UNIVERSITY OF ALABAMA
Department of Physics and Astronomy

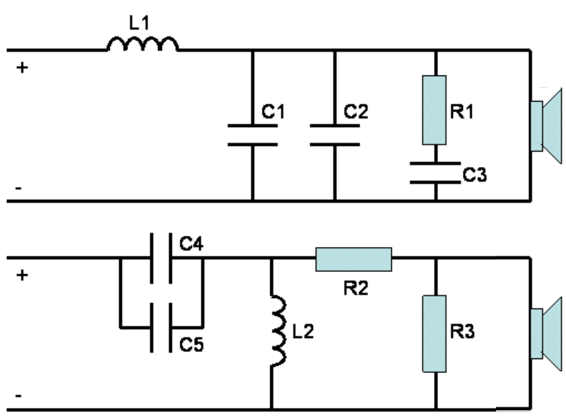
PH 102 Spring 2015

# Exam 4

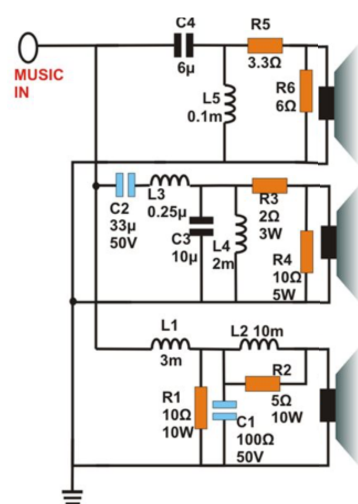
**Instructions**

1. Solve **three** of the four problems below.
2. All problems have equal weight. Do your work on separate sheets.
3. You are allowed 1 sheet of standard $8.5 \times 11\,\text{in}$ paper and a calculator.

□ **1.** Carl is trying to upgrade his stereo system. He is looking at audio crossover circuits, whose main function is to send low frequency signals to the larger speakers (woofer) and high frequency signals to the smaller speakers (tweeter). Help Carl analyze the two different crossover circuits. **(a)** In the figure at left, two circuits power two different speakers from the same audio source. Based on the components in each circuit, which speaker receives the low frequency signals and which receives the high frequency signals? Explain your reasoning carefully. **(b)** The circuit at right also uses a single audio signal source, but now the music signal input is sent to three speakers: low, mid, and high frequency range speakers. Identify which speaker is which, explaining your reasoning carefully.



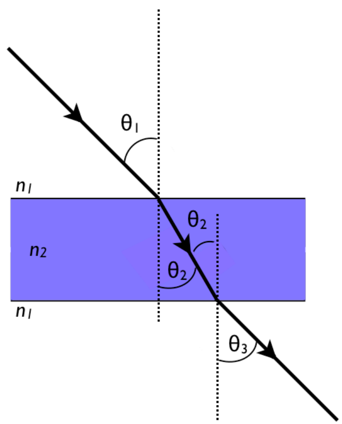

adapted from
http://www.8audio.com/image/diyspeaker/crossovercircuit.gif




adapted from
http://www.brighthubengineering.com/commercial-electrical-applications/57202-what-is-a-speaker-crossover-network/

□ **2.** Meatwad is looking through a homemade microscope, which has a thin positive front lens $L_1$ of 2 cm focal length, 10 cm behind which is another positive lens $L_2$, with a 5 cm focal length. (In other words, the object is in front of $L_1$, and $L_2$ is 10 cm behind $L_1$.) **(a)** Locate the image of an object 3 cm from the front lens and **(b)** compute the net magnification of the *final* image.

□ **3.** A slab of glass with refractive index $n_2$ floats freely in air with index of refraction $n_1$. **(a)** Prove that the incident and exiting angles for the slab are the same, i.e., $\theta_1 = \theta_3$. **(b)** Provided the first part of this question is true, the exiting ray will travel parallel to the path the original ray would have taken if the glass were not present, but slightly displaced. This could prove useful in thwarting Mooninite laser attacks. Derive an expression for the displacement between the actual path and the path if the glass were not present, presuming the glass to have thickness $d$. (Consider the perpendicular distance the ray with the glass present and the ray without the glass present.)




□ **4.** **(a)** Master Shake stands in front of two front-surfaced plane mirrors set at right angles to each other. How many images of himself will Master Shake see? Explain your answer. **(b)** A concave spherical mirror of 20 cm **radius** is to be used to project an image Frylock onto a wall 110 cm away. Where will Frylock have to stand relative to the mirror, and what will the image look like (magnification, inverted or not, real or virtual)?

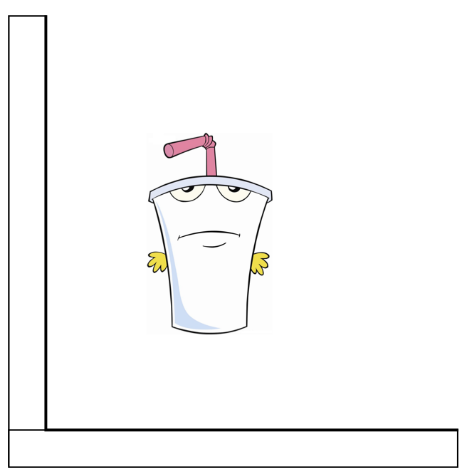


image from http://villains.wikia.com/wiki/Master_Shake

**Optics:**

$$\mathscr{E} = hf = \frac{hc}{\lambda}$$

$$n = \frac{\text{speed of light in vacuum}}{\text{speed of light in a medium}} = \frac{c}{v}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{c/n_1}{c/n_2} = \frac{n_2}{n_1} \quad \text{refraction}$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \quad \text{Snell's refraction}$$

$$\lambda f = c$$

$$M = \frac{h'}{h} = -\frac{q}{p}$$

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{2}{R} \quad \text{mirror \& lens}$$

$$\frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R} \quad \text{spherical refracting}$$

$$q = -\frac{n_2}{n_1} p \quad \text{flat refracting}$$

$$\frac{1}{f} = \left(\frac{n_2 - n_1}{n_1}\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad \text{lensmaker's}$$

| Power | Prefix | Abbreviation |
|---|---|---|
| $10^{-12}$ | pico | p |
| $10^{-9}$ | nano | n |
| $10^{-6}$ | micro | μ |
| $10^{-3}$ | milli | m |
| $10^{-2}$ | centi | c |
| $10^{3}$ | kilo | k |
| $10^{6}$ | mega | M |
| $10^{9}$ | giga | G |
| $10^{12}$ | tera | T |

**ac Circuits**

$$\tau = 1/\omega_c = L/R \quad \text{RL circuit}$$

$$\tau = 1/\omega_c = RC \quad \text{RC circuit}$$

$$X_C = \frac{1}{2\pi f C} \quad \text{“resistance” of a capacitor for ac}$$

$$X_L = 2\pi f L \quad \text{“resistance” of an inductor for ac}$$

$$\omega_{\text{cutoff}} = \frac{1}{\tau} = 2\pi f$$

| Derived unit | Symbol | equivalent to |
|---|---|---|
| newton | N | kg·m/s$^2$ |
| joule | J | kg·m$^2$/s$^2$ = N·m |
| watt | W | J/s=m$^2$·kg/s$^3$ |
| coulomb | C | A·s |
| V | W/A = m$^2$·kg/·s$^3$·A | |
| farad | F | C/V = A$^2$·s$^4$/m$^2$·kg |
| ohm | Ω | V/A = m$^2$·kg/s$^3$·A$^2$ |
| tesla | T | Wb/m$^2$ = kg/s$^2$·A |
| electron volt | eV | $1.6 \times 10^{-19}$ J |
| - | $1\,\text{T} \cdot \text{m/A}$ | $1\,\text{N/A}^2$ |
| - | $1\,\text{T} \cdot \text{m}^2$ | $1\,\text{V} \cdot \text{s}$ |
| - | $1\,\text{N/C}$ | $1\,\text{V/m}$ |