. The wave travels at speed V_0. What would you need to do in order to make the wave travels at $2V_0$?

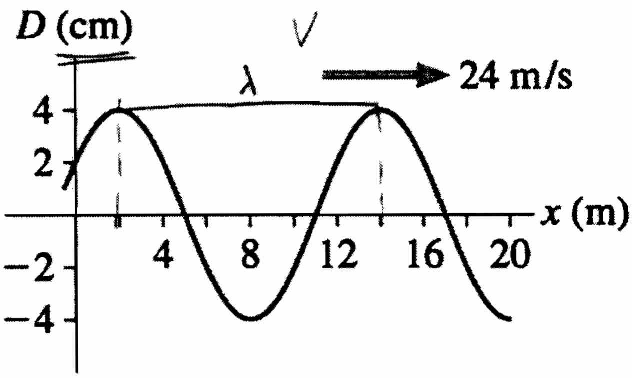
5

$V_{string} = \sqrt{\frac{T_s}{\mu}} \qquad \mu = \frac{m}{L}$

$\Rightarrow V_0 \uparrow \Rightarrow 2V_0$ REQUIRES TO RAISE $\frac{T_s}{\mu}$ BY 4 TIMES $\Rightarrow$ $m_f = \frac{1}{4} m_i$, $T_{sf} = 4T_{si}$, $L_f = 4L$

5

2. **(5 points)** The snapshot graph (at $t = 0$ seconds) below is of a sinusoidal traveling wave moving toward the right with a wave speed of 24 m/s. Calculate the period and initial phase of the wave.



Snapshot graph at $t = 0$ s

$V = \frac{\lambda}{T} \Rightarrow \boxed{T} = \frac{\lambda}{V} = \frac{12m}{24 m/s} = \boxed{0.5s}$

$x=0 \quad t=0 \quad D=0.02m \quad A=0.04m$

$D = A\sin(\cancel{kx} - \cancel{\omega t} + \phi_0)$

$\Rightarrow D = A\sin\phi_0 \Rightarrow \phi_0 = \sin^{-1}\left(\frac{D}{A}\right)$

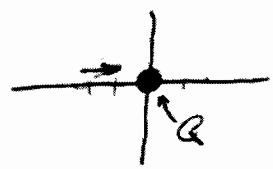
$\phi_0 = \sin^{-1}\left(\frac{0.02}{0.04}\right)$

$\boxed{\phi_0 = 0.5236}$

3. **(5 points)** A point charge Q=-5nC is placed at the origin of the coordinate system. Find the MAGNITUDE direction of the electric field at point x=-2.0 m $\vec{i}$

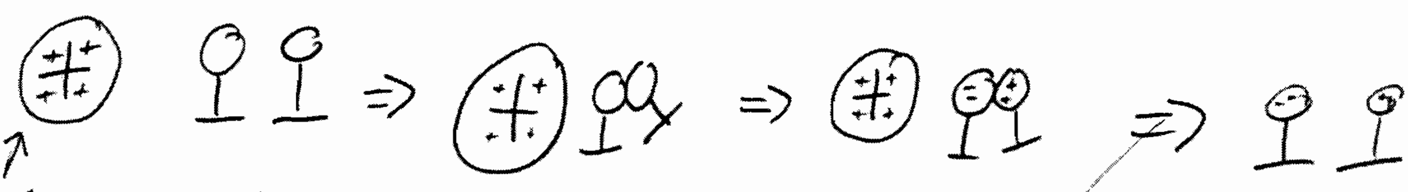
+5

$\vec{E} = \frac{q}{4\pi\epsilon_0 r^2} = \left(9\times10^9 \frac{Nm^2}{C^2}\right)\left(\frac{5\times10^{-9}C}{(2m)^2}\right) = 11.25 N/C$



$\boxed{\vec{E} = -11.25 N/C (\hat{i})}$

4. **(5 points)** You have two neutral metal spheres on wooden stands. Describe using words and pictures a procedure for putting ***exactly equal and opposite*** charges on the two spheres.



LARGE CHARGED OBJECT

TOUCH SPHERES TOGETHER HOLD NEAR LARGE CHARGED OBJECT

CAUSES POLARIZATION ELECTRONS FROM ONE WILL MIGRATE TO THE OTHER VIA CONDUCTION AS THEY ARE ATTRACTED OR REPELLED FROM LARGE CHARGE

PULL SPHERES APART THEN MOVE IMMEDIATELY FROM VACINITY OF LARGE CHARGE OPPOSITE CHARGES REMAIN

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5. **(10 points)** What are the speed *and* direction of a traveling wave whose displacement is given by the following equation: $D(x,t) = 5\sin(3.5x - 7.0t)$? (Assume that x is measured in meters and t in seconds).

$D(x,t) = A\sin(kx - \omega t + \cancel{\phi})$

$\Rightarrow k = 3.5\,(m^{-1}),\ \omega = 7.0\,(Hz)$

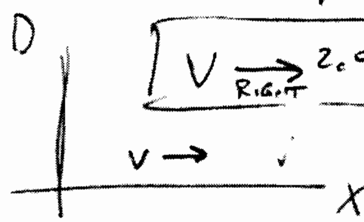
$k = \frac{2\pi}{\lambda} \Rightarrow \lambda = \frac{2\pi}{k}$

$\omega = 2\pi f \Rightarrow f = \frac{\omega}{2\pi}$

$V = \lambda \cdot f = \frac{\omega}{k} = \frac{7.0}{3.5}$

$\boxed{V = 2.0\ m/s}$

$\boxed{V \xrightarrow[\text{RIGHT}]{} 2.0\ m/s}$



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6. **(10 points)** An organ pipe with one end open and the other end close is to resonate in its 3rd harmonic frequency at 210 Hz. Assuming the speed of sound in air is 343 m/s, calculate the required length for this pipe.

3rd HARMONIC $\Rightarrow n = 3$

$f_n = (2(n)+1)\frac{v}{4L}$

$\Rightarrow f_3 = (2(3)+1)\frac{V_s}{4L}$

n = 1

$\Rightarrow f_3 = \frac{7}{4}\frac{V_s}{L}$

-6

$\Rightarrow L = \frac{7}{4}\frac{V_s}{f_3} = \left(\frac{7}{4}\right)\left(\frac{343\,m/s}{210\,Hz}\right) = \boxed{2.8583\,m}$

9

7. **(10 points)** A tornado warning siren on top of a tall pole radiates sound waves of power 15 Watts uniformly in all directions. (a) Calculate the intensity of the wave at 10 m away from the siren. (b) By how many times does the sound intensity level drop when you move ten times as far away from the siren?

a) $I_1 = \frac{\text{POWER}}{\text{AREA}}$ AREA $= \pi r^2$ $\Rightarrow I = \frac{P}{\pi r^2} = \frac{15W}{\pi(10m)} = \boxed{0.0477\ W/m^2}$

b) $I_2 = \frac{P}{A} = \frac{P}{\pi(10r)^2} = 0.00477\ W/m^2$

Area $= 4\pi r^2$

$\Rightarrow \boxed{I_2 = \frac{1}{100} I_1}$

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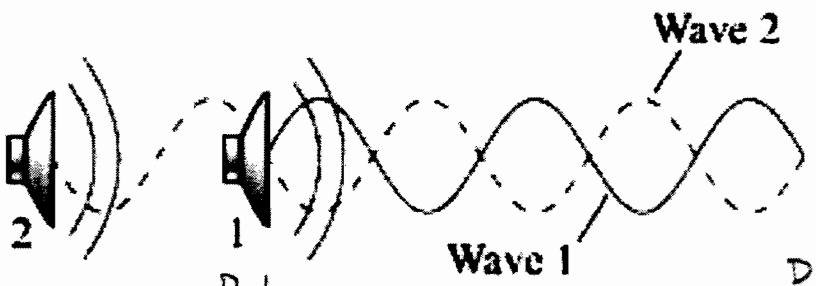
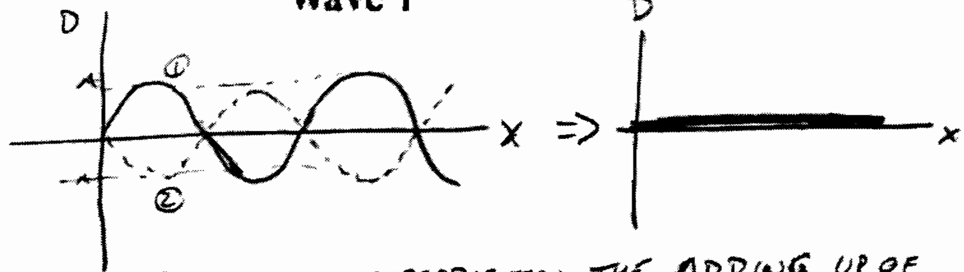
8. **(10 points)** (a) Draw a picture of and describe in words the interference of wave 1 and wave 2 (pictured below).





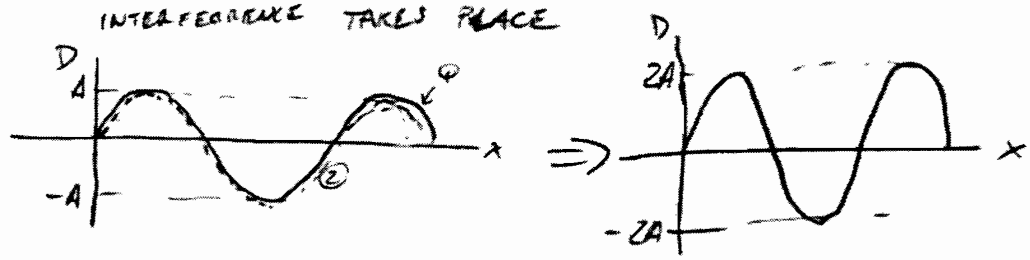
+5

DUE TO SUPERPOSITION THE ADDING UP OF WAVE DISPLACEMENT AT ALL POINTS THE NET AFFECT IS PERFECT DESTRUCTIVE INTERFERENCE SINCE THE PHASE DIFFERECE BTWN WAVES IS $n\pi$ (n IS INTEGER)

(b) What would happen if microphone 2 was moved backward half a wavelength.

MOVING MICROPHONE 2 BACK $\frac{1}{2}\lambda$ CAUSES THE PHASE DIFFERENCE TO BECOME $2n\pi$ (n IS INTEGER) $\Rightarrow$ CONSTRUCTIVE INTERFERENCE TAKES PLACE

+5



9. **(10 points)** A positive charge 0.6 μC exerts an attractive force with a magnitude of 0.500 N on an unknown charge 0.25 m away. What is the unknown charge (magnitude and sign)?

$$F = \frac{k q_1 q_2}{r^2} \quad \Rightarrow \quad q_2 = \frac{F r^2}{k q_1} = \frac{(0.5N)(0.25m)^2}{(9\times10^9 \frac{Nm^2}{C^2})(0.6\times10^{-6}C)}$$

$$\boxed{q_2 = -5.787\,\mu C}$$

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ATTRACTIVE $\Rightarrow q_2$ OPPOSITE q_1

$q_1(+) \Rightarrow q_2(-)$

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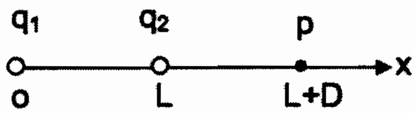
10. **(10 points)** Two charges q_1 and q_2 are placed a distance L apart on the x-axis (see Figure). What must be the value of q_1 in terms of q_2 (including sign), L and D to ensure that the electric field is zero at point P on the x-axis a distance D from q_2 and $D+L$ from q_1?



$\Sigma E_x = E_{q_1} + E_{q_2} = 0$

$E_{q_1} = -E_{q_2}$

10

$\frac{kq_1}{(L+D)^2} = \frac{-kq_2}{D^2}$

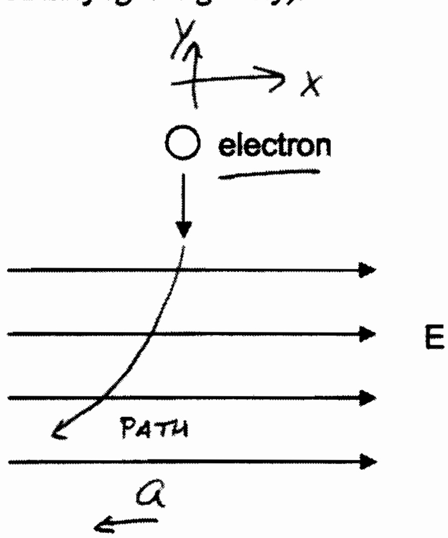
$E = \frac{kq}{r^2}$

$r_1 = L+D$

$r_2 = D$

$\Rightarrow \boxed{q_1 = -q_2\left(\frac{L+D}{D}\right)^2}$

11. **(10 points)** An electron enters a uniform electric field $\mathbf{E} = 4\text{x}10^{-2}$ N/C $\vec{i}$. (a) Find the magnitude and direction of the acceleration after the electron enters the **E** field. (The mass of the electron is $9.11\text{x}10^{-31}$kg). (b) Sketch the trajectory of the electron after it enters the electrical field (you may ignore gravity).



$\vec{F} = m\vec{a} \qquad \vec{F} = q\vec{E}$

$\vec{a} = \frac{q\vec{E}}{m}$

$\vec{a} = \frac{(-1.6\times10^{-19})(4\times10^{-2}\,N/C)}{(9.11\times10^{-31}\,kg)}$

$\boxed{\vec{a} = -7.025\times10^{9}\,m/s^2\ (\hat{i})}$

10

ELECTRONS FALL "UP" IN AN ELECTRIC FIELD

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12. **(10 points)** Four charges each has q=1nC are arranged at the corners of a square of side 5cm. What is the magnitude and direction of the Electric Field at (a) Point A, the center of the square and (b) Point B, midway up the left hand side.

$E = \frac{kq}{r^2}$

a) ASSUME COORDINATE AXIS ALONG DIAGONALS ⇒ SINCE $q_1 = q_2 = q_3 = q_4$

$\Sigma E_x = E_1 - E_3 = 0$ AND $\Sigma E_y = E_4 - E_2 = 0$

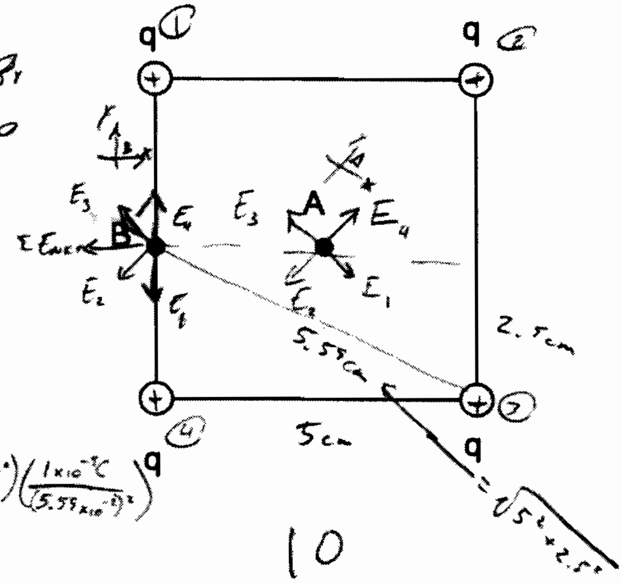
$\Rightarrow \boxed{\Sigma E_{NET_A} = \Sigma E_x + \Sigma E_y = 0}$

b) AS BEFORE ALONG Y-AXIS THE ELECTRIC FIELDS ALL CANCEL LEAVING $\Sigma E_x = E_{2x} + E_{3x}$

$\Rightarrow$ SINCE $|E_{2x}| = |E_{3x}|$

$\Sigma E_{NET_B} = 2E_{2x} = 2\left(\frac{5}{5.59}\right)\left(9\times10^9 \frac{Nm^2}{C^2}\right)\left(\frac{1\times10^{-9}C}{(5.59\times10^{-2})^2}\right)$

$\Sigma E_{NET_B} = -5152.37\ N/C$ ↑



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Extra Credit (10 points)

A ring of radius R has a charge Q uniformly distributed over its perimeter. ~~Calculate~~ DERIVE the field at a point P a distance z from the center along the axis of the disk. Check your answer by consider the two limits, Z=0 and Z very much greater than R.

$\vec{E} = \int d\vec{E} = \int \frac{dq}{4\pi\epsilon_0 r^2}\hat{r}$

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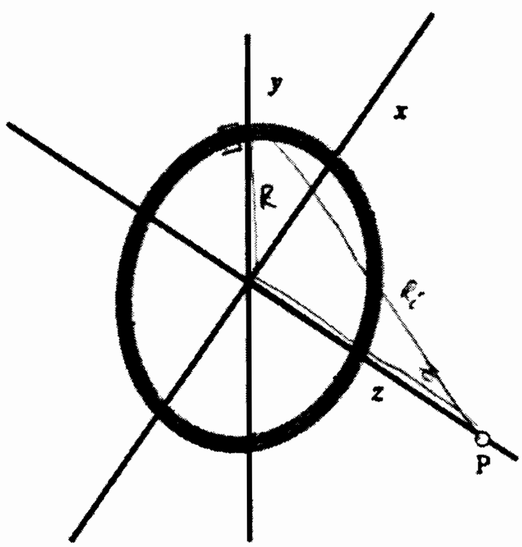
$dq = \frac{Q}{L} dR_i$

$E = k\frac{Q}{2\pi R}$



$R_i = \sqrt{z^2 + R^2}$

$S = \theta R$

$L = 2\pi R$

6

FROM DATA SHEET

$E = \frac{1}{4\pi\epsilon_0}\frac{zQ}{(z^2+R^2)^{3/2}}$

$z = 0 \Rightarrow E = 0$

EACH PT ON RING

✓ 3

$z >> R$

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

FALLS TO ZERO

Electricity

$\vec{F}_{12} = \dfrac{1}{4\pi\varepsilon_o}\dfrac{q_1 q_2}{r^2}\hat{r}_{21}$	Coulomb's Law. This is the electrostatic force between two charges, q_1 and q_2, separated by a distance r.
$\vec{F} = q\vec{E}$	The relationship between electric field and electrostatic force.
$\vec{F} = m\vec{a}$	Newton's Second Law.
$\vec{E} = \int d\vec{E} = \int \dfrac{dq}{4\pi\varepsilon_0 r^2}\hat{r}$	Equation for calculating the electric field from a charge distribution.
$\vec{\tau} = \vec{p}\times\vec{E}$	The net torque acting on a dipole in an electric field.

Some electric field magnitudes and constants

$\varepsilon_0 = 8.85x10^{-12}\dfrac{C^2}{Nm^2}$ $\qquad k = \dfrac{1}{4\pi\varepsilon_o} = 9x10^9\dfrac{Nm^2}{C^2}$ $\qquad e = 1.6x10^{-19}C$

$E = \dfrac{\eta}{2\varepsilon_o}$ A nonconducting plane of charge (η = surface charge density)

$E = \dfrac{\eta}{\varepsilon_o}$ A conducting plane of charge (η = surface charge density)

$E = \dfrac{1}{4\pi\varepsilon_0}\cdot\dfrac{Q}{r\sqrt{r^2+\left(\frac{L}{2}\right)^2}}$ A charged wire of length L and total charge Q

$E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$ A point charge

$\vec{E} = \dfrac{2\vec{p}}{4\pi\varepsilon_0 r^3}$ A dipole (on-axis) $\qquad \vec{E} = -\dfrac{\vec{p}}{4\pi\varepsilon_0 r^3}$ A dipole (off-axis)

$E = \dfrac{1}{4\pi\varepsilon_0}\cdot\dfrac{zQ}{\left(z^2+R^2\right)^{\frac{3}{2}}}$ A ring of charge of radius R and total charge Q

$E = \dfrac{\eta}{2\varepsilon_0}\cdot\left(1-\dfrac{z}{\sqrt{z^2+R^2}}\right)$ A disk of charge of radius R and surface charge density η

Waves

$v_{string} = \sqrt{\frac{T_s}{\mu}}$	The equation for the wave speed on a string.
$v = \lambda \cdot f$	The relationship between frequency, wavelength and wave speed.
$\kappa = \frac{2\pi}{\lambda}$	The definition of wave number.
$\omega = 2\pi f$	The definition of angular frequency.
$I = \frac{power}{area}$	The definition of intensity
$f_{\pm} = \frac{f_0}{1 \mp \frac{v_s}{v}}$	The Doppler shift equation when the source of the waves is moving and the detector (observer) is stationary.
$f \pm = f_0\left(1 \pm \frac{v_o}{v}\right)$	The Doppler shift equation when the source of the waves is stationary and the detector (observer) is moving.
$D(x,t) = 2A\sin(\kappa x)\cos(\omega t)$	The equation for a standing wave
$f_n = n\frac{v}{2L}$	Allowed frequencies for standing waves on a string with both ends fixed or a pipe with both ends closed or both ends open.
$f_n = (2n+1)\frac{v}{4L}$	Allowed frequencies for standing waves in a tube with one end open and the other end closed.
$\Delta\phi = 2\pi\frac{\Delta x}{\lambda} + \Delta\phi_0$	The definition of phase difference between two waves oscillating with the same frequency.
$D(x,t) = A\sin(\kappa x - \omega t + \varphi_0)$	The equation for a sinusoidal traveling wave

Simple formulae and constants

Sound wave speed v=343 m/s

Area of a disk of radius r = πr^2 Circumference of a circle of radius r = $2\pi r$

Volume of a sphere of radius r = $\frac{4}{3}\pi r^3$ Surface area of a sphere of radius r = $4\pi r^2$

Volume of a cylinder of radius r and length l = $\pi l r^2$

Surface area of a cylinder or radius r and length l = $2\pi rl + 2\pi r^2$