

SIMG-215-02 Fundamentals of Imaging Science
Solutions to Quiz #3 – 26 October 2006

1. The ear of a young human can hear audio signals that oscillate with frequencies from about $\nu_{\min} = 20$ Hz to about $\nu_{\max} = 20,000$ Hz = 20 kHz.

(a) What is the *bandwidth* of the human audio system?

$$\text{Bandwidth } \Delta\nu = \nu_{\max} - \nu_{\min} = 20,000 \text{ Hz} - 20 \text{ Hz} = 19,980 \text{ Hz}$$

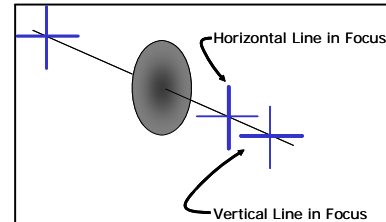
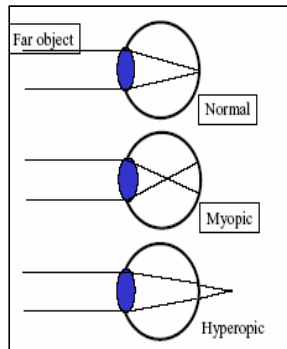
- (b) (**OPTIONAL BONUS**) How many samples per second must be measured to produce a data stream that can be reconstructed to sound like the original signal? (HINT: a factor of 2 is needed somewhere, a sketch may help; this is an important number in systems for digital sound reproduction)

To do this one, you have to recall that you must have TWO samples per oscillation of the most rapidly oscillating sinusoidal signal, so in this case the MINIMUM number of samples per second would be

$$20,000 \times 2 = 40,000 \text{ samples per second}$$

In reality, the signal is slightly “oversampled” by assuming that the maximum frequency is 22,000 Hz so the number of actual samples is 44,000 per second

2. Define **TWO (2)** of the 3 terms (a) “myopia,” (b) “hyperopia,” and (c) “astigmatism;” illustrate the reason why each occurs with sketches. (**OPTIONAL BONUS: DEFINE THE THIRD TERM**)



Schematic Diagrams of focusing of light by re-Schematic diagram of the different focusing distances for lines laxed normal, myopic, and hyperopic eyes with different orientations in an astigmatic eye.

- (a) “myopia” = “nearsightedness” where the lens is too powerful (or, equivalently, the eyeball is too “long”) so that rays from an object at ∞ come to a focus “in front” of the retina. If the object is brought closer to the lens, then the image moves back farther from the lens and eventually is focused on the retina.
- (b) “hyperopia” = “farsightedness” where the lens is not sufficiently powerful or the eyeball is too “short”. This happens in later life as the lens loses flexibility.
- (c) astigmatism is the condition where the eyelens is not “symmetrically” shaped, so that it has more power along one axis than along the other and thus focuses light at two different depths depending on the orientation of the line. It is corrected by using a lens with different curvatures along the two axes and therefore the orientation of the lens relative to the eye is important.

3. Sketch a diagram of a cathode-ray tube display including labels of its significant components. Explain briefly how a gray-scale CRT may be used to display a gray-scale image (i.e., you need not consider color).

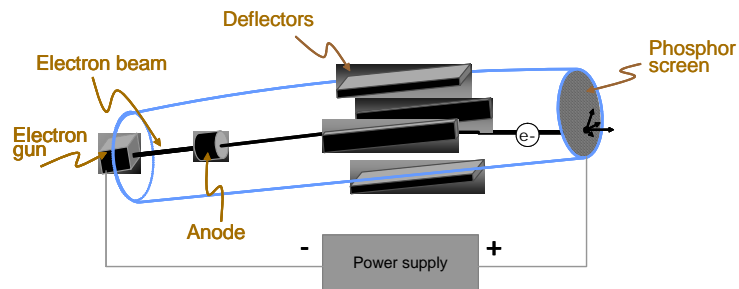
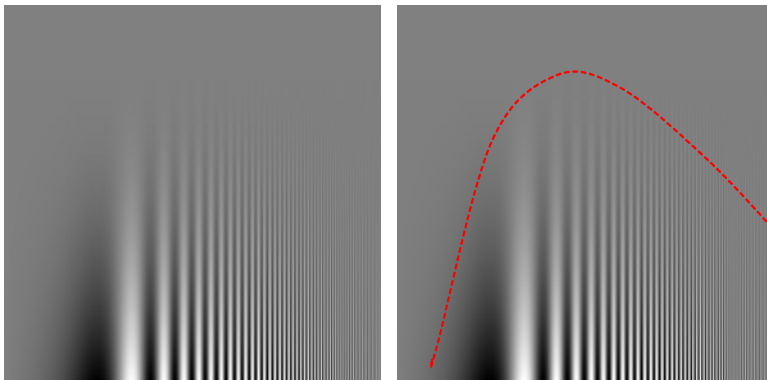


Diagram of cathode ray tube. The electrons are accelerated by the voltage that is positive on the phosphor screen. The electrons are “steered” to various locations on the screen by the electromagnetic “deflectors”. The strength of the electron current (the number of electrons striking a phosphor) determines the brightness of the signal.

4. Describe the figure shown below and what its perception indicates about the human visual system. You may sketch on the figure as part of your answer.



This is the object used to demonstrate that the receptors in the eye are connected by a neural net that does an automatic “sharpening” operation. The figure is a sinusoidal pattern whose frequency (oscillation rate) increases from left to right and whose contrast increases from top to bottom. Depending on distance from the object, the typical human observer sees an apparent “boundary” between the visible oscillations and the place where the oscillations “blur” together. This is estimated by the red dashed line. This evidence shows that the eye is most sensitive to contrast for an oscillation frequency somewhere in the “middle”. This is characteristic of a sensor with a “sharpening” response.

5. In your own words, define the important physical characteristic of a *photoconductor* for imaging systems; give **one** example of how such a material may be used in an imaging system.

A photoconductor “conducts electricity when exposed to light”, i.e., it acts as an insulator in the dark and as a conductor when photons are incident. We talked about a couple of examples: photoconductors are used in electrophotographic copiers and printers (“Xerox machines”) and in video cameras. The first photoconductor discovered was selenium.