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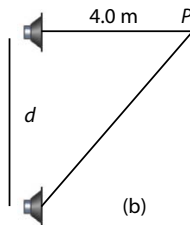
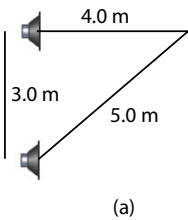
Name: _____

Recitation Time _____ Recitation Leader _____

Nov. 2, 2004

This exam is closed notes and closed book. You must show enough work on all problems to convince the grader you understand how to solve the problem. You may use a calculator. An equation sheet is on the last page. There are three problems; each counts 20 points. The points for each problem are divided approximately equally among the parts (a), (b), etc.

Problem 1. Two identical loudspeakers are connected to the same amplifier so that they are in phase. The speed of sound in air is 345 m/s.



- (a) What are the two lowest frequencies f_1 and f_2 at which the speakers in panel (a) can be driven to produce maximum intensity at the point P ?
- (b) The wires to one speaker are now reversed so that the loudspeakers are exactly out of phase, and the distance between the speakers is increased to d as shown in panel (b). (The two speakers and the point P again form a right triangle.) Find the smallest value of $d > 3.0$ m such that intensity maxima for the frequency f_1 determined in part (a) will again be heard at P . What will be heard for frequency f_2 ?

Problem 2. A violin string of length 0.33 m is tuned to a fundamental frequency of 444 Hz.

- (a) What is the velocity of a wave on this string?
- (b) What are the frequency and wavelength of the next two possible standing waves? Sketch the

form of the first three possible standing waves.

- (c) By what fractional amount should the tension in the string be increased to shift the fundamental frequency to 450 Hz? (Neglect the change in mass density when the tension is increased.)

Problem 3. A traveling wave has the form

$$D(x, t) = A \sin(\omega t - kx).$$

(a) Write the wave equation and show that $D(x, t)$ satisfies it.

- (b) Find the values of A , ω , and k if the frequency (not angular frequency) is 60 Hz, the amplitude is 0.6 m, and the wavelength is 0.1 m.
- (c) What is the velocity of the wave?

Physics 21
Fall, 2004

Equation Sheet

speed of light <i>in vacuo</i>	c	3.00×10^8 m/s	free space permeability	μ_0	$4\pi \times 10^{-7}$ T m/A
Gravitational constant	G	6.67×10^{-11} N m ² /kg ²	Planck's constant	h	6.63×10^{-34} J s
Avogadro's Number	N_A	6.02×10^{23} mol ⁻¹	electron rest mass	m_e	9.11×10^{-31} kg
Gas constant	R	8.315 J/mol K	proton rest mass	m_p	1.6726×10^{-27} kg
Boltzmann's constant	k_B	1.38×10^{-23} J/K	neutron rest mass	m_n	1.6749×10^{-27} kg
charge on electron	e	1.60×10^{-19} C	atomic mass unit	u	1.6605×10^{-27} kg
free space permittivity	ϵ_0	8.85×10^{-12} C ² /N m ²		k	8.99×10^9 N m ² /C ²

$\mathbf{F}_{12} = \frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{r_{21}^3} (\mathbf{r}_1 - \mathbf{r}_2)$	$Q = CV$	C 's in series or R 's in parallel:	$\mathbf{F} = q\mathbf{v} \times \mathbf{B}$ or $\mathbf{l} \times \mathbf{B}$
$\mathbf{F} = q\mathbf{E}$	$C = \epsilon_0 K \frac{A}{d} = \epsilon \frac{A}{d}$	$\frac{1}{X_{\text{eff}}} = \frac{1}{X_1} + \frac{1}{X_2}$	$d\mathbf{B} = \frac{\mu_0}{4\pi} \frac{I d\mathbf{l} \times (\mathbf{r} - \mathbf{r}')}{ \mathbf{r} - \mathbf{r}' ^3}$
$d\mathbf{E} = \frac{4\pi}{\epsilon_0} \frac{dQ(\mathbf{r} - \mathbf{r}')}{ \mathbf{r} - \mathbf{r}' ^3}$	$U_{\text{cap}} = \frac{1}{2} CV^2 = \frac{1}{2} \frac{Q^2}{C}$	C 's in parallel or R 's in series:	field of long wire: $B = \frac{\mu_0 I}{2\pi R}$
$\mathbf{E} = -\nabla V$	$U_{\text{ind}} = \frac{1}{2} LI^2$	$X_{\text{eff}} = X_1 + X_2$	$I = \frac{dQ}{dt}$
$\mathbf{E} = -\left(\hat{i} \frac{\partial V}{\partial x} + \hat{j} \frac{\partial V}{\partial y} + \hat{k} \frac{\partial V}{\partial z}\right)$	$V = IR$ or $V - IR = 0$	$X_R = R, X_L = \omega L, X_C = \frac{1}{\omega C}$	$\frac{V_s}{V_p} = \frac{N_s}{N_p}, \frac{I_s}{I_p} = \frac{N_p}{N_s}$
$V_b - V_a = -\int_a^b \mathbf{E} \cdot d\mathbf{l}$	$R = \rho \frac{l}{A} \quad \sigma = \frac{1}{\rho}$	RC time constant = RC	$\chi_m = \frac{\mu}{\mu_0} - 1$
$V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$	$P = IV \quad P = I^2 R$	LR time constant = L/R	$\boldsymbol{\tau} = \boldsymbol{\mu} \times \mathbf{B} \quad \boldsymbol{\mu} = I\mathbf{A}$
$u_{\text{elec}} = \frac{1}{2} \epsilon_0 E^2, u_{\text{mag}} = \frac{1}{2\mu_0} B^2$	$E = \frac{\sigma}{\epsilon_0}$ parallel plate capacitor	$Q(t)$ for RLC decay	solenoid $B = \mu_0 n I$
	$\mathbf{A} \times \mathbf{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$	$Q_0 \exp(-Rt/2L) \cos \omega t$	solenoid $L = \mu_0 N^2 A/l$
		$\omega^2 = \frac{1}{LC} - \frac{R^2}{4L^2}$	

$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{Q}{\epsilon_0}$	$\sin(a \pm b) = \sin a \cos b \pm \cos a \sin b$	$C = 2\pi r$ circumference of circle
$\oint \mathbf{B} \cdot d\mathbf{A} = 0$	$\sin(\theta \pm \frac{\pi}{2}) = \sin \theta \cos \frac{\pi}{2} \pm \cos \theta \sin \frac{\pi}{2} = \pm \cos \theta$	$C = \pi d$ circumference of circle
$\oint \mathbf{E} \cdot d\mathbf{l} = -\frac{d}{dt} \oint \mathbf{B} \cdot d\mathbf{A}$	$\cos(a \pm b) = \cos a \cos b \mp \sin a \sin b$	$A = \pi r^2$ area of circle
$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I + \mu_0 \epsilon_0 \frac{d}{dt} \oint \mathbf{E} \cdot d\mathbf{A}$	$\sin a + \sin b = 2 \cos \left(\frac{a-b}{2}\right) \sin \left(\frac{a+b}{2}\right)$	$A = 4\pi r^2$ surface area of sphere
		$V = \frac{4}{3} \pi r^3$ volume of sphere
		$ax^2 + bx + c = 0 \Rightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$\int \frac{du}{\sqrt{a^2 + u^2}} = \ln(u + \sqrt{a^2 + u^2})$	$\int \frac{du}{(a^2 + u^2)^{3/2}} = \frac{u}{a^2 \sqrt{a^2 + u^2}}$	$\int u^n du = \frac{1}{n+1} u^{n+1}$
$\int \frac{u du}{\sqrt{a^2 + u^2}} = \sqrt{a^2 + u^2}$	$\int \frac{u du}{(a^2 + u^2)^{3/2}} = -\frac{1}{\sqrt{a^2 + u^2}}$	$\int \frac{du}{a + bu} = \frac{1}{b} \ln(a + bu)$
$\int \frac{du}{a^2 + u^2} = \frac{1}{a} \tan^{-1} \left(\frac{u}{a}\right)$	$\int e^{au} du = \frac{1}{a} e^{au}$	$\int \frac{du}{u} = \ln u$
$\int \frac{u du}{a^2 + u^2} = \frac{1}{2} \ln(a^2 + u^2)$	$\int \ln u du = u \ln u - u$	

$v = \sqrt{T/\rho}$ (T =tension)	$v = f\lambda$	$\omega = 2\pi f$	$\langle P \rangle = \frac{1}{2} \rho A^2 \omega^2 v$
$v = (348 \text{ m/s}) \sqrt{T/300}$	$T = 1/f$ (T =period)	$k = 2\pi/\lambda$	